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EVALUATION OF BUS ROUTES PERFORMANCE IN THE CITY OF ADDIS ABABA USING STOCHASTIC FRONTIER MODEL *

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1. Introduction

Cost efficiency of bus routes is an important performance measure for bus service providers. Route efficiency can be regarded as a production process in which a variety of individual route inputs are used to determine its output. From the viewpoint of the bus companies, the way in which resources are used to transform routes into efficient ones is indispensable. This study has an objective of assessing the characteristics of individual route and analyzing the input factors influencing the cost efficiency of bus routes using Stochastic Frontier Model (SFM). Since the output in this study is regarded as revenue generated per route, the analysis is limited on the *cost efficiency*. Thus, based on the result, strategic recommendations would be drawn to improve the bus route performance. Bus routes provided by a solitary bus company in the city of Addis Ababa (the capital of Ethiopia), are taken as a case study.

Bus transportation is an important element of day-to-day activities in Addis Ababa city because it is a relatively affordable means of transportation. Even though the role of bus transportation is noteworthy, the service provision is not good enough as the demand is much greater than the supply. Buses provide 40% of the public transport. In the city of Addis Ababa, there is only one Bus Company called Anbessa City Bus Enterprise, which runs 93 routes. The company is not financially sustainable so that it would not be able to expand its service to match anticipated increases in urban mobility (World Bank, SSATP working paper No. 70, 2002)[1].

Among many factors affecting the overall bus transportation performance, bus route design in such a way that it generates revenue is important. The attributes related with the individual bus route affects the economic productivity of the bus company. According to TCRP synthesis of transit practice 10, 1995[2], economic and productivity standards of bus routes depend on some criteria such as passengers per hour, cost per passenger, passengers per km, passenger per trip, revenue per passenger per route etc.

Bus service input resources affect the quality of services and the quality of services in turn affects its cost efficiency. However, in Addis Ababa city, even if there is high passenger demand, the cost efficiency is low because of the fact that there is low fare set by the government, high maintenance cost etc. The problem on the ground is that the existing bus service is experiencing deficit every year despite the yearly increase in bus passenger. Therefore, investigating the input resources would help to identify factors affecting the cost efficiency and indicate measures to increase bus route performance.

In this study, Stochastic Frontier Model (SFM) is proposed to analyze the input-output relationships of the existing bus service. SFM assumes that there is a parametric function between the inputs and outputs (K. Cullinane et al, 2006)[3]. To apply the logarithmic frontier model, dependent variables (outputs) are taken as the revenue and/or the number of passengers per kilometer, and other bus route attributes are considered as independent variables. The cost efficiency of each route is calculated and based on the result, improvement measures are recommended.

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* Keywords: Stochastic Frontier Model, bus routes performance, input factors, output, Addis Ababa city, policy
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2. Overview of bus transport in Addis Ababa city

In Addis Ababa, there are only two options of public transportation; city bus and taxi. Taxis, own privately, are of two kinds; small para transit taxis with 4 seats and mini-van taxis with 11 seats. Taxis have flexible routes whereas buses run on fixed routes and stops. There is only one public bus company in the city called Anbessa City Bus Enterprise. It operates a fleet size of 524 conventional buses, with an average vehicle age of 6 years. It provides scheduled services along 93 routes as well as non-stop rapid (express) services. Although there is a system of flat fares, there is a range varying according to distance. The fare levels are low and have not been revised for many years. Anbessa City Bus Enterprise suffers loss and is subsidized by the city government. The bus system has about 1400 bus stops, 16 checkpoints and 3 main bus terminals. Buses are of high loading capacity (30 seats, with design capacity of up to 100 passengers). The company is mandated to provide public transport services to the city and the surrounding inhabitants. The company predominantly offers single-trip tickets as well as 10-trip student discount tickets. The single tickets are pre-printed with serial-numbered in the value of the applicable fares for each of the lines. Two colours of ticket are used, for the outbound and return trips, so as to assist with revenue protection and prevent immediate re-use of a ticket. The conductor completes a waybill for each trip, enabling the allocation of the relevant passenger numbers. A static conductor, positioned immediately ahead of the rear entry door onto the bus, sells the tickets. At busy times, and especially at the terminals, ticket sales transactions are carried out through the window of the bus and the passenger is only allowed to board once in possession of a valid ticket. This procedure is considered to enhance revenue integrity, but does result in extended dwell times at stops and hence contributes to the slow operating speed (IBIS Transport Consultants Ltd, 2005)[4]

The absence of an up-to-date structure in the enterprise, shortage of finance, and the reduction of subsidy from government are the biggest challenge for service improvement. Lack of well-defined performance parameters to evaluate the operational efficiency of the bus company is also a constraint for development. The spatial analysis on the bus network coverage shows that only the centre of the city, where commercial activities are abundant, shows high bus network availability. Areas with low or no bus network availability are in localities where the city is exhibiting trends of urban expansion, and residential developments are underway (Mintesnot G. and S. Takano, 2006)[5]. According to the recent structural synthesis map, prepared by the Addis Ababa Master Plan Revision Office, city expansion developments are underway in low bus availability areas (ORAAMP, 2002)[6]. This phenomena call upon the policy for expansion of the existing bus service

