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Research Article

MODELING OF OPERATING COST FOR TRUCKS AT FATUHA BIHAR

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ABSTRACT

This study is carried out to estimate the operating cost of commercial heavy trucks of Fatuha, Bihar. Operating cost is the cost incurred to operate the truck. Only variable costs are considered to calculate operating cost. Variable cost includes salary of driver and attendant, maintenance cost and fuel cost. Maintenance cost includes tire depreciation, wear and tear of spare parts and lubricant cost. A questionnaire survey form was prepared that consisting of eighteen questions to take responses of the truck drivers of Fatuha. Total of one hundred nineteen responses were taken. Three models namely as linear multiple regression model, Cobb-Douglas model and Translog model are calibrated using taken responses. Results show that Cobb-Douglas model is best suited for the study, among all the three models based on R-square and p-value. Operating cost of the truck per km and per tonne km resulted as Rs.20 per km and Rs.1 per tonne-km. In spring season, load carrying capacity of trucks reduces due to bad condition of road. Whereas, 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.

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

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$ 1.647, $1.756, $1.615, $1.677 and $1.687 respectively, Torrey, W. F., & Murray, D. (2014).

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 were 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, marginal 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. Fatuha 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.

Fig 1 Location map of Fatuha (Patna)

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 1 Summary of data

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

Questionnaire survey form consists of questions like 1. What are the origin, destination and route followed? 2. How many trucks including truck type and number of axels do you operate? 3. How many kilometers did your truck travel over the course of year? 4. Maintenance cost over a year/month? 5. Engine oil cost over a year/month. 6. Salary of drivers? 7. Salary of attendant with driver? 8. Overall cost per month/ year? 9. General types of major commodities/ products that you haul. 10. Who chooses the route travelled by the trucks? 11. Is your company assessed financial penalties by clients for missed/ late delivery or pick up time? 12. How is driver's compensation determined? Please indicate choice by circling. 13. Is driver compensation linked to on- time deliveries? 14. Do you change the rate you charge clients to account for the fluctuation in gas/ diesel price? 15. What is your approximate cost of operating each truck per km? 16. How much truckload did your firm carry in the year…? 17. Do spring load restrictions affect your firm, and if yes please answer in which ways you change your operations to conform to the seasonal restrictions? 18. How many times were your firm's trucks cited last year for weight violations during the period of spring load restrictions?

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)".

$$C = \beta_0 + \beta_1 (K / T) + \beta_2 T + \beta_3 H + \beta_4 P + \beta_5 O \qquad (1)$$

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 is 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 β_0, β_1, β_2, β_3, β_4, β_5 are the coefficients for linear multiple regression models. Therefore, "Eq. (2)" arrived after putting all the conditions in "Eq. (1)".

$$C = \beta_0 + \beta_1 (K / T) + \beta_2 T + \beta_3 H \qquad (2)$$

Regression analysis results
R^2 : 0.06, Significance F: 0.14
Intercept β_0: 3527040.66, p-value for β_0: 4.16E-23
Coefficient β_1: 6833.86, p-value for β_1: 0.03
Coefficient β_2: 49.49, p-value for β_2: 0.06
Coefficient β_3: 0.0, p-value for β_3: Not define
Hence putting all the coefficient values in "Eq.(2)", result "Eq.(3)".

$$C = 3527040.66 + 6833.86 (K / T) + 49.49 T \quad (3)$$

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)".

$$C = e^{\beta_o} (K / T)^{\beta_1} T^{\beta_2} (e^H)^{\beta_3} (e^P)^{\beta_4} (e^O)^{\beta_5} \quad (4)$$

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, data was collected from the drivers so O is zero. H is 1 if the firm hauls more than one product, 0 otherwise. In this case, all haul several goods together so H is 1. Here β_0, β_1, β_2, β_3, β_4, β_5 are the constants for Cobb-Douglas regression models. Taking logarithm on the both side of "Eq.(4)", it results "Eq.(5)".

$$Ln(C) = \beta_0 + \beta_1 Ln (K/T) + \beta_2 Ln (T) + \beta_3 Ln (e^H) + \beta_4 Ln (e^P) + \beta_5 Ln(e^O) \quad (5)$$

The coefficient β 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)".

