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Strategies for improving safety performance of repair, maintenance, minor alteration and addition (RMAA) works

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Abstract

Purpose – Managing and maintaining infrastructure assets are one of the indispensible tasks for many government agencies to preserve the nations' economic viability and social welfare. To reduce the expenditures over the life-cycle of an infrastructure asset and extend the period for which the asset performs effectively, proper repair and maintenance are essential. While repair, maintenance, minor alteration and addition (RMAA) sector is expanding in many developed cities, occurrences of fatalities and injuries in this sector are also soaring. The purposes of this paper are to identify and then evaluate the various strategies for improving the safety performance of RMAA works.
Design/methodology/approach – Semi-structured interviews and two rounds of Delphi survey were conducted for data collection.
Findings – Raising safety awareness of RMAA workers and selecting contractors with a good record of safety performance are the two most important strategies to improve the safety performance in this sector. Technology innovations and a pay-for-safety scheme are regarded as the two least important strategies.
Originality/value – The paper highlights possible ways to enhance safety of the rather under-explored RMAA sector in the construction industry.

Keywords Repair and maintenance, Safety performance, Safety strategies, Hong Kong, Maintenance programmes, China, Construction engineering works

Paper type Research paper

Introduction

Safety performance of repair, maintenance, minor alteration and addition (RMAA) works in many developed cities has been alarming. According to the Health and Safety Executive (HSE) Construction Intelligence Report (2009), refurbishment, repair and maintenance works accounted for 52% whereas new building works only accounted for 30% of the fatal accidents in the construction industry of the United Kingdom in 2008. When the economy of a society achieves a certain level of maturity, it is not surprising to see that the new construction market diminishes while repair and maintenance market expands. Safety problems tend to reshuffle from the new construction works to RMAA works amidst the natural change in construction market across most developed countries.

Despite research studies on improving safety performance of the construction industry are readily available, most of them are based on new construction projects. There is only limited research on the RMAA sector, not to mention studies focusing on investigating strategies to curb the worsening safety problems of the rising RMAA sector. Nature of works, tasks undertaken and workers involved in RMAA projects are entirely different from those in new construction projects. Hence, strategies for resolving safety problems of RMAA projects are also incongruent to new construction projects. What kinds of strategies are the most important to improve safety performance of the RMAA sector in particular? This question awaits an answer from an empirical study. This paper, drawing on part of the findings of a government-funded research project on safety of RMAA works in Hong Kong, sets out to firstly identify and then evaluate the importance of various strategies for improving safety performance of RMAA works.

The empirical study was conducted in Hong Kong which has experienced increasing value of construction output and rising number of fatalities and injuries from RMAA works. RMAA works accounted for 53.2% of the construction output in 2007 (Census and Statistics Department of HKSAR, 2008) and the percentage of RMAA accidents to all construction accidents in Hong Kong increased considerably from 17.9% in 1998 to 50.1% in 2007. As the government is going to implement a mandatory building inspection scheme to ensure regular and compulsory maintenance of aged buildings in Hong Kong, the importance of RMAA sector to the construction market is more paramount. Therefore, it is both timely and essential to find out effective strategies for improving safety performance of the RMAA sector. Findings of this study will be useful to industrial practitioners in the RMAA sector, policy makers and safety professionals not only in Hong Kong but also in other developed cities.

Principles and strategies for safety improvement

Basic principles

Traditional paradigm of injury prevention, according to Geller (2001), focuses on three ‘E’s: (1) engineer; (2) educate; and (3) enforce. These refer to ‘*engineer* the safest equipment, environmental settings, and protective devices; *educate* people regarding the use of the engineering interventions; use discipline to *enforce* compliance with recommended safe work practices’. These three ‘E’s help achieve significant improvement in workplace safety. To go beyond the current level of safety excellence, Geller (2001) puts forward a new paradigm with three new ‘E’s: (1) ergonomics; (2) empowerment; and (3) evaluation. He further develops ten principles of setting company safety strategies as follows:

1. From government regulation to corporate responsibility.
2. From failure oriented to achievement oriented.
3. From outcome focused to behaviour focused.
4. From top-down control to bottom-up involvement.
5. From a piecemeal to a systems approach.
6. From fault finding to fact finding.
7. From reactive to proactive.
8. From quick fix to continuous improvement.
9. From priority to value.
10. Enduring values.

With these ten principles in mind, Geller (2001) advocates that companies should perceive safety as part of their corporate social responsibility and not just to fulfil regulatory obligation. Safety strategies should be achievement oriented and not just failure avoidance, focused on behaviour rather than injury record, supported by all managers and supervisors and driven by the front-line workers through interdependent teamwork. Geller (2001) suggests adopting a systems approach which is fact-finding, proactive and has commitment to continuous improvement.