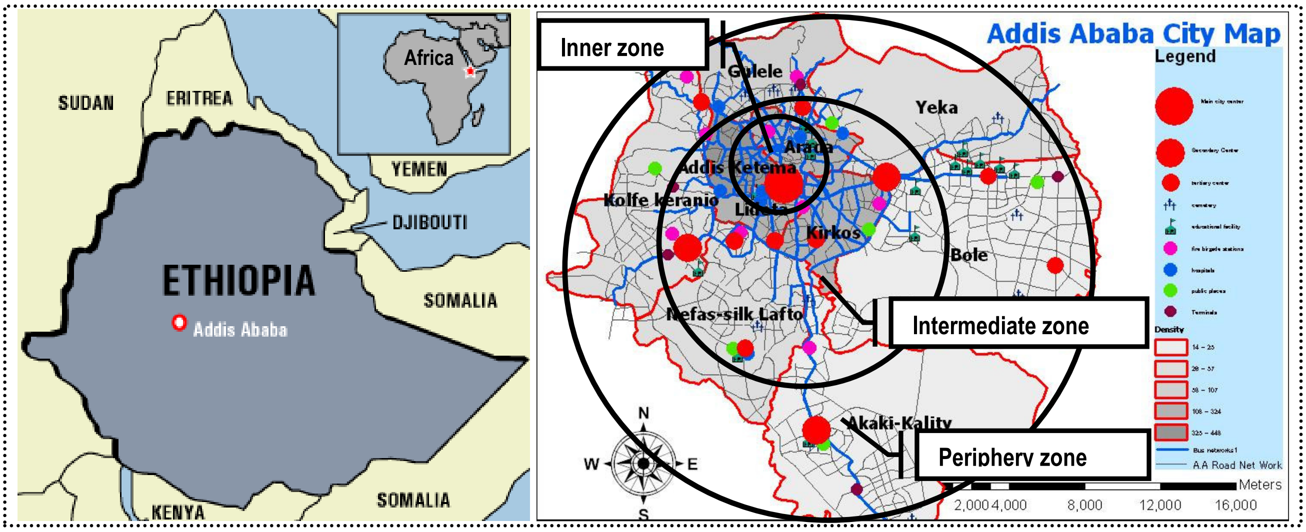


Figure 1: Addis Ababa City

3. Methodology: Stochastic Frontier Model (SFM)

The research approach implemented in this study involved analysis of bus company data, and modeling the bus route efficiency using stochastic frontier analysis to assess the functional performance of the bus routes. SFM and Data Envelopment Analysis (DEA) are the two most important alternative approaches in efficiency analysis, and have been extensively studied as methodologies in their own right and universally applied to a diverse range of industrial/organizational contexts. DEA can be roughly defined as a non parametric method of measuring the efficiency of Decision Making Unit, with multiple inputs and/or multiple outputs, where as SFM assumes that a parametric functions exist between production inputs and outputs (K. Cullinane et al. 2006)[3]. DEA has been criticized because it is deterministic and hence does not allow measurements of errors and random shocks. It is based on linear programming. On the other hand, SFM has been developed to allow measurements of errors and random shocks (stochastic factors) in addition to technical inefficiency. It is based on maximum likelihood estimate (Ondrich and Ruggiero, 2001)[7]. In this study SFM is chosen because it allows both technical (in)efficiency and statistical noise. The stochastic frontier regression model is a classical linear regression model with a non-normal, asymmetric disturbance. It has been used variously in studies of production and cost (W. Green, 2000)[8]. Stochastic Frontier Model (SFM) is introduced simultaneously by Aigner et al., 1977[9] and Meeusen and van den Broeck, 1977[10] and can be stated as a frontier production function as follows:

$$\log Y_i = \alpha + \sum \beta_i \log x_i + \varepsilon_i \qquad (1)$$

Where Y_i donates the production (output) for the *i*th producer (i = 1,2,…, N); x_i is a vector of appropriate functions of the input factors; α and β are estimated coefficients. ε_i is the error term made up of two independent components.

$$\varepsilon_i = v_i - u_i \qquad (2)$$

where $v_i \sim N(0, \sigma^2_v)$ is the error term representing the usual statistical noise found in any relationship, caused by random shocks outside the firm's control such as economic activities in the region, luck, weather etc., and $u_i \geq 0$ is the error term representing the *technical inefficiency*. Note that u_i measures the technical inefficiency in the sense that it measures the shortfall of output (Y_i) from its maximal possible value given by the stochastic frontier ($\alpha + \sum \beta_i \log X_i + v_i$) (J. Jondrow et.al. 1982)[11]. The inefficiency term u_i is the center of attention of this study. When the method of this form is estimated, one readily obtains residuals $\varepsilon_i = \alpha + \sum \beta_i \log X_i - \log Y_i$, which can be regarded as the estimate of the error term. $X_i\beta + v_i$ is the stochastic frontier while u_i is the measurement of deviation from the frontier of the *i*th firm. The random error, v_i can be positive or negative and so the stochastic frontier outputs vary from the deterministic part of the frontier model, $X_i\beta$. The condition, u_i is non negative, ensures that all observations lie on or below the production frontier.

