FARE LEVEL AND FLEET OPTIMIZATION OF TAXI AND BUS OPERATION IN YOGYAKARTA, INDONESIA

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abstract: This paper presents a fare level and fleet optimization of public transport modes, bus and taxi in Yogyakarta, Indonesia by using microeconomic theory. The concept of social surplus maximization is applied in the analysis. The results indicate that the present fare level for taxi is very close to optimum. However, present taxi market is already over supplied and Government policy to add 175 more taxies in the near future is not justified. Similarly, present bus fare level is close to optimum. Based on present fare level, present bus fleet is not enough. Additional 52 units of standard buses have to be added in the present fleet to make it optimum.

1. INTRODUCTION

Yogyakarta is a medium size city located in central Java having population of about half a million. The motorized public transport is served by city bus and taxi. There are two types of buses: standard bus of capacity 24 to 27 passengers and small bus of capacity 12 to 14 passengers. Under rejuvenation policy of the Government, all the small buses are being replaced by standard buses to improve the operational efficiency. The unique characteristics of the bus system in the city is that almost every single vehicle is operated by drivers as independent contractors. They lease the buses from the bus company and pay on daily basis. The revenue over the cost of operation is their income. However, the total number of fleet and fare levels for bus and taxi are regulated by Governor's Decree. This is not the case of competitive market which might be, in certain level of competition, beneficial to the society. Compared to the developed countries, owning a private vehicle is quite expensive in Indonesia and public transport service is cheaper alternative. However, the private bus companies do not get subsidies from the Government at present. Thus the city has its uniqueness in terms of public transport operation.

In this study, an economic analysis is conducted with the objectives of optimizing the fleets and fare levels for both bus and taxi operations, thereby, the results are compared with the existing situation.

Taxi operation in many cities is controlled in terms of fare and entry. Morlok (1984) concluded from his study that a privately owned public transport service can be operated at one third to two-third the cost experienced by typically publicly owned public transport service. Teal and Nemer (1983) discussed the effect of deregulation in taxi market where the prices in taxi market increased substantially resulting into decrease in demand, thereby, productivity and profitability. Savage (1991) stated that free competition between bus companies 'on road' is not desirable as it will cause problems by serving demand and supply linkages and increasing the chance of unacceptable driving and maintenance standards. Schwieterman and Schofer (1984) presented a comparison between the cost of privately owned public bus service and the publicly owned rail service. Their study in Chicago revealed that the cost was as low as half in case of private bus service. This study tries to find out if the regulated fare and fleet is optimum from the view point of social surplus maximization.

2. SOCIAL SURPLUS MAXIMIZATION

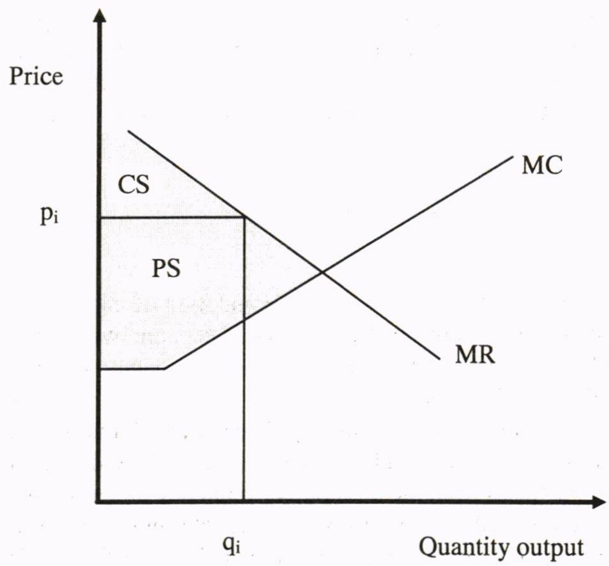

Figure 1 Social surplus indicated by shaded area

Each point on the demand curve reflects the highest single price that a consumer is willing to pay for the corresponding quantity of output. The consumer's surplus is given by the area under the demand curve less the amount consumer pays for the commodities (Henderson and Quantt, 1980). Producer's surplus is the excess of total revenues from sales of commodity over the total cost of producing the commodity. The social surplus is the sum of consumer's surplus and the producer's surplus. Referring to figure 1, the shaded area, sum of consumer's surplus, (CS), and producer's surplus (PS) gives the social surplus. Mathematically, social surplus can be expressed as

$$SS = \int p(q, h)\, \delta q - C(q, h) \tag{1}$$

where SS: social surplus.
p(q, h): inverse demand function.
C(q, h): total cost of production.
q: quantity output.

h: measure of service quality (head way in case of bus operation and occupancy rate in case of taxi operation).

