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The Bus Rapid Transit System in Taipei City —ridership forecast for the New Light Industrial area in Neihu

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Abstract

This paper aims to explore the related issues of Bus Rapid Transit (BRT) and forecast the ridership in the New Light Industrial Area in Neihu, where the BRT will be implemented. First of all, it briefly discusses the current development of BRT system in Taipei City. The performance of BRT system is illustrated based on the figures derived from official reports. Secondly, this paper forecasts a transferring ridership from the MRT to BRT for Neihu, a district of Taipei City using disaggregate model of mode choice. The results show passengers tend to ride the MRT system and transfer to BRT based on a foundation of substantially upgraded bus system performances. Finally, this paper proposes a set of feasible strategies for creating an ameliorated public transportation environment, which will ensure a sustainable transportation development in Taipei City.

1 Introduction: the necessity of building a convenient bus system

Bus systems provide a versatile form of public transportation with the flexibility to serve passengers throughout metropolitan area. However, traffic congestion, urban sprawl, and air pollution have deteriorated the level service, due to the conspicuous traffic growth in Taipei metropolitan area last decade. As a result, fewer passengers would to take buses as the level of service kept declining, due

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to the cumulative effects of traffic congestion, traffic signals, and long boarding time. Therefore, it is a crucial issue to build up a convenient, high quality public transportation system.

This paper outlines the history and BRT development in Taipei City, and forecast ridership for a new light industrial area in Neihu, a district of Taipei City if the BRT strategy can be implemented there. Finally, a set of a set of feasible strategies for creating an ameliorated public transportation environment is proposed, which will ensure a sustainable transportation development in Taipei City.

2 Current bus system development in Taipei City

The bus system in Taipei used to play an essential role of the public transportation throughout Taipei area. It used to be the most convenient public transportation system in Taipei metropolitan area and reached its peak at 950,114 thousand passenger in 1985, which was 2.6 million passengers on average per day (Table.1). However, the boomed economy and the abolishment of ban on imported automobiles, cause the conspicuous growth of traffic.

Bus Rapid Transit (BRT) network schemes were proposed have been implemented in Taipei City as the concept was drawn as a policy to balance citizens' mode choice in Taipei City. Seven exclusive bus lanes were firstly constructed with great efforts casting various barriers aside (Table 2) in 1996. This policy made bus a more attractive transportation mode by allowing passenger transferring much more conveniently from MTR. It has reduced private mode form 66% in 1996 to 46% in 2000 (Fig.1). An official investigation shows that the bus priority network in Taipei City has successfully drawn back about 13% passengers, and increased the bus driving speed from 5-15 km/hour to 11-20 km/hour on bus exclusive lanes. On other hand, the disorder mixed traffic is greatly improved as the car and bus traffics are separated (Photo1, 2 and3).

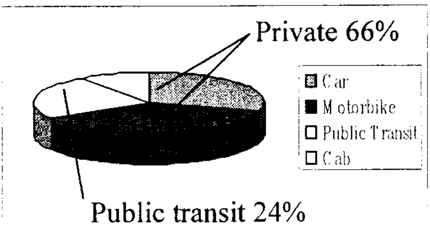

Fig.1. Mode choice of Taipei City in 1996

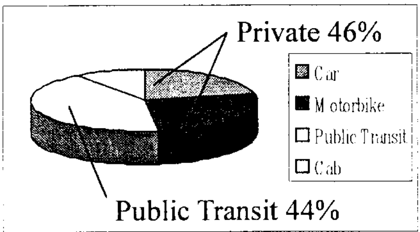

Fig.2. Mode choice of Taipei City in 2000

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Table 1. The capacities of Taipei City Bus system

Items	Total Passenger (thousand)	Average Passenger Per Day
1985	950,114	2,603,053
1991	781,843	2,142,036
1995	640,148	1,753,829
1999	722,607	1,979,745
2000	679,345	1,856,135

