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The influence of a goal programming approach for safety management practices on the performance of a selected Indian construction organization

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Abstract
The construction industry in India is the second most important contributor to its gross domestic product. However, high rate of accidents and fatalities have tarnished the image of industry in India. Although the industry contributes significantly to the Indian economy, safety management is the primary concern alongside with frequent workplace accidents. The role of safety management is vital to improve safety performance of an organization. The functions of safety management include planning, organizing, staffing, directing, controlling and coordinating safety activities with an aim to minimize accidents/injuries. Safety trainings, employee participation, compliance of safety procedures and motivational schemes are part of safety management which influences the overall safety performance. Several metrics were developed to measure the safety performance of an organization but not a single measure will reflect the overall performance. The present study considered parameters pertaining to the safety management which have influence on the safety performance of a construction organization in India. The parameters are analyzed by formulating a goal programming model. The results of the study suggests that much improvement is needed in the area of safety trainings and the revised targets were established.

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1. Introduction

Construction sector is an integral part of infrastructure development which provides tremendous boost to India's economy. The economic growth of developing countries mainly depends on the extent of construction activity. Notwithstanding its importance in boosting economic growth, a higher level of risk is experienced during execution of construction activities across the globe (Guha et al., 2005).The Indian construction industry currently lacks any readily available safety performance measure to assess performance. To judge safety performance, the industry currently relies on the segregated reported number of the different types of accidents. The statistics pertaining to accidents and occupational diseases are not well documented by the Indian Government (Beriha et al., 2011). In India, construction safety performance is traditionally assessed based on workplace conditions and analyzing accident statistics, there is no provision to consider the safety management systems which affect the site safety (Devendrakuma et al., 2015).

The construction industry requires an appropriate mechanism to assess safety practices at organizational level instead of implementing prevention approaches based on the reactive data. Efforts undertaken by the Indian government to enforce occupational health and safety (OHS) rules; and regulations have no marked impact on the safety performance (Kanchana, et al., 2015). Analysis of accident metrics is not useful in evaluation of safety performance as there is every possibility of under reporting of accident information (Fakhradin Ghasemi et al., 2015). Safety performance has been monitored by safety metrics which are useful to make comparison with industry averages/other organizations. Analyzing safety metrics over a period of time is vital to identify the trends in construction industry (Hinze et al., 2013). Regression analysis was applied to examine the injury rate in Malaysian manufacturing industries and the results show that there is negative relation between organization size and injury rate (Saad et al., 2012). Indian standard was developed in 1983 regarding method for computation of frequency and severity rates for industrial injuries and classification of accidents (IS 3786, 1983). There is

an ambiguity and no single safety metric will present actual status of safety but the standard was still in force. The reason being a serious accident has a considerable effect on the severity rate but it does not greatly affect the frequency rate. Many accidents and property damage not causing man days lost are not properly indicated by safety metrics. It is also not good practice to compare two construction organizations based on their frequency and severity rates as the type of hazards, working conditions differ from organization. Severity rate does not represent actual pain and suffering of a worker. Low frequency rate does not mean that severity rate is also low, that is one fatal accident is best example (Rajaprasad at al., 2016). Practically the safety metrics are the partial indicators of injuries and no index is capable of giving complete overview of safety performance.

Occurrence of accidents and occupational diseases has been reduced substantially after the implementation of establishment of occupational health safety management systems (OHSMS) and it is a tool to improve safety performance (Kim et al., 2016). The role of safety management is crucial in the development of safety performance and accident control measures. The relationship between OHSMS and company performance was studied and the results showed that safety management has a positive impact on safety performance (Fernandez-Muniz et al., 2009). Implementation of integrated safety management systems in combined cycle power plant, Iran has reduced accidents. Despite establishing OHSMSs in the workplace, there is a lack of comprehensive, robust evidence to demonstrate their effectiveness. This may be due to the fact that their effectiveness is evaluated by retrospective performance indicators, such as man days lost and the injury/ severity rates. It is important to frame a comprehensive, informative mechanism to evaluate the quality of OHSMS based on both lagging and leading indicators, which will enable all the stakeholders to gauge the accomplishment of success of their OHSMS (Podgorski, 2015).

The present study considered parameters pertaining to the safety management that are having direct impact on the safety performance of a construction organization in India. The parameters considered are number of employees injured / imparted safety training/ awarded under incentive schemes / reported immediate causes of accidents / and violated site safety rules. Safety performance of an organization depend on multiple objectives; so goal programming approach was proposed for formulating the model. With regard to the past studies, there is a dearth of research focusing on safety management practices to measure safety performance. Thus, the present study was attempted aiming at investigating the influence of safety management parameters on safety performance of an Indian construction organization.

