SENSITIVITY ANALYSIS OF SAFETY PERFORMANCE OF INDIAN CONSTRUCTION ORGANIZATIONS

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ABSTRACT

Rapid growth of construction activity coupled with utilization of versatile construction equipment has resulted in complex occupational health and safety issues in Indian construction sector. The construction scenario in India is more complicated and governs to exposure to various hazards compared to other industries and it is essential to execute valid approaches of hazard control measures for improving safety performance of construction organizations. The main purpose of the study is to develop suitable construct to benchmark the safety performance in Indian construction organizations. Data envelopment analysis (DEA), being a robust tool, has been employed to evaluate the performance of industries. DEA, basically, takes into account the input and output components of a decision making unit (DMU), to calculate technical efficiency (TE). TE is treated as an indicator for safety performance of DMUs and comparison has been made among them. Fifty Indian construction organizations under ten construction segments including both real estate and infrastructure categories are chosen for comparison purpose. The analysis was conducted by considering two cases; with and without first aid cases in the total number of accidents. Data envelopment analysis was adopted under constant return scale model. The mean efficiency scores of basic and special case are 0.63, 0.75 and 0.77, 0.83 respectively. It is observed that all the efficient organizations are from infrastructure segment only. It has been observed that safety performance of construction organizations under real estate sector is consistently low as compared to infrastructure sector. The number of first aid cases in total number of accidents is influencing the technical efficiency scores of construction organizations.

Keywords: *Data envelopment analysis, constant return to scale, technical efficiency*

INTRODUCTION

Unlike in manufacturing and other industries, implementing safety measures in construction industry is dynamic and accident prevention controls needs reinforcement at every stage of construction. The progress of work changes on hourly basis and safety systems needs to be strengthened in the changing work place conditions (Jayakrishnan, Thomas, Bhaskara Rao, & George, 2013). Any slackness in adapting to the changing construction scenario results into accidents and further worsens safety performance. The significance of construction industry to the economic and social life of India is noteworthy, though it is treated as hazardous. In India, traditionally construction safety performance is assessed based on workplace conditions, analyzing accident statistics, while there is no provision to consider the safety management systems which affect site safety (Devendra Kumar, & Jha, 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. The efforts of Indian government to enforce occupational health and safety regulations have no marked impact on the safety performance (Kanchana, Sivaprakash & Joseph, 2015).

Information pertaining to safety performance indicators is quite useful to execute proactive safety measures. Data pertaining to safety is a filtering mechanism through which the actual safety scenario is known. In India, safety performance is analyzed based on different safety indices; frequency, severity and incident rates (IS: 3786, 1983). It is not practicable to take decisions or to implement safety strategies on the basis of safety indices. A comprehensive standard was developed in India in 1983 regarding method for computation of frequency and severity rates for injuries and classification of accidents. There is an ambiguity in drawing conclusions from the results of safety indices as no single indices will provide factual position of safety performance but still it is being followed (Mistry, 2008). The reason being a serious accident has a considerable effect on the severity rate but it is does not greatly affect the frequency rate. Many accidents and property damage may not cause the man-days lost are not considered in calculation of safety indices. Severity rate does not represent the actual pain and suffering of a worker. Low frequency rate does mean that severity rate is low. It is also not a healthy practice to compare two or more construction organizations based on the safety indices as type of hazards and working conditions vary across organizations. Practically the safety indices are the partial indicators of injuries and it is difficult to gauge overall safety performance (Mistry, 2008).

To ascertain performance in various construction organizations involved in execution of different works and to identify efficient organization, the input and output parameters influencing safety performance were considered. Several studies were conducted in the past by considering safety expenditure and type of accidents as inputs and outputs respectively to measure efficiency of organizations but ignored cost of accident damages (El- Mashaleh. Al-Smad, Hyari & Rababeh, 2010; Beriha, Patnaik & Mahapatra, 2011). In the present study, the safety performance of construction organizations was analyzed by using data envelopment analysis to calculate technical efficiency. The inputs considered are expenditure incurred towards purchase of safety equipment, for organizing safety training to employees, welfare and health measures. The outputs are total number of accidents applicable as per legislation, man days lost due to an accident and cost of accident damages to the organization. Finally, the benchmarking units are identified basing on efficiency scores.

LITERATURE REVIEW

Construction industry accounts for improving national economy and its contribution is approximately 10% of the global GDP (Chockaligam, & Sornakumar, 2012). In countries like South Africa and Botswana, construction sector contributes 5% and 7% towards national GDP (Murie, 2007). The accident trends show higher rate of accidents in construction industry mainly due to non-existence of safety policy, safe operating procedures, safety awareness among employees and role of site management (Evelyn, Ling, & Weng, 2005). From previous studies, it is revealed that inadequate safety training, ignoring inspections and compliance of PPE are the reasons for poor OHS performance in Jordanian construction industry (El- Mashaleh. Al-Smad, Hyari & Rababeh, 2010).

The results of a study conducted in Chilean construction organizations confirm the strong the association between safety practices and injury rate. Orientation and training, planning and participative practices will improve safety performance at organization level (Carlos, Lusi, & Diethelm, 2007). The construction industry in Europe was utilizing the services of about 7.5% of the total labour and the percentage of fatal accidents is 22.5. In developed countries the accident causation is primarily due to unsafe behaviour of workers (Tiwary, & Gangopadhay, 2011). In Indian context, the low performance is mainly owing to the fact that construction works are temporary, target oriented and failure to enforce legislation (Berger, 2000). Since construction activities are multifaceted and exigent, improving safety performance has become a critical issue and its demand has been proven in studies conducted by the researchers (Small Man, & John, 2001).

