BENEFIT ANALYSIS OF FARE DISCOUNTS FOR TRANSFERRING BETWEEN PUBLIC TRANSPORT MODES

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ABSTRACT

Discounts are one of the most important marketing strategies for increasing market share. Promoting mode sharing in public transport contributes to sustainable urban transportation. However, whether fare discount significantly promotes use of public transportation remains controversial. This study analyzes the determinants of travel behaviours for urban commuters in Taipei, Taiwan. After identifying the crucial influences on mode sharing, a nested logit model is estimated to optimise fare discount for passengers transferring between public transport modes as well as to optimise shared financial responsibility of stakeholders benefiting from the fare discount strategy. The analytical results indicate that a positive profit exists if the transfer discount is less than half the bus fare, i.e. seven New Taiwan dollars (NTD) per trip. Excluding the external effects concerned by government, the fare discount strategies result in each public transport operator having negative profit. This implies that the fare discount should be regarded as a policy for mitigating negative externalities rather than a marketing strategy for operators. Moreover, government, mass rapid transit operators and bus operators underwrite the cost of the fare discount at 61.92%, 16.55% and 21.53%, respectively, under the optimal fare discount of four NTD per trip.

Keywords: fare discount, nested logit model, cost-benefit analysis

INTRODUCTION

Providing sufficient urban transportation infrastructure and services is a key issue for most metropolitan areas worldwide. Urban transportation in large cities typically comprises a mix of public transport modes, including: guided mass rapid transit (MRT) systems, buses as well as taxis, and private vehicles, such as automobiles, motorcycles and bicycles. Asian cities have experienced fundamental socio-economic changes resulting from increased population and use of private vehicles. Actually, the relationships between rising incomes, extensive car ownership, and improvements in road network have increased private vehicle use (Asensio, 2002). The rapid growth of private vehicle ridership has negatively impacted quality of life through increases in accidents, travel time, natural resource consumption, congestion, and environmental damage. However, comparing current urban transportation demand patterns with those in recent decades reveals a remarkable increase in private vehicles use as well as a continuous decline in the market share of public transport (Pucher and Lefèvre, 1996). Because promoting mode sharing of public transport encourages sustainability in urban transport, it is essential to determine an efficient and effective approach for improving mobility, accessibility and environmental quality, by enhancing urban public transport design (Alterkawi, 2006).

Before evaluating the performance of invested public transport infrastructures, the factors influencing travel mode choice should be identified. Moreover, a consensus exists that improving usage of public transport assists in solving metropolitan congestion. Hodgson et al. (1997) suggested that motorists would switch to public transport if bus services are promoted appropriately. Previous studies concluded that investment in rail offers the best solution to public transport problems (Hensher and Waters II, 1994; Kain, 1988). Furthermore, many cities utilize bus-based systems as legitimate alternatives to rail systems (Wright and Hook, 2006) owing to the lower associated risks, including less potential for cost overruns, and greater responsiveness to forecast demand (Hensher, 2007).

In fact, Hine and Scott (2000) argued that seamless public transport is designed to make public transport more attractive and user friendly via improvements to service quality, reliability, safety and infrastructure. Transfer between public transport modes thus has become a significant part of the move towards seamless travel by public transport (Steer Davies Gleave, 1998). Besides integrating land use and transport planning, Ibrahim (2003) determined that MRT and bus networks should be integrated to reduce duplication of service, and reduce transfer barriers, with consequent modifications made to transfer facilities including bus-shelters and link-ways, advanced traveller information systems, and ticketing systems.

Reducing transfer costs is an important issue in seamless transport. Discounting is most effective strategies for increasing market share. Additionally, transfer costs stimulate demand for public transport including both monetary costs as well as time spent waiting and transferring between vehicles. However, whether fare discounting significantly affects increased use of urban public transport is controversial. Accordingly, a prototype model is constructed to analyze the impact of fare discounting for transfer between public transport modes on the determinants of travel behaviours for urban commuters in Taipei, Taiwan. After identifying the crucial factors which influence the mode share, a nested logit model is estimated to evaluate an optimal fare discount for passengers transferring between public transport modes, as well as the financial responsibility shared by stakeholders benefiting from the fare discount strategy. The background of seamless public transport system development in the Taipei metropolitan area is illustrated in the next section, after which the methodology and data collection are described in detail. The empirical results of the disaggregated choice model are then expressed in section 4. Finally, section 6 presents conclusions and future research directions.

