ASSESSMENT OF COSTS OF BUS TRANSIT OPERATIONS IN METRO MANILA

Cresencio MONTALBO Jr.
Graduate Student
Institute of Policy & Planning Sciences
University of Tsukuba
1-1-1 Tennodai, Tsukuba City
Ibaraki Prefecture, 305 Japan
Fax: +81-298-53-5591
Email: montalbo@shako.sk.tsukuba.ac.jp

Haruo ISHIDA
Professor
Institute of Policy & Planning Sciences
University of Tsukuba
1-1-1 Tennodai, Tsukuba City
Ibaraki Prefecture, 305 Japan
Fax: +81-298-55-3849
Email: ishida@shako.sk.tsukuba.ac.jp

abstract: The performance of bus transportation is influenced by factors internal and external to the system. Internal factors refer to the characteristics of operators. External factors are the characteristics of the operating environment. Using these factors as independent variables, unit cost models were developed by multiple linear regression. A methodology was demonstrated showing the relative efficiency of operators. This uses average unit cost and expected unit cost as bases for comparison. Best, worst, and middle performing operators were identified. This methodology can be extended to the more detailed unit cost models to diagnoze specific areas of efficiency or inefficiency.

1. INTRODUCTION

Cities in developing countries are characterized by rapid increase in population due to natural growth and rural-urban migration. Majority of urban people are dependent on public transportation. In 1990, 70% of the 17.65 million daily person trips in Metro Manila were by public mode of which 24% is by bus (National Center for Transportation Studies, 1995). Bus transportation plays an important role in the urban setting. Ideally, public transportation should be given preferential treatment by policymakers on equity grounds since the majority of the urban population are public transportation users. However, it continues to be threatened by the growing number of cars which cause road congestion. Because of worsening traffic conditions, operating costs of bus transportation are rising. Without any government subsidy and with limited financial resources available to operators, it is all the more important to ensure effective and efficient bus transit operations in the midst of rising costs and deteriorating traffic conditions.

The objectives of this study are:

1. To determine the relevant internal and external factors and the levels at which these factors influence cost of bus operations in Metro Manila.
2. To analyze the levels of efficiency of transit operators

The performance of bus transit is influenced by factors internal as well as external to the system (Figure 1). In this figure, internal factors refer to the characteristics of operators such as scale of operations (fleet size, vehicle hours, vehicle kilometers, maintenance), characteristics of hardware or facilities (old or new buses, airconditioned or ordinary buses), ownership type (public or private). External factors refer to the characteristics of the environment in which the system is operating such as road conditions (speed, level of congestion, road network configuration), characteristics of the market being served (population, land use), and institutional setting of the system (regulated, deregulated).

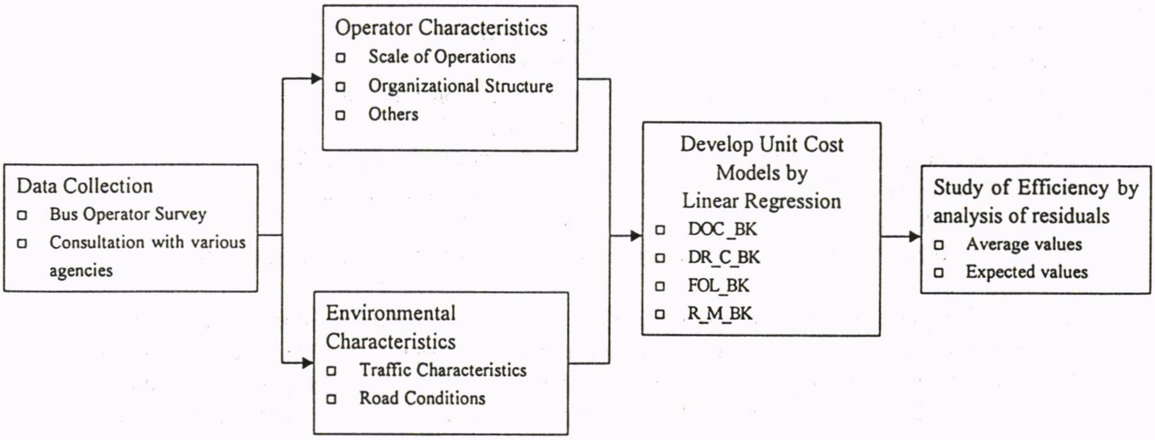

Figure 1 – Study flow also showing factors influencing transit performance

In this study, unit operating cost models were developed using multiple regression analysis because a.) unit costs are measures of efficiency; and b.) regression analysis can show the interaction between the internal and external factors influencing operating costs. The model is of the form:

$$C = a_0 + a_1x_1 + a_2x_2 + \ldots + a_nx_n$$

where $x_1, x_2, \ldots, x_n$ are the factors hypothesized to be related to cost and $a_1, a_2, \ldots, a_n$ are the estimated coefficients of the regression.

Relevant factors were considered from a wide spectrum of operator and environment variables using a bus operator interview survey conducted in August and September 1996. Internal factors refer to the scale of operations and characteristics of hardware or facilities. (All bus companies are privately owned). External factors are average speed and percentage of route length in EDSA (Epifanio de los Santos Avenue), the major bus corridor in Metro Manila. This study is restricted to the financial performance of bus transit operations focusing on the costs incurred by the operator. Costs borne by other sectors such as those due to pollution are beyond the scope of the present study.

The results of this study may be useful to the transport planner as it can provide information on the interaction between operator characteristics and the operating environment in relation to cost efficiency of the transit system. It can also provide useful management information for the transit operator by determining its efficiency and performance relative to other operators and identify areas of inefficiency. This is in pursuit of delivering cost efficient service to public transportation users.

2. LITERATURE REVIEW

Cost modeling has been done in many studies in the past. Costs have been modeled in terms of several independent variables:

1. System output measures, such as vehicle kilometers and vehicle hours
2. System characteristic indicators such as fleet size and ownership
3. System environmental factors such as age of city of operation and demographics

Cost models may be classified according to three bases: analysis type (regression or cost allocation model), structure (aggregate or disaggregate model), and objective function (total or unit cost model). These are shown in Table 1. A regression model uses multiple regression procedure. A cost allocation model is one in which cost components are assigned to the output measure that most directly influences it. An aggregate model expresses total cost by a single equation. A disaggregate model means that total cost is broken down to its components and a cost function is developed for each component. Total cost is then obtained by summing over the individual cost components. Models can also be classified according to the dependent variable being modeled: either total cost or unit cost.

