Return on Investment of Safety Risk Management System in Construction

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Abstract

The construction industry has a reputation as one of the most unsafe industries in terms of high incident, injury and fatality rates. A successful Safety Risk Management System (SRMS) can reduce accident rates and protect construction company's physical, organizational and human capitals, hence bring benefit to the project and the company. However, unlike investment in IT or real estate projects which will benefit the firm by selling products such as software and properties, the benefits of inputting money and human resources into safety management cannot be measured easily in tangible and physical terms. In addition, the prior expenses on accident risk prevention measures and approaches always seem very expensive, hence safety risk management system has been considered as a non-returnable investment that is not of benefit to anyone. This misunderstanding widely exists among construction contractors and clients. This paper aims to develop a quantitative measurement model to analyse the return on investment (ROI) of safety risk management systems in construction projects. The model introduced in this research was validated by a case study using data acquired from a real project. Through this study, the economic benefit of a SRMS has been expressed in monetary values hence the stakeholders of construction projects will have a better understanding of the significance and value of (aka return on) investment in safety risk management in construction.

Keywords: return on investment, construction safety management, risk management, cost of construction accident, investment in safety

1. Introduction and research gap

The construction industry is dynamic and diverse, and is of critical importance to a nation's economy. For example in Australia, in 2006-07, the industry employed 936,000 people, represents 9% of the Australian workforce and creates 6.4% of the Gross Domestic Product (GDP) (ASCC, 2008). However, due to the complexity of construction sites, market fragmentation, and high level of small sub-contractors, the construction industry also has a reputation as one of the most unsafe industries (Ore, 1992; Gambatese et al., 1999; Haslam, 2005; Zou et al., 2007; ASCC, 2008; and Gambatese et al., 2008). For example, in Australia in 2006-07, 14,120 claims for compensation were made by employees in construction industry, accounting for 11% of all serious workers' compensation claims, which means there were 39 employees per day requiring one or more weeks off work because of work-related injury or disease. The incidence and fatality rates of construction remained much higher than the average level of Australia for the past several years (ASCC, 2008). On the other hand, the costs of construction accident/incident are also very expensive (Feng, 2009). The cost of work-related injury and illness of construction industry bears 11% of the total costs from 17% of the total number of incidents, accounting for approx 6.3 billion and ranked as the 3rd highest among all industries, only after manufacturing (9.3 billion) and health and community services (6.7 billion) (ASCC, 2009). These data indicate that the construction industry is one of the most dangerous industries so safety management is of critical importance to human life and substantial savings can be made by preventing incidents, which has been considered as the main driving force behind the industrial safety movement (Teo et al., 2009).

Construction safety risk management is not where a company generates revenue but it is a place that does generate profit by reducing safety risk and thus the potential for loss. Effective safety risk management system (SRMS) can be used as a company strategy by construction firms to earn a competitive position of optimum advantage (Rechenthin, 2004). There are three sources of competitive advantage: physical resources, organisational resources, and human resources. Physical resources refer to the organisation's plant, equipment and finances; organisational resources are the organisation's structure, planning, and coordinating abilities; while human resources refer to employees' skills, judgments and intelligence (Barney and Wright, 1998). An effective SRMS protects physical resources and implies an effective organisational resource, but the greatest impact of safety on competitive advantage is the human capital resources. Effective safety management can develop the human capital elements of skills, behaviours, and management system.

Successful SRMS has the potential for assisting the company in cost leadership and providing differentiation. The reduction in construction accident rates can lower operating costs and perhaps most importantly reduce the risk of large losses due to catastrophic injury events (Rechenthin, 2004). Decision makers' motives for the most introduction of a SMS may stem from various concerns such as humanitarian, legal, company image and cost. Studies in construction and in industry in general indicate that the most important motive, however, is the economical one (Laufer 1987). In reality, however, safety is still not one of the main concerns by stakeholders of the project. Although nowadays there is a growing urge for a shift from 'lowest-price wins' to 'multiple-criteria selection' practices in tendering stage, the price that the contractor firm offers is still the most important factor the client concerns when selecting a contractor (Holt et al., 1994; Egemen and Mohamed, 2006).

