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TRIP COSTS ANALYSIS OF BUS RAPID TRANSIT

Shyue-Koong Chang
Professor
Department of Civil Engineering,
National Taiwan University
E-mail: skchang@ntu.edu.tw
Tel: 886-2-23660619
Fax: 886-2-23631558
No.1 Roosevelt Road, Sec.4
Taipei 10617, Taiwan

Yu-Jian Guo
Ph.D. Student
Department of Civil Engineering,
National Taiwan University
E-mail:D92521012@ntu.edu.tw
Tel: 886-2-23625920
No.1 Roosevelt Road, Sec.4,
Taipei 10617, Taiwan

Abstract: Bus rapid transit (BRT) is a kind of public transportation with the characteristics of high quality as rail system and flexibility as bus operation. The development of BRT system is a cost-effective approach to improve traffic congestion and promote public transit without increasing financial burdens. In this study, we established trip cost models in the view points of social cost and applied the model to analyze the trip cost as well as the performance of BRT system in Taipei metropolitan area. In the performance analysis, we evaluated the trip costs of conventional bus and BRT and conducted sensitivity analysis for BRT trips in order to understand the performance and the potential contribution of BRT. The results can be used as the basis for formulating BRT strategies and assessing urban transportation policies related.

Keywords: Bus rapid transit, Social cost, Transportation policy

1. INTRODUCTION

Litman (2000) indicated that the total cost of automobiles includes 33% external costs, and it can reach to 46% in the peck hour of urban area (Table 1). The automobile contravenes the principle of the resource allocation with effectives and fairness, and diverges from the sustainable development with high percentage of external costs. Taipei is the main metropolitan in Taiwan, consisting of area of 2529.14 square kilometers and population of 6.73 millions, respectively. There are 13.5 million trips daily and the percentage of private transportation (i.e., automobile and motorcycle) and public transportation (i.e., urban rail, bus, and taxi) are 58.21% and 29.36%, respectively (Asian Technical Consultants, 2002). According to the above-mentioned statistics, we can find the percentage of using private transportation in Taipei is comparatively higher than other neighborhood cities, such as Hong Kong, Singapore, and Tokyo. If taking into account the high percentage externality costs of private transportation, our society and environment had paid huge social costs for the high

percentage of using private transportation. Therefore, it is eager to promote public transportation and look for solutions of public transit systems with high efficiency, low pollutions and less construct costs in order to lower the misuse of the social resource and reduce the social costs.

The rail transportation systems are often thought that have the highest efficiency than other systems and are the best way to solve the transportation problems in metropolitan areas with high dense population. But the huge infrastructure cost as well as operation and maintenance costs of the rail systems causes serious financial burdens for governments. Therefore, the BRT system that combines the advantages of rail service quality and bus operation flexibility has been considered as a better and timely solution to solve the urban transportation problems. The advantages of BRT are low construction cost, short construction period, high capacity that can reach to the level of light rail transit, and less fuel consumption and air pollution than the traditional bus transit. BRT system is environmentally sustainable, financially sustainable and socially sustainable with a view point of sustainable transportation. Although BRT has many advantages than other public transit systems, its fairness and reasonableness have not been analyzed quantitatively.

In this study, we established the trip cost models in the view points of social costs and applied the models to analyze trip costs and performance of BRT system in Taipei. In the performance analysis, we measured the trip costs of bus and BRT and conducted the sensitivity analysis for BRT trips in order to understand the performance and the potential contribution of BRT trips. Besides, we compared the construction costs of BRT and the reduction of total costs caused by increasing the BRT ridership. Finally, based on the quantitative analysis, we reviewed the current BRT policies and proposed suggestions for BRT policies.

Table1. Average Automobile Costs as a Percentage of Total Cost in Canada

	Total Costs	Internal Costs		External Costs	
Units	per mile	per mile	% of Total	per mile	% of total
Urban Peak	$ 1.32	$ 0.71	54%	$ 0.61	46%
Urban Off-Peak	$ 1.05	$ 0.71	68%	$ 0.34	32%
Rural	$ 0.84	$ 0.64	76%	$ 0.20	24%
Weight Average	$ 0.99	$ 0.67	68%	$ 0.32	32%

Source: Litman (2000)

*Total costs, internal costs and external costs mean that the average costs of every mode in metropolitan

2. ASSUMPTIONS AND MODEL ANALYSIS

In this analysis, social cost consists of four parts: user cost, basic facility cost, travel time cost and external cost while seven modes are analyzed, which include walk, bicycle, motorcycle, automobile, taxi, bus and metro. It is worth noting that classification of each part of the social cost has some limitations and special features. User cost is the monetary payment for each of the mode and include fixed cost and variable cost in a year basis. For public transportation, the fare is a transfer payment and therefore it is not included in social costs while we view operation cost of the public transportation as basis for user cost.

