SAFETY INVESTMENT AND SAFETY PERFORMANCE OF BUILDING PROJECTS IN SINGAPORE

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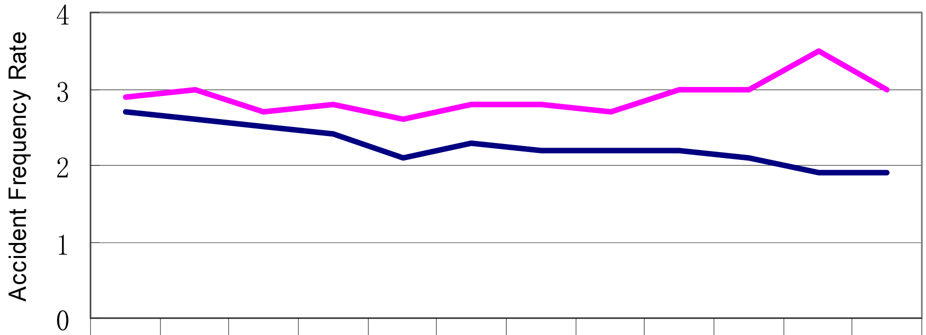
ABSTRACT
Safety investment is aimed at protecting the health and physical integrity of workers and the material assets of a contractor. A popular assumption holds that increased investment in safety produces improved safety performance. However, close examination of previous studies on safety investment reveals that the relationship between the level of safety investment and safety performance remains debatable. The purposes of this study are therefore to: (1) investigate the relationship between safety investment and safety performance in the context of building construction in Singapore; and (2) identify factors influencing the relationship between safety investment and safety performance of building projects. Data were collected by means of conducting a survey. The population of the survey consists of all building contractors in Singapore and the sampling frame is a list of 234 large and medium general registered building contractors with the Building Construction Authority (BCA) of Singapore. Moderated regression is used to analyze the data and describe the relationship between safety investment and safety performance. The findings indicate that the strength /or direction of the relationship between safety investment and safety performance may be influenced by factors, such as safety culture, hazard level, and complexity of a project. Additionally, their relationship might vary under different project conditions. With the establishment of the relationship between safety investment and safety performance, the research can be used as a basis for assisting building contractors to determine a budget for safety management of a building project.

Keywords: Occupational health and safety, Safety performance, Safety investment, Project hazard level, Building projects

INTRODUCTION
For the past few decades, efforts have been made by the government and industries in Singapore to address the problems of workplace safety and health. Safety performance of all industries has experienced a continuous improvement from 1996 (the accident frequency rate was 2.7 accidents per million man-hours worked) to 2007 (the accident frequency rate was 1.9 accidents per million man-hours worked) (MOM, 2008). Conversely, there is no apparent improvement in the construction safety performance. As shown in Figure 1, the accident frequency rate of construction industry has been stagnating at around 3 accidents per million man-hours worked since 1996 (MOM, 2008). Moreover, the collapse of Nicoll Highway along with two other major accidents in 2004, which claimed a total of 13 lives, was a stern reminder that more needs to be done to protect workers on sites (Teo and Ong, 2005; MOM, 2007). Such high fatal rate had prompted the government to examine various strategies for enhancing construction site safety performance.



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
All Factories	2.7	2.6	2.5	2.4	2.1	2.3	2.2	2.2	2.2	2.1	1.9	1.9
Construction	2.9	3	2.7	2.8	2.6	2.8	2.8	2.7	3	3	3.5	3

Figure1: Industrial Accidents by Frequency Rate and Industry
(Source: Occupational safety and health division, MOM (2008))

In 2005, the government undertook a fundamental reform in the WSH framework in order to achieve a quantum improvement in the safety and health for workers. The target was set to halve the occupational fatality rate from 4.9 fatalities per 100,000 workers in 2004 to 2.5 by 2015 so as to attain standards of the top ten good safety records developed countries (MOM, 2007). The new framework is guided by three principles as shown in Table 1.

