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Benchmarking the Yearly Performances of the Indian Railways

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Abstract: ***This paper uses a Data Envelopment Analysis (DEA) based analysis to benchmark performances of Indian Railways over a period 2002-03 to 2016-17. An output based model revealed that the performances have remained far from being efficient, though a steady improvement has been seen in the sector throughout the period over which the model was applied. The results indicate that inefficiencies may largely have been brought about due to excess staff, whose reduction over the years has led to improvement in efficiencies. Furthermore, the operations seem to achieve economies of scale in recent times. The results also indicate that there has been a huge notional loss of revenue due to the performances remaining muted and inefficient, and hence sector reforms to improve performances should remain an urgent and sought after agenda for the Indian government.***

Keywords : Data Envelopment Analysis, benchmark, Indian Railways, economies of scale, sector reforms

I. INTRODUCTION

Indian Railways (IR) represent the world's largest Government Railway network [1]. The railways have historically been responsible for important task of driving trade and industrial growth of India by offering economical, reliable and safe mode of transport. In fact, IR runs more than 20,000 trains of which almost 13,000 trains carry passenger to the tune of 2.3 crore passengers on a daily basis. The remaining trains carry the freight of around 0.3 Crore gross tonnes per day as per the Ministry of Railways, Government of India [2].

When it comes to performance of the IR, there exists a big gap between supply-side services and demand-side expectations. The efficiencies of Indian Railways remain unmeasured till date, and benchmarking studies on the topic are virtually non-discoverable. This paper therefore, attempts a singular benchmarking study for the IR using the framework of Data-Envelopment-Analysis (DEA), a technique often employed in operations-research (and economics too) for estimating a "best-practice frontier" (analogous production frontier in economics) [3] to empirically measure efficiencies of decision making units (DMUs) to determine performances .

The present work thus focuses on DEA-based benchmarking of the Services of Indian Railways over time with the objective of evaluating the time-variation in efficiencies of Indian Railways.

II. REVIEW OF LITERATURE

Data Envelopment Analysis (DEA) is a mathematical technique for determining the relative efficiencies of firms. Its applications spread widely across various infrastructure sectors such as Airports [4-6], Irrigation [7-9], Coal [10], Electricity-sector [11], Water-sector [12-13], and Solid Waste [14] etc. However, benchmarking studies in the Railway sector are rather rare and there exists a deficiency of studies that employ DEA for the Railways. Apparently, not many studies seem to be available in the literature for benchmarking of services of the Indian Railways in its entirety.

Internationally, a study on railways was carried out by Yu and Lin (2008) [15], who studied a multi-activity network DEA model to enable insights from results, and to propose strategies to enhance performances of operations by this model. Lan and Lin (2005) [16] measured performances of railways with modification in environmental effects and data noise to address policy issues. Kuang (2018) [17] evaluated Railway Transportation efficiency by constructing a DEA based super-cross efficiency model for and found the super-cross efficiency results in conformity with actual situation in China. Similarly, inefficiencies in Japanese Railways were evaluated using DEA by Jitsuzumi T., Nakamura A, 2010 [18].

III. METHODOLOGY EMPLOYED

The current work employed DEA to benchmark services of Indian Railways and suggests some policy perspectives depending on the output of the model. The DEA was formulated as per [13], and employed two different models with constant-returns-to-scale (CRS) model, and the variable-returns-to-scale (VRS) model.

A. The CRS model

This model was suggested by [19], and employs a constant-return- to- scale assumption.

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Efficiency = Σ weighted outputs / Σ weighted inputs (1)

If the sample has z utilities, each having outputs and inputs m and n respectively, the efficiency of utility p can be attained as:

$$\max \quad \sum_{k=1}^{n} v_k y_{kp} / \sum_{j=1}^{m} u_j x_{jp}$$

$$s.t. \quad \sum_{k=1}^{n} v_k y_{ki} / \sum_{j=1}^{m} u_j x_{ji} \le 1 \quad \forall i$$

$$u_{j,} v_k \ge 0 \quad \forall j,k \qquad (2)$$

where i= 1 to z, j= 1 to m, k= 1 to n, y_{ki}= amount of output k produced by DMU i, x_{ji}= amount of input j utilized by DMU i, v_k= weight given to output k and u_j= weight given to input j.

