LAUTECH JOURNAL OF ENGINEERING AND TECHNOLOGY 4(1) 2007: 33 – 37

ONE ROUTE MARGINAL COST (ORMC) MODEL FOR ROAD TRANSPORTATION IN OYO STATE

K. A. Adebiyi*, A.O. Ajayeoba and L. O. Mudashiru

Department of Mechanical Engineering Ladoke Akintola University of Technology, P. M. B. 4000, Ogbomoso, Nigeria

*** Corresponding Author**

Abstract

Determination of transportation cost is important to ensure that the price paid by transportation users correctly reflects the true costs of providing transportation services. This study proposes one route transportation cost model. The model was developed in terms of operating cost; infrastructure cost; accident and congestion cost; and contingency cost.

In the application, data were collected from 200 auto vehicle users; Oyo State Ministry of Works and Transport and through review of previous works on: road maintenance and improvement works in Oyo State between 2000 and 2001; traffic count along Ibadan – Ilorin road; rates, dues, levies etc by auto users and fuel consumption, maintenance and parking data. The operating, infrastructure, contingency costs parameters were estimated using the data collected while the accident and congestion cost parameters were adapted from literature. The cost of transportation for mini buses and cars (passengers) per trip along Ibadan – Ilorin route was estimated as ₦426.00 and ₦585.00 per passenger per trip, respectively, with vehicle operating cost being major contributor.

Keywords: Accident and Congestion, Contingency, Infrastructure, Auto Transport Users, Transportation Cost Parameters

Introduction

Transportation is undoubtedly one of the backbones of economic development in any country (Gregory and Eric, 2002). It has been regarded as formative power of economic growth. It serves as ignition for the start of any economic development and it continues to play vital role in the determination of market prices commodities as well as forming the backbone of communication system (Ottong, 1997).

Traces of early roads have been found with antecedent recorded history. The first hard surfaces appeared in Mesopotamia soon after the discovery of the wheel in 3500 BC. Modern highways are however dated back to middle of 19^{th} century (FRSC, 1997). In Nigeria the first main trunk of road was constructed in Ibadan northerwest to Oyo in 1905 (FRSC, 1997 and DPRAS, 1997).

Modern scientific and technological innovations have brought about many developments that contribute to the road transportation and the determination of its cost of service by the users. Determination of transportation cost is significant in the developed and underdeveloped countries of the world where all the movements of human and luggages from one point to another are through the use of automobile vehicles. The main reason is to ensure that the price paid by transportation users correctly reflects the true costs of providing transportation services. Thus, users charges should be equally estimated to value and cost of resources consumed, through the use of transportation facilities and amenities for road users. This will be of great benefit to every individual in the society in the sense of creating full awareness of equal and justified responsiveness of transportation users to the level of service rendered by the automobile monetarily. Thus, road user will be able to know how much exactly is equivalent to the service of self mobility from one place to another by the transporter. This enhances road user's satisfaction. However, Shankar et al (2006) stated that customer satisfaction results when the service performance matches with the customer expectations after the service. This improves market share and profitability which in turns aid the national economy.

In this study, One Route Marginal Cost model for road transportation in Oyo State is proposed to estimate the full cost of highway passengers' transportation with particular preference to Ibadan – Ogbomoso – Ilorin highway.

The Cost Model Development

Model Assumptions

The following assumptions are made:

- Consistency of operational conditions is guaranteed
- Stability of government policies
- Costs are based on standard values

Inflationary effect is not taken into consideration.

Theoretical Consideration

The full measures of highway transportation costs are usually categorized as direct and indirect costs. The various classifications are shown in Table 2.1 below:

Table 2.1: Direct costs of Highway Transportation

S/N	Main Cost	Cost Components
1	Vehicle self operating costs	i) Vehicles depreciation ii) Fuel/Gas iii) Oil iv) Tire – Wear v) Insurance vi) Parking Fees vii) Tolls viii) Regular and Unexpected Maintenance
2	Infrastructure costs	i) Facility Construction ii) Material iii) Labour iv) Administration v) Right of Way vi)

The infrastructure costs also include the interests over the life time of the facility, regular maintenance expenditures of keeping the facility in a good state and occasional capital expenditure for traffic-flow improvement.