2. Literature review

Safety management role is pivotal and provides indication prior to an accident. Managing safety in an organization is a proactive approach rather than implementing measures on accident data. Proactive safety management requires a transfer of information flow in a systematic and efficient manner (Zhipeng et al., 2015). The objective of safety management is to involve in the accident causation process and it is an integration of plan, do, check and act activities implemented in a safety system for continual improvement. Safety management aims at molding an organization to achieve total safety and to ensure better working conditions for better health and higher productivity. A proactive safety management needs organization commitment towards OHS, safety organization, safety trainings, safe working procedures, and documentation; and reviews (Needleman, 2000). Studies have shown that outstanding safety performance is closely associated with projects where an effective safety management programme is established, implemented and maintained (Hislop, 1991; Tam et al., 1998).

Evaluation of safety performance is an extremely significant part of safety management (Mitchell, 2000). Construction safety management framework is yet to be developed in developing countries like India (Kanchana et al., 2013).Establishing OHSMS in an organization leads to decline of occupational hazards and diseases. Construction organizations often adopt safety management practice to manage their safety functions in an attempt to achieve performance excellence. The concept of safety should be embedded as a management concept on every level of an organization and every part of a cross-organizational project. The project sites are the main source of fatalities and accidents in the Malaysian construction industry, the concept of the safety management with well-defined organization structure and the safety planning has a potential to improve the performance (Husrul et al., 2008). Workers are not protected in Indonesian construction projects due to poorly established safety management practices (Permana, 2007). Construction Safety Management is a dynamic process aiming to achieve the desired goals and is supposed to be adjusted to meet the process of improving performance (Cheng et al., 2004).

Even though numerous studies have been reported in safety management from various parts of the world, there is not much research evidence from India where safety management is yet to get the priority it deserves (Vinodkumar et al., 2010). The literature on safety management suggests that the Indian construction industry require much improvement in this area as it was not prioritized. OHSMS includes the organizational structure, planning activities, responsibilities, practices, procedures, processes and resources for developing, implementing, achieving, reviewing and maintaining the organization's OHS policy. Safety management system is performance oriented as opposed to compliance oriented (Mohd Kamar et al., 2014). It is generally felt that safety practitioners encounter difficulties in dealing with the safety management issues. One of the reasons is the presence of a number of variables and interaction among these variables relating to OHS. From the literature review, it is observed that the safety management practices are crucial to improve the safety performance. In the present study, an attempt has been made to analyze the influence of safety management practices on OHS performance in a Indian construction organization.

3. Materials and Methods

In situations where the system may have multiple or conflicting goals, a compromise solution based on the relative importance of each objective is achieved by using the goal programming. The technique can solve multiple objectives simultaneously by determining the optimal and compromise solution to achieve all objectives and also aims at minimizing the deviations from the targets that were set by the management. Goal programming start with the most important goal and continues until the achievement of a less important goal (Taha, 2017). Goal programming models were developed and analyzed in the areas of financial management banks in Malaysia (Lam et al., 2017) Rubber Production In Malaysia (Nasruddin et al., 2013)D and production planning of perishable products (Leung, 2007).

3.1. Goal Programming Model

In the present study, the construction organization has to achieve conflicting goals comprising maximizing as well as minimizing, goal programming model is best suited to solve the problem. In goal programming model, the weights will be assigned as the coefficient of the variables indicating the importance of each goal. The goal programming is formulated as follows.

$$\text{Min } Z = w1\,G1 + w2\,G2 + w3\,G3 + \ldots + wi\,Gi \quad (1)$$

where, i = 1,2,3……n.

Subject to

$$\sum_{j=1}^{m}(aij\,pj + di - - di+) = gi \quad (2)$$

x_j , d_i^- , $d_i^+ \geq 0$

where,

Z = objective function;

W_i = weight for i = 1, 2, 3,…..,n;

d_i^- = negative deviation variable(underachievement) for i = 1,2,3,…..,n;

d_i^+ = positive deviation variable (over achievement) for i = 1,2,3,…..,n;

p_j = decision variable for j = 1,2,3,…..,n;

a_{ij} = parameter for decision variable;

g_i = aspiration level for i = 1,2,3,…..,n.

d_i^- and d_i^+ are added to the constraints as under satisfying or over satisfying of a goal. The deviation variables are used to determine the underachievement or over achievement of each goal (Taha, 2017).