Basic facility cost includes road use cost and parking cost. Based on the analysis of Qin (1996), the road use cost is proportional to user cost in $ per kilometer. Travel time cost includes every components of trip time, including in vehicle and out of vehicle travel time costs. External cost has four categories, i.e., air pollution, noise, accident, and congestion.
Based on the results of Lin (1997) and Liu (2001), the contents of the total costs for each mode are summarized in Table 2.

Table2. Contents of Social Costs

Mode	Contains
1.Walk	1.walk user total travel time costs
2.Bicycle	1.bicycle user costs 2.bicycle user total travel time cost
3.Motorcycle 4.Automobile 5.Taxi 6.Bus 7.Metro	1.mode user costs（taxes is not involved） 2.mode user total travel costs 3.the basic facility that mode user should bear 4.the external cost caused by mode user

Source: Lin (1997) and Liu (2001)

2.1 Trip Behavior Analysis

Considering travel patterns in Taipei Metropolitan, we divided the transportation systems into three main categories: (1) public transit, including bus and metro; (2) private mode, including walk, bicycle, motorcycle, and automobile; and (3) para-transit, i.e., taxi, as shown in Fig 1. Furthermore, in viewing of transfer and feeder systems, metro trips have most complex trip chain. Table 3 summarizes all possible trip patterns in Taipei.

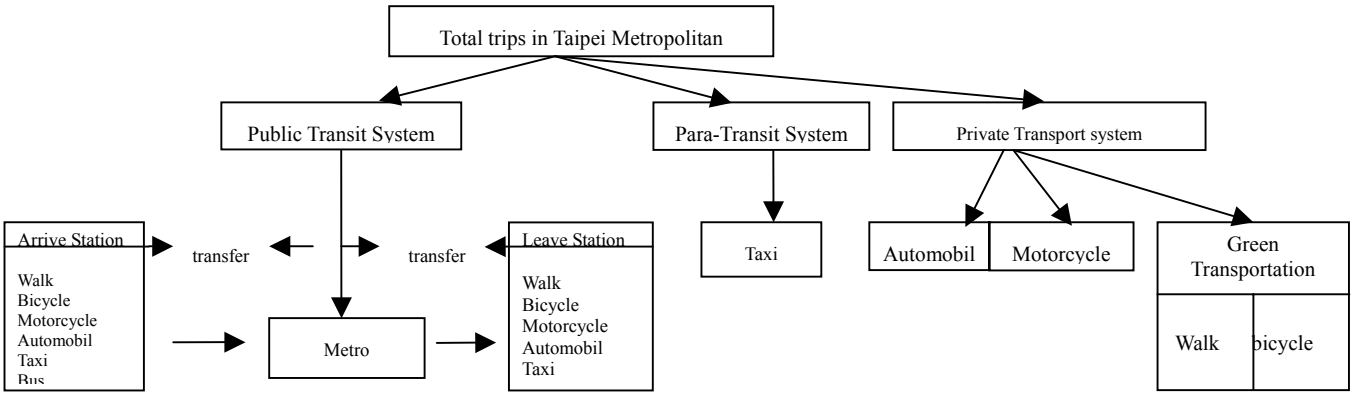

Figure 1. Trip Classification

Table 3. Trip Patterns and Classification

(1) Trips without Transfer Behavior		
1.walk trip		
2.bike trip		
3.motorcycle trip		
4.automobil trip		
5.taxi trip		
6.bus trip (include bus transfer to bus trip)		
7.metro trip (include metro transfer metro trip)		
(2) Trips with Transfer Behavior		
Arrive Station	Major Mode	Leave Station
1.walk	metro	walk, bicycle, motorcycle, automobile, taxi and bus
2.bicycle		walk, bicycle, motorcycle, automobile, taxi and bus
3.motorcycle		walk, bicycle, motorcycle, automobile, taxi and bus
4.automobile		walk, bicycle, motorcycle, automobile, taxi and bus
5.taxi		walk, bicycle, motorcycle, automobile, taxi and bus
6.bus		walk, bicycle, motorcycle, automobile, taxi and bus

2.2 Cost Assumptions

In order to calculate the trip cost, there is a need for reasonable assumptions. According to the result analyzed by Department of Rapid Transit Systems (1994), it has found that most passengers live within 500 meter of the metro station are all walk trips to the station while passengers live between 500~800 meter have about 50% of walk trips to the station. Hence, it is assumed in our analysis that trip length of walk trip is 500 meters and bicycle is 800 meters. I is also assumed based on the 2001 Taiwan Highway Capacity Manual in Taiwan (Chinese Institute of Transportation, 2001) that the walking speed is 2 KPH. The average trip length, occupation ratio and average speed of various modes are given in Table 4.