$$Ln(C) = \beta_0 + \beta_1 Ln (K/T) + \beta_2 Ln (T) + \beta_3 Ln (e^H) \quad (6)$$

Regression analysis results
R^2 : 0.88, Significance F: 2.67E-16
Intercept β_0: 5.58,p-value for β_0: 1.52E-08
Coefficient β_1: 0.81, p-value for β_1: 1.07E-18
Coefficient β_2: 0.85, p-value for β_2: 2.00E-18
Coefficient β_3: 0.0, p-value for β_3: Not define
Hence putting all the coefficient values in "Eq. (6)", it becomes "Eq. (7)".

$$Ln(C) = 5.58 + 0.76 Ln (K/T) + 0.80 Ln (T) \quad (7)$$

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)".

$$Ln C = \beta_o + \beta_1 Ln (K/T) + \beta_2 Ln T + 0.5 \beta_3 (Ln (K/T))^2 + 0.5 \beta_4 (Ln T)^2 + \beta_5 Ln(K/T) Ln(T) + \beta_6 P + \beta_7 O \quad (8)$$

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)".

$$Ln C = \beta_o + \beta_1 Ln (K/T) + \beta_2 Ln T + 0.5 \beta_3 (Ln (K/T))^2 + 0.5 \beta_4 (Ln T)^2 + \beta_5 Ln(K/T) Ln(T) \quad (9)$$

Regression analysis results
R^2: 0.71, Significance F: 2.17E-16
Intercept β_0: 95, p-value for β_0: 1.02E-08
Coefficient β_1: -16.21, p-value for β_1: 2.73E-07
Coefficient β_2: -12.83, p-value for β_2: 6.78E-09
Coefficient β_3: 1.58, p-value for β_3: 4.96E-14
Coefficient β_4: 1.03, p-value for β_4: 6.86E-19
Coefficient β_5: 1.30, p-value for β_5: 5.93E-09
Hence putting all the coefficient values in "Eq. (9)", it results "Eq.(10)".

$$Ln C = 95 - 16.21 Ln (K/T) - 12.83 LnT + 0.79(Ln (K/T))^2 + 0.515(Ln T)^2 + 1.3 Ln(K/T) LnT \quad (10)$$

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 2 Models comparisons statistically

Models Variable	Statistical parameters	Linear regression model	Cobb-Douglas model	Translog model
Inter-cept	β	3527040.66	5.58	95
	p-value	4.16E-23	1.52E-08	0.61
	Std -Error	282143.53	0.92	186.55
	t-stat	12.50	6.10	0.50
K/T	β	6833.85	0.76	-16.21
	p-value	0.03	1.07E-18	0.58
	Std -Error	3162.02	0.07	29.42
	t-stat	2.16	10.60	-0.55
T	β	49.49	0.80	-12.83
	p-value	0.06	2.00E-18	0.67
	Std -Error	26.02	0.08	30.89
	t-stat	1.90	10.49	-0.41
H	β	0	0	0
	p-value	-	-	-
	Std -Error	-	-	-
	t-stat	65535	65535	-
$(Ln(K/T))^2$	β			1.58
	p-value			0.49
	Std -Error			2.33
	t-stat			0.68
$(Ln T)^2$	β			1.03
	p-value			0.68
	Std -Error			2.56
	t-stat			0.40
Ln(K/T)*Ln(T)	β			1.30
	p-value			0.59
	Std -Error			2.43
	t-stat			0.53
R^2		0.06	0.88	0.71
Sample size		119	119	119

Intercept value for linear multiple regression model is highest (Rs.3527040.66) as compared to Cobb-Douglas and Translog model so the intercept of linear model is not acceptable because when all the independent variables are zero, cost of Rs.3527040.66 is not possible. Coefficient of K/T for linear multiple regression model is highest (6833.85) as compared to Cobb-Douglas (0.76) and Translog model (-16.21). Coefficient of T for linear multiple regression model is highest (49.49) as compared to Cobb-Douglas (0.80) and Translog model (-12.83).Coefficient of H is zero for the linear multiple regression model, Cobb-Douglas model and Translog model. Hence, it represents that there is no effect of H on all the three models. So if the firm haul one product or more than one product, no matters in calculation of cost. Coefficient of $(K/T)^2$, T^2 and (K/T)(T) for Translog model is 1.58, 1.03 and 1.30 respectively.