Organizing safety awareness programmes for new workers, issue of safety equipment, services of qualified safety officer and regular site safety inspections substantially enhance performance (Koehn, Kothari, & Chih-Shing, 1995).Though there is marginal improvement of safety, the construction industry continues to be hazardous due to maximum number of fatalities (Somik, & Deborak,2009).The strategies adopted towards OHS in developed countries mainly focus on enforcement of legislation and familiarity with risk assessment (Shibani, Saidani, & Alhajeri, 2013). A study conducted in Indian construction industry reveals that management commitment is vital besides completing the project on time (Tabish, & Jha, 2015). Role of management, labour relations, safety policy and establishing safety management systems affect safety performance (Yung, 2009). Analysis of accident metrics is not useful in evaluation of safety performance as there is every possibility of under reporting of accident information (Lingard, Wakefield, & Cashin, 2011; Dingsdag, Biggs, & Shehan, 2008; Mohammed, 2003; Beriha, Patnaik, Mahapatra, & Padhee, 2012). Sustaining safety is the need of the hour and can be accomplished through prioritization. The previous studies mainly concentrated on analyzing the accident causation (Chockaligam, & Sornakumar, 2012).

Due to non-availability of data relating to safety performance in developing countries has become deterrent to establish stringent safety measures (Chiocha, Smallwood, & Emuze, 2011). The concept of leading safety parameters came into existence due to limitations of reactive data measure safety performance (Reiman, & Pietikainen, 2012; Hinze, Thurman & Wehle, 2013). The gap in the literature has given enough confidence to develop suitable construct to benchmark the safety performance and analyse the effect of first aid cases in total number of accidents in Indian construction organizations.

CATEGORIZATION OF INDIAN CONSTRUCTION INDUASTRY

The Indian construction industry is broadly categorized into real estate and infrastructure segments. The categorization of segments is depicted in Fig.1(NSDC, 2012). The infrastructure segment is a key driver of the growth of the construction industry. Real estate segments comprise residential buildings, commercial and special economic zones while the infrastructure segment includes power, irrigation, urban infrastructure, roads, railways, ports and airports. The risks associated with construction activities in segments differ and complete mechanization is required in case execution of infrastructure projects like underground metro, tunnelling in hydro power projects, roads and railways.

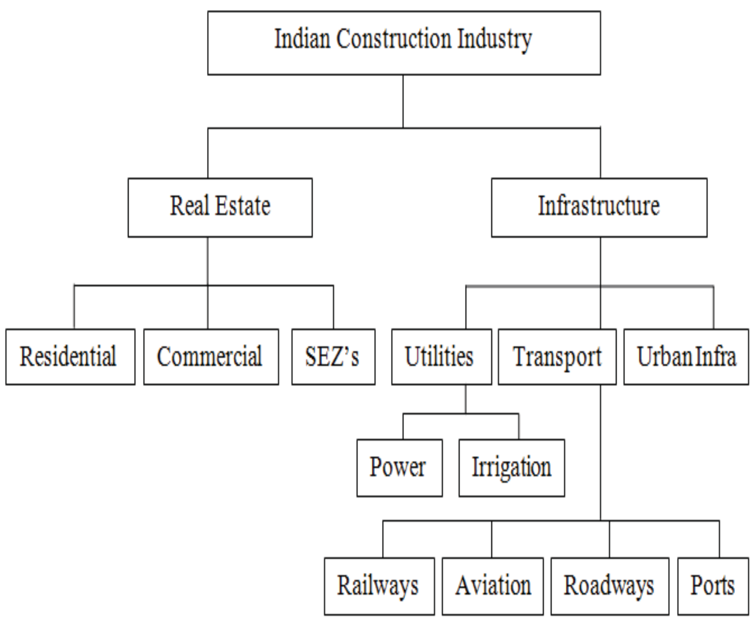

Figure 1: Classification of construction segments

Real estate segment

Real estate segment is one of the largest and fast growing activities in India at an annual growth rate of 10 per cent. The anticipated growth rate will be approximately 19 per cent by 2022. The contribution to the national GDP is 4.8 per cent in 2012-13. Shortage of housing, construction of new office buildings, shopping malls, medical infrastructure and rise in income levels are the factors responsible for rapid development real estate segment (Kaja, 2015).

Infrastructure segment

The share of infrastructure segment is approximately 40 per cent of the construction industry and expected to attain 4774 billion rupees by 2017. Infrastructure segment is cruising ahead of other segments with on hand public partnership projects, construction of irrigation projects, up gradation of existing road network, metro rail construction in major cities, urban housing and construction of power plants. Massive infrastructure development will be seen in near future and consistent safety performance is one of the performance indicators at the project level (Toor, & Ogunlana, 2010; Luu, Kim, & Huynh, 2008).

