EVALUATION OF SAFETY PERFORMANCE IN INDIAN CONSTRUCTION SEGMENTS USING DATA ENVELOPMENT ANALYSIS

SVS Rajaprasad, YVSSV Prasada Rao, and P Venkata Chalapathi

ABSTRACT

Safety in the construction segments is one of the most unprotected within the unorganised labour sector in India. The purpose of the study is to apply data envelopment analysis (DEA) to evaluate safety performance of construction segments in India. Essentially, DEA takes into account the input and output components of a decision making unit, calculates technical efficiency, and is treated as an indicator for safety performance of Decision Making Units (DMUs). Fifty Indian construction organisations under infrastructure and real estate segments are selected for the study. The findings show that safety performance in the real estate segment is consistently low.

Keywords: Constant returns to scale (CRS), Data envelopment analysis (DEA), Decision making unit (DMU), Technical efficiency (TE), and Variable return to scale (VRS).

INTRODUCTION

The purpose of the study is to employ data envelopment analysis (DEA) to evaluate safety performance of construction segments in India. 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 hospitals, a set of schools, a set of banks, etc. DEA is a methodology based upon application of linear programming. It was originally developed for performance measurement, and has since been 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. The principles of DEA date back to Farrel (1957).

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Most of the clients are relying closely on contractors' or subcontractors` bid proposal in the selection process when allocating work. The lowest bid is the criteria for finalising contractors/sub contractors in most selection processes, which can contribute to project delays, cost overruns, non-confirmation on quality, lost time accident, and increasing numbers of claims, litigation and contractual issues. The tender price should be assessed and include budgets for safety related issues and implementation at project level. The expected standards and safety requirements should be listed in the contract document. The past record of safety performance of the contractor/sub contractors is to be examined before finalisation and allocation of works (Kozlovska & Strukova 2012).

DEA, with its ability to measure the relative performance of organisational units that have multiple inputs and outputs, was applied for prequalification of contractors in a construction project in Canada (McCabe, Tran & Ramani 2005). One of the important aspects which influence the efficiency of projects is the high rate of accidents at the workplace. Lower numbers of accidents and lost working days through lower safety costs are efficient. DEA with the BCC model was implemented in Iranian projects and the approach provides an objective statement of how safety systems have been implemented (Shirouyehzad & Dabestani 2011). DEA was applied to estimate the performance efficiency of 2,298 Vietnamese construction firms in 2002 by considering net revenue as output, and the average number of laborers in the year together with net capital considered as inputs. The results of the study showed that the average technical efficiency of these firms was 58.6 % (Nguyen & Giang 2005). In another study conducted in Norwegian construction firms, DEA was applied by considering revenue as output based on the type of construction, i.e., residential construction, non-residential construction and civil engineering construction, with inputs based on external expenses (materials, subcontractors, energy, transportation, etc), labor in man-year, and capital. The results of the study showed an average efficiency score of 83.4% (Edvarsen 2003)

Safety performance in India is presently based on the method for computation of frequency and severity rates for industrial injuries, and classification of industrial accidents (IS: 3786 1983). The Indian standard is framed with an objective to help evaluating relative need for taking accident preventive measures, making an appraisal of the program of an accident prevention campaign and to encourage accident prevention in organisations. The standard includes details of work injury and computation of frequency severity rates. The drawback of injury rates are the partial indicators of injury cases only, and does not include property damage or time losses. However, new methods are still to be developed to offer insights to both researchers and practitioners in lieu of the drawbacks of the code. A point of departure for the DEA approach compared to IS code is that DEA relates resources expended on a certain performance to the level of success for that particular performance.

Under existing methods, construction segments that suffer the same numbers and types of accidents are considered to be of identical performance. It makes more sense to consider the construction segment that commits fewer resources to arrive at a certain safety performance, as a better performer. The main features of DEA are its capability to incorporate multiple inputs and multiple outputs, no need to assign weights to the different inputs/outputs, and the measurement units of the different inputs/outputs need not be congruent. DEA is the input–output framework and relates resources expended on safety to safety performance. The DEA approach can be utilised by a particular organisation to gauge its own safety performance over a period of time and considers every year as a single DMU, which is useful for comparison purposes and enables appropriate steps to be initiated to improve safety performance (El-Mashaleh, Rababeh & Hyari 2009). The benchmarking program developed by the Construction Industry Institute (CII) in the United States was also described by Lee, Thomas and Tucker (2005). In addition, Ramirez, Alarcon and Knights (2004) describe the benchmarking system that was established in the Chilean construction industry, which incorporates qualitative management aspects and performance indicators.