BACKGROUND TO SEAMLESS PUBLIC TRANSPORT IN TAIPEI

To obtain a baseline of bus ridership, a relational analysis without external impacts, such as served MRT systems, fare discount strategies, and seasonal factors, is employed to explain trends in bus ridership in the Taipei metropolitan area from 1986 to 1995. Figure 1 illustrates that during this period bus ridership decreased by 46%, from 926 to 640 million trips annually. Currently, almost two-thirds of commuters use private vehicles to complete trips and buses are rapidly losing share to private vehicles.

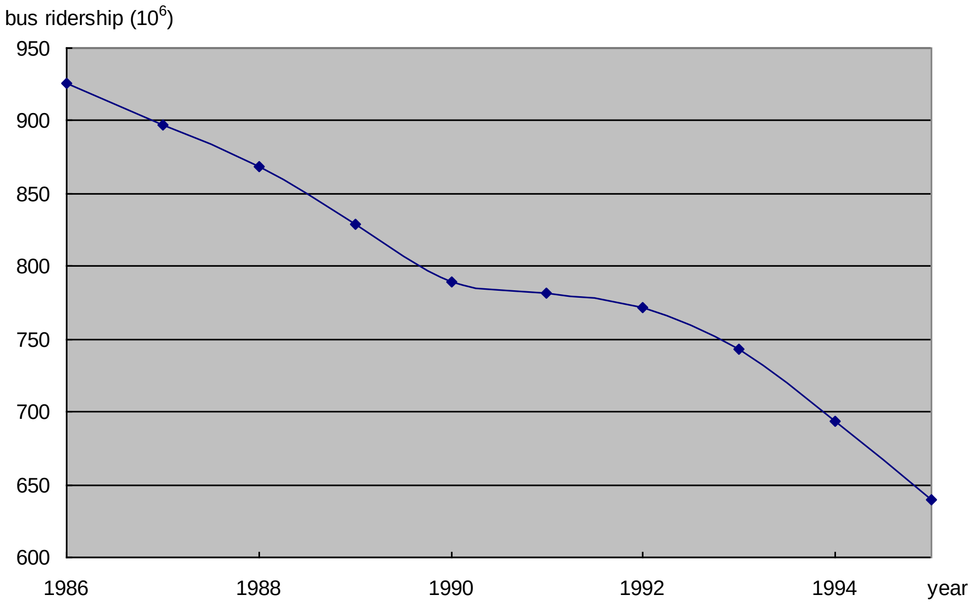


Figure 1 – Bus ridership trend baseline

Taipei's first MRT line started service on Mar. 28, 1996, and was intended to provide an alternative to bus travel. MRT ridership has steadily increased since the introduction of the service, except in 2003 when it declined steeply in response to Severe Acute Respiratory Syndrome (SARS). Notably, Figure 2, indicating the opposite in downward trend of bus ridership from 1996 to 1999, reveals that MRT and bus services possess a complementary rather than substitutive relationship. A preliminary study using an intervention model of time series analysis was undertaken to determine the critical influences on public transport ridership. Along with disasters, the operational length of the MRT and long-term transfer discount significantly increase public transport ridership.