METHODOLOGY

Data Envelopment Analysis (DEA) is a mathematical programming technique that has found a number of practical applications for measuring the performance of similar units, such as a set of financial institutions, transport organizations, industrial organizations and so on. Data envelopment analysis is a methodology based upon the application of linear programming. It was originally developed for performance measurement and successfully employed for assessing the relative performance of a set of firms that use a variety of identical inputs to produce a variety of identical outputs.

DEA has been applied in various fields of research. To determine labour productivity in construction industries in Europe (Joanicjusz, & Ewa,2015), to compute the efficiency of environment, health and safety performance of contractors in oil and gas industry (Abbaspour, Hosseinzadehlotfi, Karbassi, Roayaei,& Nikoomaram, 2009), applied to assess safety performance in coal mines(Lei,& Ri-jia, 2008), to examine safety performance of 15 European countries in four economic sectors – manufacturing, construction, trades and transportation(Eugenia, & Agnese, 2011), to rank on time completion construction projects (Mazyar, Mohammadreza, Shahrzad, & Hamidreza, 2014), to benchmark safety performance of construction contractors(El.Mashaleh. Shaher, & Khalied, 2010), to measure technical efficiency of 44 state road transport undertakings (Venkatesh, 2006), to benchmark safety performance in construction, steel and refractory industries in India(Beriha, Patnaik,& Mahapatra, 2011), to measure performance of departments of a University in Turkey(Yilmaz, Onur,& Bilge, 2015), to develop a model for computing relative efficiency of banks in Nepal(Karan, & Shashank, 2013), to appraise effectiveness of research and development centres of Czech manufacturing industry(Marie, & Nina, 2013) and to evaluate operational performance of solar cell industry in Taiwan(Hao-En, &Jie –Yi, 2012). DEA, basically, takes into account the input and output components of a decision making unit (DMU), to calculate technical efficiency (TE). TE is treated as an indicator for safety performance of DMUs and comparison has been made among them. Basing on the literature on applications of DEA, it has instilled copious confidence to apply the methodology in the present study.

Mathematical formulation of DEA

DEA is a mathematical programming technique. DEA is a useful tool in measuring the relative performance of group of organizations or departments commonly designated as decision-making units (DMUs). The inputs are transformed into outputs in a decision making unit whose performance is measured. DEA is a linear programming based tool for measuring the relative efficiency of each unit in asset of comparable organizational units using theoretical optimal performance for each organization.

DEA makes use of fractional programming problem and corresponding linear programming problem together with their duals to measure relative performance of DMUs (Charnes, Cooper, Golany, Seiford & Stutz, 1985; Charnes, Cooper, Lewin, & Seiford, 1994). The Charnes, Cooper and Rhodes (CCR) model is a fractional programming problem model that measures the efficiency of DMUs by calculating the ratio of weighted sum of its outputs to the weighted sum of its inputs. DEA also determines the level and amount of inefficiency for each of the inputs and outputs and the magnitude of inefficiency of the DMUs is determined by measuring the radial distance from the inefficient unit to the efficient one.

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Constant returns to scale model

Let there be 'p' DMUs whose efficiencies have to be compared. Let us take one of the DMUs, say the q^{th} DMU, and maximize its efficiency according to the formula as shown in Equation 1. Here the q^{th} DMU is the reference DMU. The mathematical program is,

$$\text{Max } G_q = \sum_{a}^{A} c_{aq} d_{aq} \; / \; \sum_{b}^{B} e_{bq} f_{bq}$$

Subjected to,

$$0 \leq \sum_{a}^{A} c_{aq} d_{ap} \; / \; \sum_{b}^{B} e_{bq} f_{bp} \leq 1; \; p = 1, 2 \; ....P \qquad (1)$$

$c_{aq} \; e_{bq} \geq 0$; b = 1,2, ...B, a = 1, 2 ... A

Where,

G_q is the measure of efficiency of q^{th} unit.

d_{aq} is a^{th} output of q^{th} DMU

c_{aq} is the weight of output

f_{bq} is b^{th} input of q^{th} DMU

e_{bq} is the weight of input

d_{ap} is the a^{th} output of a^{th} DMU

f_{bp} is the b^{th} input of a^{th} DMU

The fractional programme shown in Equation 1 is converted into linear programming problem as shown in Equation 2.

$$\text{Max } G_q = \sum_{a}^{A} c_{aq} d_{aq}$$

Subjected to,

$$\sum_{b}^{B} e_{bq} f_{bq} = 1$$

$$\sum_{a}^{A} c_{aq} d_{ap} - \sum_{b}^{B} e_{bq} f_{bp} \leq 0;\ p = 1, 2 \ldots\ldots P \qquad (2)$$

$$b = 1, 2 \ldots B,\ a = 1, 2 \ldots A$$

The model is called CCR output-oriented maximization DEA model. The efficiency score of 'p' DMUs is obtained by running the above LPP 'p' times.

Selection of construction organizations

In order to identify decision-making units, fifty Indian construction organizations from two segments, i.e. infrastructure and real estate have been considered. Five organizations under each category, where DMUs (RE1 to RE5, C01 to CO5 & SEZ1 to SEZ 5) represent real estate segment and (POW1 to POW5, IRR1 to IRR5, UI1 to UI5, RAI1to RAI5, CA1 to CA5, ROA1 to ROA5 & POR1 to POR5) represent infrastructure segment have been considered and the details are shown in Table 1.

