INTRODUCTION

As India is a developing country and rural oriented economy, so transportation sector plays an important role in transporting goods from one place to another place. Since resources available are less and demands are heavy, so the investment on infrastructure carried out by considering economy. Central Road Research Institute establishes the relationship between vehicle operating cost component and characteristics of road, factors affecting road condition and vehicular characteristics. Truck-operating cost is of two types namely fixed cost and variable cost. Fixed costs are the investments that a company or truck owners do whether the truck is hauling a load or is in the parking lot. Fixed costs are constant in nature as they do not change with the output obtained [1]. The variable that affects the operating cost of truck into truck characteristic, local factor and characteristics of road. Vehicle operating cost refers the cost incurred to operate the vehicle used. Vehicle operating cost has calculated to reflect the entire cost spectrum, which is borne by owner/operator as they provide service. Operation cost varies with the size of the vehicle, class of the vehicle and other characteristics. Operating cost of the vehicle increases with the vehicle cycling. Rough surface affects the rolling resistance of the pavement. Due to rough surface fuel consumption increases, wear and tire of the tire and spare parts increases resulting into the increased operating cost, Levinson, D. et al. (2011). The operating cost of personal vehicle (car) and commercial trucks in Minnesota per mile obtained was 15.3 cent for personal vehicle (car) and 43.4 cent for commercial truck to use it in cost benefit analysis of highway project, Levinson, D. et al. (2005). The operating cost of truck per mile, per hour, per trip, per tonne as $1.04, $46.65, $362.82 and $0.055 respectively, Barnes, G., & Langworthy, P. (2003). The spring load restriction (SLR) to reduce the damage, occurring on the pavements during spring seasons and to protect the investment in road construction by restricting the load. It were found that Cobb-Douglas model is best for estimating the average cost per km for commercial trucks ($0.69), average cost per truckload ($250) and marginal cost per km ($ 0.65) Berwick, M., & Farooq, M. (2003). The operating cost of truck per km is $0.69, Hashami, M. (2004). The operating cost per km of single straight operation in congested condition and without congestion were $0.791 and $0.674, Barton, R. (2006).A study carry out to the cost models for pre and post haulage road freight transport in Sweden (Europe). Cost formula of separate variables was used to calculate the cost and concluded that operating cost of three-axle trailer was 98 krona per 10 km, Hossain, K. S. (2009).

Average marginal cost per mile for Midwest, Northeast, Southeast, Southwest and west region of Arlington (USA) were...
A very extensive investigation on vehicle operating cost needed because this cost plays a vital role in estimating the transport costs. Savings in operating costs can bring about if the transport plans are prepared carefully. Economic developer needs truck cost estimates to compare transportation modes and precisely estimate transportation costs. Users of trucks need truck cost information to benchmark performance against industry standards and competitors. It was observed that work on modelling of operating cost for owned truck mainly in Bihar is not carried out so far. The aims of this paper are (i) to develop model for operating cost of truck at Fatuha, Patna and (ii) to determine the operating cost per km and per tonne-km of the truck for trucking industry of Fatuha (Patna).

METHODOLOGY

The methodology of this paper is selection of study area, collection of data, analysis of data, calibration and validation of models. Three models have been considered namely Linear multiple regression model, Cobb-Douglas model and Translog model. Afterwards calibration of these models using obtained data, best model is used for determining average operating cost per km, margin cost per km and operating cost per tonne-km. Effect of operating cost of truck on route decided responses and spring season pattern etc are evaluated.

Study area

Study area is selected on the basis of availability of data sources. Fatuha is nearby to Patna in India and it was possible to take data from there so Fatuha was the best possible site for data collection. Patna is 24 km east from state of Bihar, Patna. Latitude and longitude of Fatuha is 26.7740° N and 84.9674° E respectively. Study area is located in the Fig. 1.

