Indian Management Studies Journal 15 (2011) 159-174

Indian
Management
Studies Journal

An Enquiry into the Production Efficiency of Haryana Roadways

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Abstract

This paper measures the relative performance of 20 depots of Haryana Roadways (STHAR) for the 6 year period (2001-02 to 2006-07) using data envelopment analysis (DEA). This study identifies the relatively efficient and inefficient depots, sets benchmarks for the relatively inefficient depots, suggests alternative action that would make inefficient depots relatively efficient, and also measures the scale-size effect on the relative efficiency. In this study, fleet size, total staff and fuel consumption have been selected as inputs and passenger kilometres as an output. The study finds out that of 20 depots only 3 depots turned out technical efficient, 7 depots came out pure technical efficient and only 3 depots were found to operate at the most productive scale size (MPSS). The mean technical efficiency comes out to be 0.891. On average, a technical inefficient depot may reach on the efficient frontier if it is able to reduce its fleet size by 14.90%, total staff by 15.58% and fuel consumption by 13.12%. The paper also observes differences in the average efficiency scores of depots across zones.

Key Words

Data Envelopment Analysis, Efficiency, Road passenger Transport, CRS and VRS Models.

INTRODUCTION

In times of competition and budget constraints an economic unit needs to know by how much it may increase its production, without absorbing additional resources. The quantitative monitoring of the production process allows for an effective administration of the resources available and the observation of predefined research patterns and goals. In this context, we developed a production model based on the input-output data of its research unit, the Haryana Roadways (STHAR). The performance assessment helps the managements to adopt proper operational and maintenance strategies and thus achieve social and economic goals. According to the objectives laid down in the Road Transport Corporation Act 1950, the State Transport Undertakings (STUs) have been constituted to provide adequate, well-coordinated, economical, safe and efficient passenger transport services to people of the country. As an STU the Haryana Roadways is entrusted with the responsibilities of achieving the above objectives. In addition to that though the STU is principally service-oriented, it should earn a little profit on passenger transportation for its perpetual succession and expansion. Haryana State Road Transport was bifurcated from Punjab Roadways in the year 1966 (Haryana state was carved out of Punjab on 1 November, 1966). At that time it had a fleet strength of only 475, 3 depots, 8 sub-depots and three bus stands and operating on 213 routes, at present it has 20 depots and 7 sub-depots having fleet of 3420 operating on 1610 routes all over the state. In the year 1970, Haryana government totally nationalized the passenger transport in the State and thus in the year 2007 it completed 37 years of bus transport service to the travelling public in the region. In the changing economic scenario, it is felt necessary to make a detailed study of the performance of the Road transport in Haryana.

In this paper, an attempt has been made to evaluate the performance of Haryana Roadways and suggest some concrete measures to improve the operational efficiency and financial viability of the STHAR.

In the changing situation, the challenge before the STHAR is to improve the quality of service it provides to the travelling public. A depot in a state transport undertaking (STU) is an important research area, it is a profit making unit of STU and hence our research units in this study are 20 depots of Haryana Roadways (STHAR).

Singh (2000) used index number approach to estimate the growth and relative level of productivity of 21 STUs for the period 1983-84 to 1996-97. The regression analysis has also been used to investigate the source of growth and differences in levels of productivity. Venkatesh and Singh (2002) compared the efficiency of 21 STUs by the estimation of Stochastic Frontier Production using the method of maximum likelihood. Jonathan and Darnika (1999) calculated the efficiency of British bus transport industry by using Data Envelopment Analysis. A Heteroskedastic Error Component model with unbalanced panel data is used by

Kumbhkar and Battacharyya (1996) to measure total factor productivity growth and technical change in passenger transport. Urakami and Mizataniad (2002) compared efficiency of private and public sector bus operators by using econometric methods to estimate the cost function of the bus service and wage function. The studies based on DEA are relatively very few. Anjaneyulu et al. (2006) evaluated performance of STUs by using CCR-Model of DEA. The studies indicate that DEA is an appropriate method to estimate the efficiency of a service sector activity such as transport sector. Accordingly in the present paper, DEA has been employed for assessing the performance of Haryana State Road Transport (STHAR).The paper attempts to estimate technical and scale efficiencies of the depots, set benchmark for inefficient depots, examine inter-zone variations in the efficiencies; and suggests alternative actions that would make them relatively efficient.