The linear model and Translog model is not a good fit for our data. Independent variable is not significant for Translog model because p-value is more than 0.05.Independent variable is significant ($p < 0.05$) for linear model but R^2 is 0.06. In the Cobb-Douglas model, three independent variables are statistically significant with p-value less than 0.05 and R-squared is 0.88.

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)".

$$\ln(C) = 5.58 + 0.76 \ln(K/T) + 0.80 \ln(T) \quad (11)$$

Eq. (11) can be written as also

$$C = e^{5.58} . (K/T)^{0.76} . T^{0.80} \quad (12)$$

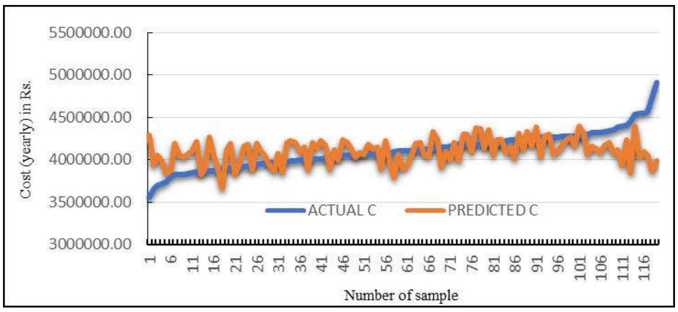

Fig 2 Cost (actual/ predicted) versus number of samples

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 = Total average cost of operating (C)/Total distance travelled (K) (13)

Hence average operating cost per km = $= e^{5.58} . (K)^{0.24} . T^{0.04}$ (14)

In the "Eq.(14)" putting average value of all the parameters (K, T)and obtained as

K_{avg} = 212429.74km

T_{avg} = 5957.78 tonnes

Average operating cost per kilometre = $e^{5.58} . (212429.74)^{0.24} . (5957.78)^{0.04}$ = Rs. 20

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 (15)

Hence marginal cost function is

$$= \beta_1 e^{\beta o} K^{\beta 1-1} T^{\beta 2-\beta 1} \quad (16)$$

$$\text{Marginal cost (MC)} = 0.76\, e^{5.58} K^{0.76-1} T^{0.80-0.76}$$

$$= 0.76\, e^{5.58} K^{-0.24} T^{0.04} \quad (17)$$

Using average value of K and T

K_{avg} = 212429.74km

T_{avg} = 5957.78 tonnes

Marginal cost C = $0.76\, e^{5.58} (212429.74)^{-0.24} . (5957.78)^{0.04}$ = 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) ≈ 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%.

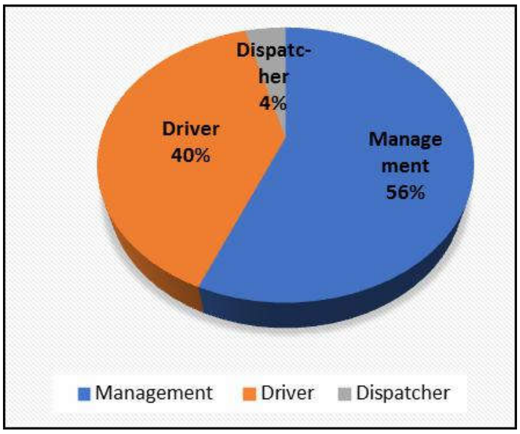

Fig 3 Route decision responses

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.

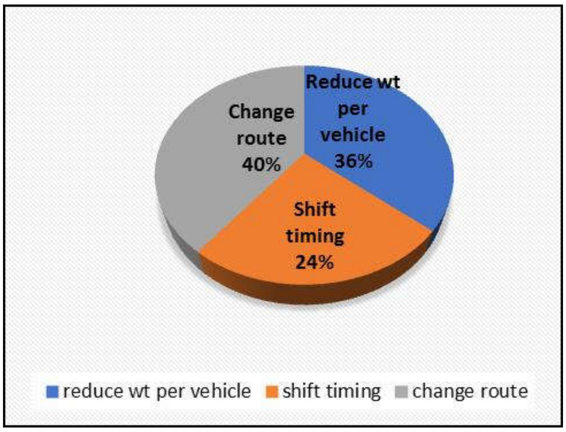

Fig 4 spring season pattern

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.

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