Since intense competition makes construction market dominated by clients groups (Egemen and Mohamed, 2006), their ignorance of safety may force contractors to cut off their inputs into safety management. In addition, compared with the large amount of inputs at the beginning, it always takes years to identify the benefits of safety management, especially when many benefits are intangible and hard to calculate in monetary value, such as company image and worker's satisfaction (Muñiz et al., 2009). Those barriers lead to a misunderstanding that accident prevention and safety management is a non-returnable investment that is not of benefit to anyone (Occupational Health and Safety Research Institute, 2007). Therefore, the **research gap** can be identified as follow: *in order to promote effective SMS in the construction industry, convincing evidence must be provided to prove the economic benefits of investing in safety risk prevention and management*, which has not been done by previous studies. To fill this gap, a return on investment (ROI) model has been developed. Then the model was verified by a case study using the data from a real construction project.

2. Return on investment and cost-benefit analysis theory

Analysing the cost versus benefits (CBA) and return on investment (ROI) to guide company's investment decisions is clearly important for business and organizations (Stone *et al* 2005). ROI can be defined as a type of cost-benefit analysis conducted from investor's perspective (Stone *et al* 2005). It represents a project's net output (cost savings and/or new revenue that results from a project less the total project costs), divided by the project's total inputs (total costs), and expressed as a percentage (see equation 1). The inputs are all of the project costs such as hardware, software, programmer's time, external consultants, and training (Jeffery 2004).

$$ROI \quad = \quad \frac{TPO - TPI}{TPI} \times 100\% \qquad (1)$$

Where: ROI – Return on Investment; TPO – Total Project Outcomes; TPI – Total Project Investments.

The complexity of the ROI calculation model differs from project to project. Basically, the more complicated the investment, the more complicated the formula becomes. But the main steps for calculating return on investments are very similar and can be briefly described as six steps: data collection; isolate effect of training; converting data to monetary value; identify intangible benefits; tabulate program costs; and calculating the return on investments (ROI) (Rohs 2006, Phillips 1997). The ROI evaluation process can be very complicate. Many factors should be considered when conducting an ROI calculation (Jeffery 2004). For example, the assumptions underlying the cost and benefits of projects; the ability to measure and quantify the costs and benefits; the risks that the project will not be completed on time and on budget and will not deliver the expected outcomes; whether there is a sensitivity analysis and how it is interpreted; whether the project have senior management and end user support; how important the intangible benefit is; etc.

2.1 Costs of construction accidents

The above section tells us that the investment and outcome are the two main elements to analyse the ROI. From the perspective of safety management, the investment refers to construction company's resource inputs in accident prevention and management strategies, such as on-site accident prevention facilities, personal protection equipments (PPE), staff training, design for safety, etc. On the other hand, the outcomes or benefits of investing in safety management refer to the reduction of accident rates, which can be measured by benchmarking the improvement of safety performance and calculating the savings on account of no accident. To measure the savings, we must have a clear understanding of the cost of construction work-related accident.