DATA ENVELOPMENT ANALYSIS (DEA)

Data Envelopment Analysis (DEA) is the non-parametric mathematical programming approach to frontier estimation. More detailed reviews of the methodology are presented by Seiford and Thrall (1990), Lovell (1993), Ali and Seiford (1993), Lovell (1994), and Charnes et al. (1995). The piecewise-linear convex hull approach to frontier estimation, proposed by Farrel (1957), did not receive wide attention until the paper by Charnes et al. (1978) which coined the term 'data envelopment analysis' (DEA). There have since been a large number of papers which extended and applied the DEA methodology. Charnes et al. (1978) proposed a model which had an input orientation and assumed constant returns to scale named after Charnes, Cooper and Rhodes, i.e., CCR. It is also called CRS model. Another basic model of DEA is BCC model, which is given by Banker, Charnes and Cooper (Banker et al., 1984). It is also called variable returns to scale (VRS).

EFFICIENCY MEASUREMENT USING DEA

DEA uses linear programming (LP) to obtain the measures of technical efficiency (TE). The input-oriented DEA LP is set up so as to maximize the TE score of i^{th} firm, subject to production remaining within the feasible set of production possibilities (DEA models can be either inputs or output-oriented). In the input orientation the efficiency scores relate to the largest feasible proportional reduction in inputs, while in the output orientation it corresponds to the largest feasible proportional expansion in outputs for fixed inputs. It is common practice to use an input orientation in analysis of network utilities because the firms are generally required to supply services to a fixed geographical area, and hence the output vector is essentially fixed (see discussion in Coelli et al., 2003, p. 41). This involves the solution of the following LP problem :

$$\begin{aligned} &\text{Min}_{\theta,\lambda}\ \theta, \\ &\text{st} \quad -y_i + Y\lambda \geq 0 \\ &\qquad \theta x_i - X\lambda \geq 0 \\ &\qquad \lambda \geq 0 \qquad \text{.... (1)} \end{aligned}$$

where, y_i is a M×1 vector of outputs produced by the i-th firm, x_i is a K×1 vector of inputs used by the i-th firm, y is the M×N matrix of outputs of the N firms in the sample, X is the K×N matrix of inputs of the N firm, λ is a N×1 vector of weights (which relate to the peer firms) and θ is a scalar measure of TE, which takes a value between 0 and 1 inclusive. This problem is solved N times - once for each firm in the sample (The discussion here is based on that in Coelli et al., 1998).

The above DEA LP has become the constant returns to scale (CRS) DEA model because the resulting technology will be a CRS technology. Thus, the efficiency scores obtained from this DEA model will be influenced by scale effects, if they exist. This may not be desirable in some cases, since firms cannot always influence scale in the short run. The above CRS DEA LP can be adjusted in order to allow a variable returns to scale (VRS or BCC) DEA technology. This is done by adding in convexity constraint to the original problem, resulting in the following LP :

$$\begin{aligned} &\text{Min}_{\theta,\lambda}\ \theta, \\ &\text{st} \quad -y_i + Y\lambda \geq 0 \\ &\qquad \theta x_i - X\lambda \geq 0 \\ &\qquad \lambda \geq 0 \qquad \text{... (2)} \end{aligned}$$

where, N×1 is a vector of ones. This VRS LP produces technical efficiency scores that are either greater than or equal to those from the CRS problem. This means that the variable returns to scale specification gives "pure" technical efticiency scores, which are free of scale efficiency effects.

A scale efficiency (SE) score can be derived (for each firm) by dividing the CRS or CCR TE score by the VRS or BCC PTE. This TE score also takes a value between 0 and 1 inclusive.