Table 1: Representation of DMUs

DMUs	Segment	Division	Organizations
DMU 1 to 5	Real estate	Residential	RE 1 to 5
DMU 6 to 10	Real estate	Commercial	CO 1 to 5
DMU 11 to 15	Real estate	SEZs	SEZ 1 to 5
DMU 16 to 20	Infrastructure	Utilities /Power	POW1 to 5
DMU 21 to 25	Infrastructure	Utilities /Irrigation	IRR 1 to 5
DMU 26 to 30	Infrastructure	Urban Infrastructure	UI 1 to 5
DMU 31 to 35	Infrastructure	Transportation/ Railways	RAI 1 to 5
DMU 36 to 40	Infrastructure	Transportation/ Civil Aviation	CA 1 to 5
DMU 41 to 45	Infrastructure	Transportation/ Roadways	ROA 1 to 5
DMU 46 to 50	Infrastructure	Transportation/ Ports	POR 1 to 5

INPUTS AND OUTPUTS

DEA considers a DMU as the entity responsible for converting inputs (resources, money etc.) into outputs (performance measures etc.). The inputs and outputs to evaluate safety performance are depicted in Fig. 2. The input parameters have been identified through discussions with the safety professionals, safety managers and corporate safety heads from various construction organizations in India. The safety performance of a construction segment is affected by the total expenditure on safety activities as a percentage of total project cost. The expenditure includes annual cost of safety trainings, promotional activities, purchase of safety equipment & tools and health & welfare facilities provided.

Construction workers in India are exposed to various types of hazards resulting into more than one type of accidents is unlikely to occur at the same time. The Building and other construction workers Act, 1996 is the legislation applicable towards safety, health and welfare of construction workers in India. According to, the building and other construction workers Act, 1996 and rules framed subsequently under this act, the workplace accidents are classified into, first aid cases, accident disables a worker from working for a period of 48 hrs or more immediately following the accident, accident causing disablement subsequently results in death of a worker and dangerous occurrence, whether or not any death/disablement is caused to a worker (GOI, 1996).

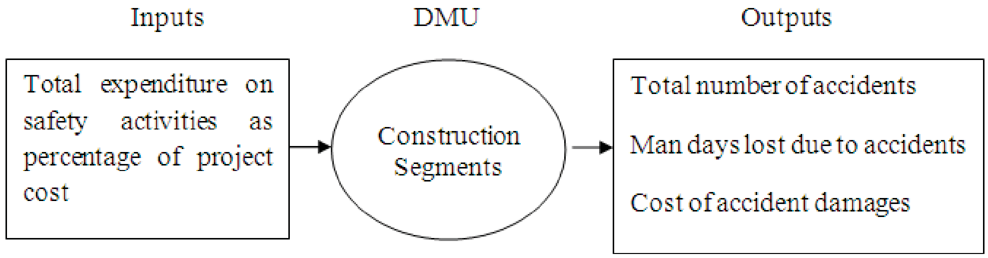
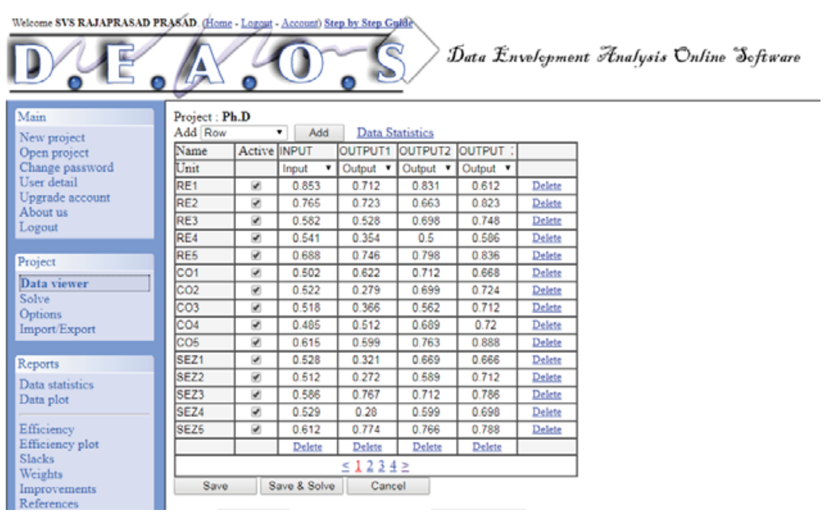


Figure 2: Inputs and outputs

The output parameters considered for analysis are total number of accidents, man days lost due an accident and cost of accident damages. Previous studies on safety performance measurement in various organizations mainly considered number of different types of accidents but not the cost of accident damages. Unlike safety indices which represent safety performance partially, the analysis in the study utilizes the data pertaining to accidents, man-days lost and cost of damages as outputs. Before analysis, all the data require normalization, since the outputs are negative nature and the values are converted into the inverse format and normalized.