Table 1 Classification of Cost Models

Classification	Cost Models	
Method of Analysis	Regression Model	Cost Allocation Model
Structure	Aggregate Model	Disaggregate Model
Objective Function	Total Cost Model	Unit Cost Model

The development and interest in cost models sprang in the United States in the 1970s from the need to evaluate the performance of state-subsidized transit systems and review the benefits for such financial assistance (Talley *et al.*, 1981). Among the models developed is the cost allocation model for average daily operating costs of a system using average daily miles, vehicle hours, passenger revenue, and number of peak vehicles for the Dade County Metropolitan Area (Ferreri, 1969). Using the American Transit Association (ATA) data for 1960 and 1968 for 45 and 40 companies, respectively, a regression model for total costs was developed using the following variables: bus-miles generated, total hourly wage rate, speed, average bus age, seating capacity, nature of ownership (public or private), and proportion of fleet purchased with capital grant (Nelson, 1979). Utilizing the 1979 Section 15 data of the Urban Mass Transit Authority for 92 transit systems, total operating expenses were modeled using total number of employees, bus age, vehicle miles, number of part-time drivers per peak period vehicle, hourly driver wage, and vehicle miles per gallon of fuel consumed (Kanok-Kantapong, 1983).

In developing and examining specific measures of transit efficiency for 86 single mode bus transit systems included in the 1982 Section 15 data, Papadimitriou extensively used regression analysis to develop cost models for total and component costs incorporating system and environmental factors in the model. System descriptor variables such as annual vehicle miles, revenue vehicles, number of employees, annual hours of operation, form of ownership, and others were analyzed as well as environmental characteristics like average monthly earning of city employees, % of work trips by public transportation, % of urbanized area, heating degree days per year, cooling degree days per year, and mean July temperature (Papadimitriou, 1986). In a macroscopic study of suburban bus services in Tokyo Metropolitan Area, developed demand and cost models involving vehicle kilometers, fleetsize, frequency, population density, network density, size of operation area, and wages (Ieda *et al.*, 1996).

This author proposes to assess the cost of bus operations in Metro Manila by developing cost models showing the relationships of internal and external factors influencing costs of operations. Metro Manila's situation is quite different from the scenarios considered in most of the modelling in the past which were done mostly in developed countries. Being an urban area in a developing country, the profile of bus operators is hypothesized to be much more varied or heterogeneous than those in developed countries. Cost performance may vary widely from operator to operator. Unit cost models using regression analysis will be developed that will show the relevant operator and environmental parameters that affect costs of operations.

3. THE DATABASE

3.1 Description of the Study Area

Metropolitan Manila is the capital of the Philippines. Situated in the island of Luzon, it has an area of 636 sq. kms . (0.2% of the country's land area). It comprises 7 cities and 10 municipalities with a total population of about 8 million based on the 1990 census (13% of the country's population). Population density is estimated at 12,465 persons per sq. km. compared to the national figure of 202 persons per sq. km. Annual population growth rate is estimated at 0.3%. The population is projected to exceed 10 million by the year 2000.

Metro Manila's road network consists of 10 radial and 5 circumferential roads as shown in Figure 2. Circumferential road # 4 also known as EDSA with a length of 25.26 kilometers from Monumento in the north to Baclaran in the south has 6 lanes per direction at its widest. It is the major transport corridor in the metropolis absorbing traffic volume of more than 100,000 vehicles per day. This thoroughfare also serves as the major bus corridor in the capital serving as the link between the major employment, commercial, institutional, and residential areas in the metropolis.

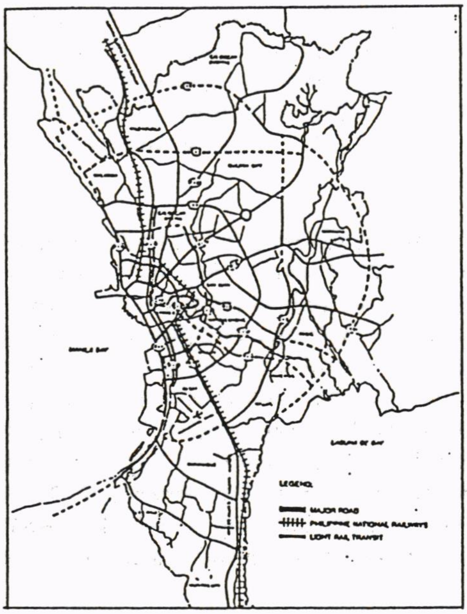

Figure 2 - Metro Manila's Road Network

Public transportation is by various modes. There is a 15-km light rail transit line (LRT) along Taft Avenue in the city of Manila. There is a limited heavy rail commuter train operating in the south corridor. Buses and jeepneys (14 to 18-passenger paratransit mode) carry the bulk of public transportation users. Tricycles (combination of motorcycle and sidecar) and pedicabs (combination of bicycle and sidecar) carry short local trips.

The 1990 total number of person trips per day in Metro Manila is 17.65 million growing at 6.68% per year from the 1980 daily trip rate of 10.97 million. It is broken down as follows. (Table 2)

Table 2 - Modal Shares of Person Trips

Year	1980	1985	1990
Population (x 10^6)	5,926	6,942	7,928
# of cars registered	210,189	222,120	257,734
Daily Person trips in 10^6	10.97	13.08	17.65
% Mode Share			
Private Vehicle	25.60	27.50	30.40
Bus	15.80	15.60	23.60
Jeepney	58.50	56.50	44.10
Commuter Train	0.10		
LRT		0.40	1.90

Source: DOTC (Department of Transportation & Communications)

It can be seen from Table 2 that urban transportation in Metro Manila is essentially road-based. Furthermore, majority of person trips (70%) was carried by public transportation in 1990. It can thus be said that there is a high level of public transport usage in Metro Manila.

There are 900,000 registered vehicles in Metro Manila or 42% of the 1993 total number of registered vehicles in the country. Of this, 340,000 are private cars. This comprises 68% of all registered private cars in the Philippines.

3.2 Bus Operations in Metro Manila

Metro Manila bus operations is characterized by the presence of few big and many small operators. As of May 1996 the LTFRB lists 437 active (with valid franchise) bus operators categorized according to fleetsize as follows:

Table 3 - Profile of Bus Operators

Fleetsize	# of Operators	% Share-Operators	# of Units	% Share- # of units
>=100	19	4.3	2,955	31.8
51 to 99	31	7.1	2,163	23.3
26 to 50	38	8.7	1,367	14.7
11 to 25	86	19.7	1,448	15.6
<= 10	263	60.2	1,359	14.6
Total	437	100	9.282	100

Source: LTFRB (Land Transportation Franchising & Regulatory Board)

Referring to above table, 32 % of all bus units are operated by 4.3% of operators. These large operators (although few in number) control a big part of the market.

3.3 The Bus Operator Interview Survey

The objective of this survey is to gather financial, operational, management, and other information about selected bus companies in Metro Manila.

This was conducted through personal interviews with bus operators. As initial step in the survey, a list of bus operators was obtained from the Land Transportation Franchising & Regulatory Board (LTFRB). Contact information on these operators were then gathered and confirmed. Appointments for interview were made by phone whenever possible. Willing respondents were visited and interviews were conducted.