DATA COLLECTION

The data of twenty depots of Haryana Roadways is collected from the annual reports, audit reports, administration reports, and action plans prepared by the transport department of Haryana for the time period 2001-02 to 2006-07.

SELECTION OF INPUT AND OUTPUT

The selected inputs and outputs along with the measure used to quantify then are given in Table 1.

Table 1

Factors	Variables
Resources inputs	
1. Capital investment	Fleet Size (Number of Vehicles with STHAR)
2. Labour	Total Staff (Number of Employees with STHAR)
3. Fuel	Annual amount of fuel consumed in lakh litres (sum of annual litres of fuel consumed for transit operation at STHAR)
Transit Output	Annual passenger kilometres (PKM) in lakh kilometres
1. Service Consumed	(Pass Kms = Load Factor × Effective Kms × Capacity)

The capital investment variable is measured by number of vehicles (Fleet Size); the use of fleet size as a surrogate or capital investment in public transit operation is standard practice in transit literature. The labour variable is represented by total staff or total number of employees. This variable is being considered vital part of transit operation. The fuel is represented by sum of annual litres of fuel consumed for transit operation. The output variable, service consumed, is measured by the frequently used effectiveness metric passenger-kilometres. It is obtained by multiplying load factor to effective kilometres and capacity (Pass Kms = Load Factor × Effective Kms × Capacity).

MODEL SPECIFICATION

In the present study, transportation depot is assumed to be an economic firm which strives to maximize its revenue by utilizing its inputs in given environment. With this objective the outputs and inputs of production process of a depot are specified. In this study, we have selected a single output, Passenger Kilometres (Pass Kms), produced by the above three inputs. Passenger-Kilometres (Pass Kms in lakh kms) is basically revenue passenger kilometres which take into account the demand side information. It is obtained by multiplying load factor to effective kilometres and capacity (Pass Kms = Load Factor × Effective Kms × Capacity). The output is taken as the outcome of utilization and combination of three important inputs—total staff, fuel consumption and fleet size. Total staff (TS) refers to the total number of employees worked in a depot. TS is representative of the labour input. Fuel Consumption (FC) refers to the fuel consumed (in lakh litres) which is measured by dividing total earned kilometer by fuel average. It is representative of the material cost. Fleet Size (FS) comprises the average number of buses held in a depot.

RESULTS AND DISCUSSION

The efficiency scores (TE, PTE and SE) of 20 depots have been estimated for the six year period (2001-02 to 2006-07). Table 2 presents the efficiency scores obtained from CRS and VRS input-oriented models along with reference set, peer weights and peer count.

TECHNICAL EFFICIENCY

TE scores are calculated through CRS model. Table 2 evinces that out of 20 depots only 3 depots [Sonepat (D6), Delhi (D8), Gurgaon (D1)] are relatively efficient (efficiency score = 1), and thus, form the efficient frontier. The remaining 17 depots are relatively less efficient as they have efficiency score d. The lower the TE-score for a depot, the higher the scope for it to reduce inputs (while maintaining output level) relative to the best practice depot(s) in the reference set. The average of technical efficiency scores works out to be 0.841, which reveals that an average depot can reduce its resources by 10% to obtain the existing level of outputs. As many as 9 depots have an efficiency score lower than the average efficiency score and 7 depots have higher efficiency score than the average level.

PURE TECHNICAL EFFICIENCY

CRS model is based on the assumption of constant returns to scale (CRS) which does not consider the scale-size of depot to be relevant in assessing technical efficiency. Therefore, in order to know whether inefficiency in any depot is due to inefficiency production operation or due to unfavourable conditions displayed by the size of depot, VRS efficiency (PTE) is always greater or equal to CRS efficiency (TE). Hence, number of depots on the frontier under VRS model are always greater or equal to the number of depots on the frontier under CRS model.

