A Cost-Benefit Analysis of Bus Rapid Transit System in the Taichung City, Taiwan

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Abstract: This study aims to identify some possible issues and challenges for Taichung's Bus Rapid Transit (BRT) system, which was first BRT system in Taiwan and was constructed and is operated under a framework of sustainable development. This study first presents Taichung's BRT system development and the description of fundamental parameters. Second, this research conducts an ex post cost–benefit analysis (CBA) of this transportation system. Finally, the integration between BRT and various existing transportation modes is discussed, called integrated rapid transit (IRT). Several policy suggestions are included, which are useful for the decision makers of transportation systems' entrepreneurs, the central and government, and the local authorities to derive a comprehensive post-BRT planning strategy for a more integrated transportation system. In addition, the experience of Taichung's BRT can give a different thinking of local authorizes and planner for other similar cities in the world.

Keywords: Bus rapid transit, Cost benefit analysis, Integrated rapid transit, Taichung city

1. INTRODUCTION

Bus Rapid Transit BRT, can be defined as a "flexible, rubber-tired form of rapid transit that combines stations, vehicles, services, running ways and information technologies into an integrated system with strong identity" (Levinson, Zimmerman, Clinger, Gast, et al., 2003).
The expression BRT was initially used in 1966 in a study for the American Automobiles Association by Wilbur Smith and Associates (Levinson, Zimmerman, Clinger, Rutherford, et al., 2003). The first full featured BRT was implemented in Curitiba, Brazil, in 1982 (Lindau, Hidalgo, & Facchini, 2010). This application was adapted to transit corridors in places like Quito (1995), Bogotá (2000), Los Angeles (2000), Mexico City (2003), Jakarta (2004), Beijing (2005), Istanbul (2008), and Guangzhou (2010) (Hidalgo, in press). The influence of Bogotá has been particularly relevant; the Trans-Milenio BRT System is the most powerful BRT reference for planners and practitioners worldwide (Gutierrez, 2010).

Table 1. Regional distribution of BRT and bus corridors as 2011

	Cities	Corridors	Km	Stations	Buses	Passengers/day
Africa	3	3	62	93	463	390000
Asia	33	85	1306	1658	6590	6289531
Europe	25	32	291	609	781	629369
Europe/Asia	1	2	43	33	300	700000
Latin America	33	91	1345	2717	19239	17691945
Oceania	5	12	324	142	1411	345800

North America	20	57	993	1485	1993	1013901
Total	**120**	**282**	**4364**	**6737**	**30777**	**27060546**

Source: EMBARQ BRT/Bus Corridors Database (2011)

Most cities with BRT, introduced them since 2000. Bus Rapid Transit (BRT) – a high-quality, efficient, bus-based mode of public transport – can shorten commuting times, reduce greenhouse gas emissions, and generally improve quality-of-life for city residents. Today, more 120 cities around the world use BRT and busway systems. New cities are concentrated in China, followed by Indonesia, and the Latin American region (Hidalgo, in press). Just in 2010-2011, 19 cities introduced BRT. In addition 7 cities expanded existing systems, adding 125 km, a 3% increase in the length of existing systems worldwide.

Bus Rapid Transit (BRT) has been one of the most cost-effective mechanisms for cities to rapidly develop a public transport system that can achieve a full network as well as deliver a rapid and high-quality service (ITDP, 2007). Nowadays, BRT is one of the most popular public transportation in the world (Tiglao et al., 2007; Jaensirisak and Klungboonkrong, 2009; Munawar et al., 2009; Tan et al., 2009; Wachi et al., 2009).

The Taichung City is located in central Taiwan. The government plans to construct BRT to reduce the congestion in the urban area. The Taiwan Avenue is the most crowded road in Taichung City. The congestion problem has not been solved although traffic signal re-timing plans have been implemented at least four times. The Blue Line of the BRT along the avenue is the first priority alternative to alleviate the congestion.

To make the first BRT line successful, we proposed the concept of “SPEED” to design the line. SPEED is the acronym of Sustainability, Passion, Excitement, Evolution, and Dream. This paper introduces the interests of the design works focus on BRT priority signal.

2. REASONS BEHIND THE EXPLOSIVE GROWTH OF BRT

Bus Rapid Transit has been one of the most cost-effective mechanisms for cities to rapidly develop a public transport system that can achieve a full network as well as deliver a rapid and high-quality service (ITDP, 2007). Nowadays, BRT is one of the most popular public transportation in the world (Tiglao et al., 2007; Jaensirisak and Klungboonkrong, 2009; Munawar et al., 2009; Tan et al., 2009; Wachi et al., 2009).

BRT is expanding rapidly as a transit option due to its low cost, rapid implementation and high performance and impact (Hensher, 1999; Hidalgo, in press; Wright, & Hook, 2007). Systems costs are a fraction of those of comparable rail systems. BRT can be implemented rapidly as well, which make the systems attractive to political leaders willing to complete systems before the next election cycle (Hidalgo & Carrigan, 2010).