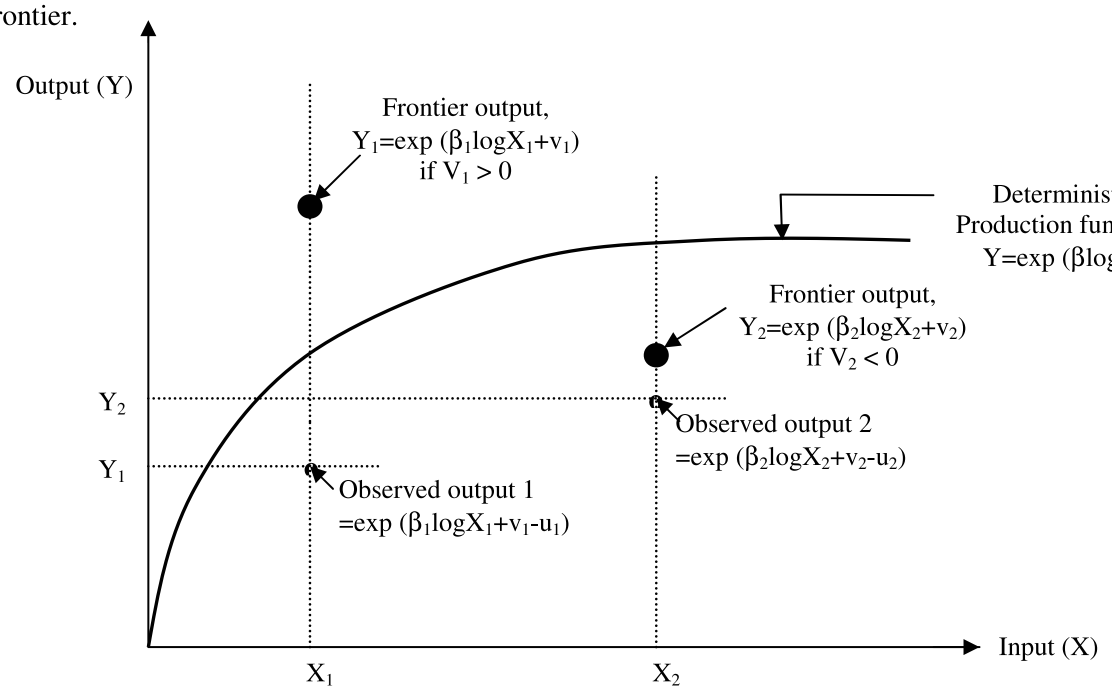


Figure 2: The stochastic frontier production function

The basic features of the stochastic frontier model are illustrated in two dimensions in fig. 2. The inputs are represented on the horizontal axis and the outputs are on the vertical axis. The deterministic component of the frontier model, Y= exp (βlogX) is drawn assuming that diminishing returns to scale apply. The observed outputs and inputs for two producers 1 and 2 are represented on the graph. Producer 1 uses the level of inputs x_1 to produce the output Y_i as it is indicated on observed input-output values. The value of the stochastic frontier output $Y_1= \exp (\beta_1 \log X_1+v_1)$, is marked with dark dot above the deterministic production function, because the random error v_1 is positive. However, in the case of producer 2, the frontier output $Y_2= \exp (\beta_2 \log X_2+v_2)$ is below the production function because the random error v_2 is negative. The stochastic frontier output Y_1 and Y_2 are not observed because the random errors v_1 and v_2 are not observable. The observed outputs may be greater than the deterministic part of the frontier, if the corresponding random errors are greater than the corresponding inefficiency effects (i.e. $Y_1=\exp (\beta \log X_1)$, if $v_1>u_1$) (Sanjay and Anand, 2002)[12]

The problem of decomposing the error term ε in to separate estimates of components v_i and u_i for each producer has remained unsolved for several years even though it was possible to calculate the average technical efficiency of *N* producers (G.E. Battese and T.J. Coelli, 1988)[13]. However, J. Jondrow et al. 1982[11] have derived a useful approximation that now the standard measure of technical efficiency for the different distribution models is possible, of which the half-normal and exponential distributions are commonly used. In this study, the half-normal stochastic frontier model is chosen for the analysis. There are no objective criteria for choosing between the half-normal and exponential specifications apart from the judgment of the individual researcher. Nevertheless, the half-normal is suggested by some literatures to be the most useful formulation (Battese and Coelli, 1988)[13]. The normal distribution is symmetrical, while half-normal distribution has no representation on the negative side of the number line. The half-normal distribution is a normal distribution with mean 0 and parameter θ limited to the domain x ε (0, ∞). The formulation of expected inefficiency value, $E[u_i]$, is given in equation 3. In the formula, λ and σ can be estimated and/or calculated with the relationship $\lambda = \sigma_u / \sigma_v$, $\sigma = (\sigma_u^2 + \sigma_v^2)^{1/2}$. ε is readily considered as a residual. σ_u and σ_v are the standard deviation of the technical inefficiency and random errors respectively. λ is the ratio of the standard deviations of the two error terms, that can be estimated with the model. ϕ (.) is a standard normal distribution and Φ(.) is its cumulative standard distribution.

$$E[u_i \mid \varepsilon_i] = \frac{\sigma\lambda}{1+\lambda^2}\left[\frac{\phi(Z)}{1-\Phi(Z)} - Z\right], \qquad Z = \frac{\varepsilon\lambda}{\sigma} \tag{3}$$

Once u_i is estimated, the technical efficiency can be calculated as;

$$TE_i = \exp(-E[u_i]) \tag{4}$$

Among the application of SFM to the transportation researches, Sanjay and Anand (2002)[12] made an attempt to quantify the technical efficiency (productive efficiency) of twenty three major Indian state transport undertakings mainly providing rural and inter-city passenger transport services for the year 2000-2001. This is done by the estimation of stochastic frontier production using the method of maximum likelihood. Anna and Raymond (1998)[14] implemented the stochastic frontier cost functions to analyze the degree of efficiency of urban bus companies and to quantify the reason for this efficiency. Farsi et al. (2006)[15] applied a number of stochastic cost frontier models to a panel of 94 regional bus companies over 12 years period to distinguish the ability of those models to estimate the inefficiency and the unobserved firm-specific heterogeneity in network industry. Gagnepain and Ivaldi (2005)[16] applied stochastic production and cost frontiers to measure inefficiencies in France transport system and European airline. Cullinane et al. (2005)[3] applied Data Envelopment Analysis and Stochastic Frontier Model to measure technical efficiency of the world's largest container ports and compared the results obtained.

4. Empirical analysis

(1) Data

The data implemented in this study is collected from the bus company, and the characteristics of each route are analyzed. The descriptive statistics of the input data is given in table 1. The dependent variable is taken to be the revenue collected per route for the year 2004. Revenue is a very good measure of route output as cost-efficiency of one producer is an important performance measure; therefore, the revenue-expense ratio can indicate the cost recovery situation of the company.

The independent variables are selected to be the number of buses allocated for the specific route, the distance covered by the route in the year, number of trips per route, government subsidy per route, the fare of the route (in the city of Addis Ababa the fixed price is implemented, with each route has different price, according to its distance), trip length, number of bus stops etc. Employed population and the population density at the origin bus station are also taken as independent variables. The entire dependent and independent variables are given in logarithm of the original value for application of the proposed model.