Table 2 provides details about DEA results drawn from this model. It is evident from the table that out of 20 depots, 7 depots (about 35%) are pure technical efficient (VRS Score = l), i.e., none of these have scope to further reduce

Table 2
Efficiency Scores, Reference Set, Peer Weight and Peer Count

Depots		CRS Model (Technical Efficiency)			VRS Model (Pure Technical Efficiency)			Peer Count
		Efficiency Score	Reference Set	Peer Weight	Efficiency Score	Reference Set	Peer Weight	
D1	Ambala	0.897	D8, D6	0.932, 0.461	0.915	8D, 2D, 6D	0.136, 0.342, 0.522	0
D2	Chandigarh	0.991	D8	2.035	1.000	2D	1.000	3
D3	Karnal	0.902	D8, D6	0.359, 0.543	0.903	11D, 8D, 10D	0.547, 0.448, 0.005	0
D4	Jind	0.852	D6, D8	0.637, 0.188	0.853	11D, 6D, 10D	0.006, 0.410, 0.585	0
D5	Kaithal	0.868	D8, D6	0.436, 0.412	0.870	11D, 10D, 6D, 8D	0.065, 0.424, 0.163, 0.347	0
D6	Sonepat	1.000	D6	1.000	1.000	6D	1.000	7
D7	Yamunanagar	0.919	D6, D8	0.341, 0.729	0.924	2D, 6D, 8D	0.351, 0.061, 0.588	0
D8	Delhi	1.000	D8	1.000	1.000	8D	1.000	9
D9	Kurukshetra	0.863	D8, D6	0.247, 0.556	0.868	11D, 8D, 10D	0.327, 0.381, 0.292	0
D10	Panipat	0.998	D6, D8	0.375, 0.328	1.000	10D	1.000	9
D11	Gurgaon	1.000	D11	1.000	1.000	11D	1.000	9
D12	Rohtak	0.918	D11, D6	0.490, 0.197	0.928	11D, 10D	0.177, 0.823	0
D13	Hisar	0.810	D6, D8	0.629, 0.290	0.811	11D, 8D, 6D	0.365, 0.172, 0.463	0
D14	Rewari	0.880	D11, D6	0.118, 0.477	0.892	11D, 10D	0.013, 0.987	0
D15	Bhiwani	0.671	D11, D6	0.484, 0.201	0.679	11D, 10D	0.172, 0.828	0
D16	Sirsa	0.792	D6, D8	0.192, 0.730	0.792	6D, 10D, 8D	0.264, 0.093, 0.643	0
D17	Faridabad	0.921	D6, D8	0.423, 0.793	0.933	8D, 2D, 6D	0.188, 0.457, 0.355	0
D18	Fatehabad	0.777	D6, D8	0.409, 0.303	0.785	11D, 10D, 8D	0.019, 0.655, 0.326	0
D19	Jhajjar	0.872	D11	0.528	1.000	19D	1.000	0
D20	Narnaul	0.894	D8, D6	0.193, 0.375	1.000	20D	1.000	0
		0.891			0.908			

inputs (maintaining same output level), while remaining 13 depots are relatively inefficient (score < 1). The efficiency score obtained by this model is known as pure technical efficiency (PTE) as it measures how efficiently inputs are converted into output(s) irrespective of the size of depot. The average of pure technical efficiency is worked out to be 0.908; this means that given the scale of operation, on average, depots can reduce its input 9.2% of its observed level without detriment to its output levels and also 9 depots have an efficiency average efficiency score.

Pure technical efficiency is concerned with the efficiency in converting input to outputs, given the scale size of depot, so we observe that Chandigarh (D2), Panipat (D10), Jhajjar (D19), Narnaul (D20), are CCR technical inefficient but pure technical efficient. This clearly evinces that these regions are able to convert their inputs into output with 100 per cent efficiency, but their overall efficiency (TE) is low due to their scale-size disadvantageous (low scale efficiency) Delhi (D8), Panipat (D10), Gurgaon (D11) have the highest peer count 9 followed by Sonepat (D6) (Peer count-7). So, these depots can be considered as the best practice depots in terms of pure technical efficiency, while Chandigarh (D2) has 3 peer count graded as low robust pure technical efficient.

