Measuring the Efficiency of Public Transport Sector in India: An Application of Data Envelopment Analysis

by

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Measuring the Efficiency of Public Transport Sector in India: An Application of Data Envelopment Analysis

- Introduction
- DEA Approach and Methodology
  - Data and Variables
  - Model Used
- Results and Discussions
  - Sensitivity Analysis
- Conclusions
- Policy Implications
Passenger Road Transport

- Private
- Public
  - State Road Transport Corporation (STUs)
    - Imperative mode of passenger mobility
    - State Government
    - Well regulated and organized
Why DEA?

State Road Transport Corporations (STUs):
- Service Business;
- Have multiple inputs and outputs;
- Difficult to determine the efficient amount of resources required to produce various service outputs;
- Unknown functional relation between inputs and outputs;
Hensher (1992), Hensher and Daniels (1995): evaluate total factor productivity (TFP) growth of public bus firms,

Tretheway et al. (1997): examine the productivity performance of Canadian Railways in transport sector by using translog production function method,

Singh (2000): uses index number approach to estimate the growth and relative level of productivity of 21 STUs in India for the period 1983-84 to 1996-97,

Hjalmarsson and Odeck (1996): assess the performance of trucks in road construction and maintenance using DEA,
Patankar (1985): assesses the productivity growth of the four largest metropolitan road transport services in India through DEA for the year 1982-83

Ramanathan (1999): applies DEA for the assessment of the productivity of 29 State Transport Undertakings (STUs) in India for the year 1993-94


Odeck and Alkadi (2001): evaluate the performance of 47 Norwegian bus companies for the year 1994, within the framework of DEA
Odeck (2005): investigates the target achievements of the 19 operational units of the Norwegian Public Roads Administration (NPRA) charged with traffic safety services. The DEA and MPI framework is applied with a unique constant input, or equivalently, with no inputs,

Odeck (2006): determines the impact of inputs on operator’s efficiency and investigates operations characteristics associated with inefficient use of inputs in the Norwegian bus industry for the year 1994 by applying DEA,

Agarwal et al. (2006): estimate the relative efficiencies of Uttar Pradesh State Road Transport Corporation for the year 2002-2003 by applying DEA-AR model,
<table>
<thead>
<tr>
<th>First Step</th>
<th>Selection of the Homogeneous DMUs</th>
</tr>
</thead>
</table>

- State Road Transport Corporations (STUs)
- 29 STUs
- Data from CIRT (2005-2008)
- Period from year 2004-05 to year 2007-08.
Selection of Input and Output Variables

Second Step

**Inputs:**
- Fleet Size (FS)
- Total Staff (TS)
- Fuel Consumption (FC)

**Output:**
- Passenger kilometers (Pass-Km)
### Selection of Input and Output Variables

#### Descriptive Statistics of Inputs and Output

<table>
<thead>
<tr>
<th></th>
<th>INPUTS</th>
<th>OUTPUT</th>
<th>INPUTS</th>
<th>OUTPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>INPUTS</td>
<td>FS</td>
<td>TS</td>
<td>FC</td>
<td>Pass Km</td>
</tr>
<tr>
<td>Min</td>
<td>28</td>
<td>720</td>
<td>4.474</td>
<td>185</td>
</tr>
<tr>
<td>Max</td>
<td>19105</td>
<td>117400</td>
<td>4395.085</td>
<td>762554</td>
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<tr>
<td>Mean</td>
<td>3189.414</td>
<td>21555</td>
<td>800.653</td>
<td>140899.45</td>
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<tr>
<td>S.D.</td>
<td>4312.449</td>
<td>27511.81</td>
<td>1012.972</td>
<td>163600.53</td>
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<tr>
<td>Third Step</td>
<td>Selection of the models</td>
<td></td>
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<tr>
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</tr>
<tr>
<td></td>
<td><strong>Input oriented</strong></td>
<td></td>
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<tr>
<td></td>
<td><strong>New Slack Model (NSM) with categorical DMUs</strong></td>
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<tr>
<td></td>
<td><strong>CRS assumption</strong>;</td>
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<tr>
<td></td>
<td><strong>VRS assumption</strong>;</td>
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</tbody>
</table>
Fourth Step