Table 1: Descriptive statistics of the dependent and independent variables

N=93 routes	**Mean**	**Std.Dev.**	**Min.**	**Max.**	**Measurement**
Passenger per km	237550	203757	11.44	979237	passenger/km
Revenue per km*	79082.1	52513.6	34.32	260330	revenue/km
Number of trips	22128.7	13765.1	24	68192	no. of trips
Subsidy	369074	265794	85.68	1253030	Ethiopian birr**
Fare	0.51	0.37	0.25	2.25	Ethiopian birr**
Route length	13.01	8.75	4.91	47.23	km
No. bus stops per km	1.57	0.40	0.53	2.80	no. of stops/km
Employee pop. at route origin	8794.35	8792.01	1038	23756	no. of population
Pop. density at route origin	418.17	182.56	7.64	700.35	no. of population
Waiting time	32.45	28.67	7	180	minute
Number of buses	3.75	1.77	1	10	no. of buses
Trip length in minute	46.11	14.90	23	99	minute
Linkage (no. of transfers)	11.81	4.93	3	24	no. of bus connections
Bus capacity	7244	5329.71	76	29766	no. of passengers
**The dependent variable*	***1USD=8.8Ethiopian birr=121JPY (Feb., 2007)*				

The route characteristics data for the year 2004 is used for route analysis as well as for the modeling. When the number of passengers served by individual routes per year is concerned, the majority (27 out of 93 routes) served between 2 million to 3 million passengers per year. Only three bus routes have 7 million and above passengers per year. 14 bus routes have passengers of less than 500,000 per year. The revenue generated by individual routes is also analyzed having in mind that it has high correlation with the number of passengers. 46 bus routes have a revenue of 500,000 to 1 million Ethiopian Birr [ETB] per year (1USD = 8.8ETB). Only 2 bus routes exhibit revenue of 2 million and above and 2 bus routes have the revenue of less that 10,000 ETB per year.

The above outputs have a direct relation with the number of buses allocated to individual routes, which ranges from one to ten. The majority (32 bus routes) have 4 buses allocated and only 2 bus routes are allocated with 10 buses. 3 routes are running with one bus, 21 with 2 buses and 19 with 3 buses. It can be said that there is still unbalanced supply of buses with the existing high demand of bus transportation. Each bus route has its own route length and travel time. The minimum route length is less than 5km (only 1 bus route) and the maximum one is greater than 40km (4 bus routes). The majority of the bus routes have a travel time of 30-40 minutes, even though there exists a travel time of more than one and half hours.

Concerning the bus frequency/waiting time of individual routes, the majority (34 bus routes) have the waiting time of 10-20 minutes. The minimum one is the waiting time of less than 10 minutes and there observed 70 minutes and above waiting time (5 routes). The waiting time is calculated as headway of consecutive buses arriving at the specific station. The linkage characteristics of the routes are also studied in this analysis. The numbers of bus routes that touch or cross the route in question are counted to view the connectedness, overlapping and transferability of the networks. 37 bus routes have 10 to 15 other routes connected to them (which are the majority). 4 bus routes have above 20 connections, 16 routes have 15-20 connections, 37 routes have 10 to 15 connections, 24 routes have 5 to 10, and 12 routes have less than 5 connections. The functional relationship of all the above bus route elements is modeled using stochastic frontier model in the following section.

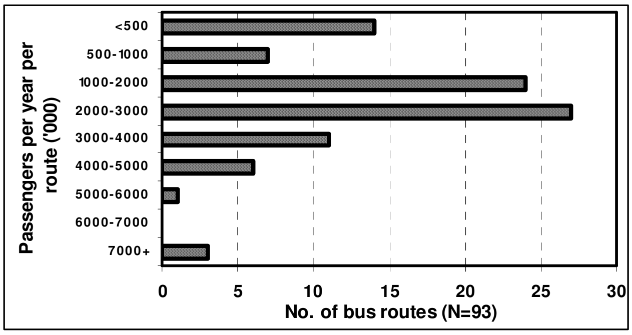


Figure 3: Number of passengers served per year per route

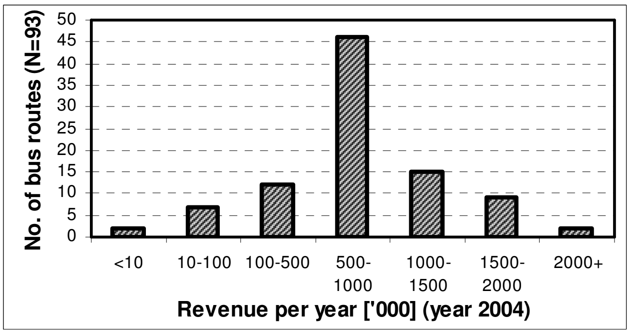


Figure 4: Revenue generated by individual routes

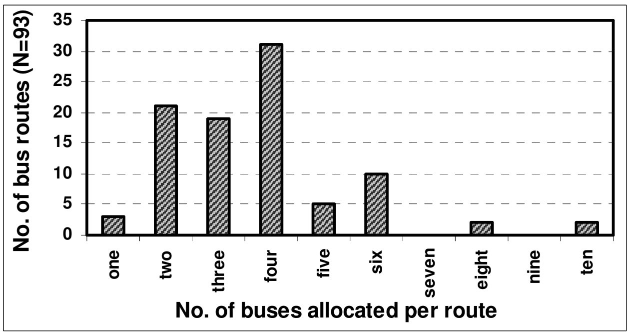


Figure 5: Number of buses allocated for individual routes

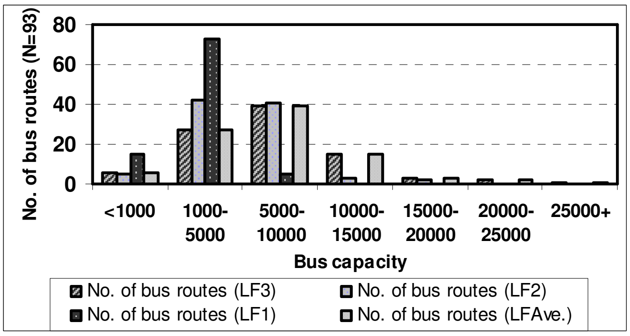


Figure 6: Capacity with different load factors (LFs)