The systematic study of accident costs was first documented by Heinrich in 1959. He classified the costs as direct and indirect, and concluded that indirect costs were about four times greater than direct costs. Direct costs are those costs of occupational incidents within the industry which are directly measurable in financial terms, while indirect costs are those measured first in labor time and subsequently translated into financial equivalents (Leopold and Lenard 1987). The classification method of direct and indirect cost is also supported by other recent studies, such as the study by Leopold and Lenard (1987). Australia Safety and Compensation Council (ASCC 2009) conduct a study on cost of work-related injury and illness for Australian employers, workers and the community. The methodology adopted by the ASCC report provides a good example of evaluating the direct and indirect costs of construction incidents that borne by workers, employers and the community. According to the ASCC (2009) report, the components of incidents costs can be summarized as in Figure 1:
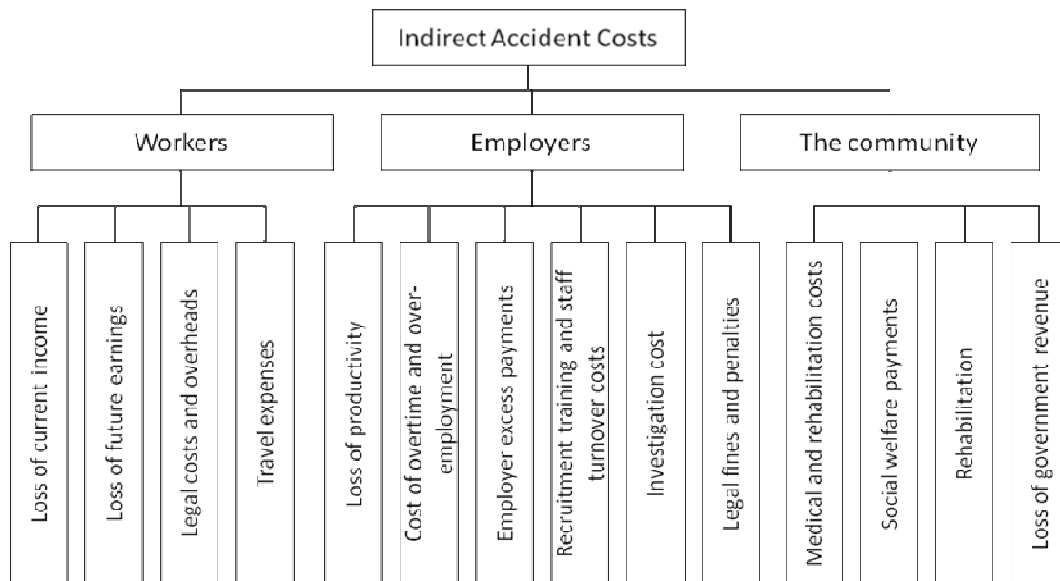

Figure 1: Cost borne by workers, employers and the community (source: ASCC 2009)

Since this study focuses on GCC's building developments in Australia, five mutually exclusive severity categories of incidents are adopted to classify the types of incidents (Table 1) and the definitions are available from the National Dataset for Compensation-based Statistics, 2nd edition (NDS2), and are based on incident severity and duration of absence. The cost items presented in Figure 1 can be distributed to the five types of incidents according to the severity type.

Table 1: Definitions of different types of incidents and severity category

Accident Type	Severity Level	Definition
Short absence	Less than 5 days off work	A minor work-related injury or illness, involving less than 5 working days absence from normal duties, where the worker was able to resume full duties.
Long absence	Five days or more off work and return to work on full duties	A minor work-related injury or illness, involving 5 or more working days and less than 6 months off work, where the worker was able to resume full duties.
Partial incapacity	Five days or more off work and return to work on reduced duties or lower income	A work-related injury or illness which results in the worker returning to work more than 6 months after first leaving work.
Full incapacity	Permanently incapacitated with no return to work	A work-related injury or disease, which results in the individual being permanently unable to return to work
Fatality	Fatality	A work-related injury or disease, which results in death.

Using this methodology, the average cost associated with each severity category can be determined as shown in Table 2. Interested readers may refer to the *"The cost of work-related injury and illness for Australian employers, workers and the community: 2005-06"* for details. Under the ASCC approach, the cost of construction incidents and injuries in 2005-06 borne by employers, workers and the community ranges from AUD$3,372 for short absence injury to AUD$1,689,193 for full or permanent incapacity. It is noteworthy that the cost for full incapacity injury is higher than fatality incident since more on-going costs will be exposed to the employers, workers and the community after the occurrence of a permanent incapacity incidence. In addition, the results summarized in Table 2 is based on the statistics of the year 2005-06, while the costs of construction incidents in the year 2006-09 should also be available since the project under study was all developed after the year 2006. To solve this problem, a discount rate of 3.9 per cent was employed to calculate the future costs for the following years. This discount rate was also used in the ASCC methodology for discounting future monetary values of new cases for the reference year.

Table 2: Summary of average cost associated with each severity category from 2005 to 2009[1]

Cost of reference year	Short absence	Long absence	Partial incapacity	Full incapacity	Fatality
2005-2006	*3,344*	*35,638*	*260,672*	*1,686,819*	*1,571,529*
Employer	*2,460*	*5,297*	*55,100*	*74,180*	*54,694*
Worker	*337*	*5,326*	*61,090*	*1,065,853*	*1,048,473*
Community	*547*	*25,015*	*144,482*	*546,786*	*468,362*
2006-2007	*3,474*	*37,028*	*270,838*	*1,752,605*	*1,632,819*
2007-2008	*3,610*	*38,472*	*281,401*	*1,820,957*	*1,696,499*
2008-2009	*3,751*	*39,972*	*292,376*	*1,891,974*	*1,762,662*

[1] The discount rate used to estimate the costs from the year 2006 to 2009 is 3.9 per cent per year.