Siriruttanapruk and Anuntakulnathi (2004) stated that the poor levels of construction safety in organisations are primarily due to inadequate implementation of safety programs and weak enforcement of legislation. Feroz, Raab and Haag (2001) have used DEA to test the economic consequences of the occupational health and safety administration caused due to cotton dust in fabric industries. Ng, Cheng and Skitmore (2005) developed a safety performance evaluation (SPE) framework for evaluating contractor's safety performance, and the model includes a range of organisation-related and project-related SPE factors.

Abbaspour, Hosseinzadeh, Karbassi, Roayaei & Nikoomaram. (2009) developed an appropriate model to evaluate organisations' efficiency and environmental performance, regarding health, safety, and environmental management system principles. The model was examined on 12 oil and gas general contractors. In another study by Beriha, Patnaik and Mahapatra (2011) an appropriate structure based on DEA was developed to benchmark occupational health and safety performance in 30 Indian organisations under three categories of construction, refractory and steel. Results of this study revealed that safety performance of construction industries is consistently low in comparison with other categories of industries.

The growing competitiveness of the construction segments motivated the firms to assess performance and implement efficient safety measures to improve safety performance. Recently, in several countries, benchmarking systems were specially designed for the construction industry (Costa, Formoso, Kagioglou, Alarcón & Caldas 2006). These systems, available in web-based platforms, typically analyse companies' performance based on a set of Key Performance Indicators, which consist of ratios representing key aspects of the companies' activity. However, no insights concerning organisation overall performance are provided. Teo & Ling (2006) developed a model to measure the effectiveness of safety management systems of construction sites, and utilised surveys and experts' interviews and workshops to collect the important factors affecting safety.

In the present study, an attempt has been made to analyse safety performance in two construction segments, i.e. infrastructure and real estate in India, using DEA. In India, safety in construction is accorded least priority by the builders, contractors and engineers. The construction industry in India today is very large and complex, but the rapid growth has led to a shortfall in terms of safety and health aspects of the construction workers. The methodology focuses directly on management commitment for benchmarking, goal setting and designing safe operating procedures in an attempt to adopt safe practices.

METHODOLOGY

Data Envelopment Analysis

DEA was initiated by Charnes, Cooper and Rhodes (1979). In the construction management sector few studies made use of DEA. El-Mashaleh, O'Brien and London (2001) proposed the

DEA methodology to measure and compare subcontractors' productivity at the firm-level. El-Mashaleh et al. (2009) deploy DEA to evaluate the firm-level performance of construction contractors. McCabe et al. (2005) utilise DEA to pre-qualify contractors. Contractors' financial performance was evaluated based on DEA by Pilateris and McCabe (2003).

DEA is a mathematical programming methodology. It has been successfully employed for assessing the relative performance of a set of firms usually called decision making units (DMU), A DMU is treated as the entity responsible for converting inputs into outputs and whose performance is to be evaluated. In this study, a DMU refers to a construction segment. DEA is linear programming-based tool for measuring the relative efficiency of each unit in asset of comparable organisational units using theoretical optimal performance for each organisation. DEA makes use of fractional programming problem and corresponding linear programming problem, together with their duals to measure relative performance of DMUs (Charnes, Cooper & Rhodes 1978; Charnes, Cooper, Lewin & Seiford 1994; Cooper, Seiford & Tone 2000). The Charnes, Cooper and Rhodes (CCR) model is a fractional programming problem model which measures the efficiency of DMU's by calculating the ratio of the 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. The magnitude of inefficiency of the DMU's is determined by measuring the radial distance from the inefficient unit to the efficient one.

CCR or Constant Returns to Scale (CRS) ***model.*** The present study makes use of the CCR model to evaluate safety performance in construction segments in India. The CCR model is based on the concept of constant return to scale. For the proportionate change in all inputs, if all outputs vary by the same proportion then the production function exhibits constant returns to scale.