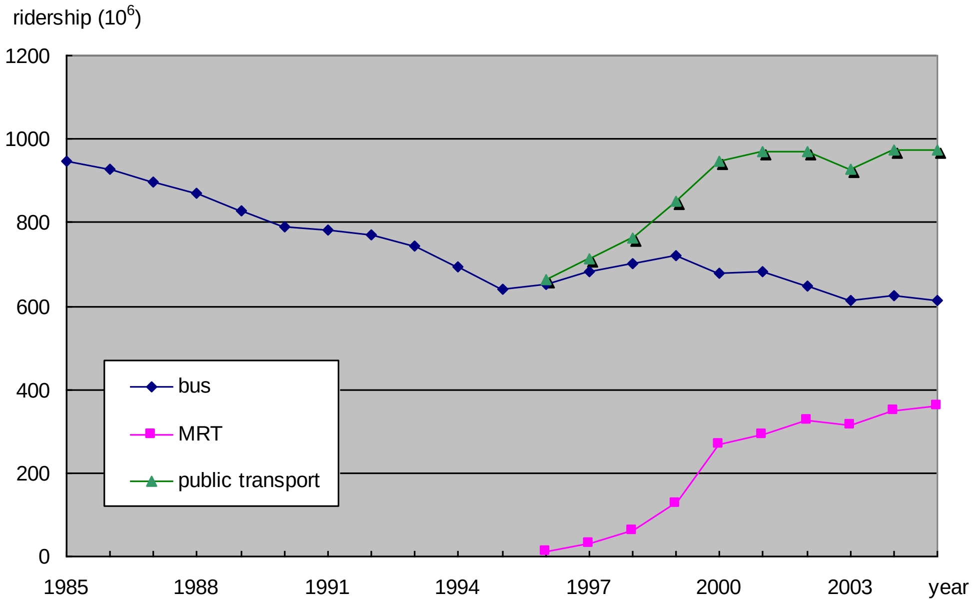


Figure 2 – Public transport ridership

Three main types of fare discounting for transfer between the MRT and buses have been adopted since November 1996, namely transfer ticket, pre-paid magnetic card and non-contact EasyCard. The New Taiwan dollar (NTD) is employed as the monetary unit. In fact, NTD 1 is equivalent to USD 0.0304 approximately. Table 1 summarises four strategies in three discount types and their effectiveness. Due to separate ticketing systems existing prior to the availability of EasyCard, three of four strategies discounted the cost of one-way transfer from MRT to bus. Although the grown rates of transfer ridership, listed in the last column in Table 1, represented positive proportion to fare discount through transferring, it is difficult to identify the isolated impact of transfer discount from compound effects related to MRT operational length and feeder bus routes. In fact, transfer ridership increased by just 31.71% for the two-way discount strategy without infrastructure improvement. Accordingly, this study employs a discrete choice modelling approach to investigate the impact of transfer discount on the choice behaviours between public transport modes.

Table 1 – Historical transfer discount strategies

Initiation	Type	Direction	Discount amount (NTD)	Growth rate (%)
Nov. 1996	Transfer ticket	One-way: from MRT to bus	4	7.58
Apr. 1997	Transfer ticket	One-way: from MRT to bus	7	109.00
Jul. 1999	Magnetic card	One-way: from MRT to bus	15	254.37
Nov. 2003	EasyCard	Two-way	8×2=16	31.71

RESEARCH APPROACH

The discrete choice model has been extensively adopted to analyze the selection of one among a set of alternatives by a decision maker who is a household or an organisation - such as a firm or government agency (Schmöcker et al., 2006; García and Hernández, 2007; Frenkel, 2007; Espino et al., 2007; Dubin, 2007; Hensher and Rose, 2007; Wong et al., 2008). The principle of utility maximization assumes that an individual facing multiple discrete choices from a universal but finite number of alternatives will select the alternative with the highest utility. The discrete choice model may not be the newly advanced methodology. However, it is an appropriate approach to easily determine the user behaviours through the economic rationality. The utility of each alternative consists of an observable component and a random error term. Let subscripts n and j represent individual $n = 1, 2, \cdots, N$ and alternative $j = 1, 2, \cdots, J$, respectively. The utility function of alternative j for individual n can be expressed as Equation 1.

$$U_{jn} = V_{jn} + \varepsilon_{jn} \tag{1}$$

where U_{jn} indicating the marginal utility associated with alternative j for individual n comprises an observable component of utility, V_{jn}, related to each alternative j for individual n, as well as a random component ε_{jn}. Linear-in-parameter utility functions are usually employed due to their computational simplicity and ease of interpretation in parameter estimates (Tsai et al., 2007). Equation 2 shows the observable component of utility involving a vector of exogenous variables x_{jnk} associated with different attributes $k = 1, 2, \cdots, K_j$ associated with each alternative j and their parameter estimates β_{jk}.

$$V_{jn} = \sum_{k=1}^{K_j} \beta_{jk} \times x_{jnk} \tag{2}$$

Moreover, the random components of utility ε_{jn} are assumed to possess an independently and identically extreme value type I distribution. In the decision process, individual n ranks penalty combination i higher than non-i if $U_{in} > U_{i'n}$. Equation 3 defines the logit probability of individual n choosing alternative i, $P_n(i)$.