It can be shown that maximization of social surplus is exactly equal to maximization of consumer's utility with reduction of income by the total cost with quasi-linear utility function (Varian,1992). Therefore, this study adopts the optimal condition as social surplus maximization.

The first order condition of social surplus maximization is achieved by setting the derivatives of social surplus with respect to quantity output and quality to zero. Mathematically,

$$\delta SS / \delta q = p (q, h) - \delta C (q, h) / \delta q = 0 \quad (2)$$

$$\delta SS / \delta h = \delta [\int p (q, h) \delta q] / \delta h - \delta C(q, h) / \delta h = 0 \quad (3)$$

Social surplus is maximized when price equals the marginal cost with respect to quantity and marginal value equals the marginal cost with respect to headway. i.e.

$$\delta [\int p (q, h) \delta q] / \delta h = \delta C(q, h) / \delta h \quad (4)$$

Let $\delta^2 SS / \delta q_2 = A$, $\delta^2 SS / \delta q\, dh = B$, $\delta^2 SS / \delta h_2 = C$, then the second order condition for social surplus maximization is described in the following form.

$A < 0$, $C < 0$ and $AC - B^2 > 0$ (Sydsaeter and Hammond, 1995). In order to obtain the social optimal solution, it is necessary to specify and estimate the demand and cost functions. Section 3 and 4 explain the specifications of demand and cost functions adopted after several trials.

3. SPECIFICATION OF DEMAND FUNCTIONS

As the demand function is the utility maxizing consumption level for a given level of price, p, and service level, h, its fucctional form should be consistent with the quasi-linear indirect utility fuction which justifies the social surplus maximization. Thus the taxi demand function is specified as

$$x_1 = a_1 / (p_1 - b_1 h_1 - c_1 h_1^2) \quad (5)$$

where x_1: occupied distance (km / taxi / day).

p_1: fare level (Rp. / km).

h_1: occupancy rate, ratio of occupied distance to total distance traveled (dimension less)

a_1, b_1, c_1: constants.

Thus the information required for taxi demand function estimation is total number of trips per taxi per day, length of each trip, total kilometers traveled per taxi per day, total occupied kilometer per taxi per day and flag drop and other additional charges.

Similarly, bus demand function is specified as

$$x_2 = a_2 / [p_2 - (b_2 / h_2) - c_2 / h_2^2)] \quad (6)$$

where x_2: passenger demand (passenger / route / day).

p_2: fare level (Rp. / passenger / ride).

h_2: headway (min.).

a_2, b_2, c_2: constants.

Associated indirect utility function is given as

$$V (p_1, p_2, h_1, h_2) = -a_1 \ln (p_1 - b_1 h_1 - c_1 h_1^2) - a_2 \ln[p_2 - (b_2 / h_2) - (c_2 / h_2^2)] + m \quad (7)$$

where m: income level of househld. This is because the demand functions are derived from the Roy's identity which is given as

$$x_1 = -(\delta V / \delta p_1) / (\delta V / \delta m) \quad (8)$$
$$x_2 = -(\delta V / \delta p_2) / (\delta V / \delta m) \quad (9)$$

The information required for bus demand function estimation is number of passengers per route per day, fare level and headway.

4. SPECIFICATION COST FUNCTIONS

The total cost is the sum of fixed cost and variavle cost. It is experssed as a function of output, x and headway, h. The total cost function for taxi is specified as follows.

$$TC_1 = (d_1+e_1 / h_1)\, x_1 \quad (10)$$

Average cost is the total cost per unit output. So the average cost function is given as follows.

$$AC_1 = d_1+e_1/h_1 \quad (11)$$

where TC_1: total operating cost (Rp./taxi/day), AC_1: average operating cost (Rp./km), x_1: occupied distance (km/taxi/day), h_1: occupancy (ratio of occupied distance to total km traveled), d_1 and e_1 are constants. Thus the data required for the taxi cost function estimation are fixed costs (Rp./taxi/day), variable costs (Rp./taxi/km), total kilometers traveled per taxi per day and total occupied distance (km) per taxi per day.