<table>
<thead>
<tr>
<th>Selection of the category of the STUs</th>
</tr>
</thead>
</table>

- **Category 1**: operated in the *Rural* areas: the most advantageous situation,
- **Category 2**: operated in the *Hill* areas: the severe situation,
- **Category 3**: operated in the *Urban* areas.
**Fifth Step**

Calculate the OTE of a STU

\[
\text{Min} \quad \overline{\theta}_k = \theta_k - \frac{1}{m + s} \left[ \sum_{i=1}^{m} \frac{s_{ik}^-}{x_{ik}} + \sum_{r=1}^{s} \frac{s_{rk}^+}{y_{rk}} \right]
\]

subject to

\[
\sum_{j=1}^{n} \lambda_{jk} y_{rj} - s_{rk}^+ = y_{rk} \quad \forall \ r = 1, \ldots, s
\]

\[
\sum_{j=1}^{n} \lambda_{jk} x_{ij} + s_{ik}^- = \theta_k x_{ik} \quad \forall \ i = 1, \ldots, m
\]

\[
\lambda_{jk} \geq 0 \quad \forall \ j = 1, \ldots, n
\]

\[
s_{rk}^+, s_{ik}^- \geq 0 \ ; \ r = 1, \ldots, s, i = 1, \ldots, m
\]
| Sixth Step | Calculate the OTE of a STU |

The solutions of the NSM-DEA models are carried out by using **MATLAB**.
# Results and Discussions

## Descriptive Statistics of Overall Technical Efficiency

<table>
<thead>
<tr>
<th>Years</th>
<th>2004-05</th>
<th>2005-06</th>
<th>2006-07</th>
<th>2007-08</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min</td>
<td>0.321</td>
<td>0.314</td>
<td>0.270</td>
<td>0.326</td>
</tr>
<tr>
<td>Max</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Mean</td>
<td>0.672</td>
<td>0.662</td>
<td>0.587</td>
<td>0.631</td>
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<tr>
<td>S.D.</td>
<td>0.194</td>
<td>0.210</td>
<td>0.205</td>
<td>0.192</td>
</tr>
<tr>
<td>No. of efficient STUs</td>
<td>3 (10.3%)</td>
<td>3 (10.3%)</td>
<td>3 (10.3%)</td>
<td>3 (10.3%)</td>
</tr>
<tr>
<td>No. of STUs</td>
<td>29</td>
<td>29</td>
<td>29</td>
<td>29</td>
</tr>
</tbody>
</table>
## Results and Discussions

### Descriptive Statistics of Scale Efficiency

<table>
<thead>
<tr>
<th>Years</th>
<th>2004-05</th>
<th>2005-06</th>
<th>2006-07</th>
<th>2007-08</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min</td>
<td>0.502</td>
<td>0.544</td>
<td>0.494</td>
<td>0.555</td>
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<tr>
<td>Max</td>
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<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Mean</td>
<td>0.860</td>
<td>0.883</td>
<td>0.866</td>
<td>0.882</td>
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<tr>
<td>S.D.</td>
<td>0.145</td>
<td>0.148</td>
<td>0.168</td>
<td>0.140</td>
</tr>
<tr>
<td>No. of efficient STUs</td>
<td>3 (10.3%)</td>
<td>3 (10.3%)</td>
<td>4 (13.8%)</td>
<td>3 (10.3%)</td>
</tr>
<tr>
<td>No. of STUs</td>
<td>29</td>
<td>29</td>
<td>29</td>
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</tbody>
</table>
Results and Discussions

Distribution of OTE scores across years

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<tbody>
<tr>
<td>0.80-0.99</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>0.60-0.79</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>0.40-0.59</td>
<td>9</td>
<td>10</td>
<td>11</td>
<td>12</td>
</tr>
<tr>
<td>below 0.40</td>
<td>13</td>
<td>14</td>
<td>15</td>
<td>16</td>
</tr>
</tbody>
</table>
Results and Discussions