2.2 Investment in Safety Risk Management

Safety investment often refers to those costs of accident prevention activities, which aim to protecting the health and physical integrity of workers and the material assets of a contractor (Tang et al 1997). The components of safety investments have been discussed in many previous studies, such as training, drug testing, safety incentives, staffing for safety, personal protective equipments, safety facilities, safety programs, etc (Laufer 1987, Brody et al 1990, Tang et al 1997, and Hinze 2000). Feng (2009) summaries the components of safety investments and classifies them into six main categories, which together with their sub-categories are demonstrated in Figure 1. In our study, the Safety Investment Ratio (SIR) was used to enable the comparison of the level of safety investment among projects of different sizes and scopes (Feng 2009). The SIR is therefore defined as follows:

$$SIR = \frac{Total\ Safety\ Investment}{Contract\ Sum\ of\ Project} \times 100\% \qquad (2)$$

Where the total safety investment is the sum of safety investment components listed in Figure 2, and the contract sum refers to the total budget of the project.
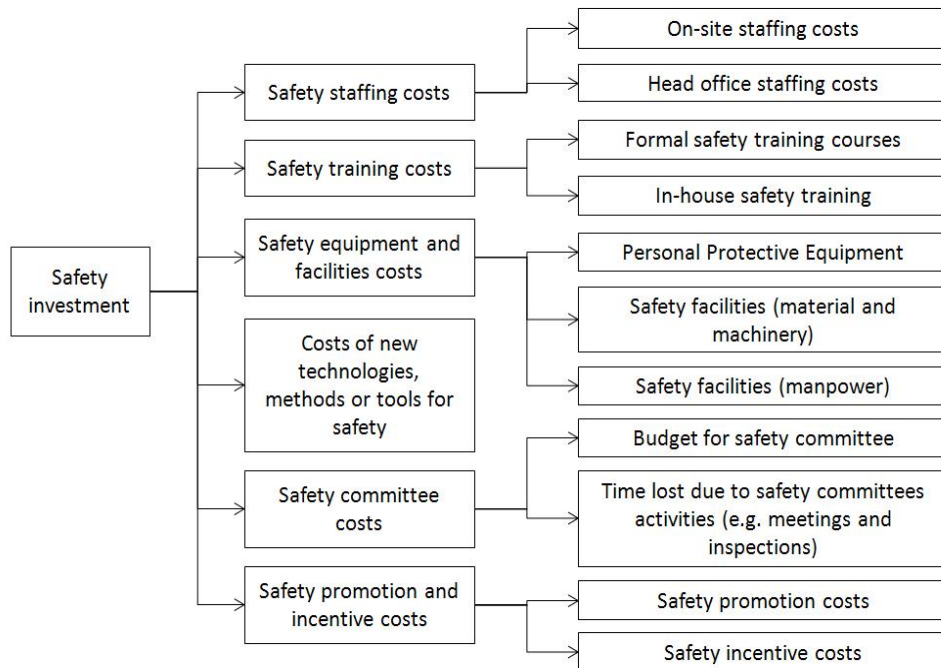
Figure 2: Components of safety investment

3. The proposed ROI model

Based on the literature review, the specific model for calculating the return on investment of construction safety management system is illustrated as Figure 3. The step-by-step process of the ROI model is described in the following sections:

Step 1 – Calculating the cost of construction incidents

This step is critical to the research because accident cost is the key data to calculate the benefit – savings amount from improvement of safety performance. Therefore, a comprehensive and accurate methodology is essential for analyzing the ROI. The 'incidence approach' and 'ex-post approach' which have been used in an Australia Government report (ASCC 2009 and NOHSC 2004) are applied in this study to calculate the accident cost. A serious of data is needed at this step, such as the number of incidents under different severity categories, staff training and/or retraining costs and durations, medical and rehabilitation costs, investigation costs, etc. The calculation processes will not be given in this paper, interested readers may refer to the full report for details.
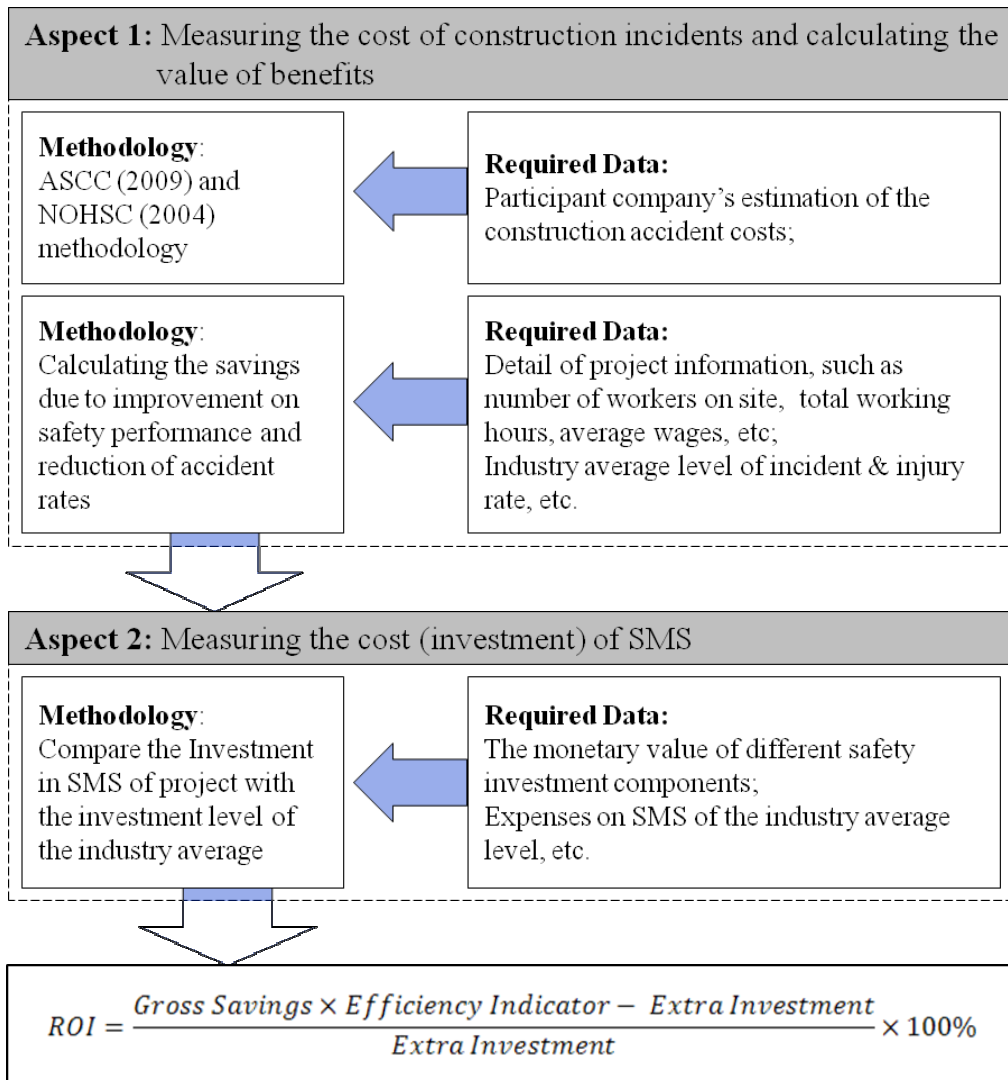
Figure 3: ROI Model proposed by this study

Step 2 – Calculating the benefit (ie savings) of SRMS

This step is the core element of the study, because convincing benefits can prove the significance and necessity of safety management that accident prevention is not a non-returnable investment, but has huge impact on people and company finance. For construction companies with a systematic and better safety management system, the prior inputs into safety management seems much more expensive than their competitors, but once the benefits are calculated in monetary value, one can see how much economic benefits can be generated through an effective safety system. Direct benefit of SMS can be defined as the savings on costs of no incidents; those can be calculated through comparing the accident rates of target project with national or industry indicators, then multiplying the difference with the cost per accident or with workers' hourly wage. On the other hand, the direct benefit can also be reflected by the savings on working hours of the project compared to the industry average. The

monetary value of savings on hours of no accident can be measured by multiplying the saving on hours with worker's hourly wage.