The reform in the WSH framework suggests that if the prescriptive rules and enforcement procedures do not produce desired results, attention should be directed toward a self-motivating or self-regulating approach to this problem. The Robens Report, *Safety and Health at Work* (1972) takes the view that too much law encourages apathy and apathy is what causes accidents at work. Therefore, voluntary, self-generating effort is the only way to reduce accidents in industry (Nichols, 1997). One way in which such a self-motivating solution could occur would be if decision makers of a business had in-depth understanding of the financial cost and its implications of WSH issues. The main driving force behind the industrial safety movement is the fact that accidents are expensive, and substantial savings can be made by preventing them (U.S. Department of labor, 1955). 'Safety pays' is regularly used by government as a way of motivating employers to attend to occupational health and safety (Hopkins, 1999). Brody et al. (1990) pointed out that when prevention activities are perceived as sufficiently profitable, the investor will be likely to undertake the investments voluntarily.

Table 1: Principles of the New WSH Framework

Three Principles	Desired Mindset Change	
	From	To
Reduce risk at source by requiring all stakeholders to eliminated or minimize the risks they created	Managing risks	Identifying and eliminating risks before they are created
Greater industry ownership of WSH outcomes	Compliance with "Letter of the law"	Proactive planning to achieve a safe workplace
Prevent accidents through higher penalties for poor safety management	Accidents are costly	Poor safety management is costlier

(Source: Occupational safety and health division, MOM (2007))

However, there remain many debates in the literature on whether the increase of investment in construction safety can result in the improvement of safety performance of building projects. Safety investment was assumed by many researchers (Levitt, 1975; Laufer, 1987; Brody et al. 1990) to have positive impact on the safety performance without the support of empirical evidence. The decision tree developed by Hinze (2000) indicates that this impact is largely a game of probabilities, as there might be no injuries even if there is no investment in safety. Recognizing the potential of safety investment to reduce the risk of work injuries, researchers become more concerned about the empirical examinations on the relationship between safety investment and safety performance. Crites (1995) compared safety performance with the size and funding of formal safety programs over an 11-year period (1980-1990). However, it was found that safety performance was independent of – or even inversely related to – safety investment. Tang et al. (1997) examined the function of the relationship between safety investment and safety performance of building projects in Hong Kong and found a weak correlation coefficient (0.25) between safety investment and safety performance. They assumed that the low coefficient of correlation (0.25) might be due to the difference in safety culture of the different companies. However, Tan (2007) gave another possible explanation for the low coefficient of correlation that there might be no relationship between safety investment and safety performance. Therefore, the purposes of this study are therefore to (1) test the relationship between safety investment and safety performance, and (2) identify factors influencing the relationship between them for building projects.

LITERATURE REVIEW

Safety investment for building projects

Safety investment is defined as the costs which are incurred as a result of an emphasis being placed on safety control, whether it be in the form of safety training, safety incentives, staffing for safety, Personal Protective Equipment (PPE), safety programs, or other activities (Hinze, 2000). The components of safety investments have been discussed in some previous studies (e.g., Laufer, 1987; Brody et al., 1990; Tang et al., 1997; Hinze, 2000). Accident prevention cost comprises expenses for safety planning, acquisition of equipment and protective installations, personnel training, salaries for safety staff, safety measurement and accident investigations (Laufer, 1987). Brody et al. (1990) classified safety investments into three types: (1) Fixed prevention costs (FPCs); (2) Variable prevention costs (VPCs); and (3) Unexpected prevention costs (UPCs). FPCs are incurred before production takes place and exist regardless of the accident rate. Examples of FPCs include human resources allocated to safety. VPCs are proportional to accident frequency and severity. They include time taken by accident analysis specialists attempting to identify causes and to prescribe corrective measures. UPCs relate to measures initially unforeseen when a production procedure is originally conceived or when machinery is designed or purchased.