Safety strategies

There are different strategies to improve safety but it is not easy to decide which one is more effective than the others. Guastello (1993) quantitatively compares the effectiveness of 53 accident prevention techniques identified from professional journals. These techniques are grouped into 10 approaches by Geller (2001) as: (1) behaviour-based programs; (2) comprehensive ergonomics; (3) engineering changes; (4) group problem solving; (5) government action; (6) management audits; (7) stress management; (8) poster campaigns; (9) personnel selection; and (10) near-miss reporting. Robson *et al.* (2007) have launched a systematic literature review to evaluate the effectiveness of occupational health and safety management system (OHSMS) interventions on employees' health and safety and associated economic outcomes. A total of 13 articles meeting both the study's relevance and methodological quality criteria have been analysed. Results suggest that OHSMSs have some positive effects but there is insufficient evidence to make recommendations either in favour of or against OHSMS. Recently, Bottani *et al*. (2009) have conducted an empirical investigation between adopters and non-adopters of safety management systems (SMSs) to compare their performances in four different aspects: (1) definition of safety and security goals and their communication to employees; (2) risk data updating and risk analysis; (3) identification of risks and definition of corrective actions; and (4) employees training. The study finds that those companies adopting SMSs have in general achieved significantly better performances in all aspects.

Loosemore and Lam (2004) conduct an empirical study on construction safety and personal attribute. They investigate the role of locus of control as a determinant of opportunistic behaviour in construction health and safety. Locus of control is defined as 'the self-perceived influence over decision-making'. Their study concludes that the overall locus of control is high in safety and health issues in Australia and suggests addressing the congruent of locus of control between different occupational, gender and ethnic groups to achieve further safety performance improvement.

The study of Mahalingam and Levitt (2007) on safety issues of global projects discusses the effectiveness of safety strategies in terms of enforcement and education. With reference to institutional theory, Mahalingam and Levitt (2007) conclude that coercive safety measures are effective in the short-term only. The improvement, however, may not last long. Although education seems to be ineffective in the short-term, it can change ones' mindset towards safety. The authors explain that institutional change or mindset change does not occur in a day but may be as long as decades. Education is often regarded as a key or even the most powerful strategy to improve construction safety; however, according to their findings, this may not be the case. International contractors prefer employing enforcement strategy to improve safety of global projects because of one-off nature of these projects and changing safety practices by education takes time. To achieve immediate change in unsafe work practices and long-term safety performance improvement, contractors can adopt a dual approach which employs enforcement strategy together with safety orientation and training.

Ling *et al.* (2009) have developed and evaluated 41 strategies to minimize fatalities by six safety managers from Singapore and the United States. The top two effective strategies are 'site supervisors should also be on a look out for the high risk groups' and 'carry out thorough risk assessment of complex projects'. Their study recommends changing organizational safety culture, enhancing the penalty system and improving communication between site management and front-line workers. For organizational safety culture, leadership and support from top management are perceived to be the key to successful safety management systems. For enhancing penalty system, the study suggests that the insurers should attach insurance premiums to contractors' safety records and clients should emphasize safety performance to be one of the important selection criteria of tendering contractors. For communication, it is suggested that site management staff should be able to communicate effectively with multi-nationalities of workers.

Gangwar and Goodrum (2005) investigate the effect of time on safety incentive programme in the US construction industry. There are two types of safety incentive systems. One is injury/ illness-based and the other is behaviour-based. Injury/ illness-based incentives tend to entice non-reporting of injuries, difficult to discontinue because workers see it as their entitlement, and if it is not administered fairly it can be a de-motivator. For behaviour-based incentive, there is a problem of measurement and monitoring because workers' behaviour is complex and difficult to gauge. Incentives over time become less viewed as a motivation and more perceived as an entitlement. It must be reinvented through new reward schemes and measures to maintain the interest and motivation of the workforce to improve jobsite safety.

Hinze (2002) discusses what kinds of safety initiatives are more effective in driving down injury rates. Safety incentives are more effective when they are given more frequently, to supervisor as well as workers. However, incentives of considerable value should be avoided because it may discourage reporting of injuries. The study of Hinze (2002) also notes that injury rates are lower in companies sponsoring safety dinners for workers. Safety performance is particularly magnificent in some cases that company president and family members are invited to the safety dinner. Although it requires more effort of implementation, safety incentive scheme should be designed to reward workers' safety behaviour on the process of doing the work rather than merely absence of injuries. Effects of safety incentive scheme should also be carefully evaluated to check whether there are any change in safety practices and safety behaviour. Safety performance of workers should possibly be included as a criterion for their job promotion. Negative reinforcement for unsafe behaviour through written or verbal sanctions is also useful but proper record must be kept of every reprimand.

Closely related to this study, Anumba *et al*. (2004) have conducted a study on health and safety in refurbishment involving demolition and structural instability. Their study recommends a number of strategies to improve safety of refurbishment work. These include selection of suitable procurement routes; demolition design and planning; selection and use of plant and equipment; workforce pre-qualification, selection and supervision; communication of project requirements and health and safety information; and health and safety education and training systems.

Research methods

A sequential mixed research approach, which starts with qualitative and then quantitative methods, was adopted to achieve two objectives set out in this study. Qualitative approach in the form of semi-structured interview was initially employed to derive categories of strategies for improving safety performance of RMAA works (Objective 1). Sequential quantitative research method in the form of Delphi survey was designed to numerically rank the relative importance of these categories (Objective 2).

Semi-structured Interviews

To explore various strategies for improving the overall safety of RMAA works, a series of face-to-face interviews were conducted with senior management representatives of eight RMAA contracting companies between December 2008 and February 2009. The actual number of interviews to be conducted was determined by the saturation of data when no more new category emerged. Interview companies were chosen based on purposeful sampling method stratified by the scale of RMAA projects undertaken. As shown in Table I, interviews A to C, D to F, and G to H represent views of RMAA contractors undertaking large, medium and small sized RMAA projects in Hong Kong respectively. Besides, interviewee (I) expressed his opinions by providing written answers to the interview questions. Each interview lasted for about an hour and dialogues were transcribed into written reports after interview. Each interview report was verified by the representatives in the interview.