SCALE EFFICIENCY

A comparison of the results for CRS model and VRS model gives an assessment of whether the size of a depot has an influence on its technical efficiency. Scale efficiency (SE) is the ratio of TE to PTE scores. If the value of SE score is one, then the depot is apparently operating at optimal scale. If the value is less than one, then the depot appears either small or big relative to its optimum scale-size. Table 3 represents the scale efficiency score of the depots at fifth column. Results show that out of 20 depots, only 3 depots are scale efficient while remaining 17 depots are scale inefficient. The average of scale efficiency is 0.983. It indicates that an average depot may be able to decrease its input by 1.7% beyond its best practice targets under variable returns to scale, if it were to operate at constant return to scale.

Column six of Table 3 presents the returns to scale of the concerned depots. Return to scale retlects the extent to which a proportional increase in all inputs increases output. Constant returns to scale (CRS) occurs when a proportional increase in the value of all inputs result in the same proportions increase in outputs of the depot. Increasing returns to scale (IRS) occurs when a proportional increase in all inputs results in a more than proportional increase in outputs, whereas decreasing returns to scale (DRS) occurs when proportional increase in all inputs results in a lesser than proportional increase in output. Table 5 shows that out of

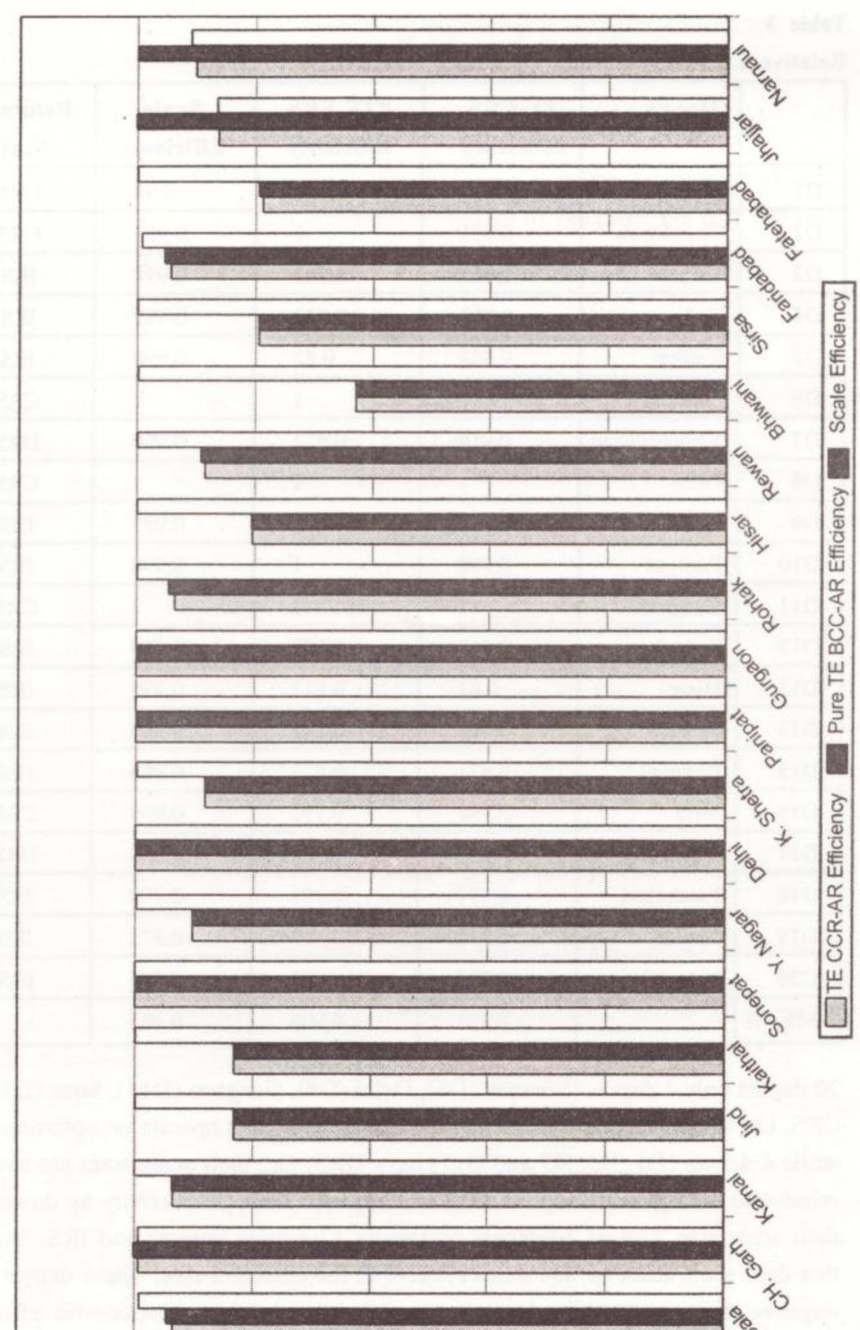
Table 3

Relative Efficiencies, Scale Efficiency and Return to Scale

	Depots	TE CRS Efficiency	PTE VRS Efficiency	Scale Efficiency	Return to Scale
D1	Ambala	0.897	0.915	0.98	DRS
D2	Chandigarh	0.991	1	0.991	DRS
D3	Karnal	0.902	0.903	0.998	IRS
D4	Jind	0.852	0.853	0.999	IRS
D5	Kaithal	0.868	0.87	0.998	IRS
D6	Sonepat	1	1	1	CRS
D7	Yamunanagar	0.919	0.924	0.995	DRS
D8	Delhi	1	1	1	CRS
D9	Kurukshetra	0.863	0.868	0.995	IRS
D10	Panipat	0.998	1	0.998	IRS
D11	Gurgaon	1	1	1	CRS
D12	Rohtak	0.918	0.928	0.989	IRS
D13	Hisar	0.81	0.811	0.999	IRS
D14	Rewari	0.88	0.892	0.986	IRS
D15	Bhiwani	0.671	0.679	0.989	IRS
D16	Sirsa	0.792	0.792	0.999	CRS
D17	Faridabad	U.921	0.933	0.987	DRS