Table 2. List of Bus Priority Lanes in Taipei City

Exclusive Bus Lanes	**Length**	**Flows**	**Dates of Opening**
North Sec. of 9th Ave.	1.5km	Concurrent flow	1996.1
South Sec. of 9th Ave.	1.8km	Concurrent flow	1996.6
2nd Blvd.	9.0km	Concurrent & Contraflow	1996.7
3rd Blvd.	6.2km	Concurrent & Contraflow	1996.7
7th Blvd.	8.4km	Concurrent flow	1996.7
9th Blvd.	9.9km	Concurrent flow	1996.8
12th Ave.	3.2km	Concurrent flow	1996.8
4th Ave.	2.0km	Concurrent flow	2001.1
2nd Ave.	1.9km	Concurrent flow	2001.3

Source: http://www.tcc.taipei.gov.tw/index.htm

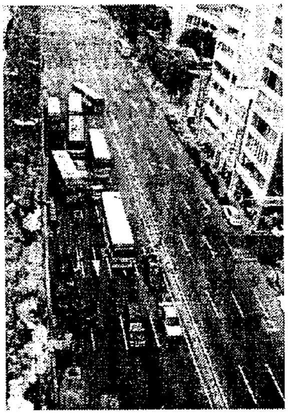
Photo 1. before

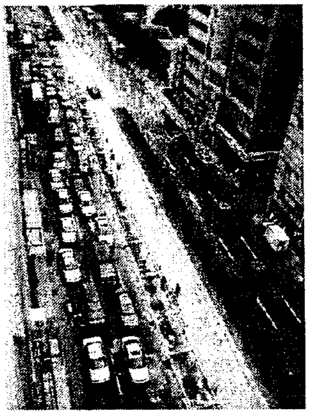
Photo 2. constructing


Photo 3. after

3 Introduction of New Light Industrial District in Neihu

The New Light Industrial Area is in Neihu District of Taipei city. There are several important developed projects, which are in process in this area. Those projects will enable the Neihu Light Industrial Area to be a multi-function commercial area and industrial park, including entertainment and media district,

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high-tech industrial park, high quality riverside residential area, and warehouse and wholesale district in future.

88.6% bus passengers think the bus service need to be improved, and the items of bus service that need to be improved are:
(1) Arise in the bus frequency (63.8%); (2) Provide door to door service by transferring between MRT station and the destination (54.0%); (3) Increase bus routes (49.7%); (4) Increases mini bus service (20.1%).

Table 3 presents the results of the alternatives priority of the commuters' mode choices. The results show that the most private mode users are willing to choose the public transportation when the private modes are not available.

Table 3 Commuters' Alternatives Priority

<table>
<tr><th rowspan="2">Mode Choice</th><th colspan="3">Alternatives Priority</th></tr>
<tr><th>1</th><th>2</th><th>3</th></tr>
<tr><td>Auto</td><td>Taxi
31.8%</td><td>Bus
29.5%</td><td>Motorbike
17.1%</td></tr>
<tr><td>Motorbike</td><td>Bus
53.3%</td><td>MRT
12.1%</td><td>Taxi
12.1%</td></tr>
<tr><td colspan="4">There are 40%-65% automobile and motorbike users, who are willing to use the transit mode (such as Bus, MRT) when the automobile and motorbike modes are not available.</td></tr>
</table>

4 A disaggregate model of mode choice

The purpose of this section is to develop the basic relation for the mode choice in this area. It primarily identifies the mode choice changes if the BRT strategies are implemented in Neihu Light Industrial District. The results will be used to evaluate the possibility of implementing the BRT strategies. The planning for BRT facilities in this area could take these results into consideration.

4.1 Data collection

The data is derived from two studies, "The Midterm Report of Strategies of Sustainable Transportation for Taipei City—The Case Study of the Light Industrial Area in Neihu" and "the study of Comprehensive Transportation System Planning for Taipei Metropolitan Area." The first report collected questionnaires based on computer-assisted design from a random sample of commuters from the Light Industrial Area in Neihu. The data acquired focus on socioeconomic variables of the commuters in this area, including gender, age, location of home base, and the information on mode choice behavior. The second data source is derived from "The study of Comprehensive Transportation System Planning for Taipei Metropolitan Area, acquired the information on various characteristics for each type of transportation mode, including mode-operating cost per km and average speed in the network of each transportation mode, etc.