Indirect Cost: This includes:

- Accidents and Congestion Costs
- Air Pollution and Noise Costs

The accident and congestion costs are interrelated to distance (Ferguson, 2001). At first glance; an accident seems to incur costs only for the parties involved, however, the resulting delay causes congestion, making for low speed operating and time loss for other users.

The Model Formulation

Based on the theoretical considerations (see 2.1), the full marginal cost function may be developed as follows:

Full Marginal Cost Function = Marginal Operation Cost + Marginal Infrastructure Cost + Congestion and Accident Cost + Contingency

That is,

$$FMCF = MC_{opr} + MC_{inf} + MC_{acc} + K_{(m)} \;\ldots\ldots (1)$$

The general form of self vehicle operating cost function may be defined as:

$$C_{opr} = f(C_d, C_{og}, C_t, C_m, C_i, C_p) \;\ldots\ldots\ldots\ldots (2)$$

Where,

C_{opr} is vehicle operating cost one year (Naira/ vehicle)

C_d is depreciation cost for vehicle over years

C_{og} is gas & oil cost Naira/Km

C_t is tire cost Naira/Km

C_m is maintenance cost Naira/Km

C_i is insurance cost naira/Km

C_p is parking fees Naira/Km

Depreciation is caused by wear and tear on the vehicle over time and by changes in demand and taste of users. Hence, depreciation cost is assumed to be related to the vehicles age (a) and mileage (ma) maintenance. Fuel, oil, tire wear cost and parking fees depend mainly on the distance traveled. Data on insurance cost, parking fees and tolls are from cost of owning and operating automobile. However, marginal vehicle operating cost is estimated in terms of distance traveled, thus the insurance cost may be neglected.

Vehicle operating marginal cost per Km can therefore be estimated as:

$$MC_{opr} = \{(C_{og} + C_m + C_t + C_p) + \alpha/a\} \;\ldots\ldots\ldots\ldots (3)$$

Where α = co-efficient of vehicle's age

a = vehicles age.

In computing Marginal infrastructure cost, new construction and land acquisition costs are ignored since these costs are not function of traffic volume.

Thus, maintenance and improvement are the only cost category that remain in our marginal infrastructure cost function. The Maintenance and improvement works are of three categories:

1. Major reconstruction with/without roadway widening (X_1)
2. Roadway widening with/without resurfacing (X_2)
3. Resurfacing with/without minor roadway widening (X_3)

However, according to Ozbay et al, (2001), the Marginal Infrastructure Cost per Km is given as:

$$MC_{inf} = \left\{\left(\frac{1}{m}\sum_{j=i}^{m} X_j\right)\times 10^{-6}\right\} \;\ldots\ldots\ldots (4)$$

where X_j is the monetary expenditure on category j of the maintenance and improvement works.

Congestion and Accident Cost

Time loss is determined through the use of a travel time function and trip characteristics such as distance between Origin – Destination (O – D pairs), traffic volume and higher capacity. Samuel and Linday (1981) gave accident occurrence rate per period as:

$$P_i = (\gamma_i M^{\beta i} Q^{\lambda i}) \ldots\ldots (5)$$

Where

P_i is accident rate

i is the class of accident

M is roadway length (Km)

Q is traffic volume (vehicle/day)

The adoption of unit cost of accident per crash will now give the generalized Marginal cost of accident as

$$MC_{acc} = \frac{1}{n}\sum_{i=1}^{n} C_{i1} P_i \quad \ldots\ldots\ldots (6)$$

where C_{i1} is the unit cost of accident class i

Substituting equation 5 in 6 gives

$$MC_{acc} = \frac{1}{n}\sum_{i=1}^{n} C_{i1}\gamma_i M^{\beta i} Q^{\lambda i} \ldots\ldots (7)$$

γ is accident rate proportionality constant.