In an attempt to optimize construction safety cost, Tang et al. (1997) collected the data on the investments in safety of building projects in Hong Kong. The information on safety investments was divided into three major investments components, namely (1) safety administration personnel, (2) safety equipment, and (3) safety training and promotion. Investments in safety administration personnel comprise the salaries of these personnel, such as safety officers, safety supervisors, or safety managers in some large companies, and their supporting staff such as clerks and typists. Investments in safety equipment include the expenditure on personal protection equipment and other equipment that involve the provision of safety on building sites. Expenditures on safety training and promotion are also part of safety investments.

Hinze (2000) discussed the most salient components of a safety program for the construction industry while numerous experts were consulted about the costs of the various components of a safety program primarily associated with the petro-chemical and industrial sectors. These safety program elements include: (1) substance abuse testing, (2) staffing, (3) training, (4) personal protective equipment, (5) safety committees, (6) investigations, (7) preparation and implementation of safety program, and (8) safety incentives.

Factors affecting safety performance of building projects

Hazard has been defined as a real or potential situation that may cause unintentional injuries or fatalities to people or damage to, or loss of, an item or belongs (Asfahl, 1990). Therefore, the assessment of safety performance can be conducted by evaluating all on-site hazard elements. With the decrease of its potential hazard, its safety performance improves (Fang et al., 2004). According to the abovementioned definition of hazard, factors determining hazard level of construction sites can be classified by referring to the classification of accident causes (Fang et al., 2004). DeReamer (1980) has grouped the causes of accidents into two categories: immediate causes of accidents and contributing causes of accidents. The former includes unsafe acts and unsafe conditions, while the latter includes mental and physical conditions of the workers and the management policies. In construction industry, Abdelhamid and Everett (2000) have grouped all unsafe conditions on construction sites into four categories: management actions/inactions, unsafe acts of worker or coworker, non-human-related events and an unsafe condition that is a natural part of the initial construction site conditions.

Fang et al. (2004) divided hazard factors into two categories: (1) factors outside the construction site, such as the safety involvement of the employer, designer, subcontractor, consultant, insurer and the public demand and concern on occupational health and safety; and (2) on-site hazards, including the physical conditions and all on-site activities of managers, workers and other organizations, which are then grouped into two categories: immediate factors and contributing factors. An immediate hazard factor is a factor that can cause an accident physically and directly, whether the accident happens or not, including unsafe acts and unsafe conditions. A contributing hazard factor is a factor that can further explain immediate hazard factor, including safety management policy, manager and worker's mental or physical conditions, initial construction site conditions, and so on. Heinrich's accident causation theory (1941) was summarized into two main points: (1) people are the fundamental reason behind accidents; and (2) management is responsible for the prevention of accidents (Peterson, 1982). It is suggested that accidents could be somewhat prevented through endeavors of management.

Therefore, based on the review of causes of accidents on construction site, two hypotheses are postulated as (1) Safety investment has positive effect on safety performance of building projects, and (2) The relationship between safety investment and safety performance of building projects is affected by project hazard level.

RESEARCH METHOD

Instrument

A questionnaire was designed with the objective of examining the relationship between safety investment and safety performance of building projects. The questionnaire consists of four major parts as described below:

- The first part collects the information about the general characteristics of the project, e.g. company size, project size, duration, man-days worked, height of building, type of the project, type of client, and so on.
- The second part asks the respondents to provide information about the safety performance of the project, which is measured by the Accident Severity Rate (ASR). ASR is derived by the following formula:

$$\textit{Accident Severity Rate (ASR)} = \frac{\textit{No. of Mandays Lost to Workplace Accidents}}{\textit{No. of Man-hours Worked}} \times 1{,}000{,}000$$