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4.2 Description of the data

The data verify some of the findings. The mode choice results are shown as Table 4 and 5. The primary and second modes chosen are automobile and motorbike at 65.3 %. The MRT and bus use account for 33.1% of the five-mode total. It is also shown in Table 4 that the taxi, motorbike, and bus modes can be chosen for general work trips to the Light Industrial Area in Neihu. Table 5 shows that there are two or three alternatives for work trips.

Table 4. Actual mode choice market share in Neihu Light Industrial Area

Mode	Actual mode choice	Percentage (%)	Alternatives	Percentage (%)
Auto	113	35.0	131	40.6
Taxi	5	1.6	246	76.2
Motorbike	98	30.3	227	70.0
Bus[1]	76	23.5	258	79.9
MRT[2]	30	9.6	59	18.0
Total	322	100.0	919	284.7

Table 5. Num. of alternative distribution

Num. of Alternatives	Sample size	Percentage (%)
2	110	34.0
3	152	48.3
4	40	14.9
5	10	2.8
Total	322	100.0

4.3 Study method

The paper will forecast the mode choice behavior with five modes by the approach of Multinomial Logit Model. It is the most widely used function for transportation demand analysis, as well as mode choice.

The five alternative modes are considered including automobile, taxi, motorbike, bus (with walking access), and MRT (with bus access). Variables of the model are shown in Table 6. The probability of choosing one mode depends on these explanatory variables. We can get that the utility function of travel time, travel cost, mode dummy variables and the location of passengers' homes. For example, the negative coefficient of travel time indicates that when time spent in a particular mode decreases, the probability of choosing that particular mode increases, while the travel cost stays the same. When the coefficient of travel cost is negative, it means that there is a higher the travel cost and a lower probability of choosing that particular mode. Dummy variables allow attractiveness of a particular mode trip to differ from that of other mode trips for

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reasons other than travel cost and travel time. The variable of the location of passengers' home measures the effect of the automobile use in CBD. When the automobile is chosen, it causes the roads to be more crowded and increases travel time or travel costs.

Table 6. Explanatory variables in MNL

Variables	Explain
Auto mode constant	= 1 for auto alternatives, = 0 otherwise
Taxi mode constant	= 1 for taxi alternatives, = 0 otherwise
Motorbike mode constant	= 1 for motorcycle alternatives, = 0 otherwise
Bus mode constant	= 1 for bus alternatives, = 0 otherwise
Location of home	If the commuters live in the CBD use auto frequently, it may cause the crowded roads, even increase the travel time and travel cost that auto used will be affected.
Travel time	Minutes one-way from origin to the destination, including in-vehicle time, waiting time and walking time to destination and origin (for auto alternatives)
Travel cost	NT dollars one-way from origin to destination, including transit fare, parking fee, gasoline, or taxi fare for all alternatives

4.4 Result of the estimation

Estimated results are shown in Table 8, in which each variable is discussed. The variables used in the mode choice model are significantly higher in Rho-square value, while travel time, travel cost, and dummy variables are processed.

Travel time is negative; it indicates that an increase in travel time will decrease utility of all alternative modes. The negative sign for the coefficient of the travel cost variable indicates that an increase in travel cost will decrease utility of alternative modes.

Travel time have a high time-value of approximately NT$4.69 per minute. This result indicates that travel time is decisive factor for choosing a transportation mode for work trips.

A dummy variable for the alternatives is notable. The positive sign for the Automobile constant variable indicates that people are more likely to choose automobile as a travel mode. Indeed, those people value the greater comfort, privacy and safety of this mode.

The living environment variables, such as location of home, have negligible effects on mode choice behavior for works trips in this model.