Table 4. Average Trip Length, Occupancy Ratio and Average Speed of Each Mode

Mode	Walk	Bicycle	Motorcycle	Automobile	Taxi	Bus	Metro
Average Trip Length (km)	0.50	0.80	8.40	18.50	4.45	7.90	7.68
Occupancy Ratio (people/mode)	1.00	1.00	1.07	1.72	1.87	25.88	651
Average Speed (kph)	2.00	12.00	29.22	29.22	21.28	22.88	33.78

2.3 Trip Cost Analysis

(1) User Cost

Considering a comparatively small payment for walk and bicycle trips, it is assumed that the user costs of these two trips are neglected. The user costs of other private modes calculated in unit of $ per kilometer per trip. Due to the complicated process of calculation, the details can refer to the study of Guo (2002). Although the fare of buses is defined as the transfer payment but it also reflects the bus operation cost of bus given an average costing approach and supervised by Taipei City Government. Therefore, we considered regular bus fare (i.e., NT$ 15) as a standard to measure the user cost of bus trips. Besides, the tax should be taken out in user cost for bus trips. For user costs of metro, we also refer to the annual report of Taipei Rapid Transit Corporation (2002) and with the concept of average cost pricing. According to the foregoing methods, we used 3 % price fluctuation per year as basis to calculate the user cost of each mode, as shown in Table 5.

Table 5. User Costs of Each Mode

Mode	Walk	Bicycle	Motorcycle	Automobile	Taxi	Bus	Metro
User Costs of Each Trip (NT$/trip)	0	0	23.35	139.68	12.55	14.38	13.27
User Costs of Each Trip Per Km (NT$/per km)	0	0	2.78	7.55	2.82	1.82	1.73

(2) Basic Facility Cost

The basic facility cost includes road use cost and parking cost. We estimated road use cost based on the analysis of Qin (1996), in which the road use cost is defined as a fixed ratio of the user cost in unit of $ per kilometer. Qin has obtained the ratio as 0.1. In regards of parking cost, it is estimated by the rent of parking space per month. The automobile parking cost is therefore NT$ 5047.48 per month while the parking cost of motorcycle is NT$1,061.38 which is estimated by an equivalence of automobile parking space, i.e., each automobile parking space can be divided into an average 4.5 motorcycle parking space.

In order to keep the fairness, we had added the basic facility costs. To avoid calculate the parking cost repeatedly, we had listed that in the user costs. And we divided the parking costs

into the movement time and the motionless state time. The movement time would be took off in the daily parking fare according to the drive time of motorcycle, automobile and taxi which have been changed into parking fare. Finally, we calculated the parking fare of each trip and each trip per kilometer by the occupancy ratio. In public transit, we considered the replacement fund instead of depreciation as basic facility of metro. In this way, we indicated the ratios of users have paid and users should pay, the relevant study can refer to Chang and Guo (2003). Table 6 shows estimated ratio of basic facility, automobile equivalency and the basic facility cost of each mode.

Table 6. The Basic Facility Cost of Each Mode（2002）

Mode	Walk	Bicycle	Motorcycle	Automobile	Taxi	Bus	Metro
Estimate Ratio	0.00	0.00	0.10	0.10	0.10	0.10	
Automobile Equivalency	0.00	0.00	0.30	1.00	1.00	2.00	
Basic Facility Cost of Per Km（NT$/km）	0.00	0.00	2.06	4.73	1.03	9.44	replacement fund
Basic Facility Cost of Each Trip（NT$/per trip）	0.00	0.00	16.17	50.88	2.45	2.88	
Basic Facility Costs of Each Trip Per Km（NT$/per trip per km）	0.00	0.00	1.93	2.75	0.55	0.36	

(3) Travel Time Cost

According to the research results of travel time by Department of Rapid Transit Systems, Taipei City Government (1994) with a 3% annual inflation rate, the in vehicle travel time value and out of vehicle for the private transportation are NT$ 1.13 per minute NT$ 2.34 per minute, respectively. As the studies of travel time values of walk and bicycle were lack, we referred to studies of Goodwin (1974) and Liu (2001) to obtain the travel time values of these two modes. It is assumed that passengers live within 2 km of the station would still accept walk way while bicycle trip would still be acceptable within 9 km of the station. With these assumptions, it is estimated that the travel time values of walk and bicycle are NT$ 1.885 per minute and NT$ 1.41 per minute, respectively. We assumed that the out of vehicle travel time value was the same for public transportation.

According to the above assumptions and calculation, the results of travel time values are summarized in Table 7.