Similarly, the total cost function for the bus is specified as

$$TC_2 = x_2(x_2-d_2-f_2h_2)/e_2 \quad (12)$$

Then the average cost function takes the following form.

$$AC_2 = (x_2-d_2-f_2h_2)/e_2 \quad (13)$$

where TC_2: total operating cost (Rp/route/day), AC_2: average operating cost (Rp./passenger), x_2: passenger demand (passenger/route/day), h_2: average headway for bus, d_2, e_2, f_2 are constants. The data required for bus cost function estimation are number of bus per route, length of each route (km), average speed (kmph), fixed costs (Rp./bus/km), total number of passengers per route per day and average headway (min.) in each route.

5. ESTIMATION RESULTS

Parameter estimation of demand and cost functions is done by linear regression. Estimation results of demand and cost functions both for taxi and bus are discussed below.

To get the representative data required for estimation of demand and cost functions for taxi operation, 5 taxi drivers were asked to keep a diary each for seven days. The information collected include total number of trips per day, number of passengers per trip, length of each trip, duration of each trip, total kilometer traveled per day and the total occupied kilometers per day. The data show that a taxicab travels 265 kilometers per day of which in about 160 kilometers the taxi carries passengers giving an average occupancy rate of 60%. The number of occupied trips per day is 23.32 with an average trip length of 6.83 kilometers. The average number of passengers per trip is 2.13 and total passenger kilometer per taxi per day is 350.

Estimation results give the following demand function for taxi.

$$x_1 = 7782.75/(p_1-1280.9h_1+977.64h_1^2 \quad (14)$$

(t = 5.1) (t = 26.94) (t = -18.05), R-squared = 0.98

Equation (14) gives the inverse demand function as follows.

$$p_1 = (7782.75/x_1)+1280.9h_1-977.64h_1^2 \quad (15)$$

Total cost function for taxi is estimated as

$$TC_1 = (40.75+246.6/h_1)x_1 \quad (16)$$

(t = 7.9) (t = 9.6), R = squared = 0.85

From equation (16), the average cost function for taxi is given as follows.

$$AC_1 = 40.75+246.6/h_1 \quad (17)$$

A major city bus survey in Yogyakarta Municipality was conducted in 1994 by Wirasta Setia PT and the University of Gadjah Mada under the direction of the Directorate General of Land Transport of Ministry of Communications. Most data for the city bus operation analysis are extracted from this survey. There are 317 buses serving in 17 routes 7 days a week. The average route length is 38.85 km. Each bus travels 218 km per day in 5.63 trips. The total number of bus trip is 1784 per day carrying more than 213000 passengers. The average speed of bus is 17.84 kph and average trip length per passenger is 5.15 km.

The demand function for bus is estimated as

$$x_2 = 614567/[p_2-(1541/h_2)+3181/h_2^2] \quad (18)$$

(t = 3.7) (t = 10.49) (t = -10.49), R- squared = 0.95

Similarly, the total cost function is estimated as

$$TC_2 = -x_2(x_2-27580+765.7h_2)/36.8 \quad (19)$$

(t = 2.7) (t = -3.75) (t = -2.04), R-suqared = 0.71

The average cost function is given as

$$AC_2=-(x_2-27580+7655.7h_2)/36.8 \quad (20)$$

The t-statistics and R-squared values show a good fit of models.

6. OPTIMIZATION RESULTS

Maximization of social surplus gives the optimum taxi fare, p_1, as Rp. 335.73 per kilometer and optimum occupancy rate, h_1, as 0.836. In taxi operation, occupancy rate reflects the service quality. If the occupancy rate is higher, there will be less chance of getting a vacant taxi. Thus the higher occupancy rate reflects the lower service quality. In this sense, it is necessary to restrict the occupancy rate to a reasonable limit so that the service would be reliable. Observed data show that the average occupancy rate is 60% with standard deviation of 9.25%. This makes the maximum occupancy rate of 75.17% at 95% confidence level. This is also a higher figure. With reference to this value it is reasonable to limit the occupancy rate to 0.65. Then the constrained maximization gives the optimum fare level, p_1, as 420.13 Rp./km. The corresponding demand, x_1, as 196.18 km per taxi per day.

