EVALUATION OF BUS OPERATIONS USING PERFORMANCE INDICATOR AND GIS ANALYSIS: BANGKOK CASE STUDY

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Abstract: This paper examines bus performances to identify the operating deficiencies and their causes among the 13 selected bus routes in Bangkok. Fourteen performance indicators were chosen based on the availability of data. It was found that among these 13 selected bus routes, 4 routes namely routes 47, A26, 62 and 106 were classified as poor performance routes. These four routes were further examined in detail to identify the causes of deficiencies and to improve their operation. For bus route 47, results of statistical and GIS analyses have identified that operating deficiencies are caused mainly by low labor efficiency and low vehicle revenues. Operating deficiencies of bus route A26 are due mainly to low passenger trips which resulted from insufficient number of buses. Bus route 62 has problems with poor labor efficiency, low vehicle revenues and ineffective bus maintenance duration. Bus route 106 has the same problems as of bus route 62. To minimize these deficiencies, the following recommended measures are proposed: employees must be properly allocated among bus routes, provision of incentive rewards to good and proper manner drivers, increase the number of operating buses, rescheduling of bus maintenance duration and implementation of bus priority scheme.

Key Words: bus operation, performance indicator, GIS, Bangkok

1. INTRODUCTION

In spite of the fact that the first ever rail mass transit has been operated in Bangkok which is locally known as the BTS (Bangkok Mass Transit System), but with its limited route coverages, bus transit is still the most important mode of urban public transportation. Currently, the services of bus transit in Bangkok and other five nearby provinces are under the management of the state owned enterprise known as the Bangkok Mass Transit Authority or BMTA. However, despite of its significance in providing mobility to public commuters, BMTA buses are still far for being well accepted by the Bangkokians. Worst still, ineffective and inefficient bus operations have often been mentioned as one of the major causes of severe traffic congestion problems in Bangkok. As such, there is an urgent need to provide a reasonable suggestion for bus service improvement. This paper presents the results of the

performance evaluation which is applied as a diagnostic tool to identify operational deficiencies and their causes at the route level of bus operations in Bangkok. Comparison performance among bus routes by using Z-score values, statistical analysis which include the concept of Geographic Information System or GIS are applied to identify operating deficiencies and their causes of those poor-operation routes.

2. DATA COLLECTION

Thirteen bus routes of Zone 4 of the Bangkok Mass Transit Authority (BMTA) were selected to identify their operating deficiencies. Among these 13 bus routes, there were a total of 368 buses under operation, of which 93 buses are air-conditioned buses. Fourteen performance indicators were selected based on the availability of data of these 13 bus routes. These 14 indicators, which can be categorized under the resource efficiency, service effectiveness and resource effectiveness, are presented as shown in Table 1. Data were obtained during the period of October 1988 to September 1999.

3. ANALYSIS OF PERFORMANCE INDICATORS

All these 14 performance indicators were determined for all 13 bus routes and presented as Resource Efficiency, Service Effectiveness and Resource Effectiveness indicators as shown in Tables 2, 3, and 4, respectively. To determine the acceptable and unacceptable bus routes, this paper ranked the overall performance indicators among all bus routes by using Z-score values as the method of ranking. Values of Z-score represented the difference of the value from group's mean and sign of Z-score also indicated the value greater than or less than the group's mean of each indicator. The score in a bus route for ranking was determined from combining Z-score value of every indicators in the bus route. Although, this is just a relative comparison, Z-score approach was employed in this study as one of the evaluation techniques. This paper also used other approaches to identify the deficiency bus routes, however, due to the limited number of pages in presenting this paper, it is not possible to present other techniques in this paper. Nevertheless, results obtained from other approaches revealed the similar findings of Z-score approach.

It must also be noted that certain indicators appeared to inverse with their Z-score values. For example, high value of OEXP/VRKM means more expenditures in operating bus services which indicated low resource efficiency. Similarly, other indicators are BDOWN/MVRKM, OEXP/BUS, ACC/MVRKM, and OEXP/TRIP. Therefore, for Z-score ranking, it is necessary to reverse the sign of Z-score (from positive to negative and vice versa) for these mentioned indicators. Computation of Z-score values of all indicators for each individual bus route were then compared by ranking and the results are summarized as shown in Table 5.

