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Measuring Construction Site Safety in Kolkata, India

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Abstract— This paper investigates the safety status in building construction sites in Kolkata, India. The study was based on surveys conducted in construction sites. Despite existence of Indian safety codes and contractual obligations the sites were found to be deficient in enforcing the requirements. A relative importance index was proposed for comparing safety aspects among sites. A cost-benefit analysis based on Monte Carlos' simulation was used for investigating the economic forces that may hinder proper implementation of safety rules.

Index Terms— Construction safety, Developing countries, construction fatality, safety simulation, safety gradings, safety index Indian safety, Kolkata construction, safety economics, safety culture

1 Introduction

Accident risks in construction industry is much higher than the average occupation risks faced by workers. This is true not only for India but also in the rest of the world. An elaborate safety mechanism has been installed in developed economies for containing accident risks in construction sites. However, the required safety mechanisms are often ignored in developing countries spanning from Asia to Latin America [1,2]. Similar situations also exist in neighbouring countries of India. It has been reported that occupational health and safety has not been appropriately developed in Bangladesh [3]. The construction safety and health conditions of Pakistan are inadequate and fragmented [4]. A survey over 3000 participants in Srilanka indicated that the workers are generally dissatisfied with the safety conditions [5]. At about 15 years ago the construction fatalities were about 600 per hundred thousand workers in India compared to that of 70 in USA [6]. Continous vigilence had beneficial effects on safety performance. For example, United States experienced a significant reduction in its construction fatalities since 1992, when it was 18.6 per 100,000 workers that is three times greater than Sweden's rate of 6.0 per 100,000 workers at the same period [7]. By 2005, Sweden and USA had both reduced the fatality rate to 4.4 and 11 for each 100,000 construction workers [7]. In India, construction is considered as a highly hazardous industry and the rate of fatal accidents is 4 to 5 times that in the factories sector [8]. In order to improve upon the status the Indian Government in 2001 had proposed a national safety policy and an apex body in line with OSHA, USA for monitoring the safety aspect of the industry [8]. Legislations like the Building and other Construction Workers (Regulation and the Employment and Conditions of Service) Act, 1996 have been enacted [9]. There was some progress in reducing fatality rates since then. Ha¨ma¨la¨inen, Takala and Saarela estimated in 2006 that the occupational fatality rates in India and China are 11.5 and 10.5 per 100,000 workers respectively which are close to that of USA [10]. However, non fatal occupational accident rate that is accident causing more than three days of absence is about 8763 per 100,000 workers. It is better than neighbouring countries like Bangladesh and Pakistan where such rates are 20132 and 15809 respectively [10] but falls short of adavanced economies. For example, the non fatal occupational accident and construction accident rate in USA is 3959 [10] and 2395 per 100,000 workers respectively [11] which are considerably less than that of India. In short, construction safety is improving in India in the last 15 years but is still much behind than that of the advanced economies.

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2 Objectives & Scope

2.1 Measuring site safety

The first objective of this article is investigating the possibilities of measuring the construction site safety relative to neighbouring sites. Qantitative measures would allow comparing sites so that a system for remedial measures for safety ingress can be intitated for defaulting sites. This study is targeted to multistoried building sites where relatively smaller contractors operate in great heights. Analysis of the root cause of accidents is probably the best means of safety evaluation [12]. For example, a report for health and safety executives [13] in UK analyzed 100 accident reports for developing the root cause of safety violation leading to the accidents. The study used the existing databse of the accident reporting system that is RIDDOR in UK [14]. In India, fatal or major accidents are reported to the authorities but such database like RIDDOR has not been made available. Several researchers in India have individually collected accident histories for analysis. Kulkarni estimated 5-20% job related deseases to Indian construction workers [15]. Rana and Goswami [16] studied 10 numbers fatal accident cases from all over India for assessing prevention measures. Kausar and Varghese [17] analysed a relatively bigger sample consisting of 115 fatal cases in a large city. All the autopsied cases of deaths in construction sites occurred from 2001-2010 that is over a 10 years period conducted at St.