Distribution of SE scores across years

![Bar chart showing distribution of SE scores across years](chart.png)
Sensitivity Analysis

Model

Min \( \eta_{a,b} = \theta_k - \frac{1}{m + s} \left[ \sum_{i=1}^{m} \frac{S^-_{ik}}{x_{ik}} + \sum_{r=1}^{s} \frac{S^+_{rk}}{y_{rk}} \right] \)

subject to

\[ \sum_{j \in J - \{b\}} \lambda_{jk} y_{rj} - S^+_{rk} = y_{rk} \quad \forall r = 1, \ldots, s \]

\[ \sum_{j \in J - \{b\}} \lambda_{jk} x_{ij} + S^-_{ik} = \theta_k x_{ik} \quad \forall i = 1, \ldots, m \]

\[ \lambda_{jk} \geq 0 \quad j \in J - \{b\} \]

\[ S^+_{rk}, S^-_{ik} \geq 0 ; r = 1, \ldots, s, i = 1, \ldots, m \]
### Sensitivity Analysis

**Results: Descriptive Statistics of OTE**

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td></td>
<td>Efficient STUs</td>
<td></td>
<td>Efficient STUs</td>
<td></td>
<td>Efficient STUs</td>
<td></td>
<td>Efficient STUs</td>
<td></td>
</tr>
<tr>
<td>Min</td>
<td>0.321</td>
<td>0.322</td>
<td>0.379</td>
<td>0.322</td>
<td>0.314</td>
<td>0.314</td>
<td>0.354</td>
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<tr>
<td>Max</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
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<tr>
<td>Mean</td>
<td>0.672</td>
<td>0.706</td>
<td>0.684</td>
<td>0.695</td>
<td>0.662</td>
<td>0.677</td>
<td>0.675</td>
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<tr>
<td>S.D.</td>
<td>0.194</td>
<td>0.200</td>
<td>0.185</td>
<td>0.188</td>
<td>0.210</td>
<td>0.210</td>
<td>0.203</td>
<td>0.203</td>
</tr>
</tbody>
</table>
Conclusions

Performance
- Not improved over the earlier three years
- Improved in the last year
- Still very far from the optimal level.

Sensitivity Analysis
- NSM-DEA efficiency scores are robust and stable.
- All the three efficient STUs are not the outliers.
Conclusions

- Average OTE scores: gradually decreased over the earlier three years
- Improved in the last year of the sample period,
- Average SE scores: no any clear trend,
- No change in the number of STUs at MPSS for the entire period,
- Overall technical and scale efficient for the entire period: only 10.3% STUs,
- Best-practice STUs,
Policy Implications

- Recruiting motivated and trained workers
- Capacity building of the existing staff
  - training and orientation programs
- Some motivational policies should be introduced
  - Systematic assessment of their periodical work
  - Promotions
  - Performance based reward systems
  - Offer incentives to consistently better performing employees
Policy Implications

Reduce input slacks in inefficient STUs

✓ Downsizing of employee strength,
✓ Reduce aggregate expenditures by alter the practice patterns making it similar to the best practice STUs,
✓ Increase the fleet utilisation,
✓ Regular training for the drivers in new technological buses,
✓ Replacement of old buses and induction of modern buses,
Policy Implications

- Attain the better fuel efficiency
- Rationalise the number of stops,
- Maintenance of the fleet,
- Maintenance of proper tyre pressures
- Traveling at a steady speed
- Create consciousness among the operating staff so that they may appreciate the value of fuel conservation.
  - reward and promotion schemes
Policy Implications

Requiring attention on the quality of the outputs

- lack of awareness of available facilities and services offered by STUs,
- lack of consumer awareness,
- the absence of advocacy groups,
- lack of adequate equipment,
- the lack of training institutes,
- poor transport facilities


THANK YOU