It can be seen from Table 5 that the highest overall performance of bus operation is bus route number 205 while the lowest performance is bus route number 106. As summation of Z-scores for all bus routes must be equal to zero, it can separate bus routes to be either acceptable or unacceptable bus routes. The acceptable performance group is those bus routes with positive Z-score sign and these are bus routes ranking from 1st to 9th. These consisted of bus routes 205, 72, 89, 136, 13, 1, 77, 74 and 4. On the contrary, the last three rankings, ranks 10th to 13th bus routes are classified as unacceptable performance group which consisted of

bus routes 47, A26, 62 and 106. These four bus routes, are further examined to identify the causes of deficiencies to improve their operation through statistical and GIS analyses.

4. STATISTICAL AND GIS ANALYSES

The statistical mean of all fourteen indicators were calculated for all thirteen bus routes and were used as criteria to determine the operating deficiency of these unacceptable bus routes. Any indicator, which has its value less than the mean, was considered as poor performance indicator. Furthermore, the concept of GIS was used to assist in identifying causes of bus operating deficiency through the geographical presentation of bus routes on the display program. Table 6 presents those indicators that were classified as poor indicators of the four unacceptable bus routes. While the geographic presentations of these four routes are displayed as shown in Figures 1 to 4, respectively. The findings on these statistical and GIS analyses are considered together to identify deficiencies and their causes of these routes as presented on the following sub-sections.

4.1 Bus Route Number 47

As can be seen from Table 6 that to improve the bus services of route number 47, there are 6 performance indicators that this particular bus route must improve. All these 6 indicators are listed under the resource efficiency. These are VRKM/OEMP, VRKM/BUS, OEMP/VRKM, VRKM/FUEL, OEXP/BUS and ACC/MVRKM.

The first cited indicator, VRKM/OEMP indicated the poor labor efficiency. Bus route 47 needs to improve their productivity per employee. Secondly, VRKM/BUS indicated the low utilization of vehicles. Bus route 47 needs to improve their revenues per bus. The third indicator, OEXP/VRKM reflected the expenses and revenues generated per km as route 47 needs to reduce some expenditures and/or increase more revenues. While VRKM/FUEL revealed the fuel efficiency as route 47 has to improve their fuel consumption. Considering the operating costs per bus (OEXP/BUS), it can be seen that bus route 47 must reduce their expenditures for every operating bus. Finally, regarding the safety in providing services, ACC/MVRKM, bus route 47 indicated the rather high accident rates per trip.

Reviewing the characteristics of this bus route through the presentation of Arc View as shown in Figure 1, it can be clearly seen that this bus route passed many congested areas. This route served passengers along Rama 4 Road, Phya Thai Road, Democratic Monument, etc. and all these areas are considered to be congested areas in Bangkok. High level of traffic congestion along this route has resulted to the low VRKM/BUS, low VRKM/FUEL but high OEXP/VRKM and also high OEXP/BUS.

4.2 Bus Route Number A26

Unlike the bus route 47, route A26 needs to improve their service effectiveness (TRIP/VRKM, TREV/BUS and BUS/LEN) and their resource effectiveness (OEXP/TRIP, TRIP/FUEL, TRIP/BUS and TREV/OEXP). The low value of TRIP/VRKM of bus route A26 indicated the low service utilization that this bus route needs to improve. In addition, this route also needs to improve their revenues generated through ticketing (fares) as its indicator (TREV/BUS) was low. Judging from the Arc View which displays the route

configuration as shown in Figure 2, it can be seen that route A26 has shorter length as compared with bus route 47. However, it must be noted that there were only 8 buses for this route. The insufficient number of buses of bus route 47 caused BUS/LEN indicator to be much lower than the mean.

On the other hand, bus route A26 had to cut down their operating expenses per trip (OEXP/TRIP). Besides, this bus route also needs to attract more passengers to use its services (TRIP/FUEL, TRIP/BUS). Finally, if passengers can be increased, then hopefully more revenues would be generated and its indicator TREV/OEXP can improve.