$$P_n(i) = \Pr(U_{in} \geq U_{i'n}) = \frac{\exp(V_{in})}{\sum_{j=1}^{J} \exp(V_{jn})} \tag{3}$$

Equation 3 exhibiting the independence of irrelevant alternatives (IIA) property is inadequate when alternatives are correlated. The nested multinomial logit (NL) model is thus obtained under the assumption of a generalized extreme value distribution for the random term. The NL model is appropriate when the alternative set faced by a decision-maker can be grouped into nests in which the IIA property holds for alternatives within the same nest and does not hold for alternatives belonging to different nests. A two-stage NL specified in this study assumed that m refers to nest $m = 1, 2, \cdots, M$ existing in the model with A_m alternatives. Equation 4 indicates the probability of alternative i being chosen in nest m.

$$P_n(i) = P_n(i \mid m) \times P_n(m) = \frac{\exp(V_{in} / \mu_m)}{\sum_{j \in A_m} \exp(V_{jn} / \mu_m)} \times \frac{\left[\sum_{j \in A_m} \exp(V_{jn} / \mu_m) \right]^{\mu_m}}{\sum_{m'} \left[\sum_{j \in A_{m'}} \exp(V_{jn} / \mu_{m'}) \right]^{\mu_{m'}}} \tag{4}$$

where $P_n(i \mid m)$ and $P_n(m)$ denote the conditional probability of alternative i chosen by individual n among A_m in nest m and the marginal probability of using nest m, respectively. Furthermore, μ_m indicates the inclusive value, a correlation of alternatives in nest m. The inclusive value lies between 0 and 1 to ensure consistency with the random utility maximisation hypothesis (McFadden, 1981). The correlation is higher if the inclusive value approaches 0. Conversely, the alternatives are independent if the inclusive value equals 1, e.g. the NL model collapses to the multinomial logit (MNL) specification.

Data Collection

Table 2 – Descriptive statistics for respondent demographics

Factors	Attribute	Frequency (%)
Gender	Male	624 (44.54)
	Female	777 (55.46)
Age	20 or below	101 (7.21)
	21–30	511 (36.47)
	31–40	387 (27.62)
	41–50	224 (15.99)
	51–60	151 (10.78)
	61 or above	27 (1.93)
Personal income (in NTD)	20,000 or below	486 (34.69)
	20,001–40,000	472 (33.69)
	40,001–60,000	346 (24.69)
	60,001 or above	97 (6.93)
Education	Junior high school or below	70 (4.99)
	Senior or vocational high school	328 (23.41)
	College	794 (56.67)
	Graduate school	209 (14.92)
Household cars	0 or 1	945 (67.45)
	2 or more	456 (32.55)
Household motorcycles	0 or 1	649 (46.32)
	2	505 (36.05)
	3 or more	247 (17.63)
Trip purpose	Commute	723 (51.61)
	Business	117 (8.35)
	Social entertainment	291 (20.77)
	Shopping	219 (15.63)
	Others	51 (3.64)