All alternative modes utility functions are shown in (2), (3), (4), (5), (6).

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$$U_{auto} = -0.06137 \bullet TT_1 - 0.01245 \bullet TC_1 + DUM_1 \quad (2)$$

$$U_{taxi} = -0.06137 \bullet TT_2 - 0.01245 \bullet TC_2 + DUM_2 \quad (3)$$

$$U_{motor} = -0.06137 \bullet TT_3 - 0.01245 \bullet TC_3 + DUM_3 \quad (4)$$

$$U_{bus} = -0.06137 \bullet TT_4 - 0.01245 \bullet TC_4 + DUM_4 \quad (5)$$

$$U_{MRT} = -0.06137 \bullet TT_5 - 0.01245 \bullet TC_5 \quad (6)$$

Table 7. Estimates Coefficients of the MNL

Variable	Coefficient (t-statistic)
Travel time (TT)	-0.0600 (-2.6)
Travel cost (TC)	-0.0128 (-1.6)
Auto mode constant (DUM_1)	0.8571 (2.2)
Taxi mode constant (DUM_2)	-2.032 (-1.8)
Motorcycle mode constant (DUM_3)	-0.8175 (-2.2)
Bus mode constant (DUM_4)	-0.6808 (-1.4)
Location of home (CBD)	0.02465 (0.7)
LL(0)	-328.1868
LL(θ)	-175.2745
LL(M)	-234.2382
ρ^2	0. 4659
ρ_M^2	0. 2517
Sample size	322

Notes: LL(0) = log likelihood at zero
LL(θ) = log likelihood at convergence
LL(M) = log likelihood at constant

ρ^2: = likelihood ratio index $1 - \frac{LL(\theta)}{LL(0)}$ ρ_M^2 = likelihood ratio index: $1 - \frac{LL(M)}{LL(0)}$

4.5 Test based on conditional choice

The disaggregate model is suitable for forecasting the shifts in mode choice resulting from different policies that have been implemented. We utilized the model of Table 7, and calculated the probabilities of each mode for alternative strategies practiced in the future. These probabilities are summarized in Table 8, while the initial market share we obtained in the sample is on the first row.

Assume that the local government implements the BRT strategies such as exclusive bus way, the bus speed will increase form 11.37 km per hour to 14.27 km per hour. The results are shown in second row (Condition 1). The strong gainers are the bus system and MRT; and the biggest losers are automobile and motorbike. The increase in bus speed is corresponded to a lower probability of choosing either the automobile or the motorbike.

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If the BRT strategies are implemented, bus fares will rise from NT$12.7 to NT$14.625. The rate rise from 0.565 NT$/km to 0.845 NT$/km, and MRT and bus fares will be integrated (basic fare is NT$17.1: the rate is 1.81 /NT$/km) as shown in Row 3(Condition 2). The cost to passengers will remain about the same. These conditions also cause the greatest effect on the share of bus and motorbike. Compare the results of the second strategy with the third strategy. The share of bus is reduced by 0.72%, and the probability of choosing MRT will increase by 0.16%.

The empirical results show that the effect of various travel times and travel costs in mode choice. The market share of bus increases by 8%. This illustrates that if the local government implements a public transportation friendly policy in the area, there will be a higher probability of public transit.

The information was derived from the study of Comprehensive Transportation System Planning for Taipei Metropolitan Area. It surveyed bus speed, before and after the transit ways constructed in Taipei city.

Table 8. Market share sensitivities on condition choice (%)

Condition	Auto	Taxi	Motorbike	Bus	MRT
Base case	35.0	1.6	30.3	23.5	9.6
Condition 1	31.98	1.17	24.25	31.56	11.04
Condition 2	32.07	1.2	24.69	30.84	11.2

- MRT Neihu Line will be soon under construction.
- The statistics shown contain mean MRT ridership plus bus transfers.

5 Sustainable Transportation Development Strategies

In this section, a set of Sustainable Transportation Development Strategies is proposed. These strategies can ensure Taiwan urban area to develop toward sustainable transportation.