4.3 Bus Route Number 62

Similar with bus route 47, route 62 also needs to improve its resource efficiency indicators (VRKM/OEMP, VRKM/BUS, OEXP/VRKM, VRKM/FUEL, BDOWN/MVRKM, OEXP/BUS and ACC/MVRKM). However, unlike route 47, bus route 62 must also improve the resource effectiveness (OEXP/TRIP, TRIP/FUEL and TRIP/BUS). Closely examining the displayed route configuration as shown in Figure 3, it can be noticed that route number 62 also operated along congested streets like Sathorn Road, Wireless Road, New Phetchaburi Road, Ratchapranop Road and also Victory Monument. All these mentioned streets are widely known in Bangkok as the all day congested roads. As such, similar reasons as of bus route 47 can also be applied to route 62. Besides, not only bus route 62 needs to improve labor efficiency, vehicle utilization, fuel efficiency, bus breakdown problem, and operational safety, this bus route also needs to increase more passenger trips.

4.4 Bus Route Number 106

If consider only Z-scores of all performance indicators of all 13 bus routes, then it can be concluded that bus route 106 had the poorest performance among other routes in Zone 4. Unfortunately, results obtained from statistical analysis also verified that bus route 106 needs to improve almost all of its performance indicators: resource efficiency indicators (VRKM/OEMP, VRKM/BUS, OEXP/BUS, ACC/MVRKM); service effectiveness indicators (TRIP/VRKM, TREV/BUS, OEXP/BUS); and resource effectiveness indicators (OEXP/TRIP, TRIP/FUEL, TRIP/BUS, TREV/OEXP). In other words, out of all selected 14 performance indicators, only 3 indicators that were found to be acceptable. These indicated that bus route 106 needs to improve nearly all aspects. While these improvements are the same as of other three bus routes as mentioned earlier, it must be also noted that there were only 7 buses operate along this route. This yielded similar problem as of bus route A26 that the BUS/LEN indicator needs to be improved. Furthermore, viewing this bus route configuration through GIS as shown in Figure 4, it can also be stated that similar findings on the congestion conditions were also observed along this bus route. Its route begins at Sathupradit and operates along Rama 4 Road, Sathorn Road, Ladya Road and ends at Wong-Vien-Yai Roundabout. All these streets are widely known as congested streets which affected several performance indicators of this bus route.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

This paper examines performance evaluation by using performance indicator analysis to identify the operating deficiencies and their causes among the thirteen bus routes in Zone 4 of BMTA. Fourteen indicators were selected base on the availability of data. It was known that among the thirteen bus routes, four routes namely routes 47, A26, 62 and 106 were classified as poor performance bus routes. Thus, these four bus routes were examined in detail to identify their operating deficiencies and causes of deficiencies. Causes of deficiencies identified in this paper can be used to establish managerial actions for improving the operation of these bus routes. Furthermore, the Geographic Information System or GIS concept was applied to assist in revealing the causes of operating deficiencies of these bus routes.

5.2 Recommendations

Based on the findings of this paper, the following recommendations are made to improve bus operations of Zone 4.

- Bus routes 47, 62, and 106 are facing with poor labor efficiency problem. It is recommended to rearrange some employees of these bus routes to other needed bus routes such as routes 89, A26, etc. Distributing of proper proportion of employees among all bus routes can alleviate the poor labor efficiency of Zone 4.

- Although, BMTA has a policy to offer rewards to those employees who are punctual and high responsible, it is recommended that BMTA should also encourage staff in particular drivers to drive their buses safely through any incentive scheme such as an award for 25,000 km accident free driving campaign, etc. This such incentive program may help minimize the poor operational safety of certain bus routes as identified in this paper as routes 47, 62 and 106.

- Bus routes A26 and 106 operated with unreasonable and insufficient number of buses. Apparently, there should have any managerial actions to add more buses to these two routes.

- Presently, BMTA hired a contractor to maintain and repair all of their buses. The contractor prepared the maintenance schedule for each bus route. It is apparent that bus route 62 needs to reschedule its maintenance duration or else to replace its own troubled-engine buses with the new buses if possible.

- Results obtained through GIS indicated the similar findings that those unacceptable bus routes had to travel through various congested streets which affected bus performances. Concerned authority should consider to seriously implement the bus priority scheme, e.g. bus lanes effectively and efficiently.