Let there be 'n' DMUs whose efficiencies have to be compared. Let us take one of the DMUs, say the m^{th} DMU, and maximize its efficiency according to the formula as in [1]. Here the m^{th} DMU is the reference DMU. The mathematical program is now:

$$\text{Max } E_m = \frac{\sum_{j=1}^{J} v_{jm}\, y_{jm}}{\sum_{i=1}^{I} u_{im}\, x_{im}}$$

Subject to [1]

$$0 \leq \frac{\sum_{j=1}^{J} v_{jm}\, y_{jn}}{\sum_{i=1}^{I} u_{im}\, x_{in}} \leq 1;\ n = 1, 2, K, N$$

$$v_{jm}, u_{im} \geq 0;\ i = 1, 2, K, I;\ j = 1, 2, K, J$$

Where:
E_m is the the measure of efficiency for the m^{th} DMU,
y_{jm} is the known amount j^{th} output of the m^{th} DMU,
v_{jm} is the output weight. It is determined by the solution of the model and is assigned to the j^{th} output.
x_{im} is known amount of the i^{th} input of the m^{th} DMU,
u_{im} is the input weight. It is determined by the solution of the model and is assigned to the i^{th} input.
y_{jn} is the known amount of j^{th} output by j^{th} DMU
x_{in} is the known amount of the i^{th} input used by j^{th} DMU

DMU, n = 1, 2… N. The fractional programme shown in equation (1) can be reduced to LPP as in [2].

$$\text{Max } E = \sum_{j=1} v_{jm}\, y_{jm}$$

Subject to:

$$\sum_{i=1}^{I} u_{im}\, x_{im} = 1 \qquad [2]$$

$$\sum_{j=1}^{J} v_{jm}\, y_{jn} - \sum_{i=1}^{I} u_{im}\, x_{in} \leq 0\ ; \quad n = 1, 2, K, N$$

$$v_{jm}, u_{im} \geq \epsilon\ ; \quad i = 1, 2, K, I;\ j = 1,2,K,J$$

The model is called CCR output-oriented maximisation of the DEA model. The efficiency score of "n" DMUs is obtained by running the above LPP "n" times (Ramanathan, 1996).

Banker- Charnes-Cooper (BCC) or Variable Returns to Scale (VRS) model. The CRS assumption is only appropriate when all DMU's operate at an optimal scale. Constraints in the operating environment, for instance, legal requirements, financial and human resource constraints, amongst other factors, may cause a DMU to operate at a non-optimal scale. The DEA model by Banker, Charnes, and Cooper (BCC) is based on the concept of variable returns to scale. If for the proportionate changes in all inputs the output results vary by a different proportion, then the production function exhibits Variable Returns to Scale (VRS). The VRS can be further classified as Increasing Returns to Scale (IRS) and Decreasing Returns to Scale (DRS). If the outputs vary by a proportion greater than the proportion of inputs then the production function exhibits increasing returns to scale. Where the outputs vary by a proportion less than the proportion of inputs then the production function exhibits decreasing returns to scale. The VRS model is essentially the CRS with an additional constraint added to the LP problem. The most important extension of the original CCR models is outlined by Banker, Charnes and Cooper (1984) where an additional constraint was introduced in the model, as shown in equation (3):

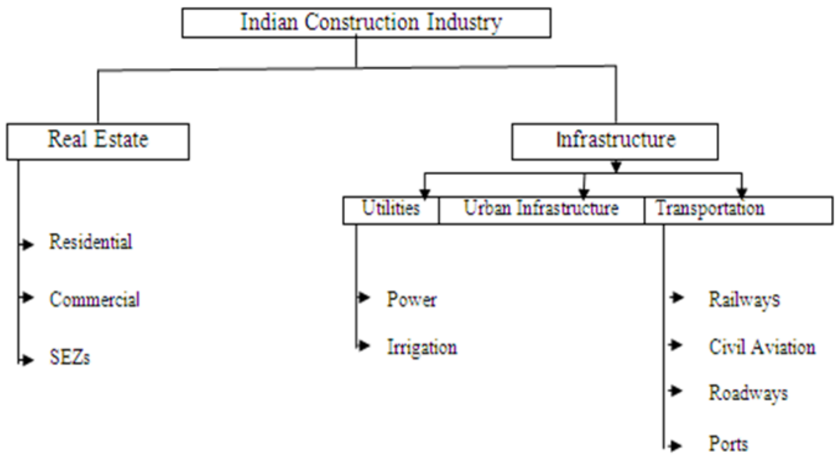
$$\sum_{J=1}^{n} \lambda j = 1 \qquad [3]$$

λ is a $I \times 1$ vector of constants,(weight assigned to unit j), I is number of DMU's.