The successes of Curitiba, Bogota, Mexico, Ahmedabad, Guangzhou, and other cities, are also helping decision makers in developing cities to adopt BRT concepts. Implementation in developed countries has been slower due to preferences of planners and decision makers for rail systems, and compliance with planning and funding regulations, including extensive public participation processes. One difficulty is lack of sufficient examples and information in developed countries.

Performance and impact of BRT is also high. Hidalgo (2012) describes the maximum values observed for indicators like commercial speed, capacity and productivity. Some of the figures are beyond those indicated in transit manuals and textbooks, which creates skepticism among planners. The figures are supported by special design features, like level of segregation,

intersection priorities, platform length, vehicle length and number of doors, boarding level, prepayment and opportunity of overtaking, and information technologies.
Regarding impacts, most systems have showed better performance than the bus operations they replaced, regarding passenger demand, user satisfaction, travel time, reliability, and externalities such as reductions in air pollutant and carbon emissions and crashes and improved urban environments (Diaz & Hinebaugh, 2009; Gutierrez, 2010; Hidalgo, in press; Wright & Hook, 2007). Concerning comfort, most systems in developing countries use very high occupancy standards (Hidalgo & Carrigan, 2010). These standards are not comfortable. Critics of BRT often cite comfort issues when comparing bus systems with rail.
BRT do not have a single meaning and image e a broad spectrum of applications, from improved bus service on mixed traffic to totally segregated systems, are considered BRT (Hidalgo, in press). There is a need to refine the definition and create categories based on objective performance measures to improve the understanding among planners and decision makers. There are ongoing efforts by researchers to create such categories.
Despite the growing evidence, idiosyncratic considerations are still dominant in the public debate regarding transit options. BRT is still often regarded as a “second best” as compared to rail alternatives without a fair evaluation or alternatives analysis (Finn et al., 2011; Gutierrez, 2010; Hensher, 1999; Hidalgo, in press). The political economy is often favorable to those candidates offering rail alternatives as part of their proposals in electoral debates.

3. CHARACTERISTICS OF THE TAICHUNG BRT SYSTEM

Taichung City is located in central Taiwan and occupies an area of 2,214 square kilometers. Its officially registered population is 2,720,000 with a population density of 1,223 persons per square kilometer. Due to its advantageous geographical location, it is a transportation hub for those traveling to and from northern and southern Taiwan. Although the general public can easily engage in various transportation behaviors of their own free will, there has been rapid growth in the number of private vehicles. Taichung City has the highest private vehicle ownership rate in Taiwan (373 cars and 606 motorcycles per 1000 habitants), leading to congestion on urban roads, intensified noise and air pollution, and deterioration of living quality.
The government plans to construct BRT to reduce the congestion in the urban area. The Taiwan Avenue is the most crowded road in Taichung City. The congestion problem has not been solved although traffic signal re-timing plans have been implemented at least four times. The Blue Line of the BRT along the avenue is the first priority alternative to alleviate the congestion.
To make the first BRT line successful, we proposed the concept of “SPEED” to design the line. SPEED is the acronym of Sustainability, Passion, Excitement, Evolution, and Dream. This paper introduces the interests of the design works focus on BRT priority signal. The relative design feature of Taichung BRT could see the Table 2.
The stations are designed to locate in the curbside of the express lanes. The same reason guides the stations setback from the stop lines rather than the far-side or near-side principles. The number of lanes will be preserved by resizing the width of lanes and slightly cutting the dividers and medians. The preservation harmonizes the supply of road area for mixed traffic and BRT vehicles, and diminishes the impacts on the level of service along the avenue.
After long periods of debate and discussions, Taichung City finally decides to build BRT to solve the congestion problem along the Taiwan Avenue. The construction follows the abstract design concept of “SPEED”. The distinguishing features include 1) stations that are designed for practicability, aesthetics and environmental awareness; 2) ITS to increase fleet operation

efficiency; 3) BPS that are not randomly activated; 4) roadway reform that slightly impacts mixed traffic; and 5) vehicles of special designs. Supporting measures consist of shuttle loop bus planning, left-turn prohibition along the Taiwan Avenue, resource integration among the administrative authorities.

Table 2. Taichung BRT design feature

BRT Feature	**Taichung BRT (1st phase Blue Line)**
Year system commenced	The beginning of 2014
Length of trunk corridors (km) 1st phase	17.2
Location of busway lanes	Curbside of express lanes
Location of doorways	Curb side (right)
Number of stations	21
Average spacing between stations (m)	820
Number of terminals	1
Number of depots	1
Number of total system passenger-trips per day	53,700
forecasted peak ridership (passengers per hour per direction)	7,890
Average commercial speed (km/h)	23
Average peak headway (minutes)	3
Average non-peak headway (minutes)	6
Average dwell time at stations (seconds)	40
Number of trunk vehicles	44
Trunk vehicle type	Bi-articulated
Trunk vehicle capacity	120~158
Type of fare collection / verification technology	Smart card and token
Number of intersections with priority signal control	57
Number of grade-separated intersections	0
Fare (US$)	0.73 (smart card), 1.4 (otherwise)
Total infrastructure cost (US$)	67 million

After operating Taichung BRT, our research did also 508 effective questionnaires for BRT survey and the improvement of BRT performance before/after the project. For used mode of users before BRT, there is 24% using the private motorized vehicles. In other words, the BRT effectively attracted the part of private motorized vehicle use. For the reasons of using BRT, the first priority is cheap fare, the second priority is convenient transfer, third priority is schedule on time and forth priority is the frequent headway. Thus, this result could support that the improved performance of public transport can attract private motorized vehicle use and also increase the quality of road service.