Table 1. Performance Indicators

Performance Indicators	Meanings of Performance Indicators
	Resource Efficiency
VRKM / OEMP	Vehicle revenues-km per operating employee
VRKM / BUS	Vehicle revenues-km per operating bus
OEXP / VRKM	Operating expenses per vehicle revenue-km
VRKM / FUEL	Vehicle revenues-km per liter of fuel
BDOWN/ MVRKM	Breakdowns per million vehicle revenue-km
OEXP /BUS	Operating expenses per operating bus
ACC / MVRKM	Accidents per million vehicle revenue-km
	Service Effectiveness
TRIP / VRKM	Passenger trips per vehicle revenue-km
TREV / BUS	Ticket revenues per operating bus
BUS / LEN	Operating buses per km of route length
	Resource Effectiveness
OEXP / TRIP	Operating expenses per passenger trip
TRIP / FUEL	Passenger trips per liter of fuel
TRIP / BUS	Passenger trips per operating bus
TREV / OEXP	Ticket revenues per operating expense

Table 2. Resource Efficiency Performance Indicators

Route	VRKM / OEMP	VRKM / BUS	OEXP / VRKM	VRKM / FUEL	BDOWN / MVRKM	OEXP / BUS	ACC / MVRKM
13	52.90	173.59	21.83	2.24	3.1	3788.75	5.4
74	58.04	186.61	19.22	2.38	1.6	3585.80	12.3
136	68.76	229.70	21.06	2.08	1.6	4836.31	6.6
205	73.77	251.88	18.24	2.41	1.2	4594.40	3.8
1	66.87	199.64	19.13	2.92	2.1	3819.62	9.6
62	49.28	176.43	29.11	1.95	4.2	5135.33	8.5
77	72.63	230.13	18.99	2.41	1.1	4371.05	12.0
89	81.99	264.27	14.80	2.86	2.1	3910.69	4.7
106	59.91	161.39	20.54	2.92	0.0	3314.91	7.9
4	48.82	182.33	29.11	1.94	2.5	5307.98	5.1
47	48.88	161.41	26.80	2.29	1.2	4326.56	8.9
72	58.05	190.40	23.18	2.21	0.4	4412.86	8.8
A26	76.51	220.26	17.62	3.78	1.6	3880.98	1.6

Table 3. Service Effectiveness Performance Indicators

Route	TRIP/VRKM	TREV/BUS	BUS/LEN
13	5.56	3,375.35	543.80
74	4.45	2,913.48	383.59
136	3.88	4,719.21	617.44
205	3.72	4,242.82	821.70
1	3.83	2,779.44	782.58
62	3.94	4,834.10	736.28
77	3.31	3,961.48	459.62
89	2.88	2,661.79	314.00
106	2.30	1,300.69	167.36
4	5.09	5,324.59	861.33
47	4.80	3,561.72	739.23
72	4.78	4,192.52	780.25
A26	1.47	1,424.43	208.93

Table 4. Resource Effectiveness Performance Indicators

Route	OEXP/TRIP	TRIP/FUEL	TRIP/BUS	TREV/OEXP
13	3.93	12.43	965.28	0.89
74	4.32	10.58	830.43	0.81
136	5.42	8.07	891.85	0.98
205	4.90	8.96	937.14	0.92
1	4.99	11.19	764.80	0.73
62	7.39	7.70	695.10	0.94
77	5.73	7.99	762.88	0.91
89	5.14	8.23	761.02	0.68
106	8.91	6.74	371.95	0.39
4	5.72	9.88	927.92	1.00
47	5.59	10.97	774.01	0.82
72	4.85	10.58	909.98	0.95
A26	11.99	5.56	323.81	0.37

Table 5. Rank of Bus Routes in Zone 4

Rank	Bus route	Sum of Z-score
1	205	7.616
2	72	3.549
3	89	3.087
4	136	3.082
5	13	3.045
6	1	2.509
7	77	1.488
8	74	0.232
9	4	0.222
10	47	-1.627
11	A26	-5.492
12	62	-6.429
13	106	-11.282