Table 7. Travel Time Costs of Each Mode

Mode	Walk	Bicycle	Motorcycle	Automobile	Taxi	Bus	Metro
Out of Vehicle Travel Time Costs of Each Trip（NT$/per trip）	-	5.80	6.79	23.47	5.10	31.11	29.30
In Vehicle Travel Time Costs of Each Trip（NT$/per trip）	28.35	5.64	20.37	42.93	14.18	19.48	12.82
Travel Time Cost of Each Trip（NT$/per trip）	28.35	11.44	27.16	66.40	19.28	50.59	42.12

Travel Time Cost of Each Trip Per Km (NT$/per trip per km)	56.70	14.30	3.23	3.59	4.33	6.40	5.48

(4) External Cost

Due to consistency and accuracy, we applied studies by Mayers (1996) for external cost with modification of Gross Domestic Product (GDP) and economy growth. Detailed analysis can refer to the study of Guo (2003). The external cost includes air pollution, noise, accident and congestion. Table 8 shows results of the external costs in Taipei Metropolitan.

Table 8. The External Costs of Each Mode in Taipei Metropolitan (2002) Unit: NT$

Mode		Walk	Bicycle	Motorcycle	Automobile	Taxi	Bus	Metro
Air Pollution Costs	mode/per km	0.00	0.00	0.20	0.35	0.35	5.47	10.70
	person/per km	0.00	0.00	0.18	0.21	0.19	0.21	0.02
Noise Pollution Costs	mode/per km	0.00	0.00	0.73	0.07	0.07	0.60	0.00
	person/per km	0.00	0.00	0.68	0.04	0.04	0.02	0.00
Accident Costs	mode/per km	0.00	0.00	7.37	2.23	2.23	12.89	0.13
	person/per km	0.00	0.00	6.88	1.30	1.19	0.50	0.00
Congestion Costs	mode/per km	0.00	0.61	1.71	5.68	5.68	19.61	0.00
	person/per km	0.00	0.61	1.59	3.30	3.04	0.76	0.00
Total	mode/per km	0.00	0.63	10.01	8.33	8.33	38.57	10.83
	person/per km	0.00	0.63	9.33	4.85	4.46	1.49	0.02
The External Cost of Each Trip		0.00	0.51	78.37	89.73	19.85	11.77	0.15

(5) Total Costs Analysis

According to the above cost analysis, we summarized the total costs of each mode in Taipei Metropolitan as shown in Table 9. It is shown that the total cost of private transportation is higher than public transit, indicating that our society has paid huge subsidy for the private transportation.

Table 9. The Total of Each Mode in Taipei Metropolitan (2002)

Mode	Walk	Bicycle	Motorcycle	Automobile	Taxi	Bus	Metro
Total Costs of Each Trip (NT$/per trip)	28.35	11.95	145.05	346.68	54.13	79.65	55.54
Total Costs of Each Trip Per Km (NT$/ per trip per km)	56.70	14.93	17.27	18.74	12.16	10.08	7.23

2.3 Total Cost Model

The problem of trip chain is an important part of trip cost models. Generally, a trip from origin to the destination often involved three trip sections. Even if a private transportation trip, the process should also include access mode of walk. In this study, we have considered the out mode travel time in the analysis of travel time costs, and the problems of trip chain were involved in our models. The transfer problems of public transit have three individual trips,

and each trip was considered as three sections as above analysis. There are 43 types of trips identified as shown in Table 3.The items of the model include user costs, basic facility costs, travel time costs and external costs, and the mode included in our models involve walk, bicycle, motorcycle, automobile, taxi and metro. The process of models established is very complicated. Detailed analysis process can refer to the study of Guo (2003). Table 10 shows a general formula for these 43 trip chain.

Table10. General Formula of Trip Costs Model

Metropolitan Trip Costs	Trip Cost=User Costs+ Basic Facility Costs+ Travel Time Cost+ External Cost	
The Contents of Each Costs	User Costs	The cash Cost and holding cost
	Basic Facility Costs	Rode use costs, facility cost and parking cost
	Travel Time costs	In mode and out mode travel time costs
	External Costs	Air pollution, noise, accident and congestion

3. TRIP COSTS ANALYSIS OF TAIPEI METROPOLITAN

In order to simplify the importance and the strategic meanings of the results in our analysis, we referred to data investigated by Department of Transport, Taipei City Government (2002). It is found that the top 10 types of trips contributed up to 92.92% of all trips in Taipei Metropolitan. Therefore, the results of we have analyzed are based on these top 10 types of trips. In the cause of understanding the burden of the trips, we will list the detail construction and the percentage of the top 10 occurrence trips in follow analysis.

3.1 Trip Cost Analysis

According to the results of cost analysis, the trip type analysis and the trip cost models, we obtained the trip costs for each mode and for the trip chains, as shown in Table 11 and Table 12.