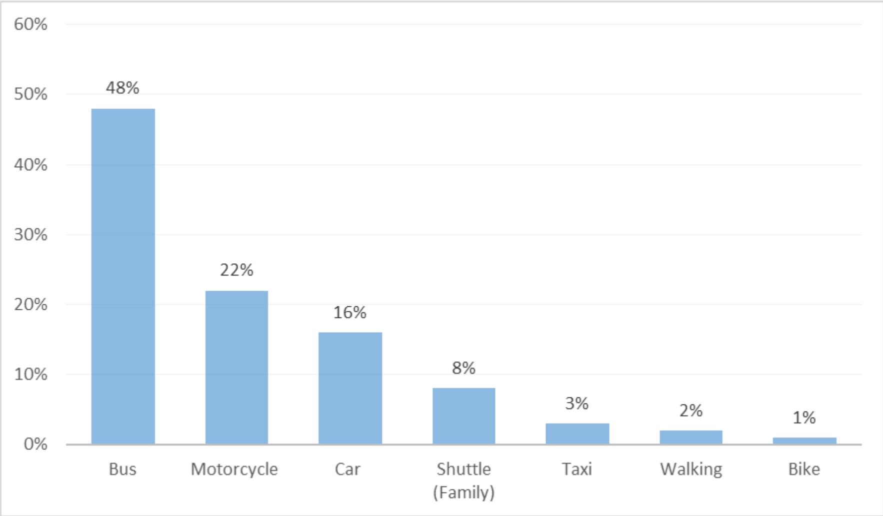

Fig. 1. The mode use before the BRT project (BRT users)

4. COST-BENEFIT ANALYSIS OF THE BRT

The cost benefit analysis is a general methodology in the public infrastructure project. In 1808, Minister of finance Albert Gallatin suggests to compare the water resources by cost-benefit analysis. In the end of 20 century, the cost benefit analysis had been widely utilized by government in countries in order to make the decision of important policy of infrastructure projects. The cost benefit analysis is an analysis tool of invest probability. This analysis method aims at evaluate the optimal application of limited resource. In economic angle, it has to choose the project which could reach a biggest of net social benefit. Under the constant of social cost, it has to seek the biggest social benefit.

The externality brought about by BRT needs to be further examined in order to evaluate the real value of BRT. De Rus and Inglada (1997) described comprehensively the methodology framework to conduct the cost–benefit analysis of introducing transit system. The social benefits of introducing transit system are generated by travel-time savings and the generation of travel. Nash (1991) also concluded that time savings, accident cost savings, and a reduced need for new infrastructure in alternative modes are the main benefits from the introduction of a Bus rapid transit.

This study refers to the approach of De Rus and Inglada (1997) in order to examine the BRT associated costs and external benefits of Taichung BRT as follows:

- Costs and revenues of the construction and operation of the project.
- Variation in costs and revenues of other transport operators.
- Time savings for BRT users.
- Time savings for road users due to the reduction of traffic congestion.
- Reduction of traffic accidents.
- Other environmental impact.

Fig. 1 indicates the introduction of the BRT leading to the reduction of the generalized cost for users of traditional bus over a certain distance. The initial generalized cost of a bus (g_t) composed by the bus fare (P_t) and the value of total journey time $\left(g_t - P_t\right)$ falls to g_h, which is the generalized travel cost of BRT.

The derived social benefits from this reduction in generalized cost can be expressed as

$$(g_t - g_h) \cdot q_t + \frac{1}{2}(g_t - g_h) \cdot (q_h - q_t) + P_h \cdot q_h - P_t \cdot q_t - (C_h - C_t) \quad (1)$$

These benefits are equivalent to the shaded are as in Fig. 2, from which the net cost of obtaining such benefits must be subtracted: the introduction of BRT (C_h) and savings derived from the closure of traditional bus services (C_t).
The social benefits of introducing BRT are generated from two major components: the benefits to existing travelers and the benefits to new travelers. The social benefits to existing travelers (q_t) are derived from time savings for passengers and can be obtained for travel diverted from other modes due to the travel time savings generated by BRT. The social benefit thus can be estimated by the time reduction in access, egress, and travel times, and multiplied by the value of time. These benefits to existing travelers are thus equivalent to the areas of the rectangles $g_t beg_h$ and $P_h fjP_t$.