Table I. Background of the interviewees

No. of Interviews	Position of interviewees	Companies' project scale/ nature
A	Director	Around USD$ 1.3 million - USD$ 13 million
B	(1) Project Safety Manager (2) Project Manager	Around USD$ 1.3 million - USD$ 13 million
C	(1) Managing Director (2) Senior Manager	More than USD$ 13 million, term contract
D	Executive Director	Less than USD$ 2.6 million
E	Managing Director	Around USD$ 1.3 million
F	General Manager	Around USD$ 1.3 million
G	Senior Project Manager	Around USD$ 1,300- USD$ 260,000
H	Director	Around USD$ 1, 000 - USD$ 1.3 million
I	Vice President (Project Development)	Hotel

Qualitative interview data were coded by constant comparative method using the qualitative data analysis software NVivo 8. Interview narratives of common themes and similar semantic meanings were initially coded as the same category. Each category was then compared with other categories continuously during the coding process for refinements until each of them represents a clear and distinct categorization.

Delphi Survey Method

To evaluate the importance of various strategies for improving RMAA work safety, Delphi survey method was adopted which is proven to be an appropriate method of item prioritization (Okoli and Pawlowski, 2004). This study specifically requires participation of key project stakeholders with insights of RMAA work safety practice. Industrial practitioners in the construction industry may not easily figure out and prioritize safety strategies effective to the RMAA sector. Instead of evaluating from one's single perspective, agreement achieved through group-decision making process of clients, contractors, OHS consultants / regulatory bodies of RMAA work is likely to yield a more unbiased and thoughtful result.

A two-round Delphi survey exercise was conducted in a focus group meeting through an interactive online survey system (see Appendix). Two to three rounds of Delphi survey are preferred and found in most studies (Mullen 2003). This minimizes fatigue and attrition of experts in repeated rounds but still allows feedback and revision of response. Design of the first round Delphi questionnaire was mainly based on the categories identified from interviews and supplemented by literature (CII-HK, 2007). As reviewed by Mullen (2003), Linstone (1978) advocates that panel size should not be less than seven while Turoff (1970) suggests that it may range from ten to fifty. According to Powell (2003), representativeness of the expert panel is assessed by its qualities rather than its numbers. It is better to have a heterogeneous group with diversified background to encapsulate a wide knowledge base. As shown in Table II, they are experienced senior management taking care of safety in government organizations, quasi-government organizations and private sector respectively. Some experts are also serving on the board of the Construction Safety Committee of the Construction Industry Council (CIC), which is a statutory co-ordinating body established in 2007 to promote the culture of self-regulation in a market-driven environment (CIC, 2010).

Table II. Background of the expert panel

Expert Panel	Position	Organization
1	Safety Manager	Contractor
2	Technical Manager	Property Management Company
3	Deputy Chief Occupational Safety Officer	HKSAR Government
4	Senior Manager (Safety and Health)	HKSAR Government
5	Representative	Self-regulatory body of insurers
6	Manager	Contractor
7	General Manager	Quasi-government body
8	Principle Consultant	Occupational Safety and Health Council
9	Chairman	Construction Industry Institute- Hong Kong
10	Manager	Private Developer
11	Senior Structural Engineer	HKSAR Government
12	Executive Director	E & M contractor
13	Safety, Health, Environment & Quality Manager	Utility service company

Data were inputted and analysed with the statistical software package SPSS 17.0. The Kendall's coefficient of concordance (W) was calculated to assess the group agreement on the experts' rankings as follows (Siegel and Castellan, 1988):

$$W = \frac{\sum_{i=1}^{n} \left(\overline{R}_i - \overline{R}\right)^2}{n(n^2 - 1)/12} \qquad (1)$$

n = Number of strategies for improving safety performance of RMAA work being ranked

$\overline{R}_i$ = Average of the ranks assigned to the *i*th strategy for improving safety performance of RMAA works

$\overline{R}$ = Average of the ranks assigned across all strategies for improving safety performance of RMAA works

W lies between 0 and 1. The value of 0 represents no agreement among the experts at all while 1 represents perfect agreement among the experts in the panel. As the number of strategies for improving safety performance of RMAA works to be ranked is more than seven, further calculation of the Chi-square distribution is necessary to test the significance (Siegel and Castellan, 1988). It is anticipated that the Delphi survey technique can improve group agreement and hence yielding a more reliable ranking of the strategies for improving safety performance of RMAA works.

The Spearman's rho correlation (r_s) between the first round and second round of Delphi ranking exercises assesses the consistency of the expert panel. Calculation is as follows (Norušis, 2008):

$$r_s = 1 - \frac{6\sum d^2}{N(N^2 - 1)} \qquad (2)$$

d = The difference in rank of the two groups for the same safety strategy
N = Total number of responses concerning that safety strategy

The Kruskal-Wallis Test is a non-parametric test for deciding whether three or more independent samples are from different populations. It tests the null hypothesis that the median scores for three or more groups are the same. If the null hypothesis is rejected, it means that at least one pair of groups has different median scores and thus are from different populations. It is calculated as follows (Siegel and Castellan, 1988):

$$H = \frac{12}{n(n+1)} \sum_{i=1}^{k} \frac{R_i^2}{n_i} - 3(n+1) \qquad (3)$$

H = Kruskal-Wallis Test
n = Total number of observations in all samples
R_i = Rank of the sample

Specifically, the null hypothesis (H_0) and alternative hypothesis (H_1) are set below:

H_0: No difference in the medians of three subgroups with respect to the importance of safety strategies.
H_1: Medians of three subgroups differ with respect to the importance of safety strategies.