(1) Public Transit Interchange (PTI)

Through well-designed public transportation interchanges, passengers can rapidly transfer to other transportation modes (Fig.3). As "public transportation" has been adopted as one of the prime policies, we shall pay attention to intermodal transportation linkage. However, poor performance is widely found, as different transportation modes are not integrated due to the rigidity of administrations, as well as departmentalism. Therefore, we are trying hard to encourage different departments work together on establishing PTI, we believe it will make a difference.

(2) Public Private Partnership (PPP)

Due to the difficulties of acquiring sufficient land and considerable capital for transportation systems, PPP has been considered to be one of the best solutions for the public constructions. With teamwork between public and private sectors, efficiency and revenue of operation can be immensely enhanced.

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(3) Transferring Bus System
Transferring bus system combined with the MRT line needs to be provided in order to efficiently expand the hinterland service scope of the MRT. Moreover, a convenient feeder bus system can also encourage the usage of public transportation, reduce the car usage at the same time. However, some of the bus routs are still overlapping and competing with the MRT, this causes the inefficiency of source. Therefore, reintegrate the bus routes and MRT is necessary.

(4) Applying Intelligent Transportation System (ITS)

a. Dynamic Information Systems
BRT and feeder bus system facilitated with the renovated Dynamic Information System are able to allow passengers to foresee the arrival time of their buses. It has been a tremendous progress for innovation as it reduces the passengers' perceptional waiting time, while other passengers have to insist waiting without knowing the bus arrival time.

b. Contactless IC Smart Cards Ticketing Systems
Both of the present MRT and bus cards are non-compatible and only suitable individually. Moreover, the present contact cards are neither convenient nor efficient for using in the crowded peak hours due to high transaction time. Accordingly, contactless IC smart cards are more useful in saving transaction time and its convenience will encourage public transportation usage.

(5) Creating Humane Environments for Pedestrians and Cyclists
To promote public transportation, we must provide a door-to-door service by create a comfortable and continuous sidewalk both for pedestrian and cyclist. Taipei City Government is now working hard to sweep away all the barriers including motorcycle parking and vendors on pedestrian sidewalk, and trying to establish a comfortable and continuous pedestrian sidewalk system.

6 Concluding remarks and suggestions

This paper reviews the Bus Rapid Transit development and its achievement in Taipei, and constructs a model forecasting the ridership in Neihu Area, in which light industrial makers and some high tech manufacturers are widely developing.

(1) This study shows that the transportation demand will rapidly grow as soon in the area and private automobile usage will boom, contributed with both the present lack of MRT line and poor bus service during the rush hours. The result of the forecast shows that quite a certain level of drivers would like to give up cars if convenient and rapid public transportation is available.

(2) Departments such as Traffic Planning, Urban Development and Mass Rapid Transit should cast the departmentalism and be more active to coordinate each other in order to cooperate together establishing sustainable environment for the future development. The department should allow denser development and diversify the land use along the public transportation

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corridor. The department of Mass Rapid Transit should consider transferring system for passengers, and build up an internalized, comfortable and rapid transferring environment while designing the MRT stations.

(3) This paper also proposes a set of strategies, which can ensure Taiwan urban area to build up a long-term sustainable transportation development. To apply these strategies can also lead Taiwan to gradually develop toward sustainability.

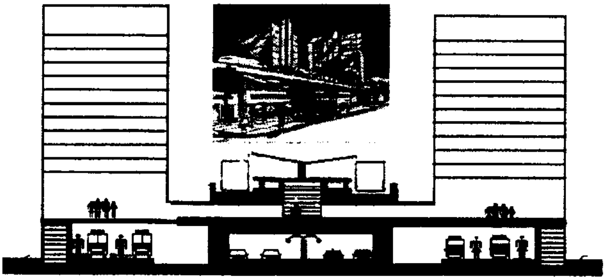

Fig.3. The concept of the PTI

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