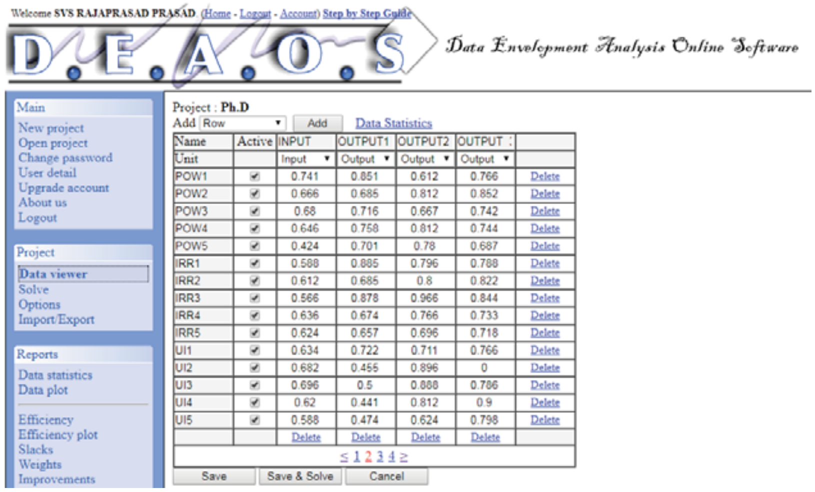
Data collection

The data was collected directly approaching the safety managers or safety officers of the organizations and explained about the purpose of the study. Many of them are reluctant to furnish the information about input/ output parameters. Some organizations took written assurance from the scholar to keep the data collected as confidential. Some organizations did not maintain safety records and such organizations were not considered under the study. The data was collected from the year 2013-14 to 2015-16. Majority of the organizations were certified under occupational health safety assessment series (OHSAS) 18001 and the clients are being Government undertakings. The data collection was restricted to five organizations under each category, mainly due to non-availability of data and few organizations reluctant to furnish the details. The normalized data of input and outputs for the 50 construction organizations was shown in Fig. 3 to Fig. 6. DEAOS software has been used to solve the model.



Name	Active	INPUT	OUTPUT1	OUTPUT2	OUTPUT :	
Unit		Input	Output	Output	Output	
RE1	✔	0.853	0.712	0.831	0.612	Delete
RE2	✔	0.765	0.723	0.663	0.823	Delete
RE3	✔	0.582	0.528	0.698	0.748	Delete
RE4	✔	0.541	0.354	0.5	0.586	Delete
RE5	✔	0.688	0.746	0.798	0.836	Delete
CO1	✔	0.502	0.622	0.712	0.668	Delete
CO2	✔	0.522	0.279	0.699	0.724	Delete
CO3	✔	0.518	0.366	0.562	0.712	Delete
CO4	✔	0.485	0.512	0.689	0.72	Delete
CO5	✔	0.615	0.599	0.763	0.888	Delete
SEZ1	✔	0.528	0.321	0.669	0.666	Delete
SEZ2	✔	0.512	0.272	0.589	0.712	Delete
SEZ3	✔	0.586	0.767	0.712	0.786	Delete
SEZ4	✔	0.529	0.28	0.599	0.698	Delete
SEZ5	✔	0.612	0.774	0.766	0.788	Delete
		Delete	Delete	Delete	Delete	

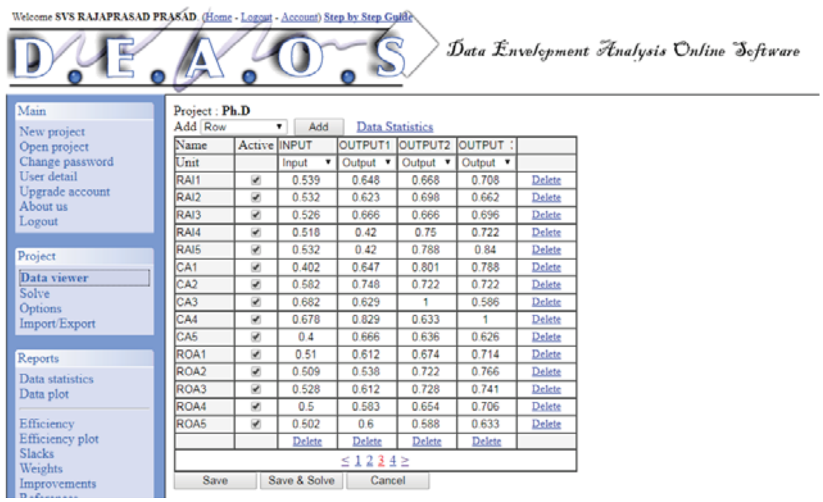
Figure 3: Normalized data of organizations RE 1to SEZ 5



Name	Active	INPUT	OUTPUT1	OUTPUT2	OUTPUT :	
Unit		Input	Output	Output	Output	
POW1	✔	0.741	0.851	0.612	0.766	Delete
POW2	✔	0.666	0.685	0.812	0.852	Delete
POW3	✔	0.68	0.716	0.667	0.742	Delete
POW4	✔	0.646	0.758	0.812	0.744	Delete
POW5	✔	0.424	0.701	0.78	0.687	Delete
IRR1	✔	0.588	0.885	0.796	0.788	Delete
IRR2	✔	0.612	0.685	0.8	0.822	Delete
IRR3	✔	0.566	0.878	0.966	0.844	Delete
IRR4	✔	0.636	0.674	0.766	0.733	Delete
IRR5	✔	0.624	0.657	0.696	0.718	Delete
UI1	✔	0.634	0.722	0.711	0.766	Delete
UI2	✔	0.682	0.455	0.896	0	Delete
UI3	✔	0.696	0.5	0.888	0.786	Delete
UI4	✔	0.62	0.441	0.812	0.9	Delete
UI5	✔	0.588	0.474	0.624	0.798	Delete
		Delete	Delete	Delete	Delete	