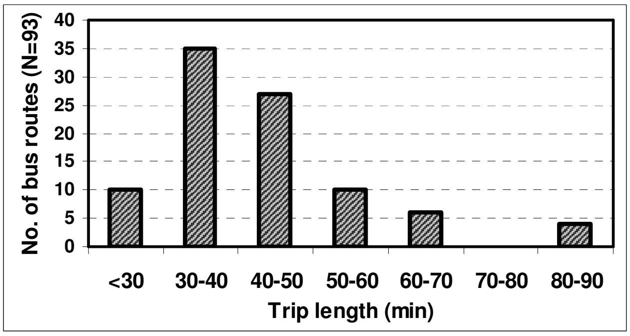


Figure 7: Trip length of bus routes

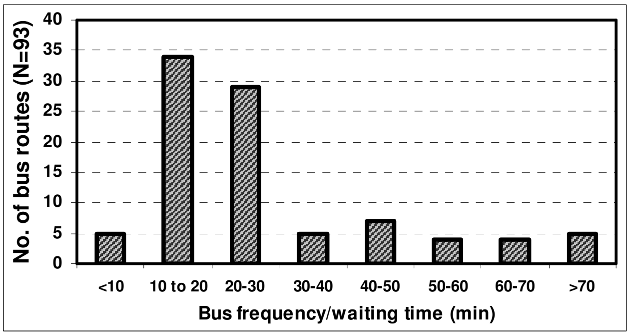


Figure 8: Bus frequency/waiting time of routes

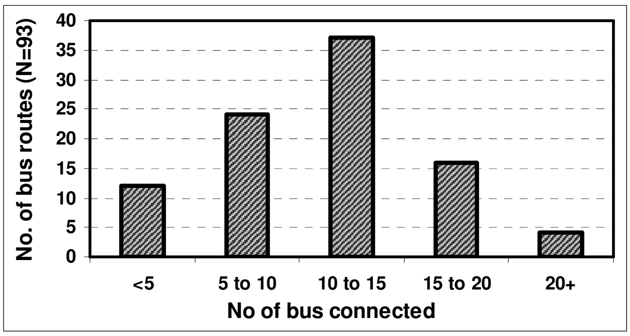


Figure 9: No. of buses linked with individual route

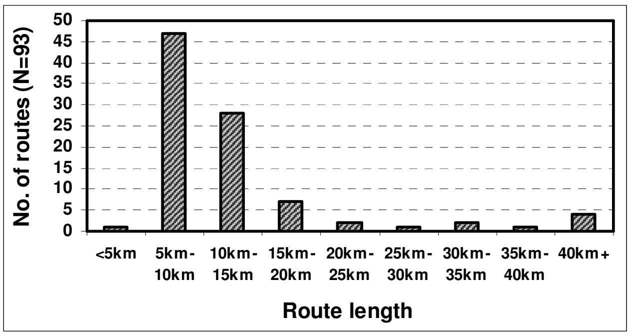


Figure 10: Route length in km.

(2) Bus route efficiency: modeling results

The maximum likelihood estimates of stochastic frontier model are made using LIMDEP 7.0, and the result is presented in table 2. Additionally the ordinary least square (OLS) is carried out and the coefficients provide a starting point for the maximum likelihood estimate process. The goodness to fit of the estimated regression equation is evaluated by R^2 of the least square method, which looks reasonably high at 0.89. This implies that the inputs to the model do satisfactorily explain the model output. The OLS can also be used for measuring the residual term ε, where as the inefficiency parameters can be calculated using the half-normal SFM results.

Rather than using the raw revenue data, the standardized revenue generated per kilometer (rev/km) is taken as dependent variable, and the logarithm of all variables is used for the analysis. According to the analysis result, an increase in the number of trips increases the revenue generated by the routes. Subsidy and fare have also a positive relationship with the route performance i.e., routes with high subsidy and fare has higher cost efficiency. One of the identified factors that reduce route performance is the number of bus stops per km. The higher the number of bus stops the route has, the lower the revenue generated. Employee population at the route origin also reduces route performance because of the very fact that employee population has a tendency of choosing mini-van shared taxis. Other factors that have negative influence on the route performance are waiting time and linkage. The higher the route is connected with others routes, the less the revenue it exhibits because of high market/passenger sharing among routes. This shows that the duplication or overlapping routes are the main factor for lower route efficiency.

Table 2: Stochastic frontier estimations

Dependent variable: Revenue per km	**Least squares**		**Half-normal SFM**	
Independent Variables	**β**	**t-ratio**	**β**	**t-ratio**
Constant	0.314	1.482	0.437	1.833
Number of trips	0.363	3.027	0.332	2.112
Subsidy	0.645	6.055	0.673	4.642
Fare	0.243	5.479	0.258	4.979
Route length in km	0.243	3.101	0.253	2.789
Number bus stops per km	-0.019	-1.802	-0.002	-1.701
Employee population at route origin	-0.015	-1.328	-0.015	-1.208
Population density at route origin	0.016	1.804	0.014	1.886
Waiting time	-0.057	-0.768	-0.055	-0.695
Number of buses	0.028	0.321	0.044	0.483
Trip length in minute	0.174	1.534	0.145	1.088
Linkage (no. of transfers)	-0.082	-3.093	-0.081	-2.862
Bus capacity	0.093	1.839	0.108	1.793
λ	-	-	0.669	1.122
σ	-	-	0.053	4.222
σ_u	-	-	0.045	-
σ_v	-	-	0.034	-
R^2, (Log likelihood)	**0.89**, (159.837)		- , (160.303)	

Apart from the input-output relationship found in the estimated model, the cost efficiency of each bus route is calculated, based on the coefficients of maximum likelihood estimates using equation (3) & (4), as given in figure 11 & 16. According to the first and the third quartile of efficiency distributions, the overall bus route efficiency is concentrated between 0.5 (50%) and 0.8 (80%). The efficiency score of 90% and above is observed, likewise, there are a number of bus routes with lower efficiency scores (10% to 50%).