In taxi operation, fare is charged as flag drop charge plus the charge per kilometer starting from third kilometer. Assuming flag drop charge is equivalent to charge for two kilometers and average trip length as 6.83 km, flag drop charge becomes Rp. 732.95 and per kilometer charge starting from third kilometer becomes Rp. 366.47. Present fare level is Rp. 800 flag drop charge and Rp. 400 per kilometer starting from the third kilometer. In Indonesia, payments are made in multiple of Rp. 50. Therefore, the existing fare level is close enough to the optimum fare level.

There are 625 units of taxicabs operating in the city. The average distance traveled per day is 262 km of which 158 km is occupied with occupancy rate 0.60. For optimal condition, based on present fare level, occupied distance per taxi per day is 182 km and the corresponding total number of fleet is 544 units. This result indicates that there is over supply of taxies in the city.

Similarly, maximization of social surplus gives that the optimum bus fare, p_2, as Rp. 218.66 per passenger per ride and optimum headway as 3.533 min. The corresponding demand, x_2, for bus is calculated as 16461 passengers per route per day. But based on the present fare level of Rp. 204 per passenger per route per day (average), the headway is 6.39 min. and corresponding demand is 15098 passengers per route per day.

In the city, composition of passengers is 64% adults and 36% students and children (DGTL-MC, 1994). Students and children are given privilege of paying only half the full fare. Calculation shows that under optimal condition, full fare is Rp. 321.56 per passenger per ride and student fare is Rp. 160.78 per passenger per ride. The existing fare level is Rp. 300 per passenger per ride for adults and Rp. 150 per passenger per ride for students and children. As the payments are made in the multiple of Rp. 50, the optimum fare level is close enough to the existing fare level.

Based on 1994 bus survey, there are 317 buses operating in 17 routes with 1784 bus trips per day with average headway of 6.86 min. (DGTL-MC, 1994). The optimum headway based on present fare level is 6.39 min. Assuming that the total number of bus trips per bus per day is constant, because of the fixed length of route and average speed, the total number of fleet is inversely proportional to the headway. The corresponding optimum number of fleet is 340 units. It is desirable to have a 10% spare out of active units making the total number of fleet 375 units. Presently, there are 323 standard buses and 72 small buses. As the small buses are being replaced by standard buses, 52 standard buses have to be added to the present fleet.

7. CONCLUSIONS

From the analysis based on social surplus maximization, following conclusions can be drawn for urban public transportation in Yogyakarta Municipality.

The current fare level for taxi, flag drop charge of Rp. 800 and Rp. 400 per kilometer starting from third kilometer is very close to the optimum fare level. Based on this fare level, optimum number of taxi fleet is 544 units. Presently, there are 625 units in operation and 175 units are being added in the near future. This will make the taxi market over-supplied. Taxi operators will have problem to generate enough revenues to cover the cost. Similarly, the current fare level for city bus, Rp. 300 for adults and Rp. 150 for students and children is also very close to the optimum level. Based on this present fare level, the optimum number of bus fleet is 375 units including 10% spare. This means some 52 standard buses have to be added in the existing fleet when the small buses are completed replaced by the standard buses. Thus this study concludes that there is over supply of taxies and under supply of buses.

There remain a number of limitations in this study. Firstly, although the specification of demand function indicates the service level, it lacks the substitutability between the bus and taxi. Secondly, this is a partial analysis and does not reflect a completeness of policy analysis. Thirdly, the unit of data taken is route. But these routes constitute a network with different links and nodes. It should, therefore, take into account the network effect such as transfer from bus to taxi. Fourthly, it neither deals with the peak hour demand nor the trip purpose. In order to solve these problems, it is necessary to carry out person trip analysis which is difficult at present due to the financial burden. It is, therefore, strongly recommended to carry out a full scale of person trip analysis for small cities in Indonesia because it helps analyze the problem more effectively.

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