4. Case study

The study was conducted in a construction organization involved in execution of nuclear power plant construction in India. The construction activity was commenced in the year 2010 and expected to complete by 2022. The construction organization has established a safety department comprising of safety manager, deputy safety manager, safety officers and supervisors to monitor OHS aspects during the execution of various construction activities. The safety department has developed and implemented safe operating procedures, trainings, emergency plan, motivational schemes, reporting mechanism, risk assessment, maintaining safety statistics, health surveillance etc. to minimize work related injuries. The management of the construction organization has established a target for frequency rate, which shall not exceed 0.18. Though the frequency rate is below the target, the safety department is planning to further improve the performance by involving the employees in all safety management activities by strengthening trainings, minimizing the violations, reporting unsafe actions/conditions and near misses; and motivating the employees for better safe and healthy work environment. The number of employees working per day on an average is 2000. The present study was considered five parameters relating to safety management which have significant impact on OHS performance of the organization. The safety management parameters were finalized after conducting brainstorming session with the representatives of safety department and management team.

4.1. Data Collection

The information pertaining to the parameters influencing the safety performance of the construction organization in the domain of safety management were collected form the safety department from the year 2014 to 2018. The parameters include number of employees injured, awarded, trained, reported unsafe actions/conditions/ near misses and penalized for violating site safety rules. The management was interested in improving safety performance by considering the above mentioned parameters only. The details of the factors are shown in Table 1. Goal programming model was developed by utilizing the data mentioned in Table 1.

Table 1. Information on safety management parameters from 2014 - 18

No	Parameters	Y14	Y15	Y16	Y17	Y18	Total
1	Injured	12	8	5	4	6	35
2	Trained	8746	8592	8142	7915	7869	41264
3	Awarded	381	358	307	262	285	1593
4	Reporting	121	107	93	78	62	461
5	Penalized	42	48	34	21	15	160
6	Total	9302	9113	8581	8280	8237	43513

4.2. Goal programming model

The multiple goals achievement nowadays have revealed the importance of accomplishing multiple goals simultaneously. Hence, there is a demand for mathematical model to solve these problems in order to obtain an optimal solution. Goal programming model can solve multiple objectives simultaneously by determining the optimal and compromise solution to achieve all objectives (Lam et al., 2017). In the present study, the construction organization has to achieve contradictory goals such as maximizing number of employees trained, awarded and reporting unsafe actions/conditions/near misses; and minimizing injuries and penalties. The goal programming model is best fitted to solve the problem.

According to Equation (2), p_j represents the number of employees for each parameter in each year. The decision variables are shown below;

p_1 = total number of workers for the parameter 1 in year 2014
p_2 = total number of workers for the parameter 2 in year 2015
p_3 = total number of workers for the parameter 3 in year 2016
p_3 = total number of workers for the parameter 4 in year 2017
p_5 = total number of workers for the parameter 5 in year 2018

The goal constraints derived from each goal in goal programming model is shown in Table 2.

Table 2 Goal constraints of safety management parameters

Parameter	Goal constraint
Injuries	$12\ p_1+8\ p_2+5\ p_3+4\ p_4+6\ p_5 \leq 35$
Trainings	$8746\ p_1+8592\ p_2+8142\ p_3+7915\ p_4+7869\ p_5 \geq 41264$
Awards	$381\ p_1+358\ p_2+307\ p_3+262\ p_4+285\ p_5 \geq 1593$
Reporting's	$121\ p_1+107\ p_2+93\ p_3+78\ p_4+62\ p_5 \geq 461$
Penalties	$42\ p_1+48\ p_2+34\ p_3+21\ p_4+15\ p_5 \leq 160$
Total	$9302\ p_1+9113\ p_2+8581\ p_3+8280\ p_4+8237\ p_5 \geq 43513$

Due to the fact that the variables are uncertain values, positive and negative deviation variables are added to the constraints to determine the increment or decrement of the goals. Based on the goal constraints identified, the goal programming model is developed and run in Lingo software as depicted in Fig. 1.

```
Min = D1plus + D2minus + D3minus + D4minus + D5plus + D6minus;
12*P1+8*P2+5*P3+4*P4+6*P5+D1minus-D1plus=35;
8746*P1+8592*P2+8142*P3+7915*P4+7869*P5+D2minus-D2plus=41264;
381*P1+358*P2+307*P3+262*P4+285*P5+D3minus-D3plus=1593;
121*P1+107*P2+93*P3+78*P4+62*P5+D4minus-D4plus=461;
42*P1+48*P2+34*P3+21*P4+15*P5+D5minus-D5plus=160;
9302*P1+9113*P2+8581*P3+8280*P4+8237*P5+D6minus-D6plus=43513;
END
```

Fig. 1 Constraints run in the Lingo Software

5. Results and discussion

The achievement of goal of the construction organization based on the results of the model is presented in Table 3.