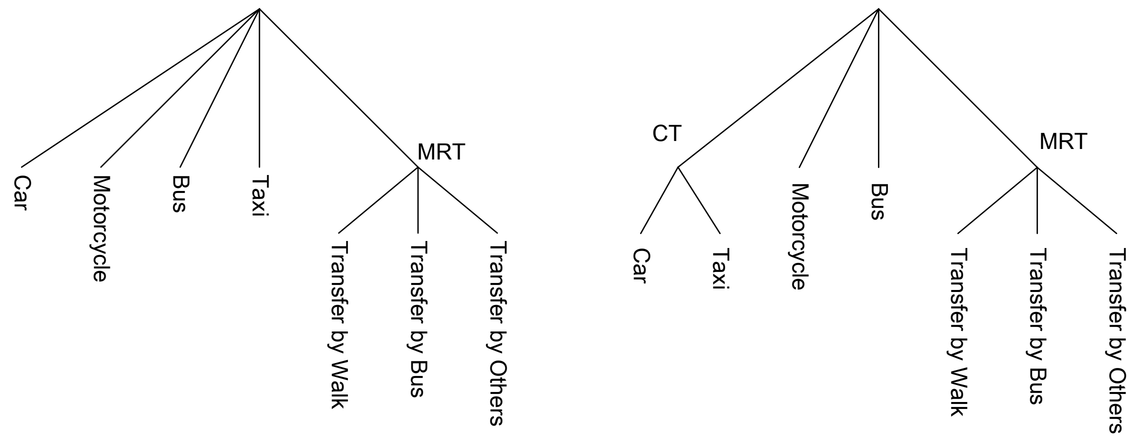
The model was estimated with a revealed preference survey that collected actual trip behaviour data. 1,700 questionnaires were distributed, and a total of 1,545 were returned, giving a response rate of 90.88%. A final sample of 1,401 observations was left after removing captive individuals, namely individuals who only experienced one alternative. Respondents were selected according to a stratified sampling framework with a pre-defined study area. Regarding the individual characteristics influencing modal choice, Table 2 lists the descriptive statistics for respondent demographics, including gender, age, personal income, education, household vehicles and trip purpose.

The alternatives are divided into two categories according to whether users take MRT. Besides four alternatives such as car, motorcycle, bus and taxi, in category one, the transferring between MRT and four mentioned modes as well as walk when users arrive and depart MRT station are considered simultaneously brings 25 ($C_1^5 \times C_1^5 = 25$) alternatives. However, the attributes of some MRT transfer alternatives were highly homogeneous owing to the existence of the similar riding characteristics based on local studies,. The full choice set comprised 25 alternatives, and thus was statistically insignificant due to lack of variability in the selected attributes. This problem is particularly prevalent in revealed preference data (Louviere et al., 2000). Moreover, the alternatives in a choice set should be both known during the decision process and feasible to the decision maker. Since some alternatives have small market share, it is almost impossible for individuals to experience all 29 alternatives. Finally, numerous alternatives and attributes increase computational difficulty and complicate the interpretation of the estimation results. Accordingly, this study simplified the modes into seven categories rather than examining 25 separate alternatives. The final sample comprised 18.42% car users, 29.48% motorcycle users, 26.41% bus riders, 5.50% taxi users and 20.21% MRT riders - of which 11.21%, 5.57% and 3.43% transferred by walking, bus and other vehicles, respectively. Notably, car users were under-sampled, whereas the opposite occurred in the case of taxi users. Consequently, the WESML estimator proposed by Manski and Lerman (1977) was adopted for stratified sampling.

EMPIRICAL RESULTS

In addition to the respondent demographics indicated in Table 2, extensive literature reviews identify travel costs and time as the exogenous variables included in the econometric choice model. Regarding private vehicle trips, trip routes based on origins and destinations were determined via a geographic information system (GIS). Consequently, accurate measurements of trip distances were obtained for private transport modes. The monetary costs borne by private vehicle users are measured as the product of trip distance and travel cost per kilometre. According to the Institute of Transportation (2000) and price fluctuations, integrated travel costs, including average expenses on petrol consumption, tolls, parking, maintenance, insurance and depreciation, are 10.8 and 2.7 NTD per kilometre for cars and motorcycles, respectively. The costs associated with public transport modes were obtained by asking respondents the costs of specific recent trips.

Moreover, travel time includes in-vehicle travel time (IVTT) and out-of-vehicle travel time (OVTT). IVTT includes time private vehicle users spend searching for parking spaces, while the OVTT comprises waiting time, transfer time between public transport modes, as well as walking time to access transport modes. The monetary cost, IVTT and OVTT are determined as generic variables, whereas respondent demographics are identified as alternative specific variables. The final models provide statistically strong evidence of the data quality in numerous multinomial and nested logit models. Detailed analyses of numerous model specifications found considerable robustness in the parameter estimate of the generic variables, in addition to a series of socioeconomic attributes.



(A) NL1 (B) NL2

Figure 3 –Nested logit tree structures

Table 3 lists the estimation results of selected MNL and NL models with tree structures that differentiate MRT and other modes (Figure 3). Two candidate NL models are stood after eliminating unreasonable structures where inclusive value exceeds or insignificantly differs from one.