β, λ, road way and traffic volume indices, respectively.

The cost component of our pollution and noise is also neglected, due to complexity in obtaining the data on those costs in Nigeria. However, according to Adebiyi (2002), road traffic accident cost can be estimated as:

$$C_{i1} = \sum_{j=1}^{m} h_{ij} + A_i \ldots\ldots (8)$$

C_{i1} = unit cost of accident class i

h_{ij} = cost of property damaged associated with accidents class i

A_i = Establishment's compensation on human disability involved in accident class i

i = counter of accident types

j = counter of number of cases of accident class i considered

N = number of cases of accident i considered.

Contingency (K_M): This includes the miscellaneous expenses such as rates dues and levies being paid to the government, transport unions and other miscellaneous expenses along the road length (M).

Substituting equations 3, 4 and 7 with the K_M in equation 1, the One Route Marginal Cost (ORMC) function may be given as

$$ORMC = \left\{\left(M(C_{og} + C_t + C_m, C_i + C_p) + \frac{\alpha}{a}\right) + M\left(\frac{1}{m}\sum_{j=i}^{m} X_j\right) \times 10^{-6}\right\} + \left(\frac{1}{n}\sum_{i=1}^{n} C_{i1}\gamma_i M^{\beta i} Q^{\lambda i}\right) + K_M$$

... (9)

Model Application

The model was used to estimate the cost of transportation per trip in Oyo state with particular preference to Ibadan – Ilorin route.

Data Collection

Data were collected from both primary and secondary sources (Nigeria Police Force, Federal Road Safety Commission, Oyo State Ministry of Works and Transport) through structured questionnaire, vetting of records and interviews. Data were collected on the following:

i. Road maintenance and improvement works in Oyo State between 2000 and 2001;
ii. Traffic count along Ibadan – Ilorin road;
iii. Fuel consumption and parking data as presented in Tables 1 through 3.

Estimation of Model Parameter Values

Estimation Procedure

Marginal Operating cost: Data collected from 200 auto users covering 5 major classifications of vehicles in Nigeria were analyzed to estimate the operating cost parameters as shown in Table 4. However, Ozbay et al (2001) gave the value of α as 1.0099 for vehicles on highway.

Marginal Cost of Infrastructure:

The parameter values for the three categories of road maintenance and improvement works are estimated from Table 1 as:

X_1= 0.3042 (₦/km)
X_2= 0.1983 (₦/km)
X_3= 0.1377 (₦/km)

Using expression 4 the Marginal infrastructural cost is estimated as 0.2134 (₦/km)

Accident Rate per Trip Parameter Indices

According to Ozbay et al,, (2001), the values of λ, β and γ for three identified classes of road traffic accidents are given in Table 5.

Contingency Cost (K_M)

K_M was estimated by taking the average value of rates, dues, levies, etc being paid by 18 – passenger seater buses and 8 – passenger seater cars as ₦50.5/passenger and ₦129.36/passenger, respectively.

Road traffic accidents are classified into three, viz fatal, serious and minor (Charles – Owaba and Adebiyi, 2001; Adebiyi and Charles-Owaba, 2006; Ozbay et al, 2001).

Employ expression (8), the cost of each class of accidents C_{i1} is estimated as:

Fatal (C_1): ₦2,752,324:00
Serious (C_2): ₦ 1,072,320.00
Minor (C_3): ₦ 1,459,725.00

The road way length, M, (Ibadan – Ilorin via Iwo) was estimated as160 Km .Q was adapted from Adebiyi and Charles-Owaba (2006) as 1733 and 3228 for buses and cars, respectively, while the average age of vehicles is taken as 10.

Substituting these estimates in expression (9), the One Route Marginal Cost along Ibadan – Ilorin road is estimated as ₦304.61/Trip/ Passenger and ₦417.87/Trip/Passenger for buses and cars respectively.

Assuming 40% mark up the ORMC is estimated as **₦426.45/Trip/Passenger** and **₦585.02/Trip/Passenger** for buses and cars respectively.