Step 3 – Measuring the extra cost (ie investment) of SRMS

In this study, the investment in certain SMS will be compared with the safety investment of the Industry Average level to examine whether higher safety investment can bring economic benefit to the project. According to the literature review, the components of safety investment can be grouped into six categories, including safety staff costs, safety training costs, safety equipments and facilities costs, safety committee costs, safety promotion and incentive costs, and costs of new technologies, methods or tools designed for safety.

Based on the three aspects discussed above, the ROI of SMS can be calculated through a simple mathematical process using the results from previous steps that related to the monetary value of costs and benefits. The final form of the ROI calculation formula is demonstrated in Table 3.

Table 3: The ROI calculation formula: definitions and description

The ROI calculation formula is illustrated as follows:	
$$ROI_c = \frac{\sum_{i=1}^{5}(IASP_i - NAPP_i) \times IC_i - (IHSPP - IHSSP)}{(IHSPP - IHSSP)}$$	
Term	Description
ROI_C	**Return on Investment for the Construction Projects**: *this ROI calculation reflects whether a higher investment in health and safety can achieve the target of safety improvement, and bring economic benefits to the project performance.*
$IASP_i$	**Industry Average Accident Level under Severity i for Standard Project**: *According to NDS2, the severity of construction accident is classified into five categories. So $IASP_i$ is the number of incidents under certain severity of a standard project, it reflects the accident level of the industry average.*
$NAPP_i$	**Number of Incidents under Severity i for Particular Project**: *$NAPP_i$ is the number of incidents under certain severity that actually occurred on construction site.*
IC_i	**Incident Cost**: *ACi refers to the cost of construction accident under certain severity category. It includes those burdened by workers, employees and the community*
IHSSP	**Investment in Health & Safety for Standard Project**: *IHSSP is the amount of expenses on SMS for a standard project. It reflects the inputs in health and safety measures of the industry average level.*
IHSPP	**Investment in Health & Safety for Particular Project**: *IHSPP is the amount of expenses on SMS for a particular project. It reflects company's inputs in health and safety for certain project.*

4. Case Study

To verify the ROI model proposed in above sector, a case study of a Medical Research Centre (MRC) project will be utilized. The MRC project is developed by General Construction Company (GCC) (For confidential consideration, the names are fictional, but the company and the project are real). GCC is one of the world's leading project management and construction companies with the headquarter located in Australia. In 2002 GCC introduced a safety management system which focuses on the current safety program, improves performance and addresses what is missing on the human and cultural side of the equation for the company to a safe workplace. This SMS has been implemented to all GCC projects across the country, including the MRC project. The project under study is owned by a large university in Australia.

Site-work of the MRC project commenced in November 2007 and the construction period lasted for about 30 months. The total project investment was approx 100 million of which 3.02% was input into safety management, which is much higher than the industry average of 2.0%. At first, its focus was to increase the initial costs of projects because of higher safety management investment, assumed and accepted by the client (university). However, under an effective safety management system, it was possible to see how, on this huge site, accident would not occur that might unfortunately occur in similar projects. The basic information of the MRI project is illustrated in Table 4; the statistics of Australia construction industry of the reference year is listed in Table 5; the comparison of statistics of safety performance between the MRC and the Industry Average is demonstrated in Table 6.

Table 4: Basic information of the MRC project

Project name	*Medical Research Centre*
Project location	*New South Wales*
Construction period (months)	*30*
Total project investment (AUD$ million)	*100*
Safety Investment Ratio (SIR, as a% of total project budget)	*3.02*
Total hours worked on this project (hrs)	*711,192*

Table 5: Statistics of incidents, injuries and fatalities of construction industry in Australia (2007-2009)