The benefits to new travelers $(g_t - P_t)$ in Fig. 2 make up the area below the demand function $(bdq_h q_t)$ less the area of the rectangle $(edif)$ representing consumed travel time. The benefits to new travelers can be broken down into two components: the first component, rectangle $(fiq_h q_t)$ in Fig. 2, is obtained from the revenue from this travel $(q_h - q_t) \cdot P_h$ and the second component, triangle (bde), is half the difference of the generalized costs for generated travel as following :

$$\frac{1}{2}(g_t - g_h) \cdot (q_h - q_t).$$

This methodology is valid for bus, with some adaptations for the car as detailed in and Coto-Milla´n et al. (2007).

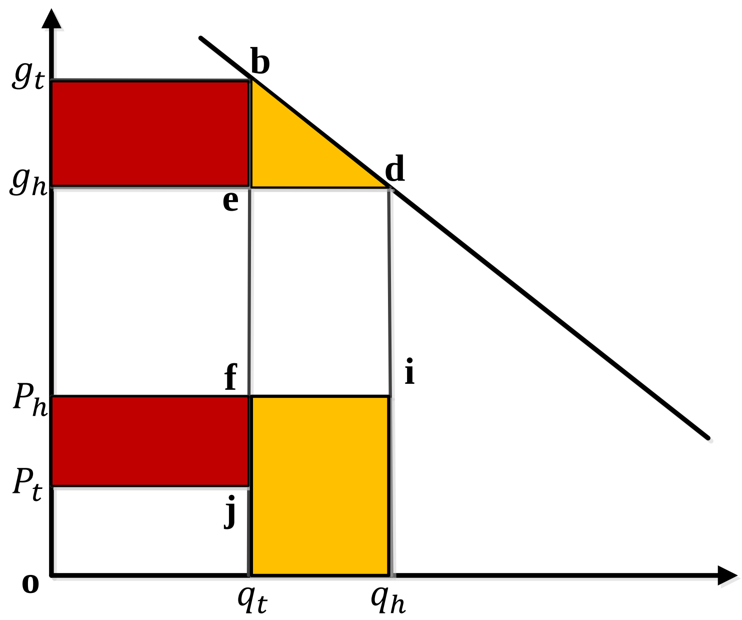

Fig. 2. BRT benefits from conventional train and bus users

The cost–benefit analysis is implemented based on the information regarding demand, cost, the value of time, and accident values with data provided by the Taichung city government and the IoT (Institute of Transportation). This study uses the cost and benefit information to estimate the net present value (NPV) of the BRT project during a 28-year period, under a GDP

increase of 2% and a discount rate of 6%. The costs of Taichung BRT can be classified into fixed, semi-fixed, and variable costs. Fixed costs include the construction cost of infrastructure and maintenance cost. Semi-fixed costs include the acquisition of rolling stock and the variable costs that correspond to the operating costs subject to demand evolution. NPV can be estimated by using the following formula:
Here, the first addend accounts for the net present value of the benefits and the second accounts for the value of the costs. The NPV of each year can be estimated by Eq. (1) from 2011 to 2038 in our case of Taichung BRT. The NPVs of each year includes two main components: a financial appraisal and an economical analysis. The major difference between these two approaches is the benefits considered. A financial appraisal estimates the NPVs considering only the BRT's financial benefits, and an economical analysis considers not only financial benefits but also the social benefits. The benefits of every year are accumulated from value of year 2011 to that year (the running total up to that year).

$$NPV = \sum_{t=1}^{n} \frac{B_t}{(1+R)^t} - \sum_{t=1}^{n} \frac{C_t}{(1+R)^t} \quad (1)$$

Based on the analysis of NPV, it could evaluate Benefit-Cost Ratio (B/C ratio). When R is greater than 1, it means the present social benefit is bigger than the present social cost, thus the net social benefit is certainly positive. The B/C ratio can be estimated by Eq. (2).

$$R = \frac{\sum_{t=0}^{N} B_t / (1+r)^t}{\sum_{t=0}^{N} C_t / (1+r)^t} \quad (2)$$

Besides the NPV and B/C ratio, it can evaluate the feasibility of infrastructure investment by Internal Rate of Return, (IRR). IRR means the value of discount rate under the condition of zero for net present benefit (NPV=0). When IRR > discount rate, it means that the output of project is greater than the input of resource ($\rho > r$). The IRR can be estimated by Eq. (3).

$$\sum_{t=0}^{N} \frac{B_t - C_t}{(1+\rho)^t} = 0 \quad (3)$$

5. THE RESULT OF ANALYSIS ON CBA OF TAICHUNG BRT

As for the result of analysis on cost-benefit analysis for Taichung BRT, it could be divided into 2 parts, as BRT costs and benefits, as following:

5.1 Evaluation of BRT costs

1. The fundamental description of parameters
   - Development duration from 2011 to 2014 (The construction duration about 3.5 years), the Taichung BRT project began to operate from July 2014 from the main train station to the station of Providence University, 17.2 km in total.
   - Evaluation period: refer to the life cycle of related road equipment, the evaluation period is 25 years after construction. Thus, the evaluation period of Taichung BRT

project is assumed from 2014 to 2038, 28 years in total (including the design and construction periods).
- Reference currency: based on the currency in 2011 for our evaluation reference.
- Discount Rate: refer to coupon rate of government bonds for 10 years and other financial risks, adopted 3% as reference rate in our evaluation.
- Growth rate of consumer price index: 2% as reference.