- The third part aims to collect costs information about safety control activities of the project. Based on the review of previous studies on safety investment, safety investment comprises expenses for all kinds of accident prevention activities. The tangible part of safety investment consists of dollars spent on the accident prevention activities. There is, however, another part of safety investment, namely intangible safety investment, taking the form of time invested in the accident prevention activities, e.g. the time invested in safety training and orientation, the time invested in emergency response drills, the time invested in safety meetings and inspections, and other activities. This part of safety investment is always unobservable, and therefore tend to be neglected by practitioners. With consideration of both tangible and intangible safety investments, the costs items consist of staffing costs, training costs (including formal training courses and in-house safety training and orientation programs), safety facilities costs, personal protective equipments costs, safety committees costs, safety promotion and incentive costs, costs of new technologies, methods or tools designed for workplace safety, and others. A dimensionless quantity, the Safety Investment Ratio (SIR) was used to enable the comparison of the level of safety investment among projects of different sizes. SIR is therefore defined as follows:

$$\textit{Safety Investment Ratio (SIR)} = \frac{\textit{Total Safety Investment}}{\textit{Contract Sum}} \times 100\%$$

- The fourth part scrutinizes the hazard level of the project by assessing each the project scope and the vicinity/location. The framework for estimating the Project Hazard Index (PHI) developed by Imriyas et al. (2008) was adopted for this study. Eleven hazardous trades in building projects and their respective attributes for assessing each trade's hazard were listed in the questionnaire. However, not every hazardous trade may be applicable to a given projects. Thus, applicable trades need to be selected and rated. Respondents were required to rank the attributes on a 5-point Likert-type scale between 1 = "low level" and 5 = "high level" to each of the statements found in this part. The PHI is derived by the following formula:

$$PHI = \frac{1}{m} \bullet \sum_{i=1}^{11} H_i$$

Where $0<m\leqslant 11$; H_1 = degree of hazard contributed by demolition works; H_2 = degree of hazard contributed by excavation works; H_3 = degree of hazard contributed by scaffolding and ladder use; H_4 = degree of hazard contributed by false works; H_5 = degree of hazard contributed by roof works; H_6 = degree of hazard contributed by erection works; H_7 = degree of hazard contributed by crane use; H_8 = degree of hazard contributed by machinery and tools use; H_9 = degree of hazard contributed by works on contaminated sites; H_{10} = degree of hazard contributed by welding and cutting works; H_{11} = degree of hazard contributed by works in confined spaces. The formula for calculating the individual scores is described below:

$$H_i = \frac{1}{n_i} \bullet \sum_{j=1}^{n_i} AS_{ij}$$

Where n_i = number of hazard attributes for i^{th} hazard trade; AS_{ij} = j^{th} hazard attribute score of i^{th} hazard trade.

Data collection

Personal interviews with a questionnaire were used to collect data for this study. The population consists of all building contractors in Singapore. The sampling frame is a list of 234 large and medium general building contractors (A1, A2, B1, and B2) who were registered with the Building Construction Authority (BCA) of Singapore. The reason why small general building contractors (C1, C2, and C3) are excluded from the sampling frame of this study is that, according to practices of Singapore construction industry, small general building contractors (C1, C2, and C3) usually perform as sub-contractors of building projects and it is not possible to acquire complete information about the whole building project from sub-contractors. The building contractors from the sampling frame were contacted via Email or telephone to request them to participate in this study and the contractors whom were interviewed so far (this study is at the initial stage of a three-year research project) are as shown in Table 2. The contact persons (project managers or safety officers) were then interviewed with the questionnaire after he or she agrees to accept the interview. The interviewees were requested to provide information for their project/s that has/have been completed within the past three years. The project managers of these projects were required to review the historical records about the cost information of safety related activities and safety performance of the projects that they had managed.

Table 2: Distribution of Sample Contractors

BCA Grade	*A1*	*A2*	*B1*	*B2*
Population	35	27	57	115
Sample	3	3	3	2

For a single project, three members of site management staff comprising project managers, construction managers, site engineers, safety officers, and safety supervisors were requested to complete the project hazard assessment form, which is the fourth part of the interview questionnaire. The average of PHI value derived from the three questionnaires was used to gauge the project hazard level.

The characteristics of the sample projects were given in Table 3. It was shown that the data were collected from a wide range of building projects in terms of firm's BCA grade, project size, type of project, type of client, percentage of work completed by sub-contractors, and height of building.