≤ 1 2 3 4 ≥

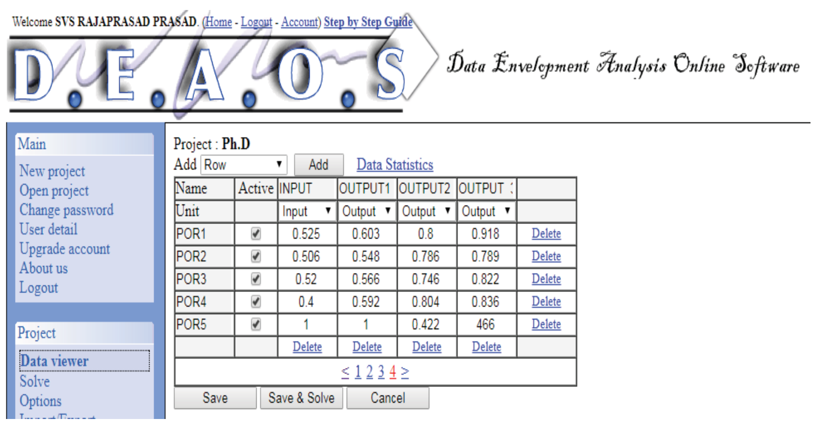
Figure 4: Normalized data of organizations POW 1to UI 5



Name	Active	INPUT	OUTPUT1	OUTPUT2	OUTPUT :	
Unit		Input	Output	Output	Output	
RAI1	✔	0.539	0.648	0.668	0.708	Delete
RAI2	✔	0.532	0.623	0.698	0.662	Delete
RAI3	✔	0.526	0.666	0.666	0.696	Delete
RAI4	✔	0.518	0.42	0.75	0.722	Delete
RAI5	✔	0.532	0.42	0.788	0.84	Delete
CA1	✔	0.402	0.647	0.801	0.788	Delete
CA2	✔	0.582	0.748	0.722	0.722	Delete
CA3	✔	0.682	0.629	1	0.586	Delete
CA4	✔	0.678	0.829	0.633	1	Delete
CA5	✔	0.4	0.666	0.636	0.626	Delete
ROA1	✔	0.51	0.612	0.674	0.714	Delete
ROA2	✔	0.509	0.538	0.722	0.766	Delete
ROA3	✔	0.528	0.612	0.728	0.741	Delete
ROA4	✔	0.5	0.583	0.654	0.706	Delete
ROA5	✔	0.502	0.6	0.588	0.633	Delete
		Delete	Delete	Delete	Delete	

≤ 1 2 3 4 ≥

Figure 5: Normalized data of organizations RAI 1to ROA 5



Name	Active	INPUT	OUTPUT1	OUTPUT2	OUTPUT :	
Unit		Input	Output	Output	Output	
POR1	✔	0.525	0.603	0.8	0.918	Delete
POR2	✔	0.506	0.548	0.786	0.789	Delete
POR3	✔	0.52	0.566	0.746	0.822	Delete
POR4	✔	0.4	0.592	0.804	0.836	Delete
POR5	✔	1	1	0.422	466	Delete
		Delete	Delete	Delete	Delete	

≤ 1 2 3 4 ≥

Figure 6: Normalized data of organizations POR 1to 5

RESULTS

The objective of the study is to evaluate and assess safety performance of DMUs in different Indian construction segments.

DEA with constant return to scale model- basic model

A construction segment is considered efficient when its objective function becomes unity. The input oriented maximization CCR – DEA model is used to obtain efficiency score. The results obtained from the models are summarized in Table 2. The efficiency scores indicate that five organizations have emerged as benchmarking units for the other 45 decision making units. The efficient units are POW5, CA1, CA5, POR4 and POR5 as the efficiency is equal to one and the other organizations are inefficient as efficiency is below one. It is also observed that POW5, CA1, CA5, POR4 and POR5 have become peer group for 20, 16, 18, 21 and 35 times respectively.

Table 2: Results of constant return to scale model – Basic model

Organization (DMU)	Efficiency	Rank	Peer group	Peer count
RE 1	0.51	23	POW5,CA1	0
RE 2	0.57	20	CA5,POR5	0
RE 3	0.60	19	CA1,POR4,POR5	0
RE 4	0.46	24	POR4,POR5	0
RE 5	0.65	15	POW5,CA5,POR5	0
CO 1	0.75	7	POW5,CA1,POR5	0
CO 2	0.67	14	POR4	0
CO 3	0.54	22	POR4,POR5	0
CO 4	0.71	11	CA1,POR4,POR5	0
CO 5	0.62	18	CA1, POR4, POR5	0
SEZ 1	0.63	17	POR4	0
SEZ 2	0.57	20	POR4, POR5	0
SEZ 3	0.79	4	CA5, POR5	0
SEZ 4	0.56	21	POR4, POR5	0
SEZ 5	0.76	6	CA5, POW5, POR5	0
POW 1	0.69	12	CA5	0
POW 2	0.63	17	POW5, CA1, POR5	0
POW 3	0.63	17	CA5, POR5	0
POW 4	0.71	11	POW5, CA5, POR5	0
POW 5	1	1	POW5	20
IRR 1	0.90	3	CA5	0
IRR 2	0.69	12	POW5, CA1, POR5	0
IRR 3	0.94	2	POW5, CA5	0
IRR 4	0.64	16	POW5, CA1, POR5	0
IRR5	0.64	16	POW5, CA5, POR5	0
UI 1	0.68	13	POW5, CA5, POR5	0
UI 2	0.65	15	POR4	0
UI 3	0.63	17	POR4	0
UI 4	0.65	15	POR4, POR5	0
UI 5	0.53	23	CA1, POR4, POR5	0
RAI 1	0.73	10	POW5, CA5, POR5	0
RAI 2	0.71	11	POW5, CA1, POR5	0