Johns Medical College, Bengaluru, India was studied. They concluded that movable crane is the major source of fatal accidents. In absence of a centrally maintained database like RIDDOR in UK these analysis suffers from inadequate sample size and might not be suitable for the present case. In other developing countries like India field research techniques have been employed. Zeng, Wang and Tam [18] studied questionnaire surveys from 20 construction sites in China for estimating the important causes of accidents. The study showed that about 70% of the accidents in building sites are related to working at height that is like fall from upper storeys, scaffolding collapse, impact of debries from above etc. They have estimated relative importance index in estimating the causes of accident. Similar studies have been conducted among 42 contractors in Gaza strip [19]. Relative importance index method was adopted for ranking problems about construction safety. The top factors include absense of personal gear and safety supervision. A similar study for assessing relative important indices was conducted in 27 multistoried building sites in Pakistan [20]. The study revealed that the workers did not wear personal protection gears like ear muff, safety belt, shoes etc. It has been felt that similar site inspections as done in these studies [18], [19], [20] would reveal site safety status of the present case. Relative importance indices have been estimated in the present study from site inspections.

2.2 Economics of site safety

The second objective of this study is investigating the economic aspects of site safety. Building construction in India like other developing countries is a fragmented and highly competitive industry. Safety issues are often marginalized in such situation [21]. In many developing countries as in India there are no reliable data partly because of lack of insurance coverage, which means that reports of accidents are frequently not filed [22]. Idoro [23] found that in Nigera, multinational, national, regional or local contractors do not differ with regard to their compliance with health and safety regulations and fall far short of the requirements. Okolie and Okoye [24] found that the regulatory framework for construction safety in Nigeria is fragmented and rarely implemented. Belel and Mahmud [25] also noted that in Nigeria the stake holders often push construction safety to the lowest of the priorities. Economic factors in developing countries are one of the reasons for poor implementation of labour laws in construction sites [26]. Enhassi et al [27] found that the safety legislation is limited and are rarely addressed with seriousness for want of resources. In a resourceful city state like Hong Kong most contractors set aside only an amount of less than 0.5%, and some even less than 0.25%, of the contract sum for investing in safety in their contracts [28]. Tang, Lee and Wong [29] concluded that safety cannot be limitless but proposed a framework for optimization after analysing about 500 accidents in Hong Kong. Tam et al [30] proposed fuzzy decision support system for construction safety. Poon, Tang and Wong [31] proposed a framework for optimizing safety cost. The principle usually applied to inventory cost optimization was used. The accident loss and safety investment has been compared for estimating the optimized safety level. In the present case study in Kolkata, India detail records of construction accidents are not collected as in Hong Kong. The methods proposed by Tam et al [30] or Poon et al [31] are not directly applicable. In this case, costs of actual accidents as occurred to the study sites have been compared with the actual safety investments. The proposal of Poon et al [31] has been employed in principle.

3 Methods and Materials

3.1 Site safety

All technical standards for construction in India have been codified in Indian Standard Codes published by the Bureau of Indian Stadard (BIS). A compendium of all building construction related codes have been summarized in a reference called 'National Building Code of India" (NBC) [32]. There are numerous BIS codes dealing with individual aspects of construction safety in details. Atleast sixty such codes have been refered in NBC, Part VII [32]. In addition, there is a compendium summarizing these individual safety codes [33]. The BIS standards are advisory but not obligatory under any statue. In order to control the safety aspect of construction workers in a comprehensive manner a statute has been enacted in 1996 by the Government of India [34]. The financial aspects of safety like accident benefit and hospitalization facilities have been covered under other statutes [35], [36], [37]. There are several other central and state acts that have been enacted for safety and welfare of workers in construction sector over a long period of governance in India [38], [39]. The provisions of these acts make it mandatory to follow minimum health and safety related rules in construction site. Such statutory requirements more or less follow the provisions of BIS codes or NBC wherever applicable. However, provisions of NBC are detailed, technically drafted and exhaustive. In most Indian construction contract, compliance to NBC is made mandatory. The Indian construction safety code [32] has been compared with that of industrialized countries like Australia [40], International labour Organization [41], Canada [42] and Hong Kong [43]. The primary safety requirements of international codes are comparable to that of Indian code SP 70 [33]. Threrfore, in theory, there are substantial safety provisions for construction workers in most construction contracts in India. However, attitudes towards the safety compliances are of concern in this investigation. The codes have been studied and a list of important safety parameters indicated in all international codes as well as in NBC of India has been selected. A survey in four numbers building construction sites was conducted for observing the level of compliances of these safety parameters. The provisions of the parameters as mentioned in the NBC of India were the yardstick for measurement. Compliances to safety parameters were tested in a five point, 1 being the best and 5 being the worst, Likert scale. Based on the level of safety non-performance, the Factor Non-Performance Index (NPI) and the Factor Performance index (FPI) were estimated.

$$\text{Non-performance Index (NPI)} = \frac{\Sigma\ (\text{Factor score x No. of sites at a particular score})}{(\text{Total no. of responses for a factor x 5})}$$

Where, "5" in denominator indicates the score at the maximum level of safety non-performance. Conversely, Performance Index (PI) = 1 – NPI. Such quantitative measurements allowed comparisions of sites in the matter of safety parameter compliances for further analysis.