Table 3: Sample Profile

Profile	*Number*	*Percent*
Project Type		
Commercial building	2	9.52
Residential building	12	57.14
Office building	5	23.81
Industrial building	2	9.52
Project Size (Singapore Dollars)		
Up to \$10 mil	2	9.52
> \$10 mil ≤ \$50 mil	11	52.38
> \$50 mil ≤ \$100 mil	6	28.57
> \$100 mil	2	9.52
Type of Client		
Private	16	76.19
Public	5	23.81
Height of Building		
Up to 5 stories	7	33.33
> 5 ⩽ 10 stories	5	23.81
> 10 ⩽ 15 stories	4	19.05
More than 15 stories	5	23.81
Firm's BCA grade		
A1	6	28.57
A2	5	23.81
B1	5	23.81
B2	5	23.81

RESULTS AND DISCUSSION

Relationship between safety investment and safety performance

The data were analyzed using the Statistical Package for Social Sciences (SPSS) software. Pearson's Correlation Coefficient was used to test the relationship between variables and safety performance of building projects. The purpose of performing a correlational analysis is to discover whether there is a relationship between variables, which is unlikely to occur by sampling error (assuming the null hypothesis to be true) (Dancey & Reidy, 2004). The null hypothesis is that there is no real relationship between the variables. The results of correlational analysis between safety investment, project hazard level, and safety performance were reported in Table 4. Safety performance and safety investment were weakly related (r = -0.339, p = 0.133 > 0.05). The negative correlation can be interpreted as meaning that an increase in safety investment correlates to an improvement in the safety performance as measured through a decreased ASR value. The correlation between project hazard level and safety performance was also found to be weak and not significant (r = 0.365, p = 0.104 > 0.05). The positive correlation can be interpreted as meaning that an increase in project hazard level correlates to an increase in ASR value. This finding does not support the commonly held assumptions that safety investment is positively correlated to the safety performance of building projects. The low correlation coefficient for safety investment and safety performance is perhaps due to the difference in project and company characteristics, e.g. firm's BCA Grade, project size, project duration, percentage of work completed by subcontractors, height of building, type of project, type of client, and project hazard level.

Table 4: Correlation among variables

Variables		*ASR*	*SIR*	*PHI*
ASR	Pearson (r) Correlation	1.000	-	-
	Sig. (2-tailed)	-	-	-
SIR	Pearson (r) Correlation	-0.339	1.000	-
	Sig. (2-tailed)	0.133	-	-
PHI	Pearson (r) Correlation	0.365	0.355	1.000
	Sig. (2-tailed)	0.104	0.114	-

To ascertain the association between safety investment and safety performance of building projects without the effect of other factors related to project characteristics, partial correlations were applied in this study. Partial correlation is a method used to describe the relationship between two variables whilst taking away the effects of another variable, or several other variables, on this relationship (Dancey & Reidy, 2004). This type of analysis helps spot spurious correlations (i.e. correlations explained by the effect of other variables) as well as to reveal hidden correlations (i.e. correlations masked by the effect of other variables). The effects of other factors on the relationship between safety investment and safety performance were get rid of by 'partialling out' other factors, by statistical means. This is also known as 'holding other factors constant' (Dancey & Reidy, 2004). The control variables in partial correlation are the variables which extract the variance which is obtained from the initial correlated variables.

Partial correlation can be computed using SPSS software. The results of partial correlations were presented in Table 5. The coefficient of correlation r would then be showing us the correlation between safety investment and safety performance when the influence of other factors related to the project and company characteristics was removed. As indicated in Table 5, the correlation between safety investment and safety performance was not significantly changed by partialling out the factors such as firm's BCA grade, project size, project duration, percentage of work by subcontractors, height of building, type of project, and type of client. Project hazard level was found to be the only factor that may influence the relationship between safety investment and safety performance. A moderate correlation (r = -0.538, p = 0.014 < 0.05) was found between safety investment and safety performance for building projects, with project hazard level partialled out. The associated p value was 0.014, which means that there is only a small chance (0.14%) that this correlation has arisen by sampling error. Thus it suggests that, in this small sample (n = 21), the association between safety investment and safety performance was partially due to the project hazard level. Similarly, the correlation between safety performance and project hazard level was significantly increased from 0.365 (p = 0.104) to 0.552 (p = 0.012 < 0.05), with the effect of safety investment removed. The findings indicate that the relationship between safety performance and safety investment is affected by project hazard level. Safety investment has positive effect on safety performance of building projects, when holding the project hazard level constant.