Table 3 – Summary of empirical results

Attribute	Parameter Estimates (*t*-value)					
	MNL		NL1		NL2	
Alternative Specific Constant						
Car	-0.266		-0.435		-0.557	
Motorcycle	0.021		-0.192		-0.190	
Bus	0.838		0.556		0.548	
Taxi	-2.115		-2.161		-1.771	
MRT – transfer by walking	1.348		1.193		1.151	
MRT – transfer by bus **(Baseline)**	--		--		--	
MRT – transfer by other vehicle	-0.782		-0.425		-0.414	
Generic Variables						
Monetary cost	-0.016	(-7.56)	-0.017	(-9.66)	-0.017	(-10.00)
In-vehicle travel time (IVTT)	-0.117	(-10.79)	-0.105	(-20.07)	-0.103	(-19.89)
Out-of-vehicle travel time (OVTT)	-0.103	(-8.81)	-0.099	(-10.16)	-0.096	(-9.97)
Alternative Specific Variables						
Income – specific to car	0.023	(4.48)	0.023	(4.43)	0.025	(4.90)
Income – specific to taxi	0.047	(5.46)	0.047	(4.83)	0.043	(4.97)
Household motorcycles – specific to MRT transfer by walking	-0.330	(-2.41)	-0.287	(-2.83)	-0.279	(-2.79)
Inclusive value	--		MRT: 0.275(16.30)		MRT: 0.269(16.91) CT: 0.310 (5.84)	
Log-likelihood at zero	-1086.528		-1086.528		-1086.528	
Log-likelihood at convergence	-726.222		-725.128		-724.592	
Likelihood ratio index (rho-squared)	0.3316		0.3326		0.3331	
Sample size	1401		1401		1401	

Analogous to the *t*-test in linear regression, the asymptotic *t*-test was employed to test whether a specific parameter differs from zero. The likelihood ratio test can provide joint tests of several parameters and facilitate assessment of overall difference between models. The likelihood ratio index (rho-squared), a goodness-of-fit measure similar to R^2 in linear regression, was used to compare different model specifications. Based on Table 3, all of the parameter estimates are robust, statistically significant and of the right sign. In fact, all generic variables including monetary cost, IVTT and OVTT significantly negatively impact utilities. This implies that the probability of choosing modes to finish trips reduces with increasing travel cost or time. Besides, the positive impact of income on the utilities of specific modes in car and taxi indicates that, all other things being equal, the probability of choosing car or taxi increases with income. The patterns are consistent with the notion that car and taxi are more premium modes in the Taipei urban transport system. Furthermore, the utility of users who ride the MRT and transfer by walking is negatively correlated with more available motorcycles in households with the lowest absolute *t*-value. As expected, users with more available motorcycles in their household are unwilling to walk to MRT stations.

The NL model considering the relationship between modes in the same nest reflects reality better than the independent alternatives in MNL model. In fact, the null hypothesis of no differences between the MNL and NL models is rejected via the likelihood ratio test at a 95% confidence level. Moreover, the goodness-of fit indices of NL2 regarding the similarity between car and taxi, such as more expenses, less OVTT and more private and comfortable services, are better than those of NL1. The NL2 model, with better specifications, thus is selected as the preferred choice model. Accordingly, the inclusive value parameter of 0.310 for the nest CT involving car and taxi is statistically significant and different from one. Furthermore, the similarity of alternatives in nest MRT reaches 0.731 (1-0.269). Based on the preferred choice model and the adjustment to the trip distance gaps between various modes, the modal shares are estimated as follows: 21.03% car users, 31.83% motorcycle users, 25.11% bus riders, 1.21% taxi users, 11.28% MRT riders transferring by walking, 5.86% MRT riders transferring by bus and 3.68% MRT riders transferring by other vehicles.