3.2 Safety cost

It has been discussed earlier that safety investment cannot be unbounded and a rational judgement for safety cost is required. Some researchers have proposed an optimization concept similar to inventory management [31]. For most stakeholders, safety mechanisms are instituted because of statutory requirements. However, researchers have universally noted that safety parameters including statutory requirements are mostly flouted in developing countries as discussed elsewhere in this article. Such a universal disregard to safety issues in developing countries is probably caused by absence of safety culture in the community. Some of the researchers have found such eveidences in studies. However, there might also be an alternate viewpoint. It could be argued that statutory requirements for strong safety parameters reflect only the political ambition of lawmakers. Costs associated with stringent safety parameters in developing countries might simply be unsustainable. The stakeholders cannot bear the safety cost for economic survival if the real cost of accident is too low in the economy.

In order to investigate such issues the cost for each selected safety parameters for each of the four survey sites were estimated. The item rate cost estimating priniciples were used. The requirements of materials and labours for attaing safety for each of the selected parameters were collected. The unit costs of these resources were collected and the sum total with an additional standard overhead would be the safety cost. Such estimates were made for the survey sites.

4 Results and Discussions

4.1 Site safety

A survey for safety compliances was conducted in four numbers building construction sites. Each of the safety items were covered in NBC of India and the main article numbers was presented in Table 1. Twenty two safety items classified into four groups have been selected. A series of site safety surveys has been conducted in the period beteen 2008 to 1012. Four medium sized building construction sites have been studied. Each of the sites consisted of three to four numbers 10-12 storied buildings each having about 50 – 70 residential apartments.

The sites were located in or near Kolkata, India. The surveys were conducted bi-weekly for the duration of six months in each site when the reinforced concrete structure and brickworks were in progress. The owners of the construction sites gave permission to the survey but the observations were not handed over to them during the course of the study. The site personnel knew this survey as an academic exercise but not directly related to the site management. The compliances of safety items in Table 1 were recorded in a one to five point Likert scale. Safety survey visits were unannounced and random but twice in each week. Each of the safety items were

TABLE 1
Non-Perrforming safety Index

Category (1)	NBC (P:VII) Article (2)	Safety Item (3)	Average NPI (4)
Personal	18.2.1.1	Safety helmet	0.37
	17.2.14	Shoes	0.60
	18.2.1.3	Gloves (when needed)	0.43
	6.2	Ear muff (when needed)	0.68
	18.2.1.2	Goggles (when needed)	0.56
Machinery	13.2.10	Safe electrical lines	0.27
	13.2.10	Covered moving parts	0.28
	4.31	Trained machinery use	0.15
		Mask (when needed)	0.75
	17.9	Harness (when needed)	0.20
	3	Organized dumping	0.50
House Keeping	14.4.1	Unobstructed path	0.70
	3	Safe general storage	0.32
	4.2.a	Safe cement storage	0.52
	4.2	Walkways railing	0.45
	7.6	Excavation ribbons	0.47
	18.2.19.2	Safe fuel storage	0.37
	2.1.1.8	Safe site illumination	0.62
Scaffolding	14.2	Safe platform boards	0.25
	32.5	Guard rails	0.50
	14.2	Scaffolding base plates	0.52
	9.1	Ladders	0.53
	9.1	Inadequate scaffolding	0.38
		Inadequate work distance	0.38
Work at height	14.2	Adequate ladder height	0.25
	14.2	Unsecured ladder	0.40
	14.2	Unsafe ladder	0.38
	9.1	Safe builders hoist	0.43
	9.1	Safe concrete pipes	0.52
	9.1	Safe mobile scaffold	0.50
	18.2.12	Catching nets	0.47