Data collection and analysis

Primary data was collected through the questionnaire survey from Fatuha (Patna). Questionnaire survey form was designed which consists of 18 attributes to collect the responses of drivers. Fatuha is the industrial area, which generates and attracts trips of trucks. Responses were taken from 119 numbers of respondents (drivers), who travel in different directions of Bihar. As a secondary data, distance between origin and destination along with route followed by drivers was taken from the Google map. As per the requirements of models, obtained data was analysed using statistical analysis. Descriptive summary of data is shown in “Table 1”.

<table>
<thead>
<tr>
<th>Description</th>
<th>Distance travelled in a year, km (K)</th>
<th>Maintenance cost in Rs. per year</th>
<th>Total cost in Rs. Per year(C)</th>
<th>Total truck load in a year in tonne (T)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of samples</td>
<td>119</td>
<td>119</td>
<td>119</td>
<td>119</td>
</tr>
<tr>
<td>Min</td>
<td>184800.00</td>
<td>45000.00</td>
<td>3553192.00</td>
<td>2340.00</td>
</tr>
<tr>
<td>Max</td>
<td>234000.00</td>
<td>95000.00</td>
<td>4906590.00</td>
<td>9540.00</td>
</tr>
<tr>
<td>Mean</td>
<td>212429.75</td>
<td>69611.76</td>
<td>4105132.01</td>
<td>5957.78</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>10779.76</td>
<td>13057.40</td>
<td>214958.20</td>
<td>2125.68</td>
</tr>
</tbody>
</table>


Model Calibrations

There are several approaches to estimate the cost per km of the trucks for firms. Each approach employs a different methodology and models to calculate the variable costs of operating Trucks. In this study, variable costs of operating trucks have been estimated after taking data from different truck owners/drivers.

Linear multiple regression model

Using total cost as a dependent variable and entering independent variables, are correlated as indicated by “Eq. (1)”.

\[ C = \beta_0 + \beta_1 \left( \frac{K}{T} \right) + \beta_2 T + \beta_3 H + \beta_4 P + \beta_5 O \]  

(1)

Where C is total annual cost in rupees, K is the distance in kilometres, T is number of truckloads in tonnes, P is 1 if firm is assessed a financial penalty for late delivery, 0 otherwise. In this study there was no financial penalty for late delivery because in India every receiver of goods who ordered for delivery knows that there can be delay due to traffic jam so P = 0. O is 1 if the firm is owner/operator, 0 otherwise. In our case data was collected from the drivers so O is zero. H is 1 if the firm hauls more than one product, 0 otherwise. In the present case, all trucks haul goods together so H is 1. Here \( \beta_0, \beta_1, \beta_2, \beta_3, \beta_4, \beta_5 \) are the coefficients for linear multiple regression models. Therefore, “Eq. (2)” arrived after putting all the conditions in “Eq. (1)”.

\[ C = \beta_0 + \beta_1 \left( \frac{K}{T} \right) + \beta_3 H \]  

(2)
Regression analysis results

\[ R^2 : 0.06, \text{Significance F: } 0.14 \]
Intercept \( \beta_0: 3527040.66, p\text{-value for } \beta_0: 4.16E-23 \)
Coefficient \( \beta_1: 6833.86, p\text{-value for } \beta_1: 0.03 \)
Coefficient \( \beta_2: 49.49, p\text{-value for } \beta_2: 0.06 \)
Coefficient \( \beta_3: 0.0, p\text{-value for } \beta_3: \text{Not define} \)

Hence putting all the coefficient values in “Eq.(2)”, result “Eq.(3)”.

\[ C = 3527040.66 + 6833.86 \text{K/T} + 49.49 \text{T} \tag{3} \]

**Cobb-Douglas Model**

Cobb-Douglas model is mainly used to estimate the cost functions and can provide a better fit than the linear model. The form of the Cobb-Douglas model is indicated in “Eq.(4)”.