Table 5: Partial correlation between SIR and ASR

Control Variables			*ASR*
Firm's BCA Grade	*SIR*	Pearson (*r*) Correlation	-0.362
Project size	*SIR*	Pearson (*r*) Correlation	-0.363
Project duration	*SIR*	Pearson (*r*) Correlation	-0.322
Percentage of work by subcontractors	*SIR*	Pearson (*r*) Correlation	-0.377
Height of Building	*SIR*	Pearson (*r*) Correlation	-0.379
Project Type	*SIR*	Pearson (*r*) Correlation	-0.259
Type of Client	*SIR*	Pearson (*r*) Correlation	-0.343
Project hazard level	*SIR*	Pearson (*r*) Correlation	-0.538(*)

** Correlation is significant at 0.05 level (two-tailed)*

Curves for the relationship between safety investment and safety performance

Based on the above analysis, the relationship between safety investment and safety performance of building projects is found to be affected by the project hazard level. According to the definition of the rating scale for assessing the project hazard attributes and the formulas for calculating the PHI, the value of PHI ranges from 1 to 5, where "1" represents the lowest project hazard level and "5" represents the highest project hazard level. Therefore, the critical value of PHI was set as "3". The 21 projects were divided into four groups based on the project hazard level (see Table 6). About 90 percent of projects fall into the category of low hazard projects (2≤PHI<3) and category of high hazard projects (3≤PHI<4).

To facilitate the comparison of the relationship between safety performance and safety investment under various project hazard conditions, two curves were plotted based on the abovementioned classification of projects. The first curve described the relationship between safety performance and safety investment under low project hazard level (2≤PHI<3); and the second curve described the relationship between safety performance and safety investment under high project hazard level (3≤PHI<4). Since there are only two projects belong to the categories of extremely low hazard projects (1≤PHI<2) and extremely high hazard projects (4≤PHI≤5), the curves for the relationship between safety performance and safety investment under extremely low or high project hazard level will not be discussed in this paper.

Table 6: Classification of Projects based on PHI Value

Category	*PHI range*	*Number*	*Percent*
Extremely low hazard projects	1≤PHI<2	1	4.8%
Low hazard projects	2≤PHI<3	10	47.6%
High hazard projects	3≤PHI<4	9	42.8%
Extremely high hazard projects	4≤PHI≤5	1	4.8%

Regression techniques were used to plot the curves of the relationship between safety performance and safety investment. Through the review of previous studies on the relationship between safety investment and safety performance, two types of regression models, including

Inverse model (Laufer, 1987) and Exponential model (Tang *et al.*, 1997) were used to determine which model provides the best fit. Table 7 summarized the regression models and parameter estimates for low hazard projects (2≤PHI<3). Both Inverse model and Exponential model provide moderate R square value (0.541 and 0.567 respectively). This indicates that, with Exponential model, 56.7% of the variance in safety performance can be accounted for by changes of safety investment. The chance of the obtained results having been obtained by sampling error, assuming the null hypothesis to be true, is only 0.012 (<0.05). The plot of safety performance against safety investment was shown in Figure 2. Thus, both regression models are suitable to describe the relationship between safety performance and safety investment of building projects when the project hazard level is low *(2≤PHI<3)*.