Table 11. Trip Costs Construction of Taipei Metropolitan（NT$/per trip per km）

sequence	Trip Types	User Costs	Basic Facility Costs	Travel Time Costs	External Costs	Total Costs
1.	Motorcycle	2.78(16.10%)	1.93(11.15%)	3.23(18.72%)	9.33(54.03%)	17.27(100.00%)
2.	Automobile	7.55(40.29%)	2.75(14.68%)	3.59(19.15%)	4.85(25.88%)	18.74(100.00%)
3.	Bus	1.82(18.07%)	0.36(3.57%)	6.40(63.57%)	1.49(14.79%)	10.07(100.00%)
4.	Taxi	2.82(23.18%)	0.55(4.53%)	4.33(35.62%)	4.46(36.67%)	12.16(100.00%)
5.	walk-walk	0.58(1.41%)	0.00(0.00%)	40.23(98.57%)	0.01(0.02%)	40.81(100.00%)
6.	Metro transfer trips: bus-bus	1.79(17.67%)	0.15(1.51%)	7.20(70.96%)	1.00(9.86%)	10.14(100.00%)
7.	Metro transfer trips: Walk-Bus	0.96(3.84%)	0.08(0.31%)	23.71(94.58%)	0.32(1.28%)	25.07(100.00%)
8.	Metro transfer trips: Bus-Walk	0.96(3.87%)	0.08(0.31%)	23.52(94.53%)	0.32(1.29%)	24.88(100.00%)
9.	Motorcycle-walk	1.50(5.50%)	0.64(2.35%)	22.08(80.75%)	3.12(11.40%)	27.35(100.00%)

10	Motorcycle-motorcycle	2.43(17.76%)	1.29(9.40%)	3.74(27.35%)	6.23(45.50%)	13.69(100.00%)

Table 12. Trip Cost Components of Taipei Metropolitan（NT$/per trip）

Sequence	Trip Types	User Costs	Basic Facility Costs	Travel Time Costs	External Costs	Total Costs
1.	Motorcycle	23.35(16.10%)	16.17(11.15%)	27.16(18.72%)	78.37(54.03%)	145.05(100%)
2.	Automobile	139.68(40.29%)	50.88(14.67%)	66.40(19.15%)	89.73(25.88%)	346.68(100%)
3.	Bus	14.41(18.09%)	2.88(3.62%)	50.59(63.51%)	11.77(14.78%)	79.65(100%)
4.	Taix	12.55(34.95%)	2.45(3.83%)	19.28(30.17%)	19.85(31.05%)	54.13(100%)
5.	walk-walk	13.27(16.64%)	0.00(0.00%)	66.46(83.36%)	0.00(0.00%)	79.73(100%)
6. Metro Transfer Trips	bus-bus	18.01(21.79%)	0.95(1.15%)	59.70(72.20%)	4.03(4.87%)	82.69(100%)
7.	Walk-Bus	15.64(19.24%)	0.47(0.58%)	63.08(77.60%)	2.09(2.57%)	81.28(100%)
8.	Bus-Walk	15.64(19.24%)	0.47(0.58%)	63.08(77.60%)	2.09(2.57%)	81.28(100%)
9.	Motorcycle-walk	30.90(17.48%)	12.21(6.91%)	74.35(42.06%)	59.31(33.55%)	176.76(100%)
10	Motorcycle-motorcycle	48.53(17.73%)	24.42(8.92%)	82.24(30.05%)	118.47(43.29%)	273.66(100%)

3.2 Discussions

From the quantitative results of the trip costs, several policy implications can be observed:

1. According to Table 11, we understood that private transportation trips accounted the highest percentage in Taipei Metropolitan, and the percentage of automobile and motorcycle trips occupied approximately 58%. From the costs of each trip, it is found that the trip of arriving and leaving metro station by walk has the highest trip costs per kilometer. The main reason of this situation is that the walk trip has the comparative high travel time costs. In the costs of basic facility, automobile and motorcycle trips have the highest cost due to their the parking fees. In the costs of external costs, automobile and motorcycle trips have also the highest costs. The results of the external costs verified that automobile and motorcycle trips have generated the huge social costs.

2. In terms of trips with transfer behavior, the travel time costs will become very large, if users arrive or leave metro station by walk or by bus. For example, the travel time costs of the transfer trips arrive and leave metro station all by using walk trips is up to 98.57%, and that arrive and leave metro station use walk or bus trips is up to 94.58% (Table 11). The results of the analysis mean that the metro trips in Taipei are the high percentage of

travel and waiting time costs. Therefore, we must improve the pedestrian facilities and the related environments, increase the service frequency, and modify transfer and feeder plane to decrease the travel time of public transit when we reviewed the transportation policies. With these recognitions, we can expect to have more users shifted from the private transportation into public transit.