This constraint enables variable returns to scale, and provides for the reference set to be formed as a convex combination of DMUs, which are in the set (those that have positive value for λ in the optimal solution). The DMU operates under variable returns to scale if it is suspected that an increase in inputs does not result in a proportional change in the outputs. The convexity constraint ensures that the composite unit is of similar scale size as the unit being measured. The BCC model yields a measure of pure technical efficiency that ignores the impact of the scale size by only comparing a DMU to a unit of similar scale. Often, small units are qualitatively different from large units and a comparison between the two may distort measurements of comparative efficiency. The measured efficiency is always at least equal to the one given by the CCR model. The envelopment surface obtained from the BCC model results in a convex hull.

Selection of decision making units. The Indian construction sector can be broadly classified into two sub-segments (NSDC report, 2008), as shown in Figure 1.

Figure 1: Classification of construction segments



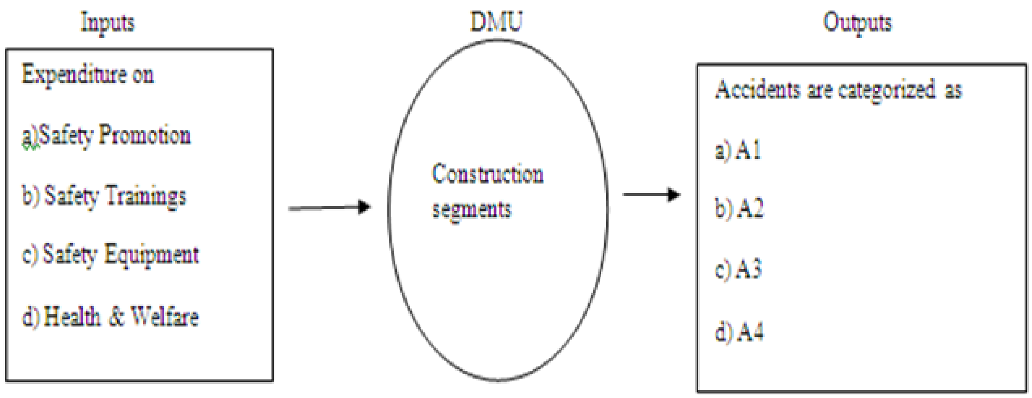
In order to identify DMUs, fifty Indian construction organisations from two segments, i.e. infrastructure and real estate, were selected. This was broken down into five organisation types within each category, with DMUs 1 to 15 (RR1 to RR5, RC1 to RC5 & RS1 to RS5) representing real estate, and DMUs 16- 50 (IUP1 to IUP5, IUI1 to IUI5, IU1 to IU5, ITR1to ITR5, ITC1 to ITC5, ITRO1 to ITRO5 &ITP1 to ITP5) representing the organisation divisions within the infrastructure segment. Details are shown in Table1.

Table 1: Representation of DMUs

DMUs	Segment	Division	Organisations
DMU 1 to 5	Real estate	Residential	RR 1 to 5
DMU 6 to 10	Real estate	Commercial	RC 1 to 5
DMU 11 to 15	Real estate	SEZs	RS 1 to 5
DMU 16 to 20	Infrastructure	Utilities /Power	IUP 1 to 5
DMU 21 to 25	Infrastructure	Utilities /Irrigation	IUI 1 to 5
DMU 26 to 30	Infrastructure	Urban Infrastructure	IU 1 to 5
DMU 31 to 35	Infrastructure	Transportation/ Railways	ITR 1 to 5
DMU 36 to 40	Infrastructure	Transportation/ Civil Aviation	ITC 1 to 5
DMU 41 to 45	Infrastructure	Transportation/ Roadways	ITRO 1 to 5
DMU 46 to 50	Infrastructure	Transportation/ Ports	ITP 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). To evaluate construction safety performance, Figure 2 shows the related inputs and outputs. The input parameters have been identified through discussions with the safety professionals, safety managers and corporate safety heads from various construction organisations in India. The safety performance of a construction segment is affected by the expenditure as a percentage of total revenues. The expenditure includes the annual cost of safety trainings, promotional activities, purchase of safety equipment & tools and health & welfare facilities provided.