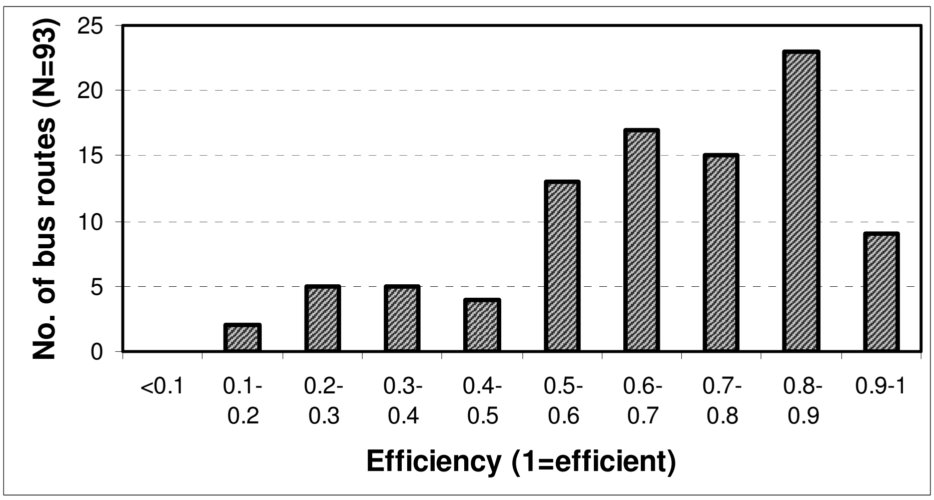
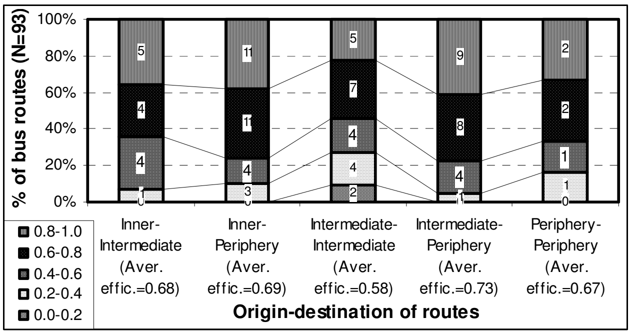


Figure 11: Efficiency estimates of bus routes

The validity of efficiency estimates is carried out by choosing some bus route parameters such as:

(a) Origin-destination of the routes,
(b) Number of buses allocated per route,
(c) Route length (km.), and
(d) Waiting time/headway (minutes) of each route.

When the origin of the route and its destination is concerned, bus routes which originate at the inner part of the city (Central Business Districts (CBDs)), and destined in the periphery areas (suburb areas with urban expansion) have higher efficiency. This is because there are high trips generated from residential areas and attracted to the business and employment centers. The bus routes originate at the intermediate zone (located in between the CBD and periphery areas) and destined in the periphery have also reasonably high route efficiency, where as within-zone routes show low route-efficiency (figure 12).



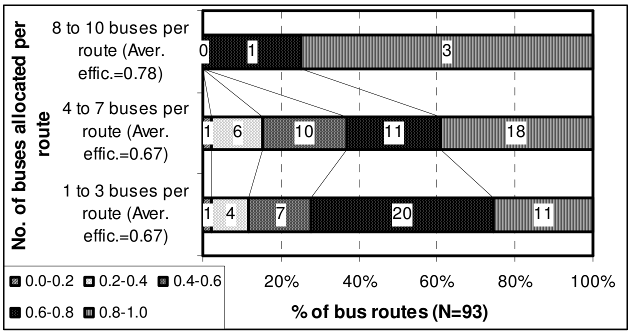
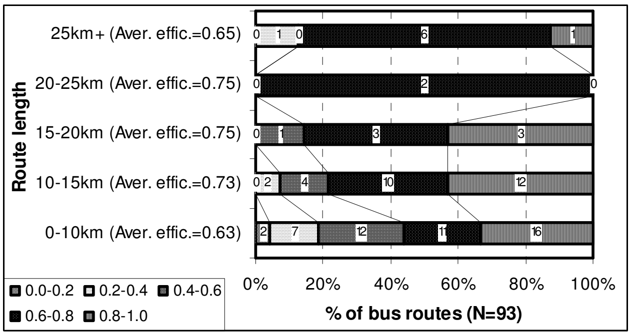


Figure 12: Efficiency vis-à-vis origin and destination (**a**) Figure 13: Efficiency vis-à-vis no. of buses per route (**b**)



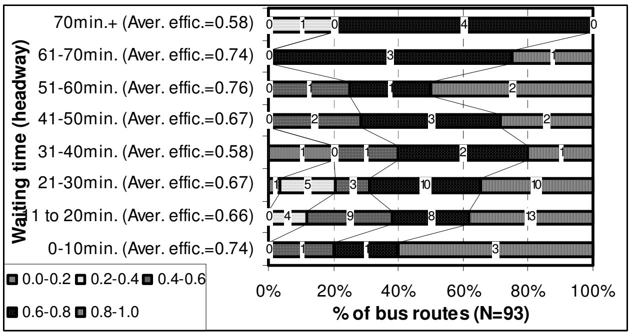


Figure 14: Efficiency vis-à-vis route length (**c**) Figure 15: Efficiency vis-à-vis headway of the route (**d**)