3. Based on Table 12, we understood that the trip length of private transportation is longer than that of public transit while the market ratio of private transportation is also higher than that of public transit. These results indicated that the general public in Taipei uses the modes with highest social costs as well as the longest trip length. In order to decrease the social costs, we should shift the private transportation into public transit, and integrate the networks with the operation of metro and bus. Besides, we also need magnify the service scope and increase the accessibility and convenience of public transit positively.

4. SENSITIVE ANALYSIS OF BUS RAPID TRANSIT

According to the analysis in previous sections, we have a clear picture on trip cost of each mode and various trip chains in Taipei. In this section, we calculated the trip cost of bus rapid transit users. Additionally, we conducted sensitive analysis for bus rapid transit in order to understand the performance and potential contribution of BRT trips

4.1 Calculate the Trip Costs of Bus Rapid Transit

Due to the bus rapid transit trips mixed with bus trips, it is difficult to divide both trips, it is assumed that the distribution of all bus trips are normal, and we decomposed of the bus rapid transit and the bus trips based on the average length of bus routes. In accordance with the data of THI Consultants (2003), the average length of bus and bus rapid transit lines are 9.07km and 2.48km, we calculate the trips of bus rapid transit are 27.38% more than the bus trips. In the calculating of the trips of bus rapid transit, according to the analysis of before and after bus rapid transit built, we found that the speed of bus rapid transit is 40% fast than that of bus, and the occupancy ratio increase 15% than bus. The external cost of bus rapid transit reduce 13% accident cost and 6% air pollution cost than did of bus trips, respectively. The results of trip cost for BRT are shown in Table 13 and 14.

Table13. BRT Trip and Bus Trip Cost Components（NT$/per trip per km）

Cost type / Trip type	User Costs	Basic Facility Costs	Travel Time Costs	External Costs	Total Costs
BRT Trip	1.59(15.26%)	0.32(3.01%)	7.48(71.98%)	1.04(9.98%)	10.42(100%)

Bus Trip	1.92(14.45%)	0.38(2.86%)	9.50(71.48%)	1.49(11.21%)	13.29(100%)

Table14. BRT Trip and Bus Trip Cost Components（NT$/per trip）

Cost type / Trip type	User Costs	Basic Facility Costs	Travel Time Costs	External Costs	Total Costs
BRT Trip	12.53(18.97%)	2.51(3.8%)	42.79(64.79%)	8.22(12.45%)	66.04(100%)
Bus Trip	15.17(18.84%)	3.03(3.76%)	50.56(62.78%)	11.77(14.62%)	80.53(100%)

According to the above analysis, the trip cost of bus rapid transit reduces NT$ 2.87 per km than bus trip. The user cost and the travel time cost reduce NT$ 0.33 and NT$ 2.2 per km, and the basic facility costs and the external costs reduce NT$ 0.06 and NT$ 0.45 per km. In addition, the trip cost of bus rapid transit reduces NT$ 14.49 per trip. The user cost and the travel time cost reduce NT$ 2.64 and NT$ 7.77 per trip, respectively while the basic facility costs and external cost reduce NT$ 0.52 and NT$ 3.55 per km, respectively. The above results have shown that the performance of reducing the social costs by bus rapid transit trip. We can therefore conclude that the BRT is an effective and useful public transit policy.

4.2 The Sensitive Analysis of Bus Rapid Transit Performance

The bus rapid transit trips in Taipei occupy 27.38% of the all bus trips. In order to understand the performance of the increasing of bus rapid trips, we analyze the sensitive of bus trip costs per km when BRT trips occupy 40%, 50% and 60%, respectively. According to the analysis, we found that the external cost and the travel time cost are more sensitive than other costs. It is also shown that the BRT trip increase 10% in the all bus trip, the trip cost of bus trip will reduce NT$ 0.22 per km. Table 15 summarized the results of sensitivity analysis.

Table15. Sensitive Analysis of BRT Trip

Cost type / BRT Trip (%)	User Costs	Basic Facility Costs	Travel Time Costs	External Costs	Total Costs
27.38%（Now）	1.82	0.36	6.40	1.49	10.07
40.00%	1.79	0.36	6.23	1.31	9.68
50.00%	1.75	0.35	6.09	1.27	9.46
60.00%	1.72	0.34	5.95	1.22	9.24

According to the situation of Taipei, bus rapid transit trips occupy 27.38% in the all bus trips. In order to understand the effect of the increasing of bus rapid trips, we analyze the sensitivity of average trip costs in Taipei metropolitan per km and per trip when BRT trips occupy 40%, 50% and 60% of all bus trips. Results of sensitivity analysis are summarized in Tables 16 and

17 as well as Fig 2 and 3, respectively.