When the null hypothesis is rejected, it implies that three subgroups have different perceptions with respect to the importance of safety strategies. When the null hypothesis is not rejected, it implies that three subgroups have similar perceptions with respect to the importance of safety strategies.

The Mann-Whitney U Test was further employed to determine whether two independent groups have been drawn from the same population. It tests the null hypothesis that the median scores for any two subgroups are the same. It is calculated as follows (Siegel and Castellan, 1988):

$$U = n_1 n_2 + \frac{n_2(n_2+1)}{2} - \sum_{i=n_1+1}^{n_2} R_i \qquad (4)$$

U = Mann-Whitney U test
n_1 = Sample size one
n_2 = Sample size two
R_i = Rank of the sample size

Specific null hypothesis (H_0) and alternative hypothesis (H_1) are set as follows:

H_0: Distributions of two subgroups do not differ with respect to the importance of safety strategies.
H_1: Distributions of two subgroups differ with respect to the importance of safety strategies.

When the null hypothesis is rejected, it implies that the two subgroups have different perceptions with respect to the importance of safety strategies. When the null hypothesis is not rejected, it implies that two subgroups have similar perceptions with respect to the importance of safety strategies.

Qualitative interview findings

Referring to Table III, strategies for improving safety performance of RMAA works can be summarized into six categories, namely: (1) incentive and penalty system; (2) legislative control; (3) safety management; (4) safety culture; (5) procurement method; and (6) safety training and education. Since all the interviewees mentioned multiple arenas of strategies for improving safety of the RMAA sector, it seems that no single strategy would be adequate.

Table III. Categories of strategies for improving safety performance of RMAA sector emerged from semi-structured interviews

Categories	Sub-categories
1. Incentive and penalty system	• Penalty • Award • Dismissal • Refrain from future tendering • Promotion
2. Legislative control	• Mandatory registration of RMAA contractors and workers • Negligent workers bear legal responsibility
3. Safety management	• Workplace safety planning and risk assessment • Strengthen site safety supervision
4. Safety culture	• Raise safety awareness • Put more safety resources at the beginning of the project • Establish good safety practices right from the start
5. Procurement method	• Select contractors with good safety performance as partners • Safety performance as one of the important criteria for selection of partners • Safety team attends tender interview • Pay for safety scheme
6. Safety training and education	• Relevant safety training • Ganger/ leader • Provide safety training to subcontractors

Strategy category 1: incentive and penalty system

Incentive and penalty system is the strategy for improving safety of RMAA works mostly mentioned by the interviewees. Safety incentives can be in the form of an award or bonus to subcontractors and site team as encouragement of good safety performance. Sometimes safety incentives have been well built-in the terms of employment as workers' entitlement. An example was given by interviewee B1:

> 'As stated in the employment contract, award or bonus of HK$1,000 (Approx. US$128) will be given to direct labour if a worker doesn't have any injuries due to work within 6 months. There are also safety management practices at site level. For each site, Safety Officer or Project Manager will assess the safety performance of different work groups. For the work group with the best safety performance, HK$1,000 (Approx. US$128) will be rewarded in every three months for each person of the winning group and HK$2,000 (Approx. US$256) for group leader to have lunch with the whole group. Not limited to the above, other safety incentives are implemented such as lucky draw. At company level, we have the best subcontractor award for the year.' (Interviewee B1)

Penalty is imposed on those with poor safety performance. These can be in the form of verbal warning, written warning and fine. For example in company D:

> 'Penalty is imposed on individual worker for unsafe behaviour. For example, there is a penalty of HK$100 (Approx. US$13) for smoking on site and HK$500 (Approx. US$64) for not wearing safety harness. Penalty on individual worker is found to be effective for raising workers' safety awareness. For more serious cases, there would be dismissal. Penalty of refraining from future tendering is also imposed on unsafe subcontractors.' (Interviewee D)

Strategy category 2: legislative control

While some interviewees thought that legislative control was a passive means to resolve safety problems, there were also a few interviewees who perceived that legislative control was an effective safety strategy to be employed in the loosely regulated RMAA sector of Hong Kong. According to Interviewee A, '… legislation is a passive means; too much legislation may not be good but I think it is still possible [to resort to legislative control]'. At present, it is the main contractor that bears most of the legal responsibilities if an accident happens. Only in some cases does the legal liability extend to subcontractor but not at all to the injured worker. Interviewees of company C, D and E coincidently advocated that even the injured worker should bear some of the legal liabilities if the accident has been proved to be his/ her negligence. One possible legislative control measure suggested by the interviewees is temporary suspension of negligent workers from working on site for a period of time. Interviewee F suggested creating a new trade category for RMAA works under the Mandatory Construction Workers Registration System.