TABLE 2
Sitewise Non-Perrforming safety Index

	NPI				
Category	Ave	Site1	Site 2	Site 3	Site 4
Personal gear	0.53	0.64	0.56	0.38	0.54
Machinery	0.36	0.35	0.36	0.35	0.36
House keeping	0.51	0.51	0.48	0.52	0.52
Scaffolding	0.42	0.45	0.43	0.23	0.55
Working at height	0.42	0.45	0.42	0.41	0.40
Average	0.45	0.48	0.45	0.37	0.47

checked during a visit. The safety non-performance index (NPI) for each of the twenty two items as observed in four sites for six month period is presented in Table 1. NPI for safety items for individual sites were similarly estimated. The

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summary is presented in Table 2. The average safety NPI for four sites is 0.45. The average safety performance index in four sites is therefore 0.55.

A review of Table 1 and 2 would indicate that safety requirements were followed in a lackadaisical manner. The Table 2 revealed that NPI in survey sites varied around 0.46 except in Site 3 where the NPI was 0.37 that is a performance index (PI) of 0.63. The worst is in Site 2 where PI was 0.52. The best safety obliging site that is Site 3 is compared with the average of all sites in Fig. 1.

Fig. 1. Average NPI of four sites is in dark shade and the NPI of Site 3 is in light shade.

A review of Fig. 1 would show the nature of safety non-performances. Personal protective gears excepting helmets are hardly used. Masks, earmuffs, goggles and shoes are generally avoided. Site illumination and unobstructed paths that are required for accident avoidance are neglected. A disturbing observation is inadequate catching nets and ladders. The average NPI for catching nets and ladders are 0.6 and 0.7 respectively. Inadequate facilities in these two items would increase the risks of fatal accidents considerably.

4.2 Safety costing

The average safety NPI for four sites was found to be only 0.45 which indicated that the safety aspect was not adequately catered for in the surveyed sites. In order to investigate the financial aspects of the issue a cost analysis of safety items were performed. The safety items in Table 1 for each site have been estimated and the standard rates then prevailing in the market have been used for estimating the safety item costs for the surveyed site. The costing includes the materials, labour, supervision and management charges that would be incurred to the project. These input resources have been assumed as the ordinary qualities that are available and the estimating was made very tight suitable for obtaining competitive tenders. In addition to safety items, Indian statutes specify compulsory insurance for workmen. The statutory terms of benefits and premiums have been fixed by the regulatory authorities so that insurance companies may not vary terms and therby premiums. The premiums depend on the type of construction and worker-days. The estimate for premiums for each site has been presented in Table 3.

The summary of the safety item costs has been presented in

TABLE 3
COST SUMMARY FOR SAFETY ITEMS

	[INR in hundred thousands]			
Category	Site1	Site 2	Site 3	Site 4
Personal gear	1.34	1.09	1.38	2.10
Machinery	3.28	3.29	5.86	4.30
House keeping	7.45	7.87	10.50	9.20
Scaffolding	7.95	8.76	12.10	12.45
Working at height	5.98	8.24	8.10	8.27
Sub total	26.00	29.25	37.94	36.32
Insurance cost	6.13	3.69	6.40	5.49
Total	32.13	32.94	44.34	41.81

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Table 3. The total cost of safety for all four sites has been found to be INR15.12 Mil.

4.3 Cost-benefit analysis

The costs incurred for safety and the estimated benefit has been compared. The direct benefit of safety investment is preventions of accident which would save costs. The direct benefit is only included in the cost benefit analysis. In addition, there are number of indirect benefits like delay prevensions, improved workers' morale and goodwill loss in the market. These indirect benefits have not been included.

The compensation payable for a workman for death or permanent disability is relatively definite under Indian statute. The workmen copmpensation act [36] and minimum wages act [35] shall be applicable. The minimum wages act [35] shall determine the daily wage of a victim depending on the skill. The workmen compensation act would specify a multiplying factor depending on the age of the victim.

Accident is a probability and the estimate of loss from accident can not be estimated with certainty. In such situations, Monte Carlos' simulations are normally used in management science. A simulation analysis has been conducted in this case. The input valus of the simulation is presented in Table 4.