RAI 3	0.76	6	POW5, CA5, POR5	0
RAI 4	0.72	10	POR4	0
RAI 5	0.74	8	POR4, POR5	0
CA 1	1	1	CA1	16
CA 2	0.77	5	POW5, CA5, POR5	0
CA 3	0.73	9	POR4	0
CA 4	0.73	9	CA5, POR5	0
CA 5	1	1	CA5	18
ROA 1	0.73	9	POW5, CA5, POR5	0
ROA 2	0.71	11	CA1, POR4, POR5	0
ROA 3	0.71	11	CA1, POW5, POR5	0
ROA 4	0.71	11	CA1, POW5, POR5	0
ROA 5	0.72	10	CA1, POW5, POR5	0
POR 1	0.76	6	CA1, POR4, POR5	0
POR 2	0.77	5	POR4	0
POR 3	0.72	10	CA1, POR4, POR5	0
POR 4	1	1	POR4	21
POR 5	1	1	POR5	35

The inefficient units have to approach peer groups to become efficient. The organization in port segment (POR 5) is to be referred by inefficient units 35 times to become efficient and it is the best among the five efficient units. The organization is under real estate segment, RE4 is ranked last with an efficiency of 0.46. All the efficient units are from infrastructure segment only and none of the organizations from real estate segment are efficient. The results of mean scores of two segments in constant return to scale model are shown in Table 3. From mean efficiency scores, it is observed that the safety performance in real estate segment is only 0.63 that requires efforts from all the stakeholders to become efficient. Civil aviation and port segments are observed relatively better performing units among other infrastructure segments and still wide scope for improving efficiency to become peer units.

Table 3: Mean scores of constant return to scale model – Basic model

Real estate divisions (Scores)		Infrastructure divisions (Scores)	
Residential	0.56	Utilities /Power	0.73
Commercial	0.66	Utilities /Irrigation	0.76
SEZs	0.66	Urban Infrastructure	0.63
		Transportation/ Railways	0.73
		Transportation/ Civil Aviation	0.85
		Transportation/ Roadways	0.72
		Transportation/ Ports	0.85
Mean Score	0.63		0.75

DEA with constant return to scale model – special case

In the basic model of measuring efficiency three outputs were considered that is total number of accidents, man days lost and cost of accident damages. The total number of accidents is inclusive of first aid cases. Usually the number of first aid cases will be high in some decision making units. The first aid cases are nothing but giving immediate relief to an employee and return to the work place to resume normal duties immediately after treatment. The first aid cases are very minor and the possibility of man-days lost doesn't arise. The first aid cases were recorded by the safety department/ first aider to have an idea about nature of injuries and to implement remedial measures. The higher number of first aid cases in an organization will have its influence on efficiency. To test the model behaviour, an attempt has been made to measure efficiency by excluding the first aid cases from the total number of accidents. The results of CRS model by excluding first aid cases are shown in Table 4.

The results indicate that POW 5, CA1, ROA 4, POR 4 and POR 5 have become efficient and ROA 4 has emerged as new efficient unit. The decision making units POW5, CA1, POR 4 and POR5 are efficient in both the cases. The number of first aid cases is influencing the efficiency of DMUs ROA 4 in the basic model and not become efficient. The efficiency of POR 3 approaching to unity (0.99) and little effort will make it efficient. The efficient unit of basic model CA 5 has become inefficient mainly due to presence of loss time and fatal accidents. The DMUs POW5, ROA4 and POR5 have become benchmarking units with peer count of 40, 43 and 37. None of the DMUs in real estate segment has become efficient and it indicates much effort are required to improve safety performance, even though efficiency scores are considerable better compared to basic model.