Table16. Sensitive Analysis of Average Trip Cost（NT$/per trip per km）

	27.38%（Now）	40%	50%	60%
Automobile	18.74	18.74	18.74	18.74
Motorcycle	17.27	17.27	17.27	17.27
Taxi	12.16	12.16	12.16	12.16
Bus	10.07	9.68	9.46	9.24
Metro	7.23	7.23	7.23	7.23
Average Trip Cost	15.26	15.18	15.13	15.09

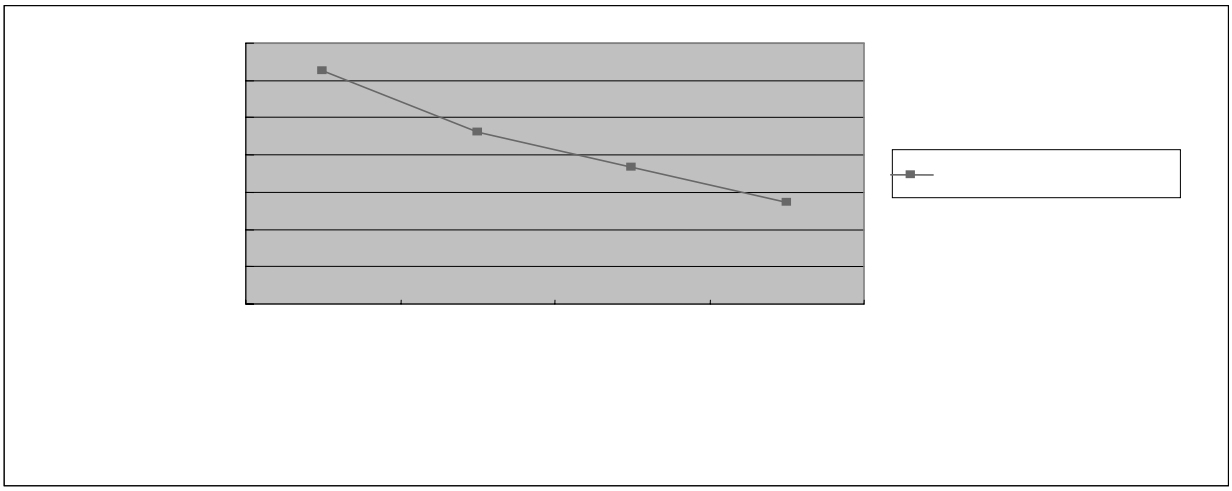

Fig 2. Average Trip Cost of Sensitive Analysis Per Km

Table17. Sensitive Analysis of Average Trip Cost in Taipei（NT$/per trip）

	27.38%（Now）	40%	50%	60%
Automobile	346.68	346.68	346.68	346.68
Motorcycle	145.05	145.05	145.05	145.05
Taxi	54.13	54.13	54.13	54.13

Bus	79.65	74.74	73.29	71.84
Metro	55.54	55.54	55.54	55.54
Average Trip Cost	177.35	176.31	176.01	175.70

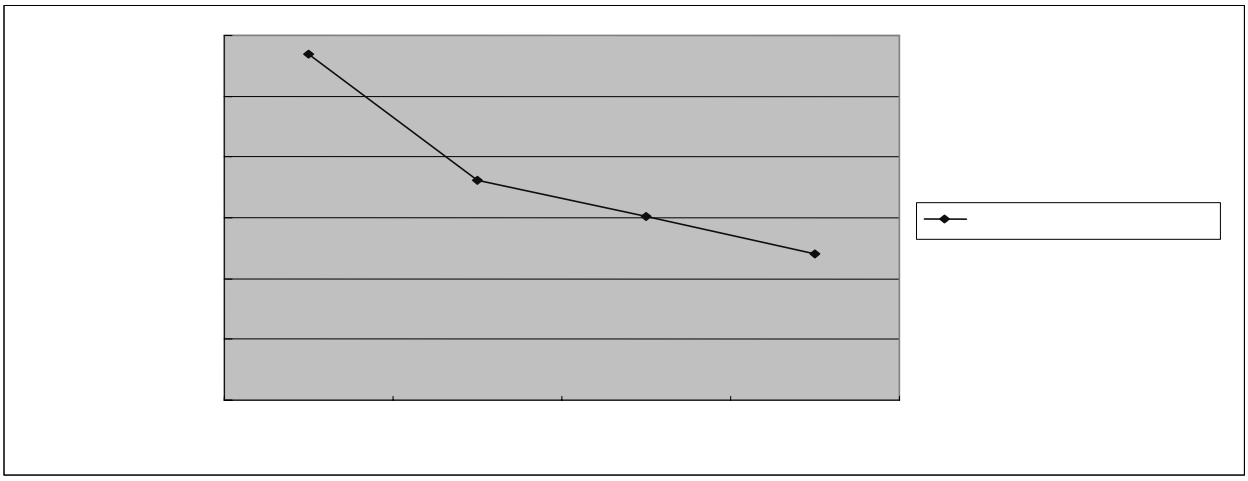

Fig 3 Average Trip of Cost Sensitive Analysis Per Trip

To stand on the analysis of the effect of average trip costs of Taipei metropolitan, when the BRT trip increase 10%, the average trip cost per km will reduce NT$ 0.45 and the average trip cost will reduce NT$ 0.31. According to the analysis of Asian Technical Consultants (2002) there are 13.5 million trips in Taipei everyday, therefore, we can save the trip costs of NT$ 4.19 million per day.