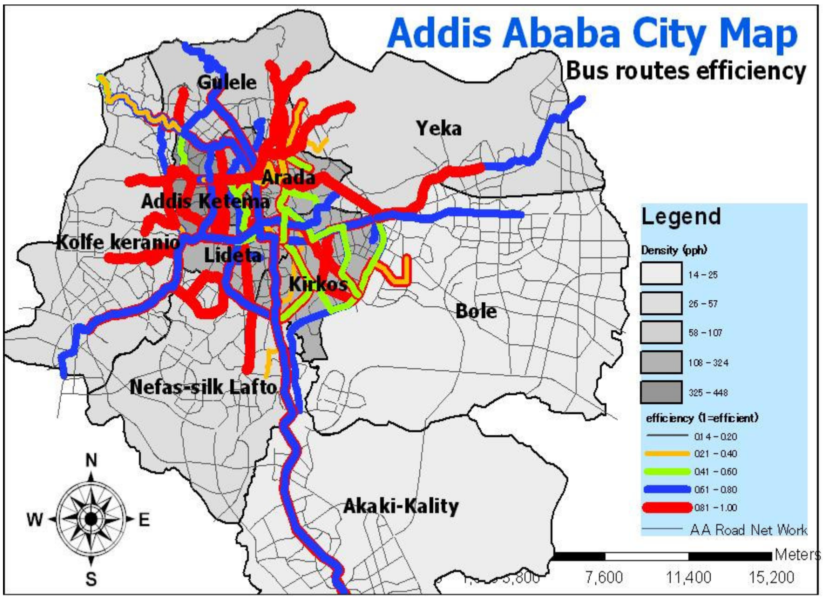


Figure 16: Efficiency scores and geographical locations of bus routes

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When the numbers of buses allocated for individual route are concerned, routes with number of buses from 4 to 7 exhibits high efficiency (figure 13). In contrast, routes with less number of buses have relatively low efficiency. This shows that, bus allocation and dispatching should match with the demand on the route. The result on origin and destination as well as the number of buses allocated per route can give a combined effect on route efficiency. Therefore, bus allocation and scheduling should take areas requiring large number of buses in to consideration. The other route feature is route length, with the longer the distance to certain kilometer, the higher the efficiency of the route (figure 14). According to the law of diminishing returns, inputs beyond some point yield less output. However, spatial coverage is an important consideration of route design so that longer distance routes are important in order the bus system to serve the periphery area residents. When waiting time is concerned, bus routes with the waiting time of up to 30 minutes experience reasonably high efficiency, while the longer waiting time fosters inefficiency in the system (figure 15).

Other route characteristics such as number of trips per route, trip length in minutes, fare, number of bus stops per kilometer, connection of the route with other routes, etc. can be added to explain better the validity of the model. The route connection, for example, can explain the relationship between the efficiency of the route and the geographical layout and the networking system of the route. The more the individual route shares the bus stops with other routes, the lower the efficiency it exhibits. This can be improved by revising the network in such a way that route overlapping is reduced based on the demand and urban function of the locality.

There are routes exhibiting high efficiency because of well input conditions (bus allocation, fare setting, geographical location etc.), where as there are routes with a very low efficiency (revenue generation and passenger served). The reason for this efficiency discrepancy is highly correlated with the resource allocation (internal factors) and some external factors such as congestion on the road corridor, land use change etc. To upgrade the inefficient routes to the efficient system, a balanced supply with the demand should be provided. However, there must be a precaution to create a balance between profit making and social welfare. The comprehensive policy recommendations are given in the following section.

5. Policy recommendations

There are four policy and strategic interventions indicated in this study, based on the analytical results and general observations:

(1) Service coverage

The results on the population density and the employed population show that there are potential areas the bus service should be diversified. According to the study on transit availability indices, it is clearly seen that the areas with low or no bus transit availability are in localities where the city is exhibiting trends of urban expansion, and residential developments are underway[5]. According to the recent structural synthesis map prepared by the Addis Ababa Master Plan Revision Office, those areas are identified for city expansion development. Therefore, it is recommended that the bus company make use of the opportunity of this attractive area of investment for its service expansion. The SFM results strengthen this recommendation because there are high efficiency scores for routes destined to the newly expansion areas.

(2) Subsidy

The Addis Ababa city bus service is believed to be provided for the urban poor. Government has its own economic as well as political interest on it. Therefore, subsidizing the existing bus service will help the company to secure its financial capability. Currently, the government is decreasing the subsidy because of that the bus fare is increasing and the burden is imposing upon the urban poor. As a strategic measure, the government may issue a policy to *subsidies the productive rout*es. This will stimulate to company to improve route productivity

(3) Bus and drivers scheduling

The number of buses and the existing demand are not compatible. The analysis result indicated that adding number of buses on the route increases efficiency, whereas, if there is route redundancy/duplication, the efficiency of the route decreases (refer table 2, variables 'linkage' and 'number of buses') Adding the number of buses and allocating to the under served areas is important. An efficient public transport is characterized by the optimal allocation of available resources. Bus scheduling and dispatching system should be prepared carefully so that a number of buses in one route will not affect the efficiency of the overall system.

(4) Bus pricing

The modeling result shows that the increase in bus fare increase cost efficiency. The result can be re-enforced by the existing inflexible demand elasticity. Currently the fixed and flat fare is implemented in the network system, even though different routes have different fares. Implementing the fares differentiated by distance and time-of-day could improve the company's financial position. Since the government subsidy is decreasing year by year, the company has to look for cost recovery mechanism. The fare differentiated by distance and peak-hour high fare can be applicable. However, political acceptability is an issue as the city bus is an interest of the government as a public service for the urban poor.

(5) General suggestions

As a general suggestion, in order to improve the existing bus service and rise up the cost efficiency of routes, the first and the most important effort is creating a competitive transit industry in the city by encouraging the participation of private bus companies. Currently, there is one bus company under the administration of the city council that there is no competitive market. Some reports from the bus company revealed that, the company is ready to compete in the market, if there are interested sectors to participate in the transit industry. In addition to this, the existing bus company has to make strategic efforts to improve quality of service and cost recovery systems.