Implication for Benefit Analysis

The estimated choice model is used to calculate the trips of each mode and evaluate the benefits associated with various scenarios involving different fare discounts for transferring between transport modes. Through the difference between the trips of each mode differs among the various transfer discount amounts, the external benefits from the decline of private vehicle trips and the operational benefits associated with the increment of public transport mode trips are assessed simultaneously. Total daily trips in the MRT service area are approximately 6.15 million according to the local literature. Accordingly, Table 4 reveals the differences between trips of each mode under the scenarios of transfer discount and the zero-discount alternative based on the estimated choice model. The bus fare is regulated as fixed values, NTD 15, 12, and 8 for adults, students and elders, respectively, for a single fare stage, increasing thereafter for trips comprising multiple fare stages. Currently the implemented transfer discounts are half the bus fare – that is NTD 8, 6 and 4 for adults, students and elders, respectively. Notably, increasing transfer discount and thus reducing public transport costs results in a shift from other public transport modes towards MRT travel with bus transfer, but with an insignificant decline in private vehicle use. Regarding the analysis of cost elasticity, the push force resulting from increasing private vehicle costs impacts trip shifting rather than the pull force from reducing public transport costs.

Table 4 – Differences in trips among different modes

Unit: trips per day

Discount scenario	Car	Motor-cycle	Bus	Taxi	MRT transferring by Walking	MRT transferring by Bus	MRT transferring by Others
NTD 1	-677	-923	-861	-123	-800	6,150	-2,768
NTD 2	-1,415	-1,846	-1,722	-185	-1,600	12,362	-5,597
NTD 3	-2,092	-2,768	-2,583	-308	-2,461	18,635	-8,426
NTD 4	-2,830	-3,752	-3,444	-431	-3,260	24,969	-11,255
NTD 5	-3,568	-4,736	-4,305	-492	-4,121	31,304	-14,084
NTD 6	-4,306	-5,720	-5,166	-615	-4,982	37,700	-16,913
NTD 7	-5,105	-6,704	-6,089	-738	-5,843	44,219	-19,742
NTD 8	-5,843	-7,688	-7,011	-800	-6,704	50,676	-22,633
NTD 9	-6,643	-8,734	-7,872	-923	-7,627	57,257	-25,462
NTD 10	-7,442	-9,779	-8,795	-1,046	-8,488	63,837	-28,291
NTD 11	-8,242	-10,825	-9,717	-1,169	-9,410	70,541	-31,181
NTD 12	-9,103	-11,932	-10,640	-1,230	-10,271	77,183	-34,010
NTD 13	-9,902	-12,977	-11,562	-1,353	-11,194	83,825	-36,839
NTD 14	-10,763	-14,084	-12,485	-1,476	-12,116	90,651	-39,730
NTD 15	-11,624	-15,191	-13,407	-1,599	-13,039	97,416	-42,559

Besides, Chang and Guo (2007) suggested that the external costs for different trip modes, including car, motorcycle, taxi, bus and MRT are NTD 89.73, 78.37, 19.85, 11.77 and 0.15, respectively, per trip. The average revenue per trip achieves NTD 22.16 for MRT and NTD 14.0 for bus. Although the discount scenarios are expressed as the adult fare (the first column of Table 4), the discount amounts for students and elders are adjusted proportionally. Accordingly, Table 5 lists revenues with the fare discount for transferring between public transport modes.

Table 5 – Revenues with the transfer fare discount

Unit: NTD per day

Discount scenario	Reduction in external cost	Increase in bus revenue	Increase in MRT revenue	Total revenue
NTD 1	211,865	74,046	57,239	343,150
NTD 2	429,946	148,953	114,479	693,378
NTD 3	643,373	224,721	171,718	1,039,812
NTD 4	866,761	301,350	231,683	1,399,794
NTD 5	1,088,938	377,979	290,285	1,757,202
NTD 6	1,311,970	455,469	350,250	2,117,688
NTD 7	1,540,510	533,820	412,941	2,487,270
NTD 8	1,764,963	611,310	472,905	2,849,178
NTD 9	1,997,241	691,383	535,596	3,224,220
NTD 10	2,230,234	770,595	599,650	3,600,479
NTD 11	2,464,789	851,529	663,703	3,980,021
NTD 12	2,706,533	931,602	729,119	4,367,254
NTD 13	2,939,169	1,011,675	793,173	4,744,017
NTD 14	3,183,328	1,094,331	859,952	5,137,611
NTD 15	3,425,569	1,176,126	926,731	5,528,426

Table 6 lists the benefits from the fare discount for transferring between public transport modes, expressed in terms of benefit cost ratio (B/C), marginal B/C and financial benefit. The total trip are calculated as the sum of discount amount and number of original undiscounted transfer trips, i.e. 309,468 trips, and the additional transferring trips for each scenario, and this figure is then multiplied by additional transfer trips for each scenario to evaluate the total cost. For the example with a discount of two NTD, $643{,}660 = 2 \times (309{,}468 + 12{,}362)$. Table 5 shows that total revenue comprises positive external effect and financial revenue. From the operator perspective, the fare discount strategies negatively impact profits.