Strategy category 3: safety management

Comprehensive company safety management has been identified as one of the strategies for safety improvement. Some RMAA contracting companies are subsidiaries of large contracting companies and follow well-established safety plan of their parent companies. Interviewees of company B and C emphasized the importance of site pre-work briefing and risk assessment to address different hazards and safety needs of RMAA works. They raised the point that, unlike new works, RMAA contractors do not have complete control over the RMAA work site environment. They emphasized the importance of workplace safety planning, anticipate potential hazards and ad hoc problems; and more importantly, come up with proper safety procedures for the workers to follow.

Safety supervision is undoubtedly an important element of safety management. Strengthening safety supervision by more frequent and regular inspections is likely to deter unsafe behaviours and hence preventing accidents. However, it is also recognized that safety supervision of RMAA projects is extremely difficult due to scattered locations. One practical suggestion was given by interviewee B2:

> '… we provide sufficient safety training to the direct labour and then they could act as a ganger or leader to enforce safety when working together with subcontractors' workers. Safety training is also provided to workers of the subcontractors. Everyone in the team can play the role of a safety supervisor by stopping unsafe behaviours of their counterparts.' (Interviewee B2)

Strategy category 4: safety culture

Building up good safety culture and raising safety awareness are suggested by many interviewees. Commitment and determination of the management to improve safety are indispensable in creating good company safety culture. According to interviewee C1, top management of their company demonstrates commitment to safety by putting more than required resources on safety at the initial stage of a RMAA project. They would rather establish strong safety culture right from the beginning than correct poor safety practices afterwards. As suggested by interviewee B1, it is important for the company to set up a system for workers to communicate safety-related information but not just blame unsafe behaviours of workers. Mindsets of workers on safety can be changed by 'providing sufficient safety training and setting up a safety mechanism for workers to have commitment and a sense of belonging to company such as job promotion, stable workforce and learning opportunities' (Interviewee B1).

Strategy category 5: procurement method

The fifth strategy category is about procurement method. It is suggested that safety should be included as one of the key criteria of awarding contracts. Contractor should select subcontractors with good track record of safety performance and develop partnership with them. Company B selects preferred partners with similar vision to put safety as their first priority. There are also some contractual arrangements that contribute to improving safety performance of RMAA works, such as pay for safety scheme and active involvement of safety management team during the tendering process. Interviewee C2 revealed that:

> 'We have adopted policies to share resources with subcontractors; part of it is the pay for safety scheme. Safety team attends the tender interview to convey the safety standards required to the project so that tenderers would not cut corners on safety issues during bidding' (Interviewee C2).

Strategy category 6: safety training and education

The last strategy category postulated by the interviewees was safety training and education. Safety training which focuses solely on new construction works does not meet the specific needs of RMAA workers. RMAA works involve danger and safety hazards different from new construction works. Hence, relevant safety training specifically on RMAA works would be required. Contrary to what one may think, interviewees expressed that the level of safety training for workers in the RMAA sector should be higher than that in the new construction sector. Other than the Construction Industry Safety Training Certificate (commonly known as the 'Green Card' in Hong Kong), RMAA workers require extra safety training to handle multi-tasks safely. Since safety supervision is difficult, RMAA workers need to have a higher level of self-requirement and standard of safety. Representative of Interview F commented that:

> 'Safety problems of RMAA works are different from new works. RMAA workers need safety training to perform RMAA works. For example, it is more difficult and dangerous to erect a bamboo truss-out scaffold with steel brackets from inside an existing premise than to install a massive bamboo scaffold outside a new building' (Interviewee F)

Analysis results of Delphi survey

The ranking agreement among the 13 experts was improved after two rounds of Delphi survey. The Kendall's coefficient of concordance (W) was increased from 0.198 with χ^2 (14, N =13) = 36.072, $p < 0.005$ of the first round to 0.210 with χ^2 (14, N =13) = 38.239, $p < 0.001$ of the second round (Table IV). Thus, the employment of the two-round Delphi survey has successfully contributed to improving agreement of the experts and reliability of our findings.

Table IV. Kendall's coefficient of concordance (*W*) results

	Round one Delphi survey	Round two Delphi survey
Number of experts (n)	13	13
Kendall's coefficient of concordance (*W*)	0.198	0.210
Actual calculated chi-square value (X^2)	36.072	38.239
Critical value of chi-square from table	23.68	23.68
Degree of freedom *(df)*	14	14
Asymptotic level of significance	0.001	0.000

H_0 = Respondents' sets of rankings are unrelated (independent) to each other within each round.
Reject H_0 if the actual chi-square value is larger than the critical value of chi-square from table.

Overall rankings of the expert panel have been consistent in the two rounds of Delphi survey. As shown in Table V, the top three important strategies for improving RMAA work safety in both rounds of Delphi survey are 'Raise safety awareness of RMAA workers'; 'Select RMAA subcontractors with good track record of safety performance' and 'Safety promotion and education towards RMAA sector' respectively. The two least important strategies in both rounds of Delphi survey are 'Technology innovations for better safety' and 'Implement the pay for safety scheme for RMAA works'.

Some noticeable changes occur in the second round of Delphi survey. In the second round, strategies of 'Relevant safety training for specific trades of RMAA works' and 'Build up good company safety culture' emerged to share the third ranking with 'Safety promotion and education towards RMAA sector'. The contractor subgroup changed the ranking of 'Legislative control' from the first in the round one Delphi to the tenth in round two Delphi survey.