2. The infrastructure costs: the construction charge, including the planning and detailed design charges, for Taichung BRT route from main train station to Providence University, 17.2 km in total, is 1.99 billions NT dollar.
3. Operation cost: refer to actual bus fare, real consumer price index and price fluctuations, the reasonable cost per kilometer of Taichung BRT is 67.6 NT dollars, including the fuel charge, maintenance charge, insurance charge, accident damage, depreciation, driver wage and administrative management charge etc.
4. Replacement cost: refer to electrical equipment and vehicle equipment, it would be renewed based on the life cycle of equipment, as the life cycle of automatic fare collection (AFC) is 12 years, bus priority signal (BPS) and operations control center (OCC) is 15 years, articulated bus is 10 years and the stations and hydropower equipment is 15 years.

The framework of BRT costs could be drawn as Fig. 3. We can make up items of BRT cost and list all costs based on the years, as Table 3.

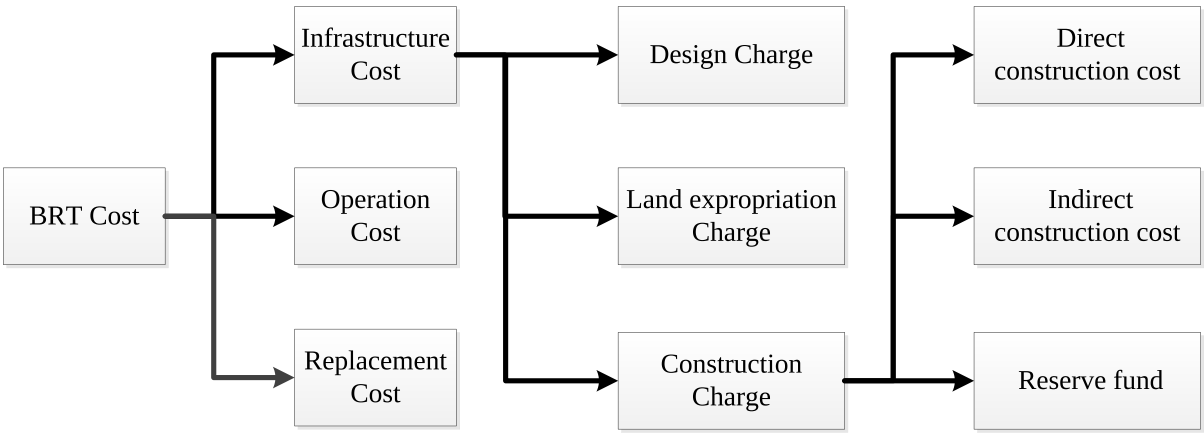

Fig. 3. The framework of BRT costs

Table 3 depicts the costs of Taichung BRT incorporating infrastructure cost, infrastructure maintenance cost, vehicles purchasing cost, and replacement costs.

Table3. Cost of Taichung BRT (NT$)[a]

Year	Infrastructure	Operation	Replacement	Total
2011	28,245,519	-	-	28,245,519
2012	598,650,367	-	-	598,650,367
2013	703,750,856	-	-	703,750,856
2014	906,281,996	105,640,000	-	1,011,921,996
2015		215,510,000	-	215,510,000
2016	-	219,820,000	-	219,820,000
2017	-	224,210,000	-	224,210,000

2018	-	228,700,000	-	228,700,000
2019	-	233,270,000	-	233,270,000
2020	-	237,940,000	-	237,940,000
2021	-	242,700,000	-	242,700,000
2022	-	247,550,000	-	247,550,000
2023	-	252,500,000	-	252,500,000
2024	-	257,550,000	448,741,248	706,291,248
2025	-	262,700,000	-	262,700,000
2026	-	267,960,000	120,000,000	387,960,000
2027	-	273,320,000	-	273,320,000
2028	-	278,780,000	-	278,780,000
2029	-	284,360,000	412,720,000	697,080,000
2030	-	290,050,000	-	290,050,000
2031	-	295,850,000	-	295,850,000
2032	-	301,760,000	-	301,760,000
2033	-	307,800,000	-	307,800,000
2034	-	313,950,000	448,741,248	762,691,248
2035	-	320,230,000	-	320,230,000
2036	-	326,640,000	-	326,640,000
2037	-	333,170,000	-	333,170,000
2038	-	339,830,000	-	339,830,000

[a] The exchange rate is US$1 to NT$32 in 2011

5.2 Evaluation of BRT benefits

The benefit items involves the travel time saving, use cost saving, accident reduction cost saving and air pollution cost saving in our project evaluation, the related parameters are referred to the report of Taiwan Institute of Economics Research (2008) and Institute of Transportation (2010).