Table 3 Goal achievement

Goal	Deviation variable	Goal achievement
G1	D1plus	Achieved
G2	D2 minus	Achieved
G3	D3 minus	Achieved
G4	D4 minus	Achieved
G5	D5 plus	Achieved
G6	D6 minus	Achieved

According to Table 3, deviation variables for all goals give zero value which implies that the construction organization could achieve all the goals throughout the five years. This is an indication of consistent safety performance of the organization. The probable gain on the target value based on the final result of the model which provide positive value of the decision variable as shown in Fig 2.

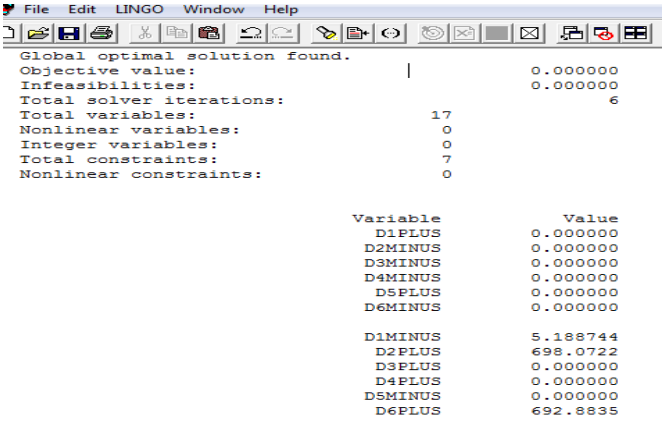

Fig. 2. Output of Lingo software

From the Fig.2, there are two potential improvements identified among the goals. Potential increment or decrement can be detected based on the positive values of deviation variables. For maximization problem, increment can be determined through positive deviation variable and vice versa for minimization problem.

The first priority, G1 is to minimize the total injuries of the construction organization. The result of the model depicts that the value for negative deviation, is zero; therefore, the goal is fully achieved and positive deviation is 5.1887 or 6, meaning that the total injuries of the construction organization must be reduced to 29 for five years. For goal 2 (G2), the value of negative deviation is zero while the value of positive is 698. This shows that the goal (G2) is achieved and the total number of employees to be trained in the construction organization can be increased up to 41962 for the next five years. Likewise, goals G3, G4 and G5 of number employees awarded, reported unsafe acts/conditions and liable for penalties are also fully achieved since the both values of (d3minus, d3plus), (d4minus, d4plus) and (d5minus, d5plus) are zero, which indicate that the total of three goals for next five years do not change. Finally the total goal achievement is to be increased by 44206.

6. Summary and conclusion

This study aims to formulate a goal programming model to investigate and optimize the safety management practices to improve safety performance of a construction organization in India. Based on the results of the goal programming model, the construction organization could achieve all goals. However there are two goals, namely injuries and trainings which need revision to enhance the aspiration level. The possible revisions determined based on the results of the model are minimization of total number of employees involved with injuries and maximization of total number of employees to be trained. The suggested model can serve as a pilot study for the construction organization in formulating safety management strategies to improve safety performance and assist revised targets for improvement. The present model can be applied to a construction organization involved in execution of various types of construction projects to compare and benchmark the

safety management practices to improve safety performance. The goal programming model acts as a tool that assists any type of organization to gauge safety performance based on safety management practices instead of relying on frequency and severity rates.

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安全管理实践的目标规划方法对选定的印度建筑组织的绩效的影响

關鍵詞
安全管理
职业健康安全管理系统
安全性能
目标规划

摘要

印度的建筑业是其国内生产总值的第二大贡献者。然而，高事故率和死亡率玷污了印度工业的形象。尽管该行业对印度经济做出了重大贡献，但安全管理仍是工伤事故频发的首要问题。安全管理的作用对于提高组织的安全绩效至关重要。安全管理的职能包括规划，组织，人员配置，指导，控制和协调安全活动，以尽量减少事故/伤害。安全培训，员工参与，安全程序的遵守和激励计划是影响整体安全绩效的安全管理的一部分。为了衡量组织的安全绩效，开发了几个指标，但没有一个指标可以反映整体绩效。本研究考虑了与安全管理相关的参数，这些参数会影响印度建筑组织的安全绩效。通过制定目标规划模型来分析参数。研究结果表明，安全培训领域需要大大改进，并确定了修订后的目标。