\[ C = e^{\beta_0} (\text{K/T})^{\beta_1} (\text{T})^{\beta_2} (\text{e}^{\beta_3})(\text{e}^{\beta_4}) \tag{4} \]

Where \( C \) is total annual cost in rupees, \( K \) is the distance in kilometres, \( T \) is number of truckloads in tonnes, \( P \) is 1 if firm is assessed a financial penalty for late delivery, 0 otherwise. In our case there was no financial penalty for late delivery because in India every receiver of goods who ordered for delivery knows that there can be delay due to traffic jam so \( P \) is 0. \( O \) is 1 if the firm is owner/operator, 0 otherwise. In this case, all haul several goods together so \( H \) is 1. Here \( \beta_0, \beta_1, \beta_2, \beta_3, \beta_4, \beta_5 \) are the constants for Cobb-Douglas regression models. Taking logarithm on both side of “Eq.(4)”, it results “Eq.(5)”.

\[ \ln(C) = \beta_0 + \beta_1 \ln(K/T) + \beta_2 \ln(T) + \beta_3 \ln(e^T) + \beta_4 \ln(e^P) + \beta_5 \ln(O) \tag{5} \]

The coefficient \( \beta \) of independent variables is the elasticity of cost with respect to that independent variable. It represents the resulting percentage change in total cost with respect to the change of 1 percent in the variable. Therefore, “Eq.(5)” becomes “Eq.(6)”.

\[ \ln(C) = \beta_0 + \beta_1 \ln(K/T) + \beta_2 \ln(T) + \beta_3 \ln(e^T) \tag{6} \]

Regression analysis results

\[ R^2 : 0.88, \text{Significance F: } 2.67E-16 \]
Intercept \( \beta_0: 5.58, p\text{-value for } \beta_0: 1.52E-08 \)
Coefficient \( \beta_1: 0.81, p\text{-value for } \beta_1: 1.07E-18 \)
Coefficient \( \beta_2: 0.85, p\text{-value for } \beta_2: 2.00E-18 \)
Coefficient \( \beta_3: 0.0, p\text{-value for } \beta_3: \text{Not define} \)

Hence putting all the coefficient values in “Eq.(6)”, it becomes “Eq.(7)”.

\[ \ln(C) = 5.58 + 0.76 \ln(K/T) + 0.80 \ln(T) \tag{7} \]

**Translog Model**

Translog model has been increasingly popular in production and cost function estimation. Translog model for truck operating cost is indicated in “Eq.(8)”.

\[ \ln C = \beta_0 + \beta_1 \ln (K/T) + \beta_2 \ln T + 0.5 \beta_3 (\ln (K/T))^2 + 0.5 \beta_4 (\ln T)^2 + \beta_5 \ln(K/T) \ln(T) + \beta_6 \ln(P) + \beta_7 \ln(O) \tag{8} \]

Where \( C \) is total annual cost, \( K \) is in kilometres, \( T \) is number of truckloads in tonnes, \( P \) is 1 if firm is assessed a financial penalty for late delivery, 0 otherwise. In this case, there was no financial penalty for late delivery because in India every receiver of goods who ordered for delivery knows that there can be delay due to traffic jam so \( P \) is 0. \( O \) is 1 if the firm is owner/operator, 0 otherwise. In this case, data was collected from the drivers so \( O \) is zero. Therefore, “Eq.(8)” becomes in “Eq.(9)”.

\[ \ln C = \beta_0 + \beta_1 \ln (K/T) + \beta_2 \ln T + 0.5 \beta_3 (\ln (K/T))^2 + 0.5 \beta_4 (\ln T)^2 + \beta_5 \ln(K/T) \ln(T) \tag{9} \]