Table 6 – Benefits from the transfer fare discount

Discount scenario	Total revenue*	Total cost*	Financial benefit*	B/C	Marginal B/C
NTD 1	343,150	315,618	-184,333	1.087	1.087
NTD 2	693,378	643,660	-380,228	1.077	1.068
NTD 3	1,039,812	984,309	-587,870	1.056	1.017
NTD 4	1,399,794	1,337,748	-804,715	1.046	1.019
NTD 5	1,757,202	1,703,860	-1,035,596	1.031	0.976
NTD 6	2,117,688	2,083,008	-1,277,289	1.017	0.951
NTD 7	2,487,270	2,475,809	-1,529,048	1.005	0.941
NTD 8	2,849,178	2,881,152	-1,796,937	0.989	0.893
NTD 9	3,224,220	3,300,525	-2,073,546	0.977	0.894
NTD 10	3,600,479	3,733,050	-2,362,805	0.964	0.870
NTD 11	3,980,021	4,180,099	-2,664,867	0.952	0.849
NTD 12	4,367,254	4,639,812	-2,979,091	0.941	0.842
NTD 13	4,744,017	5,112,809	-3,307,961	0.928	0.797
NTD 14	5,137,611	5,601,666	-3,647,383	0.917	0.805
NTD 15	5,528,426	6,103,260	-4,000,403	0.906	0.779

**Note: revenue, cost and benefit are expressed in units of NTD/day*

Additionally, the analytical results of B/C indicate a positive profit if the transfer discount costs less than half the bus fare, i.e. seven NTD per trip. However, the optimal fare discount amount for transferring between public transport modes should be four NTD, where the marginal B/C remains greater than one. Because the financial benefits cannot cover the total costs, the government should offset the additional cost associated with reducing negative externalities. For the optimal solution, government, mass rapid transit operators and bus operators share the revenue from the transfer discount strategy in proportions of 61.92%, 16.55% and 21.53%, respectively.

CONCLUSION

The nested logit model employed in this study may not be the most advanced choice modelling method, but has become the favourite of most researchers. The main contribution of this model is its recognition that improving understanding of disaggregated choice requires as much careful thought about data relevance and quality as it does regarding the econometric sophistication of the travel choice model. This study recognized the continuing practical value of nested logit models, which can relatively easily estimate and interpret behavioural outputs. Increasing transfer discount and thus reducing public transport costs stimulates a shift towards MRT transfer by bus from other public transport modes, while the share of private vehicles decline insignificantly.

The impact of alternative transport policies designed to reverse the observed trend towards increasing private vehicle use could be discussed based on the estimation results. Regarding the analytical results of cost elasticity, the push force caused by increasing private vehicles costs impacts the trip shifting rather than the pull force exerted by reducing public transport costs. In fact, transfer ridership increases only 1.59% under a NTD 15 discount compared to the situation with no fare discount. This implies that internalizing the external costs of private vehicles is the most effective strategy for improving public transport ridership.

From the operator perspective, the financial losses resulting from fare discount strategies imply that fare discounting should be considered a policy to mitigate negative externality rather than a marketing strategy for operators. Besides, the estimation results demonstrate that the current strategy based on a discount of eight NTD is inefficient due to the negative financial and external benefits. The optimal transfer discount is suggested to be four NTD, shared among government, mass rapid transit operators and bus operators at percentages of 61.92%, 16.55% and 21.53%, respectively, based on the distribution of revenues from the transfer discount strategy. The capability of the developed model can be improved through more detailed and comprehensive analysis. Along with user demand analysis, some effective strategies for restraining the use of private vehicles are recommended to incorporate supply side analysis. Furthermore, the capability of the employed model can be improved through more detailed and comprehensive analysis; for example, the destination attributes should be considered in, and compared with other advanced transport models.

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