Table 4: Results of constant return to scale model – Special case

Organization (DMU)	Efficiency	Rank	Peer group	Peer count
RE 1	0.72	18	POW5, ROA4	0
RE 2	0.73	17	ROA4, POR5	0
RE 3	0.73	17	POW5, ROA4, POR5	0
RE 4	0.73	17	ROA4	0
RE 5	0.74	16	POW5, ROA4, POR5	0
CO 1	0.76	14	POW5, ROA4	0
CO 2	0.73	17	POW5, ROA4, POR5	0
CO 3	0.70	19	ROA4, POR5	0
CO 4	0.89	7	POW5, ROA4, POR5	0
CO 5	0.72	18	POW5, ROA4, POR5	0
SEZ 1	0.92	5	POW5, ROA4, POR5	0
SEZ 2	0.75	15	POW5, ROA4, POR5	0
SEZ 3	0.83	10	POW5, ROA4, POR5	0
SEZ 4	0.84	9	POW5, ROA4, POR5	0
SEZ 5	0.80	12	POW5, ROA4, POR5	0
POW 1	0.69	20	ROA4, POR5	0
POW 2	0.73	17	POW5, ROA4, POR5	0
POW 3	0.72	18	POW5, ROA4, POR5	0
POW 4	0.75	15	POW5, ROA4	0
POW 5	1	1	POW5	40
IRR 1	0.83	10	POW5, ROA4, POR5	0
IRR 2	0.75	15	POW5, ROA4, POR5	0
IRR 3	0.96	4	POW5, ROA4	0
IRR 4	0.75	15	POW5, ROA4, POR5	0
IRR5	0.76	14	POW5, ROA4, POR5	0
UI 1	0.73	17	POW5, ROA4, POR5	0
UI 2	0.72	18	POW5, ROA4	0
UI 3	0.70	19	POW5, ROA4	0
UI 4	0.81	11	POW5, ROA4, POR5	0
UI 5	0.70	19	POW5, ROA4, POR5	0
RAI 1	0.75	15	POW5, ROA4, POR5	0
RAI 2	0.74	16	POW5, ROA4, POR5	0
RAI 3	0.79	13	POW5, ROA4, POR5	0
RAI 4	0.86	8	POW5, ROA4, POR5	0

RAI 5	0.99	2	POW5, ROA4, POR5	0
CA 1	1	1	CA1	4
CA 2	0.80	12	POW5, ROA4, POR5	0
CA 3	0.74	16	POW5, CA1	0
CA 4	0.72	18	ROA4, POR5	0
CA 5	0.91	6	POW5, ROA4, POR5	0
ROA 1	0.74	16	POW5, ROA4, POR5	0
ROA 2	0.86	8	POW5, ROA4, POR5	0
ROA 3	0.91	6	POW5, ROA4, POR5	0
ROA 4	1	1	ROA4	43
ROA 5	0.98	3	ROA4	0
POR 1	0.79	13	POW5, CA1, POR5	0
POR 2	0.83	10	POW5, CA1, POR5	0
POR 3	0.99	2	POW5, ROA4, POR5	0
POR 4	1	1	POR4	1
POR 5	1	1	POR5	37

The mean values of efficiency segment wise were presented in Table 5. The mean scores of DMUs of real estate and infrastructure segments have been improved from 0.63 to 0.77 and 0.75 to 0.83. The mean scores show significant improvement in both the segments and the overall mean of efficiency was increased from 0.70 to 0.80, which is substantial.

Table 5: Mean scores of constant return to scale model – Special case

Real estate divisions (Scores)		Infrastructure divisions (Scores)	
Residential	0.73	Utilities /Power	0.78
Commercial	0.76	Utilities /Irrigation	0.81
SEZs	0.83	Urban Infrastructure	0.73
		Transportation/ Railways	0.83
		Transportation/ Civil Aviation	0.83
		Transportation/ Roadways	0.90
		Transportation/ Ports	0.92
Mean Score	0.77		0.83

The summary of results of constant return to scale under basic model and special case are represented in Table. 6. It is observed from summary of results that DMUs POW 5, CA 1, POR 4 and POR 5 have become efficient units in all the cases. The impact of first aid cases are clear in both the cases, as inefficient DMUs in basic model became efficient in the special case and vice versa due to presence of man days lost and fatal accidents. The previous studies on safety performance was compared technical efficiency among industries like steel, refractory's and construction (Beriha, Patnaik & Mahapatra, 2011) but the present study focussed to measure performance within Indian construction industry.

Table 6: Summary of results

CRS model			
Basic model		Special case	
Efficient units	Peer count	Efficient units	Peer count
POW5	20	POW5	40
CA1	16	CA1	4
CA5	18	ROA4	43
POR4	21	POR4	1
POR5	35	POR5	37

CONCLUSIONS

The main purpose of the study is to identify inefficient units in real estate and infrastructure segments of Indian construction industry with an objective to adopt best practices followed by benchmarking units so as to become efficient. DEA methodology quantifies how much efficiency score needs to be improved to reach at benchmarking unit's score. The total expenditure on safety related activities is considered as input and the outputs are the total number of accidents, man days lost due to an accident and total cost of accident damages. In the previous studies, the outputs are mainly different types of accidents but this study considered cost of accident damages also. The main reason for considering cost of damages is some accidents may not cause injuries but cause damage to the property. Two cases are considered in CRS model; basic model in which all the accidents are considered irrespective of its impact and special case in which first aid accidents are excluded as these accidents do not cause man days lost or cost to the DMU. The presence of first aid cases in total number of accidents has significant impact on efficiency scores and overall safety performance of real estate and infrastructure segments.

In both the cases, the mean efficiency scores of DMUs in real estate are lower than that of infrastructure and not even a single DMU was efficient from real estate segment. All the stakeholders are responsible for improvement of technical efficiency by strictly implementing safety systems and procedures. The DMUs POW5, CA1, POR4 and POR5 are efficient in all cases under both the models and inefficient DMUs approach the four benchmarking units; and implement safety systems practiced by the units. The DMU POR5 is considered to be best among the other three basing on peer count, followed by POW5, POR4 and CA1. The inefficient units may implement and practice the safety procedures followed by the benchmarking units to become efficient.

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