The actual number of deaths encountered in executing works in the four numbers surveyed site is 3 which is assumed as the lowest value. Ha¨ma¨la¨inen, Takala and Saarela estimated [10] construction fatality rate based upon worker-days. The estimates of worker-days for the four numbers surveyed site was made from available bill of materials and standard labour requirements specified in government rate analysis handbooks for public works. The construction site fatality rates and the required worker days have been used in estimating the higher value of deaths that is 46.42 in Table 4. The mean safety cost of INR15.12 Mil is based on the estimate shown in Table 3. The higher value of safety cost estimate in Table 4 is made on the assumption that maximum resources technically feasible shall

TABLE 4
VARIATIONS OF COST AND BENEFITS

Descriptions	Low	Mean	High
Death	3Nos.		46.42 nos.
Compensation	0.38 Mil	0.58 Mil	0.78 Mil
Safety cost	8.63 Mil	15.12 mil	27.36 Mil

be mobilized for the work. Similarly, the lower value in Table 4 was made based on the assumption that minimum amount possible for safety investment shall be made.

A Monte Carlo's simulation was conducted for identifying the variations of outcome from accidents. GoldSim simulation software was used [44]. The scheme for simulation is presented in Fig. 2.

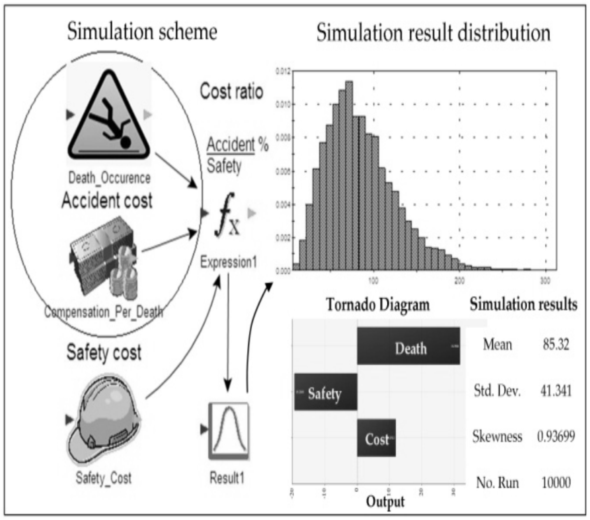

Fig. 2. Simulation scheme and results.

The simulation distribution is presented in Fig. 2. The mean value of accident cost and safety cost ratio is about 85 percent after a run of ten thousand times. It translates that the safety cost investment might be reduced by about 15 percent to equalize the accident and safety cost in an effective cost benefit analysis. The mean safety cost of INR15.12 mil may then be reduced by about INR2.2 mil. The standard deviation of 41.34 indicates that the coefficient of error is about 48% which seems to be high. Further analysis of data was conducted with Palisade [45] software for locating the source of variations. The resulting Tonado diagram is presented in Fig. 2. It shows that the result is critically dependent on the rate of death from construction work.

5 Conclusion

Researchers have regularly noted deficiencies of safety parameters in construction sites in developing countries. The present research in Kolkata, India supported the same findings. The literature survey indicated that some of the developing countries have not yet developed comprehensive statutory and technical standards for maintaining safety provisions. In case of India, such standards are available. However, this study showed that despite such requirements the standards were not followed scrupulously in the surveyed sites.

The study has used a relative importance index for grading safety parameters that are ignored. The index has allowed grading the performances of sites in safety provisions. It has been found that the average non-performance index for the surveyed sites is 0.45. It can be commented that even half of the required safety paramenters were not followed in the surveyed sites. The study did not attempt to establish any pass or fail grading. However, the sites could be compared relative to each other indicating the safety status to the stakeholders.

Researchers have noted that the absence of safety culture in the community is one of the reasons for safety drawbacks in construction sites of developing countries. This factor is one of the reasons for safety deficiencies.

The present study also investigated the economic aspects of safety deficiencies. A Monte Carlos' simulation for cost benefit analysis of safety showed that reducing safety investment for about 15 percent is justified purely from economic view point. However, it does not explain for more than 50 percent safety deficiencies as evidenced from NPI in surveyed sites. A sensitivity analysis of the cost benefit simulation indicated that a more definite probability of death from construction sites would have improved the coefficient of errors in simulation. The high probability of 46 numbers of casuality in surveyed sites if reduced would have reduced the accident costs therby allowing lesser NPI in cost benefit analysis.

Further research about the real cost of death, probability of accident and safety culture in the community are required to be investigated for understanding the safety deficiencies in construction sites in Kolkata, India.

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