- Travel time saving: Congestion is a direct consequence of unmet transportation demand in relation to available road space. Any socio-economic evaluation must clearly distinguish the effects of congestion related to transport, examine the gains or losses of time for vehicles and explore broader functions of roadway. Congestion prolongs trip duration and makes travel planning uncertain. It also increases the need for transport inventory, fuel consumption, and maintenance costs for vehicles, while contributing to air pollution and adversely affecting the quality of life. Congestion cost is inseparable from the value of time since it is measured by valorization of time wasted. In this BRT evaluation, it refers to 127 NT dollar per hour for value of time in BRT project evaluation. According to monitoring the road performance after BRT project, it shows the average speed of slow lane has increased 11~25% and the same of average speed on the fast lane before/after BRT project. Furthermore, the average speed of BRT was also increased 34.5% compared with traditional bus.
- Use cost saving: it is divided into 2 parts- fuel charge and non-fuel charge (including depreciation). Our evaluation of BRT uses the evaluation parameter (NT dollar/km) compared with motorcycle, car and traditional bus. According to monitoring the road performance after BRT project, the ridership of public transport has increased 30%.
- Accident reduction saving: Accidents associated with automobile circulation are another negative externality generated by passenger transport. The evaluation of

this cost is essential for establishing the extent of monetary consequences of accidents through their weight related to other costs. The values recommended were used to estimate the number of persons killed, injured and property damage in monetary terms. The gross hazard costs are obtained by applying the standard values of all costs (22.17 million NT dollars for those killed, 0.59 million NT dollars for the injured and 0.14 million NT dollars for property damage).

- Air pollution reduction saving: Pollution can affect either a defined geographic area or an entire region. Air pollution, with the exception of the greenhouse effect, comes from several emissions sources within different ranges, which can be distinguished as the following two types of pollution. Regional pollution: These are caused by nitrogen oxides, which travel by wind and can reach inhabited areas on their own. Thus, the harmful level is the same across the region. Local pollution: These are caused by hydrocarbons or carbon monoxide. The effects are primarily local. The harmfulness tends to appear only in the urban areas and decreases in the suburbs. Our evaluation refers to the data source from Environmental Protection Administration to calculate the air pollution reduction saving after the Taichung BRT project.

The framework of BRT benefit can be drawn as Fig. 4. We can evaluate the different benefits based on the related parameters and currency in reference year. Then, we list all the value of benefit in accordance with years, as Table 4.

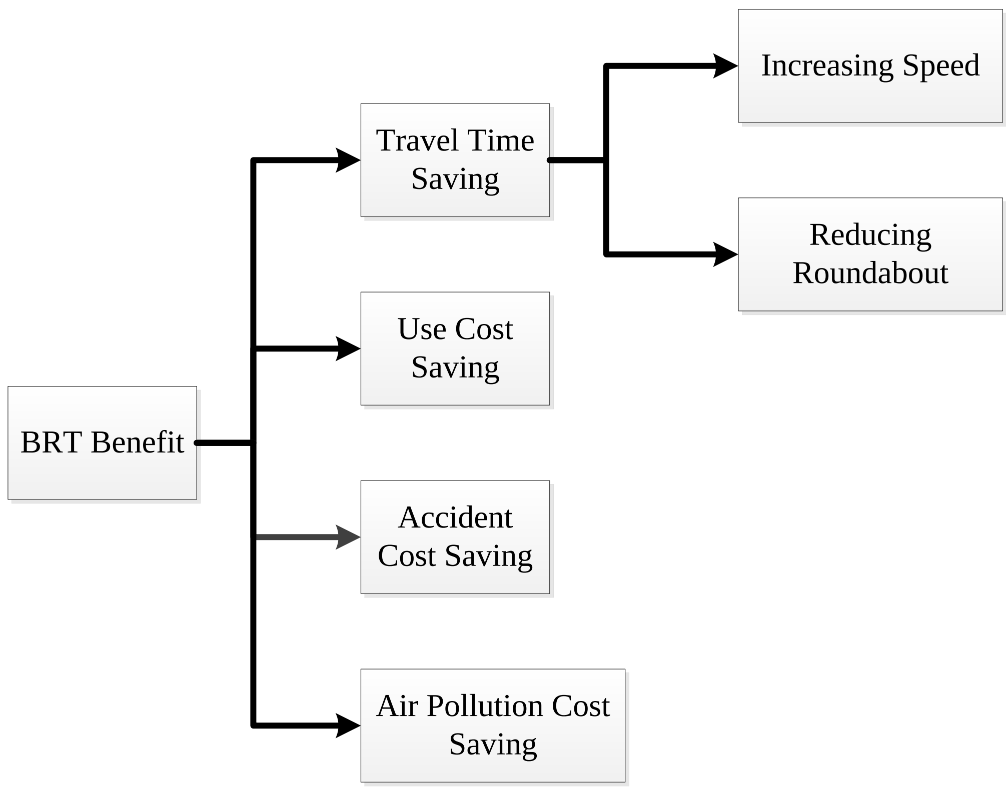

Fig. 4. The framework of BRT benefits

Table 4 indicates social benefits of Taichung BRT including the time savings from the transportation modes, generated BRT traffic, human life savings from road accidents, and reduced pollution emission from the reduced private motorized vehicles after the BRT's revenue operation started from 2014. The project life of Taichung BRT is assumed to be 28 years until 2038. Taichung BRT's revenue operation started from 2014, and the BRT financial benefit was thus calculated starting from 2014 in Table 4. Figures regarding values of time are from the research report of Taichung city government (2011). Values of time include NT$120 in 2008 value per hour and NT$127 in 2011.