Table 7: Model Summary and Parameter Estimates (2≤PHI<3)

Equation	Model Summary					Parameter Estimates	
	R^2	F	df1	df2	Sig.	Constant	b1
Inverse	0.541	9.438	1	8	0.015*	-846.424	1827.659
Exponential	0.567	10.469	1	8	0.012*	1875.615	-3.146

** Correlation is significant at 0.05 level (two-tailed)*

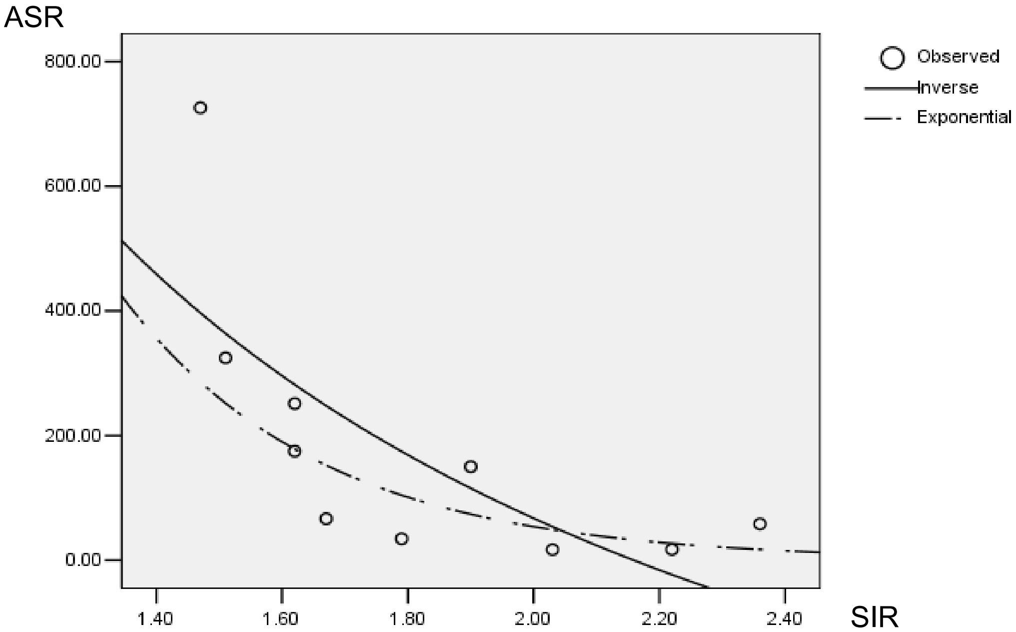


Figure 2: Plot of SIR against ASR under Low Project Hazard Conditions

Similarly, regression analysis was carried out to plot the curve of safety performance against safety investment under high project hazard conditions (3≤PHI<4). The regression models and parameter estimates were presented in Table 8 and the plot of safety performance against safety investment was shown in Figure 3. The R square values for both models were found to be high (0.722 and 0.834 respectively), which indicates a high correlation between the dependent variable and independent variable. Both the two model have an associated probability level of $p<0.05$, showing that the results are unlikely to have arisen by sampling error, assuming the null hypothesis to be true. The exponential model provides a higher R square value (0.834) than the Inverse model (0.722), which means that the exponential model is more suitable to describe the relationship between safety performance and safety investment under high project hazard conditions. 83.4% of the variance in safety performance can be explained by the variance in safety investment for projects with high hazard level.

Table 8: Model Summary and Parameter Estimates (3≤PHI<4)

Equation	Model Summary					Parameter Estimates	
	R^2	F	df1	df2	Sig.	Constant	b1
Inverse	0. 722	18.151	1	7	0.004**	-2950.164	7364.810
Exponential	0.834	35.229	1	7	0.001**	160985.759	-2.984

*** Correlation is significant at 0.05 level (two-tailed)*

The comparison of the curves for the relationship under various project hazard conditions further illustrates the interactive effects of safety investment and project hazard level on the safety performance of building projects. The relatively higher R square value, which represents the higher correlation between dependent and independent variables for the curve under high project hazard conditions, suggests that the effect of safety investment on safety performance is more significant for projects with high hazard level than those with low hazard level. The results of this study provide empirical evidence to support the suggested hypotheses 1 and 2. Safety performance of building projects is positively related to safety investments when holding the project hazard level constant. Furthermore, there is stronger positive relationship between safety performance and safety investments under high project hazard level. The interactive effects of safety investment and project hazard level on safety performance imply that in order to achieve good safety performance, different investment decisions in workplace safety need to be made under different project conditions. The same level of safety investment for different building projects does not necessarily produce the similar safety performance. To achieve a certain level of safety performance, more expenditure on safety is required for those projects with higher project hazard level than those with lower project hazard level.