		2007-2008	*2008-2009*	*2007-09 Average*
Short absence[1]	*Number of claims*	*5454*	*5520*	*5487*
	Frequency rate[2]	*16.4*	*13.1*	*14.75*
Long absence	*Number of claims*	*11560*	*11709*	*11634.5*
	Frequency rate	*8.6*	*7.9*	*8.25*
Partial incapacity	*Number of claims*	*1730*	*1838*	*1784*
	Frequency rate	*1.3*	*1.2*	*1.25*
Full	*Number of claims*	*1115*	*1133*	*1124*

incapacity				
	Frequency rate	0.8	0.7	0.75
Fatality	Number of claims	37	42	39.5
	Frequency rate	2.8	2.7	2.75

[1] The data for short absence injuries is based on the statistics of NSW rather than the national scope, because in Australia, Jurisdictions have different excess period where the costs of injury/disease are paid during the excess period before compensation from insurers is kicks off. Since the project under study is located in NSW, the statistics of NSW were selected for data analyzing.

[2] Frequency rata of occupational injuries and diseases is the number of cases expressed as a rate per 1 million hours worked by employees. Such rates are calculated using the following formula:

$$Frequency\ rate = \frac{number\ of\ occupational\ injury\ and\ disease\ cases\ \times\ 1,000,000}{number\ of\ hours\ worked}$$

Frequency rate for fatal incident is based on per 100 million hours worked by employees.

(**Source:** The Safe Work Australia Online Statistics Interactive National Workers' Compensation Statistics Databases)

Table 6: Comparison of statistics of safety performance between MRC project and Industry Average

	Number of incidents & injuries		
	MRC	Industry Average	Difference
First aid injury	50	Unavailable info	-
Short absence	2	9.28	7.28
Long absence	1	5.87	4.87
Partial incapacity	0	0.89	0.89
Full incapacity	0	0.53	0.53
Fatality	0	0.02	0.02

In Table 6, the number of claims for the Industry Average (IA) is estimated based on the statistics in Table 5 using the following steps: (1) take the number of 'long absence' as an example, the project duration for the SP1 was from FY 2007-08 to FY 2008-09, hence the frequency rate (FR) of this incidents should be the average frequency rate of these two financial years:

$$FR\ of\ long\ absence\ for\ IA = \frac{8.6 + 7.9}{2} = 8.25$$

(2) Once the frequency rate is fixed, the number of claims can be measured using the following equation:

$$No.of\ long\ absence = \frac{FR\ of\ long\ absence\ \times\ hrs\ worked}{1,000,000\ hrs} = \frac{8.25 \times 711,192\ hrs}{1,000,000\ hrs} = 5.87$$

Once the difference in number of incidents and the cost of relevant incidents are determined, the savings on reduced number of incidents can be therefore calculated. The calculation processes of the

savings for the MRC project are demonstrated in Table 7. For this project, approx AUD$1.5 million can be saved from a better safety performance compare to the Industry Average.

Table 7: Calculation of savings on account of no incidents of the MRC project

		Short absence	*Long absence*	*Partially incapacity*	*Full incapacity*	*Fatality*
MRC	*Difference in safety performance*	*7.28*	*4.87*	*0.89*	*0.53*	*0.02*
	Costs of incidents (AUD$)[1]	*3,681*	*39,222*	*286,889*	*1,856,466*	*1,732,581*
	Savings on each severity (AUD$)	*26,794*	*191,011*	*255,331*	*983,927*	*34,592*
	Saving of no incidents (AUD$)	***1,491,654***				

In terms of safety investment, data of the relevant components summarized in Figure 1 were collected from GCC. For the MRC project, the total inputs for safety management was AUD$3,021,126. With a total project budget of AUD$100 million, the SIR for this project is estimated to be 3.02% (total safety investment divided by project budget). In terms of safety investment of the Industry Average, a SIR of 2% of the total project budget will be assigned to the Industry Average. Therefore the extra safety investment of the MRC project can be calculated as follows:

$$\text{Extra Safety Investment} = \text{AUD}\$3,021,126 - \text{AUD}\$100 \text{ million} \times 2\% = \text{AUD}\$1,021,126$$

Through the above data collection and calculation processes, the return on safety investment can be calculated using simple mathematical equation as follows:

$$\text{ROI for MRC Project} = \frac{\text{Savings of no incidents} - \text{Extra Safety Investment}}{\text{Extra Safety Investment}} \times 100\% = \frac{\$1,491,654 \times 1.0 - \$1,021,126}{\$1,021,126} \times 100\% = 46.08\%$$