The details of the analysis is shown in Table 5.

Discussion

Prior to model development and subsequent theoretical consideration of transportation cost was carried out. The model consists of four main components. These are vehicle operating marginal cost; infrastructure cost; congestion and accident cost and contingency cost. Thus, one Route Marginal Transportation Cost Model (ORMC), was developed in terms of length of the road way (M), vehicles age (a), cost of each class of accidents (C_{i1}), traffic volume (Q), accident rate indices for each class of accidents (λ_i, β_i,γ_i). The model computes the payable cost of transportation per trip by a passenger along a route. It estimates the value of operation cost; infrastructure cost; congestion and accident cost; and contingency cost. Classical statistics was employed to analyse the data collected on vehicle self operating cost, in terms of fuel/oil consumption per kilometer of travel, maintenance cost, tire and parking. However, fuel/gas has greater contribution of ₦0.45/km and ₦0.5/km for buses and cars respectively, while maintenance and oil have the least cost of ₦0.117/km and ₦0.0225/km for buses and cars respectively. Table 1 shows the data collected on thirteen (13) different roads in Oyo State with their respective kilometre of distance constructed between year 2000 and 2001.

Table was analysed to obtain the infrastructure cost per kilometer for identified three categories of accident. The major reconstruction with/without widening has highest monetary effect of ₦30/km, however, the mean infrastructure cost/per km was estimated as ₦34.08/km. Based on adopted values of λ, β and γ, from Ozbay et al (2001), shown in Table 4, the congestion and accident cost was estimated at ₦109.4162/km ₦106.3797494/km for buses and cars respectively. Moreover, the contingency cost was estimated by summing the amount being paid by each vehicle at all identified points of payment rates, dues and other levels along the Ibadan – Ilorin road. This was spread over each passenger to obtain an estimated value of ₦50.5/passenger and ₦129.36/passenger for buses and cars respectively.

Therefore, the cost of transportation per trip was estimated as ₦426.45/Trip/Passenger and ₦585.02/Trip/Passenger for buses and cars respectively, with vehicle operating cost being major contributor. This may be due to poor economy that resulted into increasing cost of vehicle maintenance resources.

Conclusion

The transportation model was developed in terms of traffic volume, cost of accidents, length of travel and average age of vehicles. The model was applied to Ibadan – Ilorin road. The application reveals that the cost of transportation along this route is estimated as ₦426.00/Trip/Passenger and ₦585.00/Trip/Passenger for buses and cars respectively. This estimate quantified the price being paid by the road users to justify the service of self mobility from one place to another. However, the value of time, congestion cost and noise pollution cost were not taking into consideration.

Table1: Maintenance and improvement works in Oyo State (2000/2001)

S/n	Names of Road	Kilometers	Amount Awarded
1.	Omi Adio-Ido	9.2	150,000,000.00
2.	Labo – Olomi-Olude –Apadi	16	300,000,000.00
3.	Eletu – Kupalo – Jago – Badeku	13	179,873,355.00
4.	Egbeda-Erunmu-Lalupon	11.6	230,000,000.00
5.	Lanlate – Maya	10.1	215,696,809.00
6.	Apapa – Odan –Iware –Fiditi	13.0	200,000,000.00
7.	Ado-Awaye-Kua-Okeho	10.1	200,000,000.00
8.	Tewure –Ajinapa –Gambari	13.3	200,000,000.00
9.	Ago-Are-Tede-Oje-Owode	13	239,932,000.00
10.	Shaki –Township Roads	10.65	324,392,000.00
11.	Shaki –Oje Owode	14.5	225,676,000.00
12.	Igbo-Ora-Igangan (section one)	19	3,200,548.00
13.	Igbo-Ora-Igangan (section two)	19	3,520,150.00
Total		172.45	24,721,290,862.89

Source: - Ministry of Works and Transport, Ibadan, Oyo State.