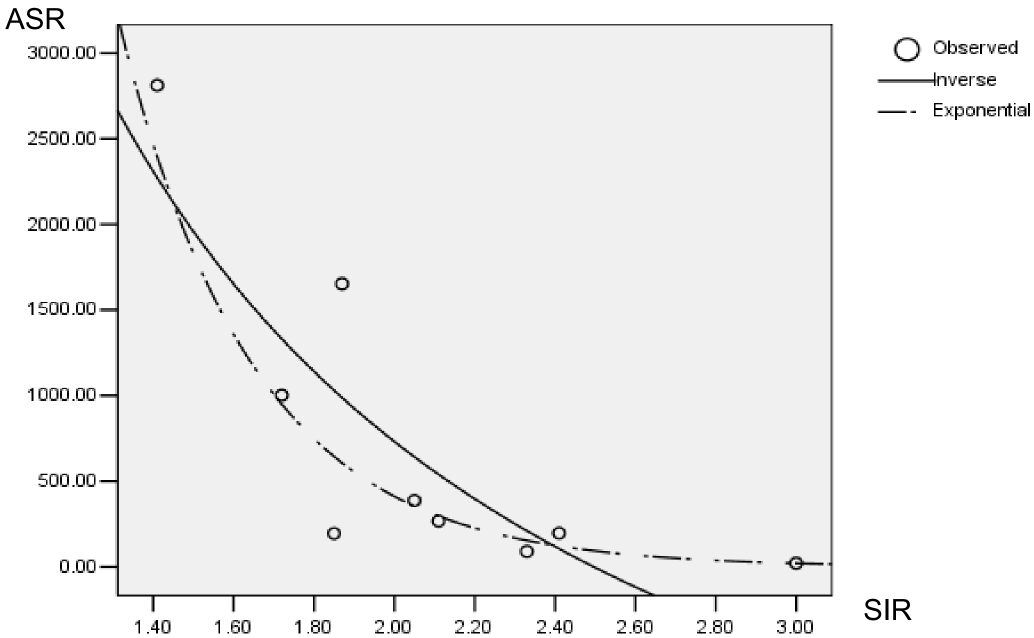


Figure 3: Plot of SIR against ASR under High Project Hazard Conditions

CONCLUSION

This study was focused on the empirical investigation into the relationship between safety performance and safety investment for building projects. The results of correlational analysis and partial correlational analysis indicate that safety performance is positively related to safety investments when removing the influence of project hazard level. Curves for the relationship between safety performance and safety investment were estimated using Regression methods. Comparison of the curves under various project hazard conditions further demonstrates the influence of project hazard level on the relationship between safety performance and safety investment. The curve of their relationship under high project hazard conditions has a relatively higher R square value than that under low project hazard conditions, showing that safety investments have a stronger positive impact on safety performance under high project hazard conditions. The role of safety investment in improving safety performance is more important for projects with high hazard level than those with low hazard level.

The findings of this study can partly explain the low correlation coefficient (0.25) between safety investment and safety performance obtained by Tang et al. (1997), and then may contribute to resolve the debates of researchers on the relationship between safety investment and safety performance. The interactive effects of safety investment and project hazard level on safety performance imply that in order to achieve good safety performance, different investment decisions in workplace safety need to be made under different project conditions. To achieve a certain level of safety performance, more expenditure on safety is required for those projects with higher project hazard level than those with lower project hazard level.

However, project hazard level may not be the only factor influencing the relationship between safety investment and safety performance of building projects. The next stage of this study will examine the effects of other factors, e.g. safety culture, on the relationship between safety investment and safety performance. More rigorous function of the relationship between safety investment and safety performance could be developed with integration of all possible influencing factors.

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