Part of the data gathered are the financial statements of bus operators for 1995. With the endorsement of the government's LTFRB and the officers of the bus operators' association (Integrated Metro Bus Operators Association or IMBOA), interviews were conducted from August 2 to September 10, 1996. From an initial list of 88 potential respondents (with available contact information) a total of 51 operators were interviewed with 28 providing financial information. In this study, the financial and operational data of these 28 operators were used in the development of the cost models. The table below (Table 4) shows the number of participating operators in each fleetsize category.

Table 4 - Profile of Samples

Fleetsize Range	# of Operators	% Share of samples
>= 100	5	17.8
51 to 99	8	28.6
26 to 50	5	17.8
11 to 25	6	21.4
<= 10	4	14.4
Total	28	100

3.3.1 Results of the Survey

Total costs are composed of direct and indirect operating costs. Components of direct and indirect operating costs are as follows:

Table 5 - Direct & Indirect Operating Cost Components

Direct Operating Cost	Indirect Operating Cost
1. Driver & conductor commission	1. Administrative salaries & wages
2. Fuel, oil, & lubricants	2. Building rental
3. Repair & maintenance	3. Utilities
Parts, tires, batteries	4. Office supplies
Garage materials & supplies	5. Interest on loans
Service & supply wages	6. Fines & penalties
Rehabilitation of units	7. Injuries & damages
4. Depreciation	8. Security services
5. Taxes & fees	9. Representation
6. Insurance & registration	10. Professional fees
7. Ticket expenses	11. Others
8. Others	

Aggregated financial data of the 28 operators show the following % shares of the major direct operating cost components: Driver & conductor commission (24%), Fuel, oil, & lubricants (24%) , Repair & maintenance (22%), Depreciation (24%), Other items (6%).

The focus of this paper is to model direct operating cost and its major component costs consisting of driver and conductor commission; fuel, oil, & lubricants; and repair & maintenance. Depreciation cost is computed by operators using the straight line method; hence it is solely a function of time and not of operation. It is therefore not included in the modeling exercise.

Several chosen operational and financial items describing the operators are shown in Table 6. Total bus-kms was computed using the detailed route information given by the respondents. Total revenue, operating cost, net income, driver & conductor commission, administrative salary, fuel & oil costs, and repair & maintenance costs were obtained from the financial statements. Franchise, fleetsize, and fuel consumption information were obtained from the interview.

Table 6 - Characteristics of samples

Characteristics of Samples						
			Fleetsize			
	>= 100	51 to 99	26 to 50	11 to 25	<=10	Total
# of samples	5	8	5	6	4	28
Total bus-kms per month	3,546,114	2,716,537	1,205,770	687,701	123,818	8,279,940
Total bus-kms per year	42,553,365	32,598,439	14,469,239	8,252,416	1,485,818	99,359,277
Total revenue per year	254,532,563	131,251,262	34,610,175	45,329,503	5,863,030	471,586,533
Total cost per year	248,691,335	131,143,448	32,572,303	49,926,312	5,907,840	468,241,237
Total direct operating cost per year	204,503,640	102,227,795	22,066,617	41,918,514	4,540,276	375,256,842
Total driver & conductor comm per year	51,307,372	25,071,384	5,858,404	7,311,817	889,228	90,438,206
Total fuel, oil, & lubricants per year	51,151,541	24,407,949	5,161,969	11,200,935	983,731	92,906,125
Total repair & maintenance per year	50,286,819	18,285,080	3,769,056	7,511,917	1,327,155	81,180,027
Total fleetsize	677	543	225	117	39	1,601
Fuel consumption (lit per month)	1,856,000	1,507,680	619,550	405,000	72,000	4,460,230
Revenue per bus-km	5.98	4.03	2.39	5.49	3.95	4.75
Total cost per bus-km	5.84	4.02	2.25	6.05	3.98	4.71
Total fuel per bus-km	0.52	0.56	0.51	0.59	0.58	0.54
Direct operating cost per bus-km	4.81	3.14	1.53	5.08	3.06	3.78
Driver & conductor comm per bus-km	1.21	0.77	0.40	0.89	0.60	0.91
Fuel, oil, & lubricants per bus-km	1.20	0.75	0.36	1.36	0.66	0.94
Repair & maintenance per bus-km	1.18	0.56	0.26	0.91	0.89	0.82

It can be seen from Table 6 that cost performance of operators differ widely. This shows that bus transit operators are far from homogeneous and there exists a wide variation in the performance and characteristics of these operators. This variation as well as the internal and external factors that affect cost of operation will be the subject of this study.

4. DATA ANALYSIS AND MODELING

4.1 Choice of Type of Model

Using the different hypothesized internal and external factors as independent variables and unit cost per bus kilometer as dependent variable, regression analysis was performed to show the relationships among these variables. The developed unit cost models are used as basis for the evaluation of operator efficiency. Unit cost models were developed for direct operating cost (DOC_BK) and its components: driver & conductor commission (DR_C_BK); fuel, oil, & lubricants (FOL_BK); and repair & maintenance (R&M_BK). Unit costs are on a per bus-kilometer basis.

4.2 Variables used in the Analysis

The variables explored in the regression analysis are as follows:

Operator Data (Internal Factors):

- total fleetsize (total number of operational and inoperational buses)
- active fleetsize (number of operational buses)
- available fleetsize (number of buses actually operating at the time of survey)
- %active buses (ratio of active fleetsize to total fleetsize)
- % airconditioned buses (ratio of number of aircon buses to total fleetsize)
- seat capacity (average seat capacity)
- bus age (average bus age)
- operating hours per week
- fuel consumption per month (liters per month)
- bus-kilometers per month (active fleetsize multiplied by distance run by 1 bus per month. This is obtained from the detailed route table gathered in the survey.)
- maintenance hours per week (number of maintenance man-hours per week)
- bus-hours per week (active fleetsize multiplied by hours of operation)
- number of bus seats (active fleetsize multiplied by average seat capacity)
- % driver and conductor commission
- seat-kilometers (average seat capacity multiplied by total bus-kilometers)
- drivers per bus (ratio of number of drivers to fleetsize)
- maintenance hours per bus per month (ratio of maintenance man-hours per month to fleetsize)
- maintenance hours per bus-kilometer (ratio of maintenance man-hours per month to bus-kilometers per month)
- bus-kilometer per bus (ratio of total bus-kilometers per month to fleetsize)
- maintenance men per bus (ratio of number of maintenance staff to fleetsize)
- firm age (age of company)

Environmental Data (External Factors):

- % route in EDSA (ratio of route length in EDSA to total route length)
- average speed (ratio of bus-kilometers per month to bus-hours per month)
- route intensity (ratio of bus-kilometers per month to total route length)

EDSA is the major bus corridor and one of the the most important thoroughfares in Metro Manila. In 1993 there were 58 ordinary (or non airconditioned) bus routes and 17 airconditioned bus routes touching a part or the entire length of EDSA (Department of Transportation & Communications, 1993). Being a major corridor, levels of congestion in EDSA are serious and traffic volumes have exceeded road capacities especially during peak hours. In effect, travel delays result which lower the efficiency of transit operations.