D18	Fatehabad	0.777	0.785	0.990	IRS
D19	Jhajjar	0.872	1	0.872	IRS
D20	Narnaul	0.894	1	0.894	IRS
MEAN		0.891	0.908	0.983	

20 depots only 4 depots (Sonepat (D6), Delhi (D8), Gurgaon (D11), Sirsa (D16) has CRS, i.e., only Sonepat, Delhi, Gurgaon and Sirsa depots operate on optimum scale, while 4 depots (D1, D2, D7 and D17) have DRS, i.e., their scale sizes are too large relative to the optimum size so, they can improve their productivity by downsizing their scale size. Out of 20 depots remaining 12 depots operate and IRS, implying that their scale sizes are too small relative to the optimum size. These depots could improve their productivity by enhancing their scale sizes. Depot-wise efficiency score of STHAR is shown in the figure below :

Figure 1 : Depot-wise DEA Efficiency Score of STHAR (2001-07)



INPUT/OUTPUT TARGETS FOR INEFFICIENT DEPOTS

When a firm is inefficient, the input-output level in equation (A) can be used as the basic for setting its targets so that it can improve its performance.

$$\left.\begin{aligned} \overline{x}_k &= \theta_k x_k - S_k^- + P\pi^* = X\lambda \\ \overline{y}_k &= y_k + S_k^+ - Q\tau^* = Y\lambda \end{aligned}\right\} A$$

Where, x_k and y_k are the target inputs respectively for the i[th] firm; x_k = actual inputs of the i[th] firm; y_k = actual outputs of the i[th] firm; θ_k = optimal efficiency score of the i[th] firm; S_k^- = optimal input of the i[th] firm; and S_k^+ = optimal output of the i[th] firm. P and Q are matrices of lower and upper bounds of input and output weights respectively π^* and τ^* are the optimal values of the dual variables corresponding to the weight restriction constraint. The input-output level (x_k, y_k) defined in (A) are the coordinates of the efficient frontier used as a benchmark for evaluating i[th] firm. Table 4 presents the target values of all inputs and outputs for inefficient depots along with percentage reduction in inputs in terms of CCR-model. It can be observed from the table that on an average, approximately 14.90% of fleet size, 15.58% of total staff and 13.12% of fuel consumption can be reduced if all the inefficient depots operate at the level of efficient depots.