Table 2: Traffic count along Ibadan – Ilorin road

Day	Cars	Buses/Van	Long Buses	Trailers	Motor-Cycle	Total Vehicle	Light	Heavy
Mon	3570	1660	331	1322	211	6900	5578	1322
Tue	3423	1367	536	1411	348	6585	5174	1411
Wed	2943	1917	433	1176	257	6326	5150	1176
Thur	2706	1449	465	992	212	5424	4432	992
Fri	2742	1674	448	1053	218	5735	4682	1053
Sat	2851	1939	567	1015	168	6040	5025	1015
Sun	4364	2116	472	1110	192	7854	6744	1110
Total	22,599	12128	3257	8087	1606	44872	36785	8087
Average	3228	1733	465	1155	229	6410	5255	1155

Source: Adebiyi and Charles – Owaba (2006)

Table 3: Fuel consumption, maintenance and parking data

Vehicle Classification	Fuel/ Gas (Naira/KM)	Oil (Naira/KM)	Maintenance (Naira /Km)	Parking (Naira/Km)	Total (Naira/Km)
Cars	0.50	0.225	0.117	0.194	1.036
Buses	0.45	0.0225	0.1275	0.202	0.802

Table 4: Accident rate indices

Accident Class (i)	γ_i	β_i	λ_i
Minor	89.81×10^{-6}	0.2317	-0.05
Serious	18.87×10^{-6}	0.501	-0.3163
Fatal	0.0022×10^{-6}	0.7366	0.5084

Source: Ozbay et al (2001).

Table 5: Details of estimation of ORMC for buses and cars

	$\left(M(C_{g}+C_{t}+C_{m},C_{t}+C_{p})+\frac{\alpha}{a}\right)$	$M\left(\frac{1}{m}\sum_{j=i}^{m}X_i\right)\times10^{-6}$	$\frac{1}{n}\sum_{i=1}^{n}C_{i1}\gamma_i M^{\beta i}Q^{\lambda i}$	K_M	Total
Cars	181.9184	0.2134	106.3797	129.3600	417.8715
Buses	144.4784	0.2134	109.4162	50.5000	304.6080

References

Adebiyi, K. A. 2002. Road Traffic Accident Cost Estimation Model. *Research Communications in Management.* 1.2: 32 – 35

Adebiyi, K. A. and Charles-Owaba O. E., (2006). "Statistical Analysis and Economic Evaluation of Road Traffic Accident" Journal of Science and Technology (in Press)

Charles- Owaba, O. E and Adebiyi, K. A. 2001.On the performance of FRSC: Oyo State Sector Command. *Nigerian Journal of Engineering Management.* 50 – 56.

Directorate of Planning, Research and Statistic (1997): The Accomplishment of Federal Road Safety Commission from 1988to Date. FRSC National Headquarters, Abuja.

Federal Road Safety Commission, 1997. The Revised Federal Republic of Nigeria, Highway code.

Ferguson E. (2001). The three faces of Eve: How Engineers, Economics and Planners Various View Congestion on Control, Demand Management, and Mobility Enhancement Strategies. *Journal of Transportation and Strategies and Statistics.* Vol. 4. No. 1, 51 – 73.

Gregory P. and Eric T (2002) "In the incidents of incidence… "Traffic Technology International. April/may.pp48 – 55

Ottong J. G. (1997) "Road Accident and Traffic Education in Nigeria" Transportation of Nigeria National Development. Proceeeding of National Conference

Ozbay, K., Bartin, B., and Berecham, J. 2001. Estimating and Evaluation of Full Marginal Cost of Highway Transportation in New Jersey. *Journal of Transportation and Statistics.* 4.1: 81-103.

Samuel C. T and Linday J. A (1981) Äccident Rates in 2-lanes Rural Highway" Before and after Re-Surfacing Public Road. *Journal of highway Development and Research*, Vol. 44.No. 4 March.

Shanker R., Vjaryaragharan P., and Narendran T. Modelling Customer Support Performance in Indian I T Hardware Industry. *Journal of Modelling in Management,* Vol. 1. No. 3, 232 – 254.