Average speed is computed as the ratio of total bus-kilometers per month to total bus-hours of operation per month. It is an aggregate data that represents the over-all speed of the system. It must be noted, however, that operating speed is that which is imposed by the environment on the moving buses and not the speed capacity of the buses itself. Speed is an attraction not only for passengers but also for operators. Operators are primarily concerned with high cycle speeds on the lines since they affect the fleet size (investment costs), as well as labor, fuel, maintenance, and other operating costs (Vuchic, 1992). Operators would generally want to run their buses as fast as conditions would permit to maximize use of vehicles. Vehicle operating speeds are mainly determined by prevailing road conditions and local traffic policies. In effect, vehicle speeds reflect the level of congestion present on the road.

The following sections discuss the hypotheses used in the modeling exercise and the resulting regression models.

4.3 Direct Operating Cost per Bus-kilometer

4.3.1 Hypotheses

1. Operating Hours

It is hypothesized that as operating hours increase, direct operating costs per bus kilometer also increase. The basic rationale for this is that vehicles are machines which decrease in mechanical efficiency over time due to wear and tear. The longer time the vehicles are operated, the more costly it becomes on a per bus-kilometer basis. Moreover, longer operating hours mean more exposure or visibility for the bus company with regards to rider patronage. With higher patronage, driver and conductor commission (which is a percentage of passenger revenue) is expected to increase. This further adds to bigger direct operating costs per bus-kilometer.

2. % Route in EDSA

As mentioned earlier, EDSA is heavily congested and traffic volumes have reached or exceeded road capacity especially during peak hours. Because of congestion, it is expected that operating costs per bus-kilometer would increase due to higher fuel consumption and more repair and maintenance works required due to lower travel speeds.

3. Speed

As mentioned earlier, speed here is that which is imposed by the environment on the running vehicles. Computed average speeds are an indication of the level of congestion on the road. Lower speeds mean lower fuel efficiency for vehicles and higher maintenance costs. This translates to higher direct operating costs per bus-kilometer.

4. Maintenance

Maintenance is one of the components of direct operating costs. Considering all other factors constant, higher values of maintenance (in terms of man-hours or number of maintenance men per vehicle) mean higher direct operating costs per bus-kilometer.

The graphs in Figure 3 show the relationships between direct operating cost per bus-kilometer and the different parameters on the other hand. The trends shown in the graphs reinforce the stated hypotheses.

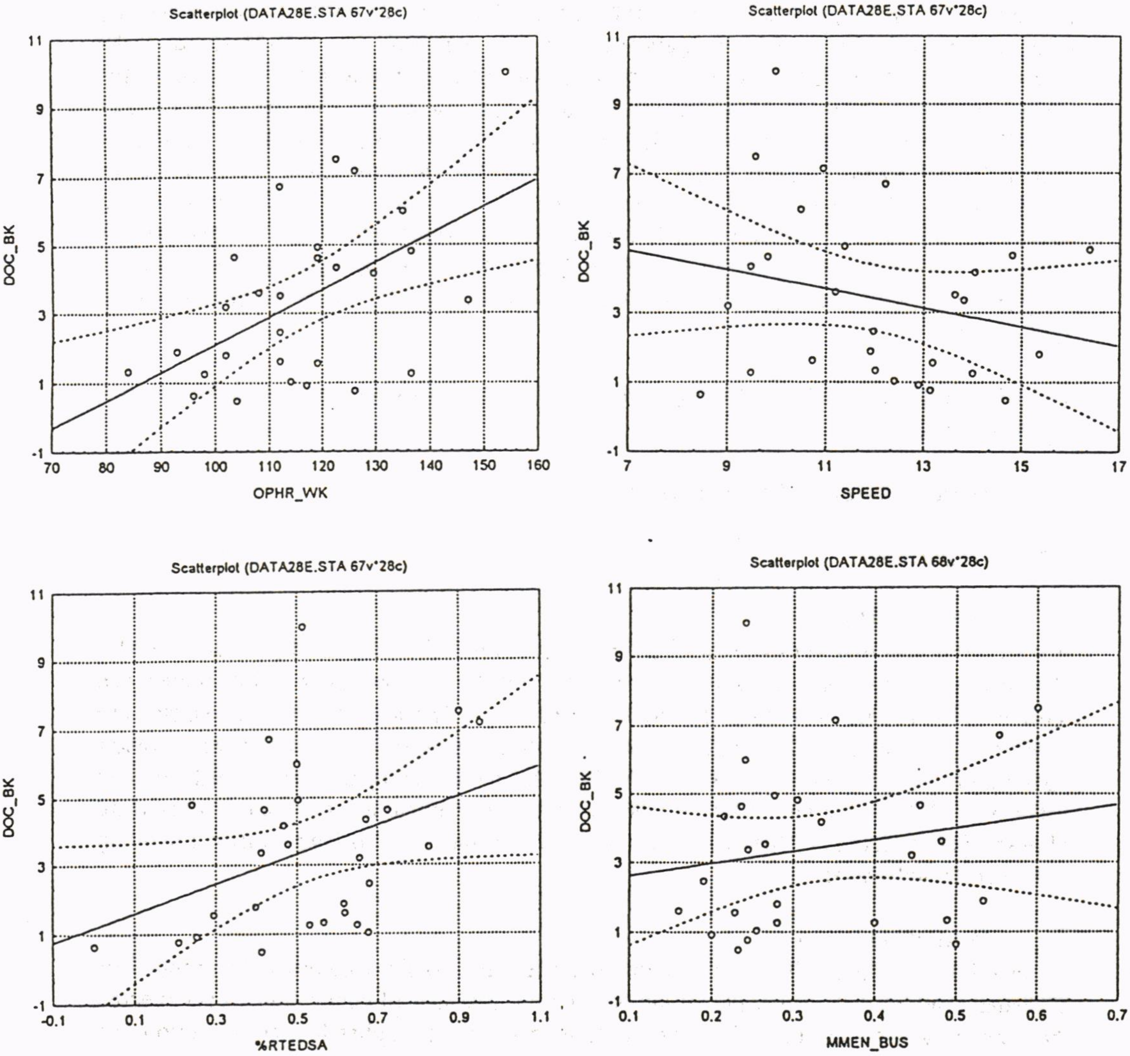

Figure 3 - Relationship between Direct Operating Cost per bus-kilometer and some Parameters

4.3.2 Resulting Model

Performing multiple regression analysis yields the following model for direct operating costs per bus-kilometer:

$$\begin{aligned} \text{DOC\_BK} = & -12.81 + 0.11\ \text{OPHR\_WK} + 3.20\ \text{\%RTEDSA} \\ & (-3.40) \qquad (5.42) \qquad\qquad (2.12) \\ & - 0.17\ \text{SPEED} + 9.45\ \text{MMEN\_BUS} \qquad \text{(Eq. 1)} \\ & (-1.05) \qquad\qquad (3.37) \end{aligned}$$

$R^2 = 0.64$

Direct operating cost per bus-kilometer was regressed on the four parameters. The best resulting model shows that operating hours per week, % route in EDSA, and maintenance (in terms of number of maintenance men per bus) are all positively correlated with direct operating costs per bus-kilometer as previously hypothesized and as shown in Figure 3. The t-values shown in parentheses at 23 degrees of freedom indicate that these parameters are significant at 95% confidence level. Speed is negatively correlated supporting the premise that lower speeds mean higher operating costs per bus-kilometer. However, the coefficient is insignificant at 95% confidence. The independent variables were checked for multicollinearity which is a common problem in multiple regression analysis. Analysis shows that redundancy of independent variables is very low indicating that multicollinearity is not a problem. The over-all F-test $F(4,23) = 10.123$ is considerably greater than the corresponding F-value of 2.80 at 95% level of confidence. The four parameters taken together explain 64% of the variation in direct operating costs per bus kilometer.