Table 4

Targeted Values of Input and Output Variables Under CRS-Input Model

	Depots	Targeted Values of Input Variables			Targeted Value of Output Variable
		Fleet Size (No.)	Total Staff (No.)	Fuel Consumption (Lac Litres)	Passenger Kilometres (Lac Kilometres)
D1	Ambala	201.12	1123.65	54.68	9998.59
		11.40	10.32	10.32	
D2	Chandigarh	231.99	1269.85	67.24	12114.32
		0.859	2.917	5.07	
D3	Karnal	152.87	863.64	40.05	7388.88
		18.25	9.85	9.85	
D4	Jind	152.56	866.51	39.22	7270.44
		14.77	20.06	14.77	
D5	Kaithal	134.49	756.48	35.75	6572.48
		13.23	15.00	13.24	

Table 4 (Contd.)

D7	Yamunanagar	153.26	855.71	41.75	7630.68
		9.85	8.087	8.087	
D9	Kurukshetra	142.74	808.83	37.01	6845.55
		16.03	13.68	13.68	
D10	Panipat	114.75	646.64	30.31	5581.73
		0.22	7.23	0.22	
D12	Rohtak	136.737	753.88	32.78	6112.99
		8.2302013	23.85	8.23	
D13	Hisar	162.664	921.46	42.21	7806.47
		23.271698	19.03	19.03	
D14	Rewari	121.371	686.86	30.158	5620.90
		12.05	14.14	12.05	
D15	Bhiwani	136.292	751.70	32.69	6096.07
		32.86	36.67	32.86	
D16	Sirsa	122.74	681.34	34.07	6199.40
		20.81	24.55	20.81	
D17	Faridabad	177.56	992.84	48.14	8809.21
		13.38	7.90	7.90	
D18	Fatehabad	118.88	670.92	31.24	5759.97
		22.30	22.62	22.30	
D19	Jhajjar	103.43	561.48	24.27	4527.33
		13.81	15.82	12.83	
D20	Narnaul	99.30	562.11	25.84	4775.03
		18.60	10.63	10.63	
	Mean	144.87	810.23	38.08	7006.47
		14.90	15.59	13.12	

INTER-ZONE COMPARISON OF EFFICIENCY

As we know 20 depots of Haryana Roadways are classified into two zones, i.e., TATA ZONE and LEYLAND ZONE; First 10 depots from D1 to D10 come in TATA ZONE and other 10 depots, i.e., from D11 to D20 come in LEYLAND ZONE. The comparative performance of depots in two zones is shown in Table 5. An observation of the table reveals that, on average, TE is found high (92.9%) in the TATA ZONE pure Technical efficiency and scale efficiency are also found high in

TATA ZONE, i.e., 93.3% and 99.5% respectively. LEYLAND ZONE have low TE (85.3%), PTE (88.2%) and SE (97%) than TATA ZONE.