Figure 2: Inputs and outputs



Construction workers in India are exposed to various types of hazards. The Building and other Construction Workers' (Regulation of Employment and Conditions of Service) Act (1996) is the legislation applicable towards safety, health and welfare of construction workers in India. According to this act, the workplace accidents are classified into the following four categories:

- First aid cases that do not cause injury/loss of work;
- Accidents that disable a worker from working for a period of 48 hours or more, immediately following the accident;
- Accidents causing disablement, subsequently resulting in the death of a worker; and
- Dangerous occurrences, whether or nor any death/disablement is caused to a worker.

Before undertaking the analysis, all the data should be normalised. Since outputs have a negative nature, the values are converted into the inverse format before being normalised. The reciprocals of the numbers of the different types of accidents, as per The Building and other Construction Workers' (Regulation of Employment and Conditions of Service) Act 1996, are used as outputs.

Wilcoxson Matched Pairs Test. The Wilcoxon test is a non-parametric test that compares two paired groups. It calculates the difference between each set of pairs, and analyses that list of differences. The whole point of using a paired test is to control for experimental variability. If sample size is large (more than 20) then the sampling distribution can be considered approximately as being normally distributed (Chandan 1998), so that the Z test can be used. The Z value is calculated as follows:

$$Z = (T - U_T) / \sigma_T \quad [4]$$

Where:

T=sampling distribution statistic; U_T= mean of sampling distribution; and σ_T = standard deviation of sampling distribution.

DATA COLLECTION

The data was collected directly by approaching the safety managers/officers of the organisations, and explaining to them the purpose of the study. Many of them were reluctant to furnish the information about input/output parameters. Some organisations required a written assurance from the author to keep the data collected confidential. Organisations not maintaining safety records were not considered under the study. The data was collected for the year 2010-11. The data collection was restricted to five organisations under each division, mainly due to some organisations not having available records.

RESULTS AND DISCUSSION

DEA with CRS Model

The objective of the study is to evaluate and assess safety performance of DMUs in different Indian construction segments. The Constant Return to Scale (CRS) and Variable Return to Scale (VRS) models are used. A construction segment is considered efficient when its objective function becomes a unity. The input oriented maximisation CCR – DEA model is used to obtain the efficiency score. Frontier analyst version 4 has been used to solve the model. The results obtained from the models are summarised in Tables 2 and 3 respectively, for the real estate and infrastructure segments.

Table 2: Results of CRS & VRS of real estate segment

DMU	Segment	Efficiency score		Ranking		Peer count	
		CRS	*VRS*	*CRS*	*VRS*	*CRS*	*VRS*
DMU 1	RR 1	0.69	0.71	48	49	0	0
DMU 2	RR 2	0.58	0.68	50	50	0	0
DMU 3	RR 3	0.68	0.76	49	45	0	0
DMU 4	RR 4	0.76	0.78	43	42	0	0
DMU 5	RR 5	0.76	0.76	42	47	0	0
DMU 6	RC 1	0.83	0.88	22	19	0	0
DMU 7	RC 2	0.84	0.80	20	35	0	0
DMU 8	RC 3	0.88	0.80	15	37	0	0
DMU 9	RC 4	0.79	0.81	37	29	0	0
DMU 10	RC 5	0.88	0.83	13	24	0	0
DMU 11	RS 1	0.76	0.79	44	41	0	0
DMU 12	RS 2	0.81	0.81	25	29	0	0
DMU 13	RS 3	0.74	0.77	45	44	0	0
DMU 14	RS 4	0.70	0.79	47	39	0	0
DMU 15	RS 5	0.87	0.90	17	16	0	0

Based on efficiencies the scores indicate that five DMUs out of 50 DMUs have emerged as benchmarking units for the other 45 DMUs. The efficient units are DMU 16, DMU 23, DMU 38, DMU 39 and DMU 50, as the efficiency scores are equal to unity. The remaining 45 DMUs are inefficient as the scores are less than unity. It is also observed that DMU 16, DMU 23, DMU 38, DMU 39 and DMU 50 have become peer units 22, 18, 26, 16 and 28 times respectively.