The independent variable with the highest explanatory power is maintenance. This is followed by % route in EDSA which indicates that it is more expensive to operate in EDSA than elsewhere. It is quite surprising to think that although EDSA operations are expensive many operators still want to operate there (many are still trying to get a franchise to operate in EDSA). The reason is that EDSA has the biggest public transport market since it is the most important corridor linking employment, commercial, institutional, and residential areas in Metro Manila. Operating costs may be higher there but so are revenues.

4.4 Driver and Conductor Commission per Bus-kilometer

4.4.1 Hypotheses

1. Operating Hours

The same reasoning for operating hours as mentioned in the preceding section applies here. As operating hours of operation increase, driver & conductor commission per bus kilometer correspondingly increases due to the longer exposure or higher visibility that the particular bus service gains. This increases passenger patronage thereby also increasing bus crew commission.

2. Maintenance

It is hypothesized that better maintained buses are expected to attract more passengers. With more passengers, revenue will increase resulting in higher crew commissions per bus-kilometer.

3. Number of active buses

The effect of the number of active buses is similar to that of the number of operating hours. With more active buses, the bus firm gains higher visibility leading to bigger patronage. Consequently, higher passenger revenues result in higher crew commissions.

4. Bus age

Between an old bus and a new one, passengers tend to choose a new one, ceteris paribus. Newer buses project an image of reliability, speed, and comfort. Hence, age is assumed to negatively affect passenger revenue and in effect, driver and conductor commission.

The following graphs show these hypothesized relationships.

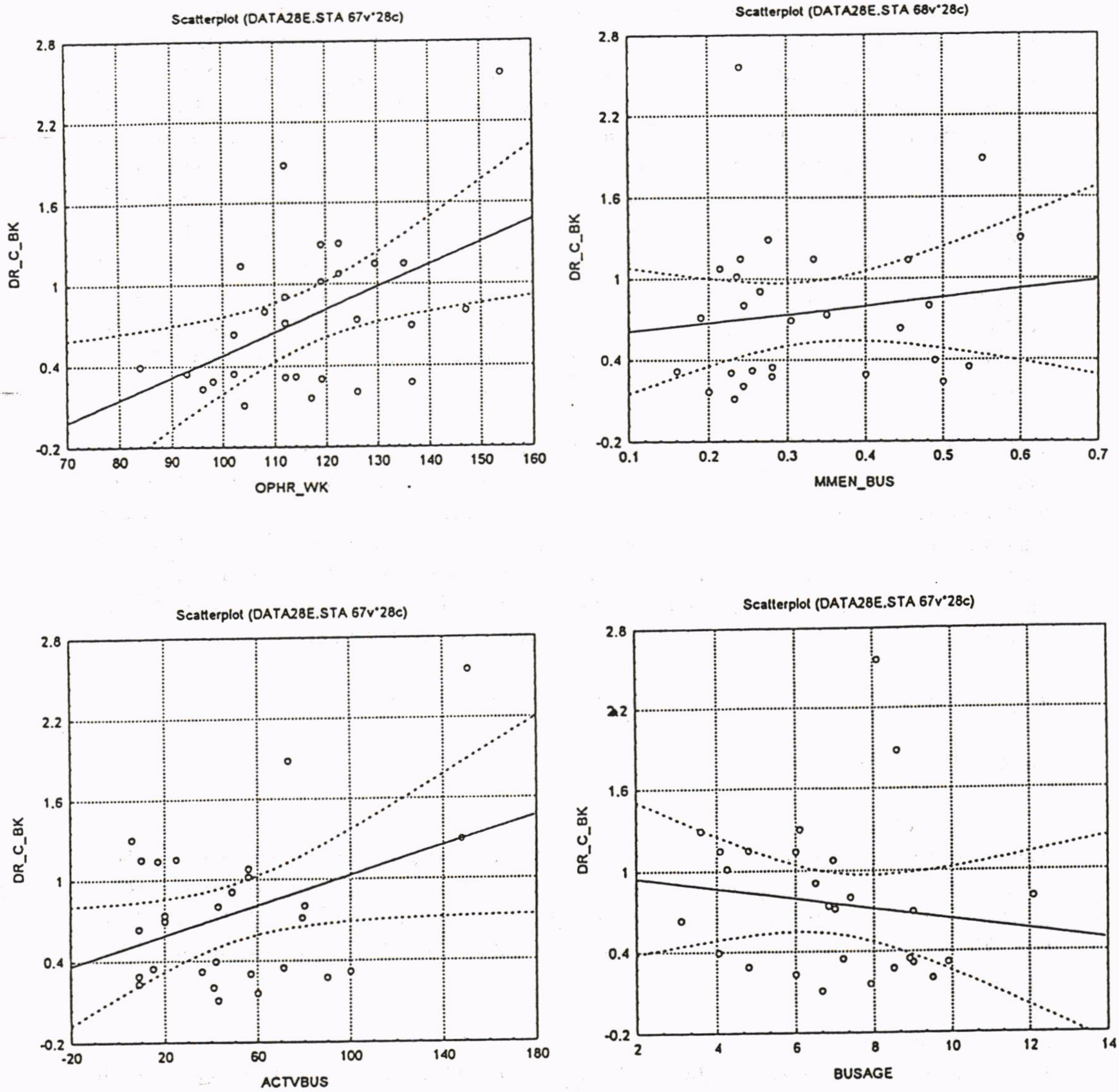

Figure 4 Driver & Conductor Commission per Bus-kilometer and some chosen parameters

4.4.2 Resulting Model

Regression analysis yielded the following model for driver & conductor commission per bus-kilometer:

$$\begin{aligned} DR\_C\_BK = & -2.73 + 0.02\ OPHR\_WK + 2.78\ MMEN\_BUS \\ & (-4.00) \quad (4.88) \quad (4.18) \\ & + 0.01\ ACTVBUS - 0.09\ BUSAGE \\ & (3.42) \quad (-2.76) \end{aligned} \quad \text{(Eq. 2)}$$

$R^2 = 0.66$

The signs of the coefficients confirm the hypotheses earlier made. Figure 4 shows that operating hours, number of maintenance men per bus, and number of active buses are positively correlated with the dependent variable. Bus age is negatively correlated as earlier postulated. The coefficients are likewise statistically significant as shown by their t-values at 95% level of confidence. The highest coefficient is that of maintenance men per bus indicating that this parameter has the greatest effect on passenger revenue and consequently, crew commission. This underscores the importance of good maintenance in attracting patronage. The over-all F-value of the regression equation is 11.36 which is significant at 95% level. The independent variables taken together explain 66% of the variation in the dependent variable.