Regression analysis results

\[ R^2 : 0.71, \text{Significance F: } 2.17E-16 \]
Intercept \( \beta_0: 95, p\text{-value for } \beta_0: 1.02E-08 \)
Coefficient \( \beta_1: -16.21, p\text{-value for } \beta_1: 2.73E-07 \)
Coefficient \( \beta_2: -12.83, p\text{-value for } \beta_2: 6.78E-09 \)
Coefficient \( \beta_3: 1.58, p\text{-value for } \beta_3: 4.96E-14 \)
Coefficient \( \beta_4: 1.03, p\text{-value for } \beta_4: 8.68E-19 \)
Coefficient \( \beta_5: 1.30, p\text{-value for } \beta_5: 5.93E-09 \)
Hence putting all the coefficient values in “Eq.(9)”, it results “Eq.(10)”.

\[ \ln C = 95 - 16.21 \ln (K/T) - 12.83 \ln T + 0.79(\ln (K/T))^2 + 0.515(\ln T)^2 + 1.3 \ln(K/T) \ln(T) \tag{10} \]

**DISCUSSION**

Statistical analysis results for linear multiple regression model, Cobb-Douglas regression model and Translog regression model are arranged in “Table 1”. These values are intercepting, coefficients of independent variables, t-stat value and standard error of all the three models and R-square value for the respective models as shown in “Table 2”. The entire model compared with respect to statistical result, then after best model decided for further computation works.

<table>
<thead>
<tr>
<th>Models</th>
<th>Variable</th>
<th>Statistical parameters</th>
<th>Linear regression model</th>
<th>Cobb-Douglas model</th>
<th>Translog model</th>
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<tbody>
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<tr>
<td></td>
<td></td>
<td>Intercept ( \beta)</td>
<td>3527040.66</td>
<td>5.58</td>
<td>95</td>
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<tr>
<td></td>
<td></td>
<td>p-value</td>
<td>4.16E-23</td>
<td>1.52E-08</td>
<td>0.61</td>
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<tr>
<td></td>
<td></td>
<td>t-stat</td>
<td>12.50</td>
<td>6.10</td>
<td>0.50</td>
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<tr>
<td></td>
<td></td>
<td>K/T</td>
<td>6833.85</td>
<td>0.76</td>
<td>-16.21</td>
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<td></td>
<td></td>
<td>p-value</td>
<td>0.03</td>
<td>1.07E-18</td>
<td>0.58</td>
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<td></td>
<td></td>
<td>t-stat</td>
<td>2.16</td>
<td>10.60</td>
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<td>Std-Error</td>
<td>3162.02</td>
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<td>26.02</td>
<td>0.08</td>
<td>30.89</td>
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<tr>
<td></td>
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<td>t-stat</td>
<td>1.90</td>
<td>10.49</td>
<td>-0.41</td>
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<td></td>
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<td>Std-Error</td>
<td></td>
<td>65535</td>
<td>65535</td>
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<td></td>
<td></td>
<td>(\ln(K/T))^2</td>
<td>1.58</td>
<td>0.49</td>
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<td></td>
<td></td>
<td>p-value</td>
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<td>Std-Error</td>
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<td>(\ln T)^2</td>
<td>1.03</td>
<td>0.68</td>
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<td>p-value</td>
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<td>Std-Error</td>
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<td>Ln(K/T)*Ln(T)</td>
<td>1.30</td>
<td>0.59</td>
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<td></td>
<td></td>
<td>p-value</td>
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<td>Std-Error</td>
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<tr>
<td></td>
<td></td>
<td>R^2</td>
<td>0.06</td>
<td>0.88</td>
<td>0.71</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sample size</td>
<td>119</td>
<td>119</td>
<td>119</td>
</tr>
</tbody>
</table>

Intercept value for linear multiple regression model is highest (Rs.3527040.66) as compared to Cobb-Douglas and Translog
Hence average operating cost per km = \( \frac{C}{K} \)  

To find the average operating cost per kilometre of the truck is total average cost incurred in operating the truck for one year is divided by total average distance travelled by the truck in a year.