Table 4. Benefits of the Taichung BRT (NT$)

Year	Time saving	Use cost saving	Pollution	Accident	Total economic benefit
2014	134, 745, 165	102, 391, 197	3, 082, 134	5, 368, 638	245, 587, 134
2015	282, 964, 846	215, 021, 513	3, 236, 241	107, 372, 759	608, 595, 359
2016	297, 113, 088	225, 772, 588	3, 398, 053	107, 372, 759	633, 656, 489
2017	311, 968, 743	237, 061, 218	3, 567, 956	107, 372, 759	659, 970, 676
2018	327, 567, 180	248, 914, 279	3, 746, 354	107, 372, 759	687, 600, 572
2019	343, 945, 539	261, 359, 993	3, 933, 671	107, 372, 759	716, 611, 962
2020	361, 142, 816	274, 427, 992	4, 130, 355	107, 372, 759	747, 073, 922
2021	379, 199, 957	288, 149, 392	4, 336, 873	121, 648, 944	793, 335, 166
2022	398, 159, 955	302, 556, 861	4, 553, 716	121, 648, 944	826, 919, 477
2023	418, 067, 952	317, 684, 705	4, 781, 402	121, 648, 944	862, 183, 003
2024	438, 971, 350	333, 568, 940	5, 020, 472	121, 648, 944	899, 209, 706
2025	460, 919, 917	350, 247, 387	5, 271, 496	121, 648, 944	938, 087, 744
2026	483, 965, 913	367, 759, 756	5, 535, 071	121, 648, 944	978, 909, 684
2027	508, 164, 209	386, 147, 744	5, 811, 824	121, 648, 944	1, 021, 772, 721
2028	533, 572, 419	405, 455, 131	6, 102, 415	121, 648, 944	1, 066, 778, 910
2029	560, 251, 040	425, 727, 888	6, 407, 536	121, 648, 944	1, 114, 035, 409
2030	588, 263, 592	447, 014, 282	6, 727, 913	121, 648, 944	1, 163, 654, 732
2031	617, 676, 772	469, 364, 996	7, 064, 309	141, 756, 213	1, 235, 862, 290
2032	648, 560, 611	492, 833, 246	7, 417, 524	141, 756, 213	1, 290, 567, 594
2033	680, 988, 641	517, 474, 908	7, 788, 400	141, 756, 213	1, 348, 008, 163
2034	715, 038, 073	543, 348, 654	8, 177, 820	141, 756, 213	1, 408, 320, 760
2035	750, 789, 977	570, 516, 086	8, 586, 711	141, 756, 213	1, 471, 648, 988
2036	788, 329, 476	599, 041, 891	9, 016, 047	141, 756, 213	1, 538, 143, 627
2037	827, 745, 950	628, 993, 985	9, 466, 849	141, 756, 213	1, 607, 962, 997
2038	869, 133, 247	660, 443, 684	9, 940, 192	141, 756, 213	1, 681, 273, 336

[a] The exchange rate is US$1 to NT$32 in 2011

Table 5 shows which year the net present value (NPV) can turn to be greater than zero during the life of the project. The evaluation is carried out at prices for 2011, because this is when rolling stock purchasing was commenced and large-scale Taichung BRT project began. The project life cycle is assumed to be 28 years.

Table 5. Analysis of cost and benefit for Taichung BRT blue line (NT$)[a]

Year	Cost		Benefit		Cash flow	Net Present Value
	Cash flow	Present value	Cash flow	Present value		
2011	28,245,519	0	0	-	-28,245,519	-28,245,519
2012	598,650,367	581,213,949	0	-	-598,650,367	-581,213,949
2013	703,750,856	663,352,678	0	-	-703,750,856	-663,352,678
2014	1,011,921,996	926,051,975	245,587,134	224,747,017	-766,334,862	-701,304,957
2015	215,510,000	191,477,844	608,595,359	540,729,094	393,085,359	349,251,250