Referring to Table VI, the Spearman's rho correlation of rankings between the first round and the second round Delphi exercise of the expert panel was highly correlated at a significance level of 0.01 (*Spearman's rho* = 0.943, $p < 0.001$). As for the rankings of subgroups in the two rounds of Delphi survey, the client subgroup was the most consistent (*Spearman's rho* = 0.962, $p < 0.001$) followed by OHS consultant/ regulatory body subgroup (*Spearman's rho* = 0.684, $p < 0.01$). However, rankings of the contractor subgroup in the two rounds of Delphi survey were found to be not consistent (*Spearman's rho* = 0.312, *n.s.*).

Table VI. Spearman's rho correlations of rankings in round one and round two Delphi surveys

Rankings in Round one & Round two Delphi surveys	Spearman's rho correlation	Sig. (2-tailed)
All experts	0.943**	0.000
Client subgroup	0.962**	0.000
Contractor subgroup	0.312	0.257
OHS consultant/ regulatory body subgroup	0.684**	0.005

** Correlation is significant at the 0.01 level (2-tailed).

Table V. Two rounds of Delphi survey results

		Round one Delphi survey								Round two Delphi survey							
		All experts		Client subgroup		Contractor subgroup		OHS consultant/ regulatory body		All experts		Client subgroup		Contractor subgroup		OHS consultant/ regulatory body	
		Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank
1.	Strengthen site monitoring and safety supervision.	4.00	5	3.80	7	4.33	1	4.00	5	4.15	6	4.00	7	4.33	1	4.20	4
2.	Legislative control.	3.69	10	3.40	13	4.33	1	3.60	13	3.77	13	3.60	12	3.67	10	4.00	10
3.	A mandatory licensing system for RMAA workers.	3.85	8	3.80	7	4.00	4	3.80	9	3.85	10	3.80	8	3.67	10	4.00	10
4.	Relevant safety training for specific trades of RMAA works.	4.23	4	4.20	4	4.33	1	4.20	2	4.23	3	4.40	4	4.00	6	4.20	4
5.	Build up good company safety culture.	3.92	6	4.00	6	3.67	8	4.00	5	4.23	3	4.20	5	4.33	1	4.20	4
6.	Select RMAA subcontractors with good track record of safety performance.	4.31	2	4.80	1	4.00	4	4.00	5	4.54	1	4.80	1	4.33	1	4.40	2
7.	Design for safety of RMAA works.	3.85	8	3.60	11	3.67	8	4.20	2	4.08	9	3.80	8	4.33	1	4.20	4
8.	Award and penalty scheme.	3.62	12	3.80	7	3.33	11	3.60	13	3.77	11	3.80	8	4.00	6	3.60	14
9.	Clear safe working procedures and guidance for RMAA workers.	3.69	10	3.80	7	3.00	13	4.00	5	4.08	7	3.80	8	4.00	6	4.40	2
10.	Improvement of site tidiness and housekeeping.	3.62	12	3.60	11	3.33	11	3.80	9	3.77	11	3.40	13	3.67	10	4.20	4
11.	Raise safety awareness of RMAA workers.	4.54	1	4.60	2	4.00	4	4.80	1	4.54	1	4.60	2	4.33	1	4.60	1
12.	Safety promotion and education towards RMAA sector.	4.31	2	4.60	2	4.00	4	4.20	2	4.23	3	4.60	2	4.00	6	4.00	10
13.	Implement pay for safety scheme for RMAA works.	3.46	14	3.40	13	3.00	13	3.80	9	3.62	14	3.40	13	3.67	10	3.80	13
14.	Technology innovations for better safety.	3.23	15	3.20	15	3.00	13	3.40	15	3.54	15	3.40	13	3.67	10	3.60	14
15.	Provide sufficient safety equipment for RMAA workers (e.g. personal protective equipment (PPE)).	3.92	6	4.20	4	3.67	8	3.80	9	4.08	7	4.20	5	3.67	10	4.20	4

As shown in Table VII, the null hypothesis testing by the Krukal-Wallis test was not rejected for all identified strategies for improving RMAA work safety. This means that the rankings of the three subgroups are not statistically significantly different from each other. This result is further verified by the Mann-Whitney U test. Except comparison between client and OHS consultant/ regulatory body subgroup on 'Improvement of site tidiness and housekeeping' which was 0.042, all other Mann-Whitney U test results were greater than 0.05. Generally speaking, the null hypothesis that medians of two subgroup's rankings are not significantly different with one another after two rounds of Delphi survey is not rejected. This inter-group comparison indicates that even though different subgroups play different roles in the construction industry, they share similar perceptions towards the strategies for improving safety performance of RMAA works.

Table VII. Results of Kruskal-Wallis test and Mann-Whitney U test in round two Delphi survey