4.5 Fuel, oil, & lubricants per Bus-kilometer

4.5.1 Hypotheses

1. Operating Hours

This is assumed to be positively correlated with FOL per bus-kilometer. As said earlier, longer operating hours decrease the fuel efficiency of vehicles. Hence, bigger values of operating hours mean higher values of FOL.

2. Speed

Higher operating speeds mean better fuel efficiency of vehicles. Therefore, a negative correlation between speed and FOL is hypothesized here.

3. Maintenance

The form of the FOL data in the gathered financial reports has an inherent weakness in that it is quite difficult to hypothesize its relationship with maintenance. FOL combines the expenses for fuel and oil and lubricants and does not clearly show the %share of each. To complicate things further, the components of FOL (fuel consumption on the one hand and oil & lubricants on the other hand) have opposite correlations with maintenance cost. Fuel consumption is negatively correlated with maintenance (better maintenance means lower unit fuel consumption) while oil and lubricants consumption is positively correlated with maintenance (since maintenance uses oil and lubricants). Because of this ambiguity, it is difficult to develop a hypothesis since no data is available on the respective %shares of fuel and oil & lubricants. Assuming, however, that fuel has a larger share, it can be hypothesized that FOL will be negatively correlated with maintenance. However, a positive correlation with maintenance can be assumed if oil and lubricants have a bigger share.

The following graphs illustrate the hypothesized relationships.

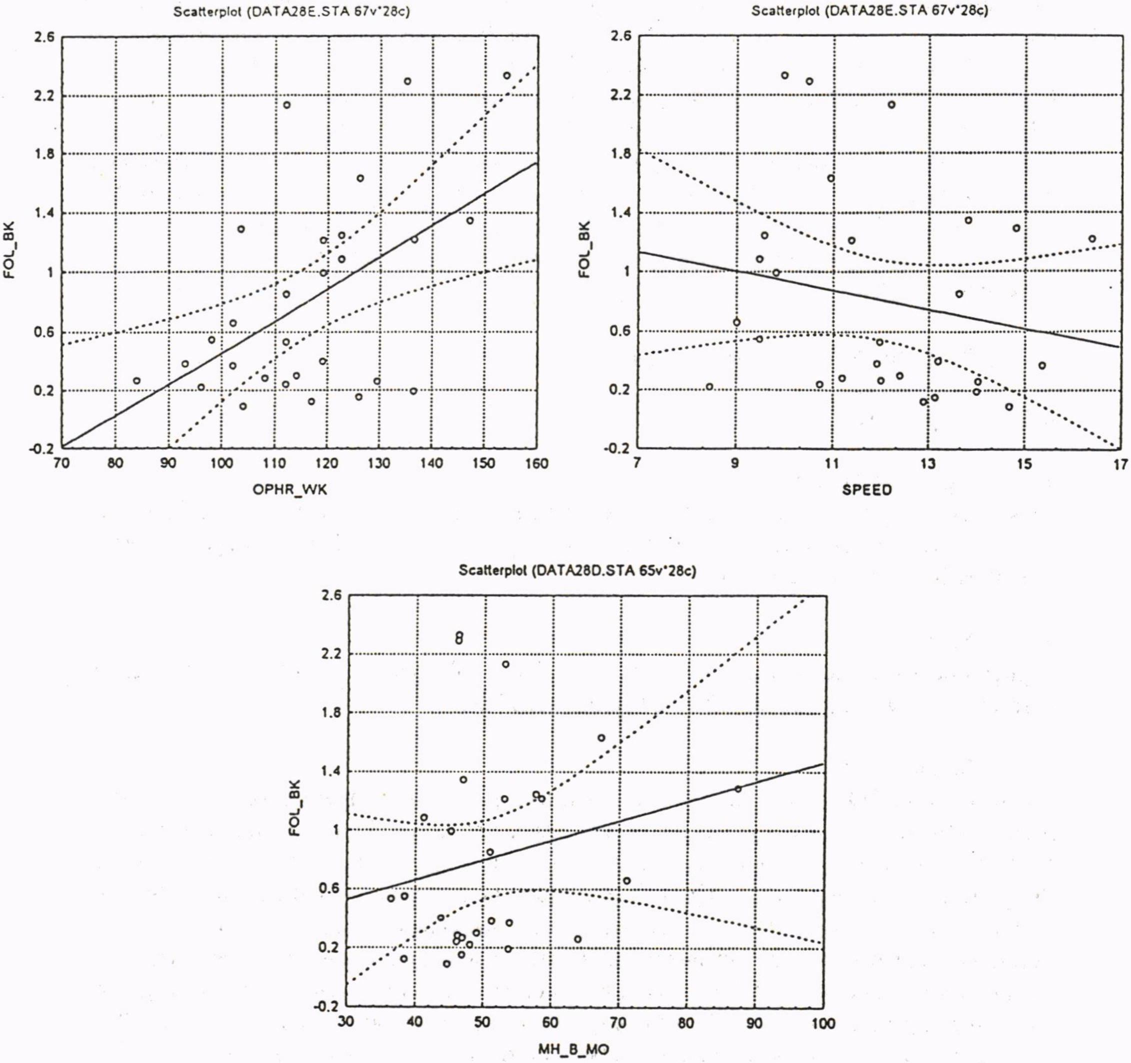

Figure 5 Fuel, Oil, & Lubricants per Bus-kilometer and some chosen parameters

4.5.2 Resulting Model

The obtained model is as follows:

$$FOL\_BK = \underset{(-1.62)}{-1.60} + \underset{(3.68)}{0.02\ OPHR\_WK} - \underset{(-2.16)}{0.11\ SPEED} + \underset{(1.96)}{0.02\ MH\_B\_MO} \quad \text{(Eq. 3)}$$

R^2 = 0.43

As hypothesized, operating hours and speed are shown to have positive and negative correlation with FOL, respectively. This is seen in Figure 5. Their coefficients are also significant at 95% level of confidence. The coefficient of maintenance (maintenance hour per bus per month) is positive indicating that higher maintenance means higher FOL. This implies that oil and lubricants have higher %share in total FOL than fuel. This should be viewed with some skepticism, however, since fuel is generally consumed much faster than oil and lubricants. The t-value of this parameter is significant at 95% but since the expected behavior is quite uncertain, then stricter criteria should be used. At 99%, this parameter is rendered insignificant.

The coefficient of multiple correlation is disappointingly low at 0.43. This may be explained by the inherent ambiguity in the definition of FOL which is considered a data constraint.