Table 6. Selected indicators for Poor Performance Bus Routes

Performance Indicators	Bus Route				Mean of Indicators
	47	A26	62	106	
Resource Efficiency					
VRKM/OEMP	48.88	76.51	49.28	59.91	62.80
VRKM/BUS	161.41	220.26	176.43	161.39	202.16
OEXP/VRKM*	26.80	17.62	29.11	20.54	21.51
VRKM/FUEL	2.29	3.78	1.95	2.92	2.49
BDOWN/MVRKM*	1.2	1.6	4.2	0.0	1.8
OEXP/BUS*	4,326.56	3,880.98	5,135.33	3,314.91	4252.71
ACC/MVRKM*	8.9	1.6	8.5	7.9	7.3
Service Effectiveness					
TRIP/VRKM	4.80	1.47	3.94	2.30	3.85
TREV/BUS	3,561.72	1,424.43	4,834.10	1,300.69	3483.97
BUS/LEN	739.23	208.93	736.28	167.36	570.47
Resource Effectiveness					
OEXP/TRIP*	5.59	11.99	7.39	8.91	6.07
TRIP/FUEL	10.97	5.56	7.70	6.74	9.14
TRIP/BUS	774.01	323.81	695.10	371.95	762.78
TREV/OEXP	0.82	0.37	0.94	0.39	0.80