	Kruskal-Wallis test	Mann-Whitney U test		
		Client: Contractor	Client: OHS consultant/ Regulatory body	Contractor: OHS consultant/ Regulatory body
	Asymp. Sig.		Asymp. Sig.	
1. Strengthen site monitoring and safety supervision.	0.853	0.636	0.734	0.693
2. Legislative control.	0.587	0.860	0.339	0.491
3. A mandatory licensing system for RMAA workers.	0.644	0.870	0.519	0.197
4. Relevant safety training for specific trades of RMAA works.	0.717	0.514	0.513	0.731
5. Build up good company safety culture.	0.892	0.624	0.905	0.747
6. Select RMAA subcontractors with good track record of safety performance.	0.517	0.558	0.221	0.870
7. Design for safety of RMAA works.	0.264	0.172	0.180	0.693
8. Award and penalty scheme.	0.693	0.636	0.910	0.237
9. Clear safe working procedures and guidance for RMAA workers.	0.590	0.873	0.316	0.520
10. Improvement of site tidiness and housekeeping.	0.101	0.495	0.042*	0.172
11. Raise safety awareness of RMAA workers.	0.737	0.495	1.000	0.495
12. Safety promotion and education towards RMAA sector.	0.202	0.112	0.166	1.000
13. Implement pay for safety scheme for RMAA works.	0.692	0.638	0.429	0.693
14. Technology innovations for better safety.	0.737	0.495	0.549	0.860
15. Provide sufficient safety equipment for RMAA workers (e.g. personal protective equipment (PPE)).	0.606	0.334	0.905	0.430

* Null hypothesis rejected at 0.05 Asymp. Sig.

Discussions of research findings

Findings derived from both semi-structured interviews and Delphi survey have highlighted the importance of human aspect when developing strategies for improving safety performance of RMAA works. While the importance of enforcement and education tactics have been well recognized by the interviewees, the Delphi survey findings also point to the importance of ergonomics, empowerment and evaluation.

Raising safety awareness of RMAA workers is of paramount importance. This can be done by building up good safety culture; providing relevant safety training for specific trades of RMAA works; and investing on safety promotion and education towards RMAA sector. As unveiled in the semi-structured interviews, RMAA workers need to have higher level of safety standard and self-regulation because safety supervision of widely dispersed RMAA works becomes difficult. Safety awareness is intrinsic and incubated by one's mindset and attitude towards safety. As suggested by Geller (2001), it would be easier to change extrinsic behaviours than intrinsic attitude. Mahalingam and Levitt (2007) point out in their study that education and training can change one's mindset and attitude towards safety and thus enhancing safety awareness but it takes time. Reward and penalty immediately change one's safety behaviours but the effect may not be long lasting. The most effective strategy is to carry out dual approaches targeting to change both extrinsic behaviours and intrinsic attitude. Resultant change in either behaviour or attitude will directly or indirectly lead to a change in the other (Geller, 2001). Comprehensive safety management system with empowered culture to the workers' level is vital. Successful safety strategies require leadership and commitment of the management, and empowerment to the workers to engage them in the process of safety management. Our findings also indicate that not only safety awareness of RMAA workers has to be raised but also the establishment of good company safety culture. Safety should be regarded as the basic value and social responsibility of any key project stakeholders in the RMAA sector (Smallwood and Lingard, 2009).

Another important aspect of safety strategy for RMAA works lies on selecting RMAA subcontractors with good track record of safety performance. This finding is comprehensible because selecting subcontractors with good track record of safety performance is one of the important strategies recommended by the Report of the Hong Kong Construction Industry Review Committee to improve the existing safety performance of the whole construction industry (HKCIRC, 2001). The strategy of selecting RMAA subcontractors with good safety performance implies an impact to consideration of procurement arrangement and tenderer selection. Similarly, Anumba *et al*. (2004) point out the importance of choosing competent contractor and appropriate procurement strategy so as to achieve good safety performance. Rather than adopting "the lowest bid gets the job" practice, safety performance should be considered as a key assessment criterion when awarding contracts. According to Smallwood and Lingard (2009), safety should gain the status as important as time, cost and quality in terms of project performance.

This strategy, however, seems to be particularly important for the RMAA sector. As many RMAA subcontractors in Hong Kong are small-to-medium sized companies with varied levels of safety competency and loosely regulated (Hon *et al*., 2010), selecting RMAA subcontractors with good track record of safety performance is particularly essential to the RMAA contractor. Smallwood and Lingard (2009) suggest incorporating OH&S into supply-chain management in which there is socially responsible buying and contracting. They advance the claim that 'socially responsible construction organizations should look beyond their own workers and consider the

OH&S performance of their key suppliers and contractors'. OH&S can be incorporated into the supply-chain by promulgating approved lists of suppliers and subcontractors and implementing mentoring schemes to assist small and medium-sized suppliers and subcontractors in developing their OH&S competency (Smallwood and Lingard, 2009). As revealed in the interviews, some large RMAA contractors have already implemented the policy to work only with those subcontractors having good safety performance record and having a partnering relationship with them. Safety performance should be properly evaluated so that it gains the same status with other aspects of project performance. Smallwood and Lingard (2009) also point out that there should be proper evaluation of safety performance.

Technology innovation often brings about a leapfrog improvement in safety; however, its impact on the RMAA sector is rather limited. It was very important indeed when many construction accidents came from machinery failure of new construction works in the earlier days. With rapid technological advancement, design and quality of equipment and machinery in the construction industry has been improved and better fit for purpose. More importantly, RMAA projects are more likely to rely on handicraft and workmanship but less on heavy equipment. Hence, it is reasonable to find that technology innovation is not so important in improving safety of RMAA works.