Equation (2) can be converted to a linear programming format that is solved using a mathematical dual to determine efficiency score θ as below

$$\min_{\theta,\lambda} \theta$$

$$s.t. \quad \theta x_{jp} - \sum_{i=1}^{z} \lambda_i x_{ji} \ge 0 \quad \forall j$$

$$- y_{kp} + \sum_{i=1}^{z} \lambda_i y_{ki} \ge 0 \quad \forall k$$

$$\lambda_i \ge 0 \quad \forall i \qquad (3)$$

Where, λi = dual variables

B. The VRS model

Banker et al. (1984) [20] added a convexity constraint as shown in equation 4, to determine efficiency under variable-returns-to–scale condition.

$$\min_{\theta,\lambda} \theta$$

$$s.t. \quad \theta x_{jp} - \sum_{i=1}^{z} \lambda_i x_{ji} \ge 0 \quad \forall j$$

$$- y_{kp} + \sum_{i=1}^{z} \lambda_i y_{ki} \ge 0 \quad \forall k$$

$$\sum_{i=1}^{z} \lambda_i = 1$$

$$\lambda_i \ge 0 \quad \forall i \qquad (4)$$

C. Model Formulation

An Output oriented DEA model (Table 1) was used for efficiency evaluation of Services of Indian Railways. Three input and output indicators were decided as per Table 1.

Table 1. Summary of output-oriented DEA model

Model No.	Input variables	Output variables
01	1. Route kilometer (km) 2. Staff employed (Numbers)	1. Revenue (`₹ Crore)

IV. RESULTS AND DISCUSSIONS

DEA was applied to various parameters affecting the services/ operations of Indian Railways. Fifteen years data (2002-03 to 2016-17) was collected from Indian Railways Annual Statistical Statements and was employed for analysis.

Table 2 shows results of output-oriented model that evaluates various efficiencies. The returns to scale (RTS) are also illustrated in Table 2. Figure 1 illustrates the time variation of efficiencies for the Indian Railways. It is evident that the CRS efficiencies have been steadily on the rise as with the progress of time, a progress that is corroborated by the fact that the VRS efficiencies have been consistently making the lower lows with time, indicating the improvement for the Indian Railways overtime in terms of the revenues collected. The improvements may also have been possible due to reductions in the staff employed over time since 2002-03 and earlier, which must have hugely curtailed cots of operation. The government data says that the level of reduction in staff has been from 16.51 lakhs in 1990-91 to 13.31 lakhs in the year 2015-16 [21]. It is noteworthy that railways had become staff heavy due to socialist inclination of the Indian State in the first few decades after independence, and since 1990s when the era of liberalization started in India, employee retirements with no new recruitments saw the employee size pruned to better sizing with passing time, leading to increase in efficiencies over the years.

Table 2 also indicates that low Scale Efficiencies and increasing returns to scale imply that operations of Indian Railways warranted scaling-up, which actually took place in the years to follow. The operational size possibly reached optimal sizing around 2015-17, when Returns to Scale turned negative or constant.

Table 3 depicts the efficiency ranges across the models. It is evident from the results presented in Table 3 that the sample mean efficiencies for CRS model were as low as only 60%. About 40% of the utilities had efficiency scores below 50%, indicating that Indian Railways have been historically quite inefficient, and it is only recently that better practices are emerging in the sector.