4.6 Repair and Maintenance per Bus-kilometer

4.6.1 Hypotheses

1. Operating Hours

It is hypothesized here that as operating hours increase, so does repair and maintenance cost per bus-kilometer. The basic rationale for this is the wear and tear of vehicles over time. As vehicles get utilized more, the required repair and maintenance works correspondingly increase.

2. % Route in EDSA

As described earlier, EDSA is highly congested and because of low speeds prevailing in this corridor, the required repair and maintenance works tend to increase. It is hypothesized here that as % route in EDSA increases, so does repair and maintenance cost.

3. Maintenance

At the risk of being trivial, this factor has a clear positive correlation with repair and maintenance cost. In the model, this is expressed as number of maintenance men per bus which is a measure of maintenance efficiency of the operator.

Figure 6 shows these hypothesized relationships. The graphs show positive correlation between repair and maintenance cost and number of operating hours per week, % route length in EDSA, and number of maintenance men per bus.

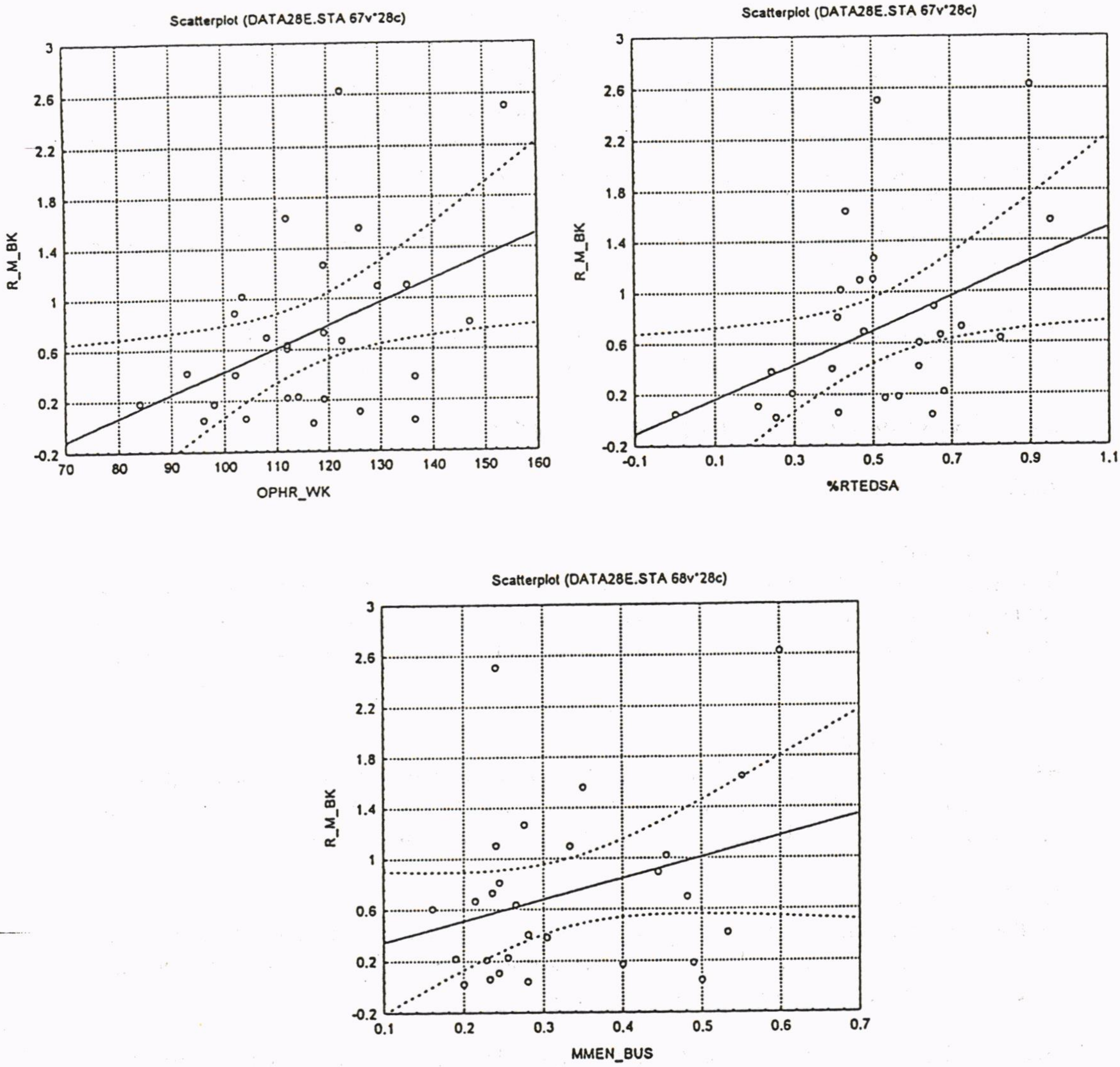

Figure 6 Repair & Maintenance Cost per bus-kilometer and some chosen parameters

4.6.2 Resulting Model

The following is the best model that shows the relationship between repair and maintenance cost per bus-kilometer and the chosen parameters:

$$R\_M\_BK = \underset{(-5.11)}{-4.42} + \underset{(4.92)}{0.03\ OPHR\_WK} + \underset{(2.85)}{1.16\ \%RTEDSA} + \underset{(4.31)}{3.34\ MMEN\_BUS} \quad \text{(Eq. 4)}$$

R^2 = 0.63

The t-values show that all coefficients are significant at 95% level of confidence. All signs behave as hypothesized with MMEN_BUS (number of maintenance men per bus) having the highest explanatory power on the dependent variable. The parameters have been checked for multicollinearity and each shows a high tolerance to be included in the model. The over-all F-value of the equation is 13.40 which is considerably higher than $F(3,24)_{95\%}$ equal to 3.01. Taken together, the parameters can explain 63% of the variation in the dependent variable.

4.7 Comments about the Developed Models

By performing multiple linear regression analysis, the models listed above have been chosen after considering numerous other models. The other models have been rejected for any of the following reasons:

- illogical or unexpected signs of regression coefficients
- insignificant regression coefficients
- extremely low R^2 values

The models presented here are the best that were developed using the currently available data and variables. However, the values of the coefficient of determination (R^2) are not as high as desired, but this may be due to any of the following:

1. Heterogeneity of samples

As mentioned earlier, the composition of bus operators in Metro Manila is that of few big and many small operators. The 28 samples used in the analysis represent a cross-section of this composition. The operators display widely varying levels of performance and efficiency. In other words, the samples are not homogeneous and to be able to explain the variation in their performance and efficiency, it is likely that other new variables should be explored and other models developed incorporating these new variables. Moreover, segmentation of samples should be tried so that homogeneous subsets of samples can be analysed and appropriate models be developed for these subgroups. Just the same, new variables may be necessary as basis for stratification of samples.

2. Data limitations

The database used in the study is limited in two respects: sample size and definitional ambiguity. There are only 28 samples included in the analysis. The number of samples was restricted by the availability of financial information from operators during the survey. (51 operators were interviewed with 28 providing financial information.) With more samples, better model results may be expected.