5. Discussions

5.1 The case studied

From this ROI calculation, we can see that although the safety investment ratio (3.02%) for the MRC project was much higher than the Industry Average (2.0%), the MRC project has also achieved a better safety performance than the Industry Average. With a higher safety investment, approx AUD$1.5 million can be saved from the reduced number of construction incidents, which could generate a return on safety investment of 46.08%. It should be noted that the figures of 'difference in safety performance' in Tables 6 and 7 were not rounded to integers, such as the number of fatal incident for Project 1 was estimated to be 0.02, which could not happen in real life. However, it is still considered reasonable to keep those numbers which are less than one (incident) because: (1) although the data collection and analyzing were based on single project, the comparison study was however designed to analyze the entire industry and the results reflect the safety performance under different safety investment levels of the industry rather than single project; (2), besides comparing the number of claims of incidents, an alternative way of comparing the safety performance is to measure the lost days (or hours) between the GCC projects and Industry Average, hence the figures listed in Table 6 and 7 can be also converted into lost days (or hours) and keeping the fraction will make the results

more convincing and accurate, and (3) the difference in safety performance can be also considered as a reflection of the probabilities of occurrence of incidents.

5.2 Limitation and recommendations for future study

The main limitation of this research is the exclusion of intangible benefits. For many reasons, the intangible benefits are often very difficult to be measured in monetary value in many industries. In terms of construction sector, intangible benefits of safety investment may include, but not limited to, worker's motivation, client's satisfaction, company's market share, image and reputation, etc. So far there are still few systematic methodologies that are able to measure the intangible benefits subjectively, which is also an important limitation faced by this research. In general, the value of intangible benefit is often considered to be much larger than the tangible benefits, hence the overall benefits will be much more significant if the value of intangibles can be calculated.

Further work can be done to replicate this research on a larger scale. For example, future studies can involve more projects from the same company. The ROI model proposed in this paper can be also used as a self-assessment tool within a company to determine the success of a SMS by comparing the safety performance before and after the implementation of a SMS. In general, the more construction projects get involved, the more accurate the research result will be. In addition, the model developed in this study can be also utilized to compare the ROI of safety investment of different construction companies. Replication of this research on a larger scale will allow researchers to assess the generalisability of the findings across the construction industry to have a better understand of safety investment.

6. Conclusion

With the development of the construction industry, the significance of safety risk management has been realized my project stakeholders. Governments, scholars, and industry players have put lots of commitment into safety risk management, developing guidelines, tools and systems to prevent incidents and injuries. However, the high prior expenses on safety management often place conflicts with traditional project objective by increasing tendering prices. Meanwhile, many previous studies were focused on the input stage (investment and management) of SRMS rather than the output stage (safety performance), some of which analyzed the costs of incidents and injuries but didn't link the incident costs with benefits. Hence inputing resources into safety are often considered as a non-returnable investment.

The focus of this research is on the return on investment (ROI) of the safety risk management system of construction projects. The main research findings of this study can be concluded as follows: first, a quantitative method has been developed to measure the ROI of safety management system, which provides an innovative and objective way to prove the important of safety management in construction projects; second, the high costs of construction incidents – especially full incapacity and fatality – will largely impact the financial performance of construction projects that reducing the number of claims will bring huge savings to the project; third, under an effective SMS, the increasing expenses on safety management will be covered by the savings from no incidents.

The ROI model proposed in this paper was verified by a case study of a Medical Research Center projected developed by General Construction Company. Using the methodology of the ROI model, the safety investment of this MRC project has achieved an ROI of 46.08%, which proves that increasing investment in SRMS can bring economic benefits to the construction project. The significance of this study is that it provides a good example of measuring the benefits of safety investment using quantitative approaches. The data analysing of this study was based on the actual statistics collected from relevant database rather than traditional methods such as questionnaire survey and interview, which guarantees the objectiveness and accuracy of data analysing and research findings. On the other hand, the way of data collection and analysing has also provides a good example for the collaboration between university and industry company. One of the departure points for this study is that the industry company (such as GCC) was urgently searching for a way to evaluate the performance of their safety management system, hence the collaboration agreement has given the advantage that the researchers had more accessory to the data which may not be acquired from other sources.

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