The inefficient units have to consult peer units to become efficient. DMU 16 has to be consulted by inefficient groups 22 times to become an efficient unit. DMU 50 is ranked as the best unit based on an efficiency score of one, and having a greater number of referring DMUs as far as safety performance is considered. DMU 2 is ranked last having an efficiency score 0.580. Not even one unit from the real estate segment has become an efficient one.

Table 3: Results of CRS & VRS of infrastructure segment

DMU	Segment	Efficiency score		Ranking		Peer count	
		CRS	***VRS***	***CRS***	***VRS***	***CRS***	***VRS***
DMU 16	IUP 1	1	0.82	1	25	22	0
DMU 17	IUP 2	0.80	1	33	1	0	22
DMU 18	IUP 3	0.80	0.85	30	26	0	0
DMU 19	IUP 4	0.81	0.85	25	22	0	0
DMU 20	IUP 5	0.81	0.81	23	27	0	0
DMU 21	IUI 1	0.84	0.84	21	23	0	0
DMU 22	IUI 2	0.90	1	10	1	0	12
DMU 23	IUI 3	1	0.92	1	12	18	0
DMU 24	IUI 4	0.80	0.80	33	37	0	0
DMU 25	IUI5	0.81	0.81	27	29	0	0
DMU 26	IU 1	0.80	0.80	28	34	0	0
DMU 27	IU 2	0.90	0.88	9	19	0	0
DMU 28	IU 3	0.78	0.81	40	32	0	0
DMU 29	IU 4	0.80	0.76	29	45	0	0
DMU 30	IU 5	0.78	0.78	40	42	0	0
DMU 31	ITR 1	0.94	1	1	1	0	14
DMU 32	ITR 2	0.79	0.81	36	27	0	0
DMU 33	ITR 3	0.81	0.79	23	39	0	0
DMU 34	ITR 4	0.80	0.80	30	36	0	0
DMU 35	ITR 5	0.87	0.91	17	15	0	0
DMU 36	ITC 1	0.88	1	12	1	0	16
DMU 37	ITC 2	0.88	0.90	16	16	0	0
DMU 38	ITC 3	1	0.96	1	9	26	0
DMU 39	ITC 4	1	1	1	1	16	24
DMU 40	ITC 5	0.79	0.81	37	32	0	0
DMU 41	ITRO 1	0.72	0.72	46	48	0	0
DMU 42	ITRO 2	0.91	1	7	1	0	21
DMU 43	ITRO 3	0.86	0.9I	19	14	0	0
DMU 44	ITRO 4	0.79	0.88	37	18	0	0
DMU 45	ITRO 5	0.80	0.87	33	21	0	0
DMU 46	ITP 1	0.8	0.92	30	10	0	0
DMU 47	ITP 2	0.80	1	11	1	0	19
DMU 48	ITP 3	0.88	0.92	14	11	0	0
DMU 49	ITP 4	0.90	0.91	8	13	0	0
DMU 50	ITP 5	1	1	1	1	28	10

The results of mean scores of the two segments are summarised in Table 4. From mean efficiency scores, it is observed that the safety performance in the real estate segment is poor when compared with the infrastructure segment. The overall efficiency of the construction industry in India, regarding safety performance, is 0.830, indicating that considerable improvement is required to become efficient units. Peer count, suggested by Charnes, Cooper, Golany, Seiford and Stutz (1985), consists of the computation of how many observations are influenced by a certain efficient observation. The peer count is reinterpreted as the average frequency that an observation influences other observations. Peer count is the number of times each firm is a peer for another. This involves the computation of the number of times an efficient DMU is a peer of an inefficient DMU.

Table 4: Mean scores of CRS model

Real estate divisions (Scores)		Infrastructure divisions (Scores)	
Residential	0.69	Utilities /Power	0.84
Commercial	0.84	Utilities /Irrigation	0.87
SEZs	0.77	Urban Infrastructure	0.81
		Transportation/ Railways	0.84
		Transportation/ Civil Aviation	0.91
		Transportation/ Roadways	0.82
		Transportation/ Ports	0.89
Mean Score	**0.77**	**Mean Score**	**0.86**