Table 2.Efficiencies of Services of Indian Railways

Year	CRS efficiency	VRS efficiency	RTS	SE
2002-03	0.26	1.00	+	0.26
2003-04	0.28	0.70	+	0.39
2004-05	0.30	0.60	+	0.50
2005-06	0.35	0.74	+	0.47
2006-07	0.40	0.85	+	0.47
2007-08	0.46	1.00	+	0.46
2008-09	0.51	0.82	+	0.62

2009-10	0.55	0.94	+	0.59
2010-11	0.60	0.90	+	0.66
2011-12	0.66	1.00	+	0.66
2012-13	0.77	1.00	+	0.77
2013-14	0.86	0.89	+	0.97
2014-15	0.97	1.00	+	0.97
2015-16	0.99	0.99	-	1.00
2016-17	1.00	1.00	=	1.00
Sample mean efficiency	0.60	0.90		0.65

"=": Constant, "-": Decreasing, "+": Increasing

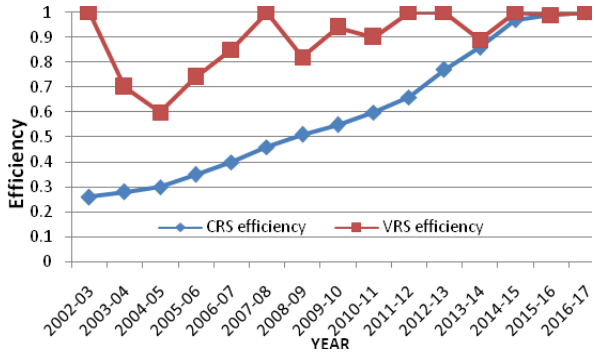

Fig 1. Time-variation of DEA Efficiencies for the Indian Railways

Table 3. Efficiency ranges

Efficiency (%)	CRS	VRS
	Number of Years (% of Total of 15 years)	
100	1 (06.67)	6 (40.00)
> 90 < 100	2 (13.33)	3 (20.00)
70-90	2 (13.33)	5 (33.33)
50-70	4 (26.67)	1 (6.67)
< 50	6 (40.00)	0 (0.00)
Total	15 (100%)	15 (100%)

Table 4. Annual Potential Earnings

Year	Revenue possibility CRS (Millions of Rs)	Revenue possibility VRS (Millions of Rs)
2002-03	302490.91	0.00
2003-04	310457.37	128231.05
2004-05	328725.71	187606.09
2005-06	354148.82	142293.60
2006-07	374111.01	94448.67
2007-08	386825.36	0.00
2008-09	393800.63	142293.44
2009-10	389159.87	55086.58
2010-11	382041.24	91868.87
2011-12	359226.85	0.00
2012-13	285776.70	0.00
2013-14	191016.50	155737.75
2014-15	46272.06	0.00
2015-16	16414.83	16021.62
2016-17	0.00	0.00
Total savings	4120467.86	1013587.67
Mean	274697.86	67572.51

Table 4 shows the scope of annual potential revenue earnings applied to the VRS model. It is evident that in theory a lot of possibility of revenue earning was squandered away during the years 2003-2006, 2008-2011 followed by 2013-14. The notional loss of revenue earnings over the time period 2002-03 to 2016-17 stands at Rs 101358.7 Crores, a huge amount lost to the inherent inefficiencies of the Indian Railways, and which could have been earned if the Railways had adopted better management practices and policies.

V. CONCLUSIONS

The work intended to carry out an analysis for assessment of efficiencies and performance of Indian Railways. At present, the efficiency of Indian Railways remains unmeasured. The results of the assessment of the efficiencies of the Indian Railways indicate that there are noteworthy inefficiencies in the 15 years that were investigated. However, to the credit of the government, the Indian Railways have over the years, consistently improved their performances.

The study results clearly indicate that Staff employed in Indian Railways plays a vital role in deciding the efficiency of Indian Railways. This conforms to the observations of the government that recognizes the lack of proper staff management in operations of services of Indian Railways. It is noteworthy that amongst the developing countries like India, it is common that services like Railways deploy significant manpower and avoid automation and mechanization. Labor-intensive policies are likely to be prudent in reducing the level of unemployment, although this excess staff leads to inefficiencies.

The study also indicates the importance of improving sector performance at priority, as it can result in significant revenue generation. In other words, if the railways remain inefficient, the government is likely to lose huge amounts of revenue. Thus, purely from the economic and commercial point of view, the Indian railways need to push reforms faster for bringing about improvements - a decision that would indeed additionally bring about significant social and political good too.

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