So, average operating cost per kilometre = \( \frac{\text{Total average cost of operating}}{\text{Total distance travelled}} \)  

Hence average operating cost per km = \( e^{5.58 \cdot \frac{(K)}{212429.74}} \cdot 0.24 \)  

Validation of Model

Actual cost and predicted cost with number of samples are indicated in Fig. 2. Standard error is 0.04, hence predicted values and actual values are close. The difference of predicted values and actual values are in terms of descriptive statistics, minimum of Rs.110562, maximum of Rs.-510404, average of Rs.-2802 and standard deviation of Rs.-65934.

Average operating cost

For calculation of average operating cost Cobb-Douglas model is used. Hence, equation of Cobb-Douglas model is indicating in “Eq. (11)”. 
\[
\ln(C) = 5.58 + 0.76 \ln(\frac{K}{T}) + 0.80 \ln(T) \tag{11}
\]
Eq. (11) can be written as also
\[
C = e^{5.58} \cdot \left(\frac{K}{T}\right)^{0.76} \cdot T^{0.80} \tag{12}
\]

Average operating cost per km

Average operating cost per kilometre of the truck is total average cost incurred in operating the truck for one year is divided by total average distance travelled by the truck in a year.

So, average operating cost per kilometre = \( \frac{\text{Total average cost of operating}}{\text{Total distance travelled}} \)  

Hence average operating cost per km = \( e^{5.58 \cdot \frac{(K)}{212429.74}} \cdot 0.24 \)  

Marginal cost per km

Marginal cost per km is the change in cost with respect to change in distance. Hence, marginal cost per km = change in cost/change in distance  

Hence marginal cost function is 
\[
MC = 0.76 e^{5.58} \cdot \frac{K}{T}^{0.76-1} \cdot T^{-0.80} \cdot 0.76 \]  
\[
MC = 0.76 e^{5.58} \cdot \frac{K}{T}^{0.24} \cdot T^{-0.04} \]  

Using average value of K and T  
\[
K_{avg} = 212429.74 \text{km} \]  
\[
T_{avg} = 5957.78 \text{tonnes} \]  

Marginal cost C = 0.76 \( e^{5.58} \cdot (212429.74)^{0.24} \cdot (5957.78)^{0.04} \) Rs. 15.01 ~ Rs.15  

Marginal cost per kilometre is Rs. 15, which is much less than average cost per km (Rs.20), indicates significant economies of scale with trip length.

Operating cost per tonne-km

It is the cost to move a tonne of load for one kilometer distance i.e. Operating cost per tonne-km = Total average annual cost / (Total annual distance * Total annual load) \( \approx \) Rs. 1.

Route decision responses

Fig. 3 shows that who decides the route where the goods are to be delivered. Out of the 119 responses of survey, the driver decides 40%, management decides 56% and dispatcher (who books the goods to deliver) decides 4%.

Spring season Pattern

When the spring season occurs, the truck owner has to change its regular delivery pattern due to bad (slippery) condition of the roads. Fig. 4 shows that out of 119 survey 40% changes the route to deliver the goods, 36% reduce the weight per vehicle i.e. overloading is avoided and 24% shift the delivery time of the goods. Shifting of delivery time of goods can be done only if the goods are not necessary to deliver on time.
CONCLUSIONS

A Cobb-Douglas model gives the best fit to estimate the total operating cost for the data of trucking industry of Fatuha (Bihar). Transport modes can decide based on cost per km and per tonne-km. Average operating cost of truck per km for Fatuha trucking industry is Rs.20 and marginal cost per km (Rs.15) is much less than Rs.20, represent significant economy of scale. Operating cost per tonne-km is about Rs.1. It means that it will take Rs.1 to haul 1 tonne goods for 1 km. In most of the cases, routes followed by truck driver from origin to destination is decided by the management (i.e. here owner of the vehicle). In spring season, load carrying capacity of trucks reduces due to bad condition of road. Out of the total responses, 40% changes the route that followed to deliver the goods, 36% reduce the weight per vehicle and 24% shift the delivery time of the goods.

References


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