DEA with VRS Model

The VRS model shows that eight DMUs are efficient units, listed as DMU 17, DMU 22, DMU 31, DMU 36, DMU 39, DMU 42, DMU 47 and DMU 50. The efficiency scores of the efficient units approach unity, while the scores of inefficient units are less than unity. The inefficient units can refer peer groups to become efficient groups. The peer counts of efficient units are summarised in Table 2. The inefficient units can make adjustments in their inputs/outputs by looking into their peer groups to become an efficient unit. These units may adopt either an input-oriented strategy or an output-oriented strategy to become efficient. The input-oriented strategy emphasises achieving the current level of output using less inputs than the current level, whereas the output-oriented strategy rests on achieving a higher level of output by the same level of inputs. The two DMUs 39 and 50 have become efficient in CRS and VRS models. The overall and segment wise efficiency of the VRS model is more than the CRS model. The results of mean scores of the two segments are summarised in Table 5.

Table 5: Mean scores VRS model

Real estate divisions (Scores)		Infrastructure divisions (Scores)	
Residential	0.74	Utilities /Power	0.86
Commercial	0.82	Utilities /Irrigation	0.87
SEZs	0.81	Urban Infrastructure	0.81
		Transportation/ Railways	0.98
		Transportation/ Civil Aviation	0.93
		Transportation/ Roadways	0.88
		Transportation/ Ports	0.95
Mean Score	**0.79**	**Mean Score**	**0.90**

Validation of CRS & VRS Models

To test for significant differences between efficiency scores calculated by using CRS and VRS models, the Wilcoxon matched pairs test was used. The hypothesis is formulated as follows:

H_o (Null hypothesis) - Efficiency scores from CRS model = VRS model
H_a (Alternate hypothesis) - Efficiency scores from CRS model ≠ VRS model

The Wilcoxon matched pairs test is carried out by STAT PLUS 2009 Professional. The null hypothesis was rejected based on the test result with a p value of 0.0014, with a value as low as 0.05. Based on the test, it allows for an alternative hypothesis that there is significant difference in efficiency scores obtained in both the models. Management must be cautious regarding use of scale assumption. A thorough understanding of behaviour of input and output variables is needed while assuming scale. For a better understanding of the problem, the number segments to be studied under real estate and infrastructure is to be increased as, DEA is quite sensitive to sample size.

CONCLUSION

The DEA is the best tool to gauge safety performance. Construction organisations involved in both the segments can use the DEA approach to compare safety performance. The methodology helps to adopt best practices of peers to become efficient. For each inefficient segment, DEA identifies a set of corresponding efficient segments. The efficient segments are said to form a reference set for the inefficient unit. The efficient unit that appears in the reference set of most of the inefficient units gives the optimal input-output mix for the inefficient units. The goal of an inefficient unit is to perform like the best of its peers, which sets the performance goals for that unit. The overall efficiency in real estate and infrastructure segments is 0.830 and 0.864, and all the stakeholders must concentrate on safety aspects to achieve efficiency as unity. The inefficient units can refer efficient units to improve safety performance. Not even a single DMU has become efficient in the real estate segment in both the models, and DMU 2 is the most inefficient unit from both the models.

The present study is based on the fact that safety and health measures can be improved through the allocation of a sufficient annual budget of the firm in critical safety activities. The inputs are considered as a percentage of the annual budget on critical safety activities. The number of accidents, as per the applicable legislation, is treated as outputs of the model. In the real estate segment, the allocation of budgets for safety activities is marginal and the percentage varies between 1 to 1.45%, which is not sufficient to achieve safety performance. In contrast, the percentage of annual budgets in the infrastructure segment varies between 2 to 3.5%. The construction safety performance in civil aviation and port divisions is satisfactory, based on efficiency scores, which is mainly due to adhering to healthy safety practices, allocation of budgets, implementation of safety systems, and strict compliance with applicable legislations.

The construction sector in India currently lacks readily available safety performance measures to assess performance. To gauge safety performance, the construction sector currently relies on certain indexes like accident rates, severity rates and the frequency severity index. The DEA approach can be used efficiently for a gap analysis approach at the organisational level, which enables achievable and desired results, and is useful for strict compliance of applicable legislations. Management commitment to implementing safety systems, like safety trainings, risk assessment, emergency procedures, review and legal requirements, will definitely improve safety performance in the construction segments in India. All the stakeholders will benefit from safety performance. The CRS and VRS models are validated by using the Wilcoxon matched pairs test, which has demonstrated that statistically significant difference exists in both models. An in depth study of input and output variables is required before the use of scale assumption.

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