Unlike new construction projects, pay for safety is not considered to be important within the RMAA sector. In Hong Kong, the pay for safety scheme (now Pay for Safety and Environment Scheme (PFSES)) is one of the important strategies of the government to take the lead to improve safety performance of the overall construction industry (Hong Kong Government, 2003). It has been adopted mostly in government or quasi-government new capital construction projects. This is a client-driven safety strategy in which a certain percentage of contract sum has been set aside as an incentive for the contractor to perform safety; however, it may be inappropriate or insignificant for RMAA projects with small contract value and short project duration to adopt pay for safety scheme. PFSES now applies to all public capital works contracts (Works Branch, Development Bureau of the Hong Kong Government, 2008), E&M contracts and Design-and-build contracts with estimated contract sum of HK$20M (approx. US$2.6M) or above; and also term contracts with the estimated expenditure of HK$50M (Approx US$6.4M) or above. Irrespective of the value of the contract, term contracts solely for maintenance works (e.g. some E&M maintenance contracts) and contracts with duration of 6 months or less need not be included in PFSES. Due to small contract value and short project duration, many government RMAA projects are exempted from the scheme. It is also unlikely that the private sector clients would consider PFSES to be an important strategy for their RMAA projects. PFSES, as a type of monetary incentive for safety, according to Gangwar and Goodrum (2005), only induces short-term safety motivation. Safety motivation will soon be boiled down as people gradually regard such incentive as their usual entitlement.

RMAA works are usually subjected to less stringent legislative control than new construction works. In view of the soaring RMAA accidents, there are public outcries from the society that legislative control of RMAA works should be tightened. However, this study shows that legislative control has not been perceived to be important in improving safety performance of RMAA works. It is interesting to find that 'Legislative control' was highly favoured by the contractor subgroup in the round one Delphi survey exercise although the contractor subgroup adjusted the ranking to be in line with other subgroups in the round two Delphi exercise. At present, the contractor subgroup has to bear most of the legal liabilities and give compensation to the injured party. It is natural that they want to resort to coercive means. This may seem to be a quick fix to unsafe behaviours and may mitigate the safety supervision effort of the contractor but it also has adverse effects on workers and the government. On one hand, it is hard for the Labour Department to trace back and justify the workers injured or die in an accident is negligent; on the other hand, it is simply unfair to blame the workers for being negligent when there may be some other underlying causes leading to the accident.

Conclusions, limitations and recommendations

This research study has successfully identified and evaluated the relative importance of various strategies for improving safety performance of RMAA works in Hong Kong. Raising safety awareness of RMAA workers and selecting RMAA subcontractors with good safety performance are the two most important strategies to improve safety of RMAA works. These two strategies are not only important to the RMAA sector but also to the whole construction industry. However, importance of these two strategies is particularly amplified in the RMAA sector. RMAA workers need to have higher safety awareness because safety supervision is difficult and they need to actively care for their own safety. The two least important strategies are technology innovation and pay for safety scheme. Although these two strategies have been rather crucial in the new construction works, they are not that important in the RMAA works because of the difference in nature and scope of work. It should be stressed that evaluation of these strategies has been based on personal perceptions only. In the future, more comprehensive evaluation criteria can be developed.

To improve safety performance of RMAA works, it is recommended that effective safety management strategies would be established by the management and supported by RMAA workers from the bottom. Project characteristics of RMAA works, which are typically small in scale and short in duration, greatly hinder safety supervision and law enforcement. Hence, it is particularly crucial in increasing safety awareness of RMAA workers so that they actively care for their workplace health and safety. To raise safety awareness of RMAA workers, a dual approach of safety strategies, which includes a mechanism of reward and penalty and complements with safety education and training, should be recommended. Reward and penalty system should be strictly enforced in RMAA contracting companies with the support from front-line safety supervisors and commitment from top management. Moreover, there should be careful consideration of procurement method. OH&S should be integrated into the company supply-chain management. This could be done by implementing mentoring scheme or establishing partnering relationship between RMAA contractors and subcontractors. Safety performance should be properly evaluated and regarded as equally important to time, cost and quality. To cultivate strong safety culture in the RMAA sector, workers need to be empowered throughout the overall safety management process and involved in evaluating safety performance. Key stakeholders of the RMAA sector should recognize safety to be the core value of their business and accept safety to be part of their social responsibility.

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Appendix: Figure 1. Delphi survey (extract)

Proposed strategies for improving safety performance of RMAA sector To what extent do you think the followings are important strategies for improving safety performance of RMAA sector? *Please indicate your opinions by clicking on the appropriate boxes.*		1 = Not important at all 2 = Somewhat important 3 = Moderately important 4 = Very important 5 = Extremely important				
1.	Strengthen site monitoring and supervision.	1	2	3	4	5
2.	Legislative control.	1	2	3	4	5
3.	A mandatory licensing system for RMAA workers.	1	2	3	4	5
4.	Relevant safety training for specific trades of RMAA works.	1	2	3	4	5
5.	Build up good company safety culture.	1	2	3	4	5
6.	Select RMAA subcontractors with good record of safety performance.	1	2	3	4	5
7.	Design for safety of RMAA works.	1	2	3	4	5
8.	Award and penalty scheme.	1	2	3	4	5
9.	Clear working procedures and guidance for RMAA workers.	1	2	3	4	5
10.	Improvement of site tidiness and housekeeping.	1	2	3	4	5
11.	Raise safety awareness of RMAA workers.	1	2	3	4	5
12.	Safety promotion and education towards RMAA sector.	1	2	3	4	5
13.	Implement pay for safety scheme for RMAA works.	1	2	3	4	5
14.	Technology innovations for better safety.	1	2	3	4	5
15.	Provide sufficient safety equipment for RMAA workers (e.g. personal protective equipment (PPE)).	1	2	3	4	5

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