2016	219,820,000	189,618,663	633,656,489	546,597,654	413,836,489	356,978,991
2017	224,210,000	187,772,345	659,970,676	552,715,051	435,760,676	364,942,706
2018	228,700,000	185,954,029	687,600,572	559,082,188	458,900,572	373,128,159
2019	233,270,000	184,145,492	716,611,962	565,700,100	483,341,962	381,554,608
2020	237,940,000	182,361,197	747,073,922	572,569,954	509,133,922	390,208,757
2021	242,700,000	180,591,593	793,335,166	590,315,869	550,635,166	409,724,276
2022	247,550,000	178,835,387	826,919,477	597,384,224	579,369,477	418,548,837
2023	252,500,000	177,098,420	862,183,003	604,717,812	609,683,003	427,619,392
2024	706,291,248	480,949,972	899,209,706	612,318,054	192,918,458	131,368,083
2025	262,700,000	173,675,648	938,087,744	620,186,511	675,387,744	446,510,864
2026	387,960,000	249,016,761	978,909,684	628,324,876	590,949,684	379,308,115
2027	273,320,000	170,323,988	1,021,772,721	636,734,979	748,452,721	466,410,992
2028	278,780,000	168,666,485	1,066,778,910	645,418,785	787,998,910	476,752,300
2029	697,080,000	409,461,033	1,114,035,409	654,378,392	416,955,409	244,917,359
2030	290,050,000	165,411,462	1,163,654,732	663,616,034	873,604,732	498,204,571
2031	295,850,000	163,804,972	1,235,862,290	684,266,986	940,012,290	520,462,014
2032	301,760,000	162,210,869	1,290,567,594	693,743,676	988,807,594	531,532,806
2033	307,800,000	160,638,512	1,348,008,163	703,515,351	1,040,208,163	542,876,840
2034	762,691,248	386,449,362	1,408,320,760	713,584,508	645,629,512	327,135,146
2035	320,230,000	157,531,940	1,471,648,988	723,953,785	1,151,418,988	566,421,845
2036	326,640,000	156,005,083	1,538,143,627	734,625,962	1,211,503,627	578,620,879
2037	333,170,000	154,489,172	1,607,962,997	745,603,964	1,274,792,997	591,114,791
2038	339,830,000	152,987,747	1,681,273,336	756,890,856	1,341,443,336	603,903,109
Total	10,328,921,234	7,140,096,577	25,545,770,422	15,571,721,683	15,216,849,188	8,403,379,587

We can observe the result of evaluation by NPV, IRR and B/C ratio, see Table 6, all signs shows us that the project of Taichung BRT blue line merit to invest, although this project may deprive of some road space for motorized vehicle users. According to our questionnaires after operating BRT project, the service satisfaction of BRT surpassed than the traditional bus. Furthermore, the frequent headway, the stability of operation and schedule on time are three first priority factors on the BRT project.

Table 6. The result of evaluation on the Taichung BRT blue line

Evaluation index	Taichung BRT	Description of analysis result
Net present value (NPV)	NT$ 8,403,379,587	NPV >0
Internal return rate (IRR)	16%	IRR > discount rate (6%)
Benefit cost ratio (B/C Ratio)	2.18	B/C > 1

6. CONCLUSION

Taiwan is small an island it has high population density. Therefore, city planning in particular with road construction faces many restrictions and road path are often complicated. Although the general public can easily engage in various transportation behaviors of their own free will, there has been rapid growth in the number of private vehicles. Taichung City has the highest private vehicle ownership rate in Taiwan, leading to congestion on urban roads, intensified noise and air pollution, and deterioration of living quality. Decreasing usage of public transportation resulted in poor service quality and insufficient number of routes. This led to further reduction in the willingness of the general public to use public transportation, or, in other words, a vicious cycle. When bus service appears to be inconvenient and non-economical, the public's willingness to travel by bus is adversely affected. As a result, the planning and construction of BRT system can provide a more efficient and friendly transportation service in order to attract the motorized vehicle users to transfer to public transportation use.

Throughout our analysis result, the BRT system has some advantages compared with Tramway and Metro, like a shortest construction time, a cheapest investment of infrastructure. Moreover, BRT has an elasticity due to using a traditional bus, simple engineering and polybasic planning of operation routes. Thus, many cities in the world have chosen BRT as the major system in the urban transportation development and also leaded in a new finance model, called Transit Oriented Development (T.O.D.) in order to successfully satisfy the sustainable financial development.
According to the analysis result of our studying, the net present benefit of Taichung BRT is greater than zero, the internal return rate is greater than discount rate and finally the cost benefit ratio is greater than 1. All of estimating results indicate this project of Taichung BRT is the benefit higher that the cost. For sustainable development in cities, if this high performance system could implemented in the cities, perhaps it can solve the problems of traffic congestion, noise and air pollution etc. Besides, through by the distribution of road space in the BRT project, the transportation based human can effectively be realized. The urban environment will became more livable and sustainable.
BRT has come a long way since the development of the concept in the late 1960s and initial implementations of high level applications in Brazil in the1980s. It is now a feature inabout120cities worldwide, with explosive development concentrated in developing countries. The rapid growth has been sparked by its intrinsic low cost and rapid implementation. Several applications show high performance and impact fostering its replication in other cities. Nevertheless there are outstanding issues that need to be solved as well as institutional and financial constraints, not necessarily associated with BR. The BRT Industry heard the wake-up call in the early 2000s (Hensher, 1999), but is still in its infancy and needs coordinated work toward its consolidation. There are good academic and professional initiatives, but there is still a long way to go.
Taichung BRT was malevolently interrupted from 2015 cause of political factor after local election in the end of 2014. The performance and benefit of BRT system still merits to clearly and objectively expounded in order to provide a reference and thinking for the similar cities in the development of urban public transportation.

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