6. Conclusion

The objective of this research was to analyze factors affecting the bus route performance and to quantify the efficiencies of each bus routes. The half-normal stochastic frontier model was implemented, using the method of maximum likelihood. It gives a fine result in estimating the technical efficiencies of bus routes. The input conditions that affect the efficiency of each route are diagnosed. The mean efficiency of the bus routes was found out to be 67.14%. The Stochastic Frontier Model (SFM), implemented in this study, is not only give the calculation of in(efficienciy) scores, but also the variables that affect the efficiency of bus routes. The identification of these variables would assist the policy recommendations to improve the existing bus service. The ability of the Stochastic Frontier Method, to consider the computation of the random error, makes it the preferable efficiency analysis technique, compared with other efficiency analysis methodologies, which treat error as well as other statistical noise as inefficiency.

This research signifies the importance of measuring bus route inefficiencies as an input for service improvement endeavors considering the individual bus route as a firm attempting to get a better output by transforming inputs. The proposed Stochastic Frontier Method is proved to give a useful approximation of efficiency scores and interesting input-output relations. Further researches can be made, adding other unforeseen variables. The methodology can also be implemented for measuring the performance of the bus (or other transit) companies. Improvement mechanism of the bus transportation in particular, and the overall transit in general are also potential future research areas.

Reference

1) The World Bank African Region Scoping Study, Urban Mobility in Three Cities, Addis Ababa, Dar es Salam, Nairobi, SSATP Working Paper No. 70, 2002.
2) Howard P. Benn. Bus Route Evaluation Standards, TCRP, Synthesis of Transit Practice 10, Transport Research Board, National Academy Press, Washington DC, 1995
3) Kevin Cullinane, Teng-Fei Wang, Dong-wook Song, Ping Ji. The Technical Efficiency of Container Ports: Comparing Data Envelopment Analysis and Stochastic Frontier Analysis, Transportation research part A, 40, pp. 354-374, 2006

4) Public Private Infrastructure Advisory Facility IBIS Transport Consultants Ltd,. Study of Urban Public Transport Conditions in Addis Ababa, Ethiopia, March 2006
5) Mintesnot G. and S. Takano. Application of Logical Planning Model for Public Transport Improvement Programs in the City of Addis Ababa, JSRSAI, Studies in Regional Science Vol. 36-3, pp. 663-682, 2006
6) Office of the Revision of Addis Ababa Master Plan (ORAAMP). Project Proposal for Addis Ababa Transport Sector, Addis Ababa, Ethiopia, 2002.
7) Jan Ondrich and John Ruggiero. Theory and Methodology, Efficiency Measurement in the Stochastic Frontier Model, European Journal of Operational Research, 129, pp. 434-442, 2001
8) William H. Green. Econometric Analysis-4ed, Prentice-Hall, inc., New Jersey, 2000
9) Aingner D.J., C.A.K. Lovell and P. Schmidt. Formulation and Estimation of Stochastic Frontier Production Function Models, Journal of Econometrics, 6, pp. 21-37, 1977
10) Meeusen W. and van den Broeck. Efficiency Estimation from Cobb-Douglas Production Function with Composed Error, International Economic Review 18, 435-444, 1977
11) J. Jondrow, C.A.K. Lovell, I.S. Materov and P. Schmidt. On the Estimation of Technical Inefficiency in the Stochastic Frontier Production Function Model, Journal of econometrics, 19, pp. 233-238, 1982
12) Sanjay K. Singh and Anand Venkatesh. Comparing Efficiency across State Transport Undertakings: a Production Frontier Approach , Indian Journal of Transport Management 27(3): 374-391
13) George E. Battese and Tim J.Coelli. Prediction of Firm-Level Technical efficiencies with a Generalized Frontier Production Function and Panel Data, Journal of Econometrics, 38, pp. 387-399, 1988
14) A. Matas and Jose-Luis Raymond. Technical Characteristics and Efficiency of Urban Bus Companies: the case of Spain, Transportation, 25, pp. 243-263, 1998
15) M. Farsi, M. Filippini and M. Kuenzle. Cost Efficiency in Regional Bus Companies: an Application of Alternative Stochastic Frontier Models, Journal of Transport Economics and Policy, 40 (1), January 2006
16) P. Gagnepain and M. Ivaldi. Measuring Inefficiencies in Transport Systems: between Technology and Incentives, IDEI working Paper No. 377, September 2005

EVALUATION OF BUS ROUTES PERFORMANCE IN THE CITY OF ADDIS ABABA USING STOCHASTIC FRONTIER MODEL

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Abstract:
The efficiency of bus routes is an important performance measure for bus service providers. From the viewpoint of the bus companies, the way in which resources are used to transform routes into an efficient route is essential. This study has an objective of analyzing the input factors influencing the cost efficiency of bus routes using stochastic frontier regression. The half-normal stochastic frontier model is implemented and it gives an excellent result in estimating the technical efficiencies and variables that affect the efficiency of bus routes. Based on the results, service improvement recommendations are provided in this study.

ストキャスティック・フロンティア・モデル (SFM) を用いたアジスアベバのバスルート効率性評価

ミンテスノット　ゲベィエフ　・高野伸栄

アブストラクト
各々のバスルートの効率性はバス事業社にとって極めて重要な指標である．バス事業者から見たとき，バスルートがバス事業者が所有する資源をより有効に活用し，設定されていることが必要不可欠である．本研究はバスルートに係わる諸要因がバスルートの効率性にどのような影響を及ぼしているかをＳＦＭ(ストキャスティック・フロンティア・モデル) を用いて，分析を行うものである．分析結果により，本手法がバスルートの効率に影響を与える種々の状況に係わる分析を行う上で有効なものであることが明らかとなった．