Table 5

Inter-state Comparison of Efficiency of Haryana Roadways

Zones	No. of Depots	Technical Efficiency		Pure Technical Efficiency		Scale Efficiency	
		Aver-age	Standard Deviation	Aver-age	Standard Deviation	Aver-age	Standard Deviation
TATA	10	0.93	0.06	0.93	0.06	0.99	0.006
LEYLAND	10	0.85	0.09	0.88	0.11	0.97	0.047
Average		0.89		0.91		0.98	

Table 6 shows INTER-ZONE comparison of input targets for inefficient depots. It is found that the highest percentage of reduction in fleet size (19.08%) is required for an average inefficient depot in the LEYLAND ZONE. An average inefficient depot in the TATA ZONE has 10.66% reduction requirement in fleet size. The LEYLAND ZONE emerges number one in terms of inefficiency in total staff, as is apparent from the higher percentage of reduction requirement, i.e., 20.29%, whereas TATA ZONE requires only 10.75% reduction in total staff which is nearly half as required by LEYLAND ZONE. The table also shows that TATA ZONE is more fuel efficient which requires reduction of 9.45% in fuel consumption, whereas LEYLAND ZONE requires 16.98% reduction which is nearly double than requirement of TATA ZONE.

Table 6

Inter-zone Comparison of Average Targeted Values of Inputs for Inefficient Depots and Percentage of Reduction Required in Observed Value of Inputs

Zones	Fleet Size (No.)	Fuel Consumption (in Lac Litres)	Total Staff (No.)	Passenger Km. (in Lac Km.)
TATA	1283.778	7191.307	345.993	63402.67
	10.66	10.76	9.45	
LEYLAND	1178.976	6582.583	301.393	55707.37
	19.08	20.30	16.99	

SENSITIVITY ANALYSIS

To investigate the robustness of the efficiency score, sensitivity analysis has also been conducted. The sensitivity analysis has been done by removing the efficient depots, i.e., Sonepat (D6), Delhi (D8), Gurgaon (D11), from the reference set. By doing this, it can be observed from the table that Chandigarh (D2) and Panipat (D10) become efficient. This reveals that these depots have structures similar to Sonepat (D6), Delhi (D8), Gurgaon (D11), they become inefficient due to the existence of Sonepat, Delhi, Gurgaon depots. The mean technical efficiency score after removing D6, D8 and D11 is 89%, and the mean pure technical efficiency is 91.2%. Efficiency score during sensitivity analysis is given in Table 7.

Table 7

Efficiency Score During Sensitivity Analysis

Efficient Depots to be Removed	Mean Technical Efficiency	New Reference Set (CRS-Model)	Mean Pure Technical Efficiency	New Reference Set (VRS-Model)
Sonepat	0.89	D10, D2	0.912	D10, D2, D19, D20
Delhi				
Gurgaon				

CONCLUSIONS

In this paper, an attempt has been made to measure the technical and scale efficiency of the depots of STHAR using DEA. The study finds that only 3 depots [Sonepat (D6), Delhi (D8), and Gurgaon (D11)] have the maximum degree of efficiency. The overall mean of TE of the region is 89.1% indicating that on average 10.9% of the technical potential of depots is not used. This implies that these regions have the scope of producing the same output with the inputs 10.9% lesser than their existing level. The efficient depots are Sonepat (D6), Delhi (D8), and Gurgaon (D11), while Bhiwani (D15) is the most inefficient depot followed by Fatehabad (D18).

The results of VRS model show that out of 20 depots 7 depots (35%) are pure technical efficient as they efficiently convert their inputs into the output. However, 4 depots out of them are technical inefficient due to scale-size effect. Jhajjar (D19) has the least scale efficiency score (87.2%) implying that Jhajjar (D19) has the maximum effect of scale-size on its efficiency score. It indicates that this depot can improve its scale of operation. It is also observed that out of 20 depots, 4 have CRS, 4 have DRS and remaining 12 have IRS.

Differences in the average efficiency score of depots are also observed across zones. On average the TATA ZONE performs better than their counter-parts. Nevertheless, position of individual zones is the same across the three types of efficiency.

Targets set for relatively inefficient depots suggest that on average, these depots can become as efficient as the region in their reference set, if they could reduce their reference set if they could reduce their fleet size by 14.90%, total staff by 15.58%, and fuel consumption by 13.12% relative to the best practice depot.

The conclusions drawn on the efficiency of depots need to be taken carefully. The results of this paper are dependent upon the choice of inputs and output and the way that DEA measures efficiency.

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