For definitional ambiguity, some financial items do not clearly delineate the costs of its components. An example is the cost of FOL (fuel, oil, and lubricants). The separate costs for fuel, oil, and lubricants are not available thereby making it necessary to take this cost in lump. It would have been more analytically appealing if detailed costs were available instead of aggregate figures.

3. Functional form

In the analysis performed in the study, only linear relationships were considered in search for good models. To some extent, non-linear transformations were done as in the use of logarithms (log and ln) but this did not really prove fruitful as the coefficients of determination improved only marginally, if at all. Between models with comparable R^2 values that are purely linear and those requiring transformation, it is preferable to choose the simpler models for reasons of parsimony. Nevertheless, other functional forms can be considered that can better explain the variation in the dependent variable. This can be part of future work that may be done in this study.

4.8 Analysis of Residuals

Analysis of model residuals was performed to see the performance and efficiency of operators relative to other operators. This is similar to performing peer-group comparison of operators to check which are performing better and worse than the norm. By comparing the actual performance with the expected performance (as indicated by the developed model), operators can be evaluated and areas of inefficiency may be identified.

Relative performance of operators may be measured from two benchmarks: *average performance* and *expected performance*. By using average performance, an operator can be compared with the others by examining its deviation from the mean performance of all operators included in the analysis. A better than average performance is obviously desired. However, such comparison does not incorporate the factors that influence the performance of operations. Using expected performance based on a chosen model does incorporate these factors and show the relative performance of operators. This will be illustrated below.

In the interest of brevity, only direct operating cost per bus-kilometer will be analysed here. The same methodology can be applied to the component unit cost models (Driver & conductor commission per bus-km; FOL per bus-km; and Repair & maintenance per bus-km).

Figure 7 shows the graph of expected (or predicted) values of direct operating cost per bus-kilometer versus the observed (or actual) values of the 28 samples. The diagonal line (45 degrees, if horizontal and vertical scales are the same) means that the observed coincide with the expected values. The horizontal line represents the average direct operating cost per bus-kilometer for the 28 samples.

From the graph, four regions (henceforth called regions of efficiency) may be identified:

Region 1. Above average, above predicted
Region 2. Above average, below predicted
Region 3. Below average, above predicted
Region 4. Below average, below predicted

Since costs are being considered here, desirable performance means below average as well as below predicted unit costs. These unit costs are the measures of operator's efficiency.

Referring to the graph, the 28 samples are divided into the four regions as follows:

Region 1: 1, 2, 6, 9, 12,14, 19, 20, 21, 22
Region 2: 13, 24, 27
Region 3: 7, 8, 16, 17
Region 4: 3, 4, 5, 10, 11, 15, 18, 23, 25, 26, 28

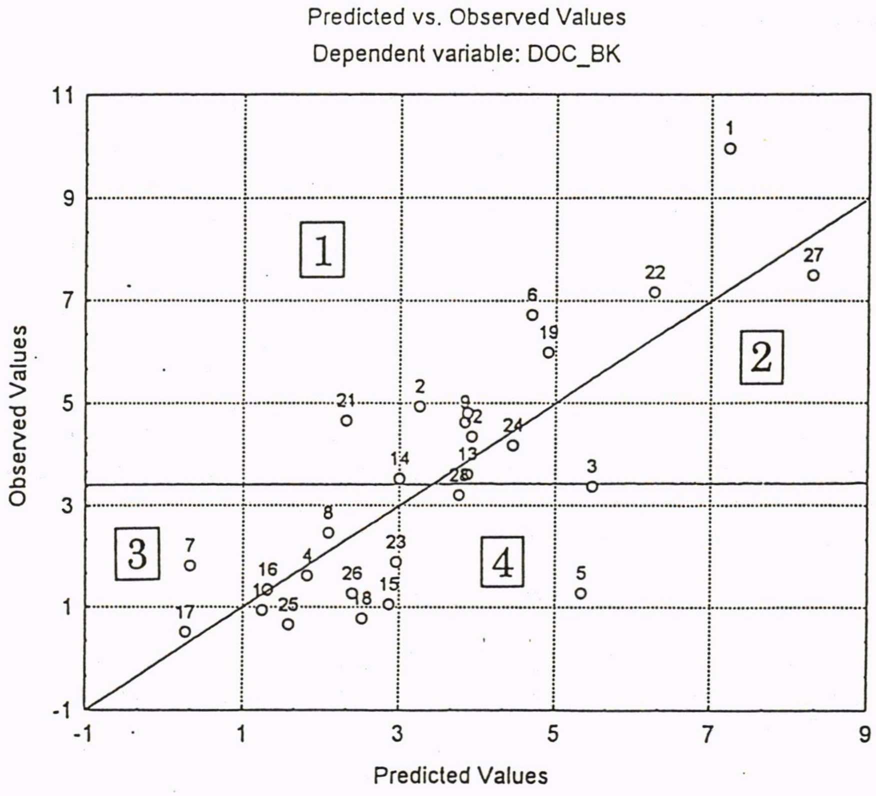

Figure 7 Regions of Efficiency of Operations, DOC per bus-km

Region 1 operators have unit direct operating costs above average value and above predicted value. These are the operators that clearly need remedial measures to improve performance. Region 2 operators have unit direct operating costs above average but below expected values. This means that they performed better than expected although there is still room for improvement. Region 3 operators have unit costs below average and higher than expected. They performed better than the average operator but not as good as expected. Region 4 operators have unit costs below average as well as below expected. These are the best performing or the most efficient operators among the 28 samples.

The above discussion shows the comparative performance of operators. By looking at its results, an operator may know how he is performing as compared to his peers. The analysis indicates an operator's relative efficiency.

Applying the same methodology to the unit cost component models (driver & conductor commission, FOL, and repair & maintenance per bus-km), the efficiency of operators may be compared and operators may be diagnozed as to whether they are performing well or performing poorly in that particular aspect of operation. In other words, the specific area of efficiency or inefficiency (whether in driver & conductor commission; in FOL; or in repair & maintenance) can be identified and necessary remedial actions be taken.

5. CONCLUSION

The performance of bus transit is influenced by factors internal as well as external to the system. Internal factors refer to the characteristics of operators such as scale of operations, management type, and characteristics of hardware or facilities. External factors refer to the characteristics of the environment in which the system is operating such as road conditions, characteristics of the market being served, and institutional setting of the system. In this study, scale of operations, characteristics of hardware or facilities, average speed, and percentage of route length in EDSA were analyzed and relationships among them were established. The unit cost models developed by regression analysis showed the relationships of these factors with the unit costs. Being unit costs, the developed models also serve as measures of efficiency.

A methodology was demonstrated showing the relative efficiency of operators. This uses average observed unit cost and expected unit cost as bases for comparison. Best, worst, and middle performing operators were identified. This methodology can be extended to the more detailed unit cost models to diagnoze specific areas of efficiency or inefficiency.

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