4.3 The Performance Analysis of Bus Rapid Transit in Taipei

According to the BRT trip cost that we have analyzed in the above chapter, we can analyze the performance of BRT in Taipei as an example. In accordance with the materials of Department of Transport, THI Consultants (2003), there are ten BRT lines in Taipei, and the length and the construction fund are showed as Table 18. The construction cost of BRT line in Taipei is NT$ 5.83 million per km, and the BRT trip increase 10% can reduce NT$ 4.19 million social costs. To increase 10% BRT trips need add 0.9km BRT line (the average length of bus line is 9.07 km), probably it need NT$ 5.24 million. BRT system is a kind of efficient transportation system than rail transportation system, it needs low construction costs but bring lots of benefit. Hence, the BRT device is a efficient public transit policy.

Table 18. The Contraction Cost Of BRT Line in Taipei

Item	Road Name	Length (km)	Construction Fund
1	Song-Jiang Rd	3.08	24,823,913
2	Sinsheng S. Rd	3.56	36,652,430
3	Sinyi Rd.	9.0	41,443,415
4	Nanjing E. Rd	8.4	71,177,686
5	Ren-ai Rd	6.2	28,784,389
6	Mincyuan Rd	7.2	39,939,542
7	Dunhua Rd	3.15	21,008,092
8	Jhongshan Rd	7.0	12,025,244
9	Ren-ai Rd(E)	2.4	10,938,838
10	Mincyuan Rd(W)	1.28	11,963,624
Average Cost(km)			5827134.25

Source: THI Consultants Inc (2003)

5. CONCLUSION

In this study, we analyzed effects of BRT with a view point of total trip cost. We have also discussed the transportation policies and proposed improvement strategies related.

1. In the establishment of the trip cost models, all the transportation modes were included. We have also considered the feeder trip of metro in this study. We divide all trips in urban area into three main categories which were then divided into 43 types of trip chains.

2. In the analysis of trip costs in Taipei Metropolitan, we have found that the highest use ratio includes automobile and motorcycle and that they have the largest number of trip and the longest trip length. In the aspect of the policies, our society has provided too much subsidy for private transportation, and it has caused the costs that private transportation users should pay are comparatively lower than they have paid. In order to resolve these problems, we can establish reasonable tax and fee policies, e.g. air pollution tax,

congestion fee and some tolls. We can also limit the convenience of road user, e.g. limiting private transportation users to enter some region and decrease private transportation road use space.

3. In the calculation of the basic facility costs and externality costs, we quoted the reference to measure these costs, and we transferred the data by local GDP and exchange rate. But if we can calculate these two costs by more accurate methodology. These research and investigation works are worth further exploring.
4. According to the analysis of this study, the trip cost of bus rapid transit reduces NT$ 2.87 per km than bus trip and NT$ 14.49 per trip. To stand on the analysis of the effect of average trip costs in Taipei metropolitan, when the BRT trip increase 10%, the average trip cost per km will reduce NT$ 0.45 while the average trip cost will reduce NT$ 0.31. According to the analysis of ATC (2002), there are 13.5 million daily trips in Taipei, therefore, we can save the trip costs of NT$ 4.19 millions per day in total. The analysis has verified the performance of reducing the social costs by using bus rapid transit.

5. In accordance with the sensitive analysis of the percentage of BRT trip, the construction cost of BRT line in Taipei is NT$ 5.83 millions per km, and the BRT trip increase 10% can reduce NT$ 4.19 millions social costs. To increase 10% BRT trips, it needs to add 0.9km BRT line (the average length of bus line is 9.07 km), probably it need NT$ 5.24 million. BRT system is a kind of efficiently transportation system than rail transportation system, it needs low construction costs but bring lots of benefit. Hence, the BRT is a cost-effective public transit policies. Actually, many countries still think that the rail transportation is the best way to solve the transportation problems, and this viewpoint will cause many new problems. Therefore, we should review our transportation policies again, and implement BRT policies to solve urban transportation problems.

6. The facility costs concern about the extensive scopes. If we can estimate the road wastage made from each transportation mode, based on the use frequency and the trip length that used by each mode, the results will be more exactly. This subject is also worth further studying.

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