Note: symbol (*) means indicators that contrary in meaning of indicator

GIS Analyses

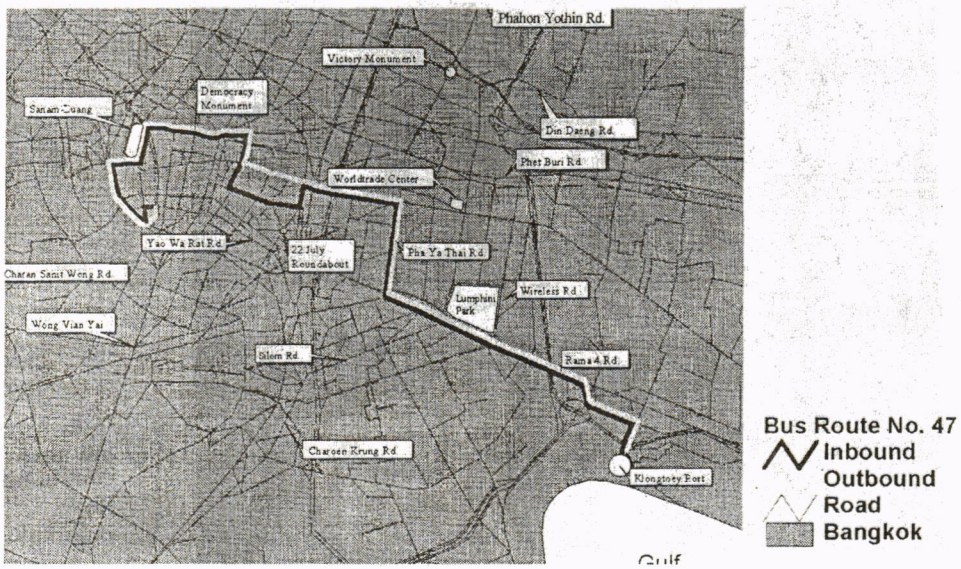

Figure 1. Geographic Presentation of Bus route 47

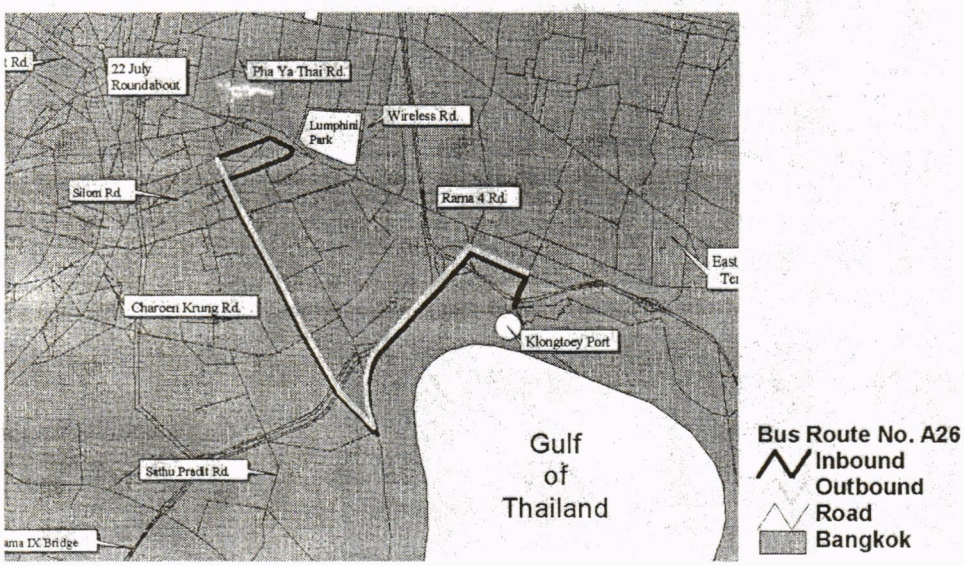

Figure 2. Geographic Presentation of Bus route A26

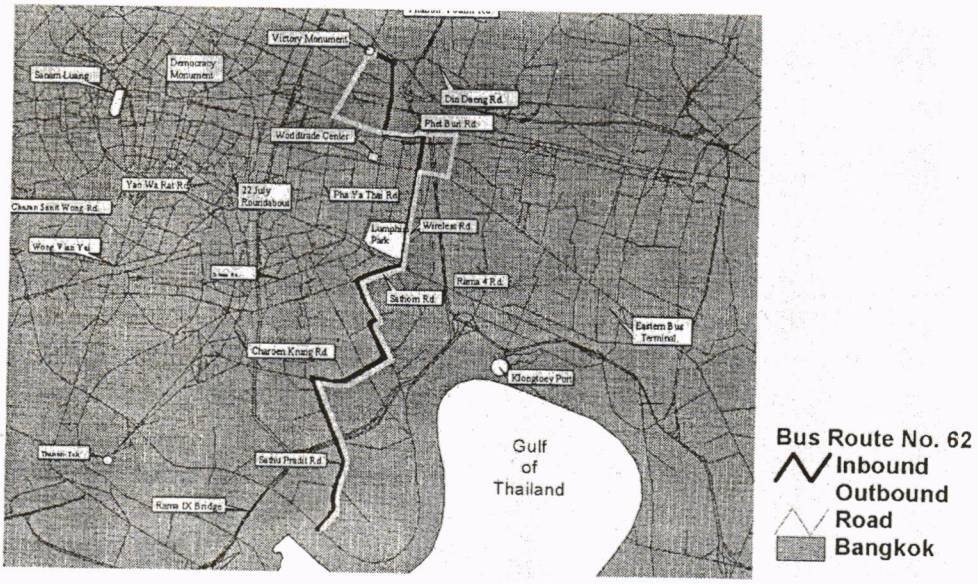

Figure 3. Geographic Presentation of Bus route 62

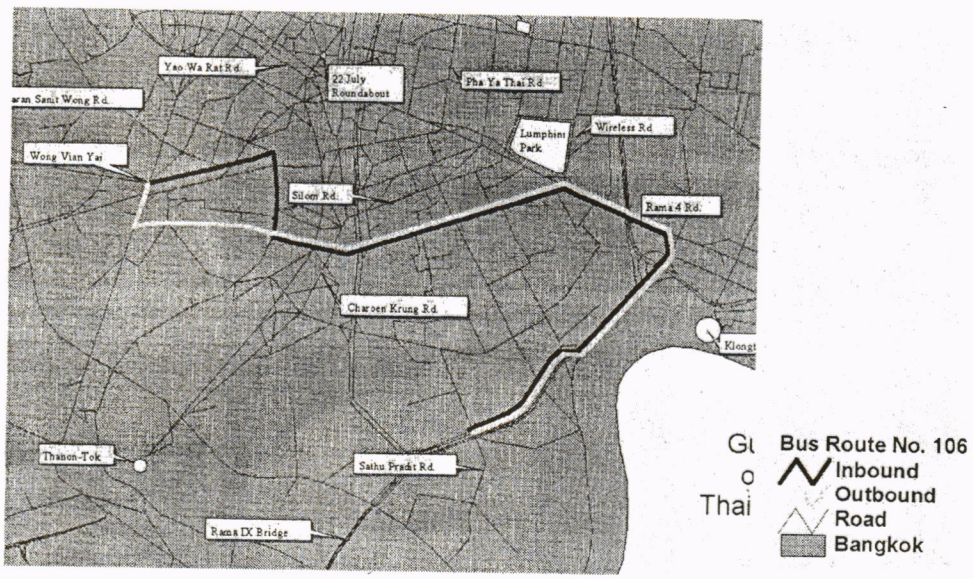

Figure 4.Geographic Presentation of Bus route 106