(4) Future Trip Generations and Attractions

The future trip generations by zone in 2004 and 2025 is shown in Figure 12.3-2. The actual estimation results are available in Section 12.1 of Appendix 12.

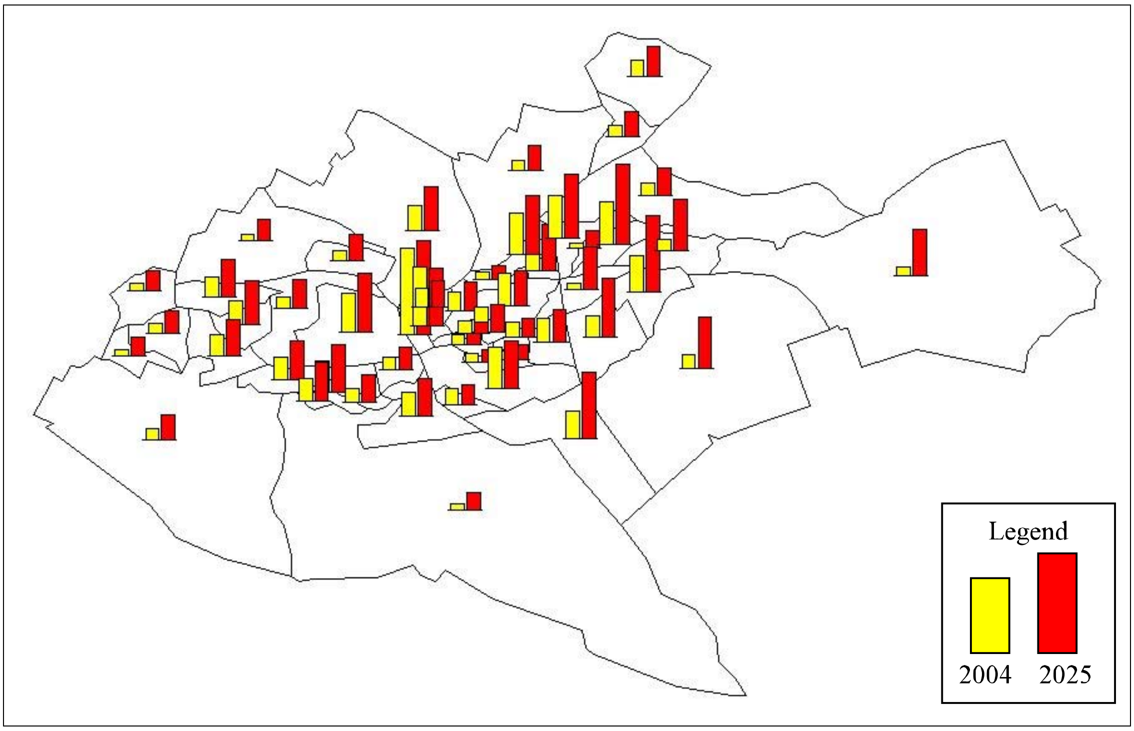


FIGURE 12.3-2 TRIP GENERATION IN 2004 AND 2025

12.4 FORECASTING TRIP DISTRIBUTION

Trip distribution is the second major step in the travel demand modeling process. Trip production (the first major step) facilitates the methodology for estimating trip generations and attractions for each purpose within each zone. Trip distribution is the process of linking trip generations and attractions as each zone pair.

(1) Building and Calibrating Trip Distribution Model

In this Study, the gravity model for inter-zonal trips and trip rate model for intra-zonal trips are applied for trip distribution forecast, as shown in following equations. Intra zonal trip length (Lii) is assumed to be 0.5 km in each zone for intra-zonal model.

Inter zonal trip $Xij = K * Oi^{\alpha} * Dj^{\beta} / Lij^{\gamma}$

Intra zonal trip $Xii = Ri * Oi$

$Ri = Xii / Oi$

Where; Xij: inter zonal trip distribution from zone i to j

Xii: intra zonal trip distribution in zone i

Oi: trip generation in zone i

Dj: trip attraction in zone j

Lij: travel length from zone i to j (km)

Ri: Intra trip rate

K, α, β, γ : model parameters

To balance a sum of trip distribution in certain zone, the doubly-constrained method is applied after estimation of each distribution by the gravity model. This type of model is also known as Fratar Balancing. The forecast matrix should then be such that the sum of each trips generated per zone is within a given convergence criterion of the corresponding forecasted generation for that zone, and the sum of each trip attracted per zone is within a given convergence criterion of the corresponding forecasted attraction.

(2) Calibrating Trip Distribution Model

Calibration results of the gravity models before applying the doubly-constrained method are shown in Table12.4-1.

TABLE 12.4-1 INTRA ZONAL TRIP DISTRIBUTION MODEL PARAMETERS

Trip Purpose	α	β	γ	Ln (K)	R-squared
HOME	0.59839	0.34889	-1.56908	-0.47929	0.79495
WORK	0.29850	0.61031	-1.39529	-0.40961	0.80500
SCHOOL	0.49024	0.29925	-1.77292	0.52697	0.68079
OTHERS	0.36936	0.57203	-1.73672	-0.27450	0.77109

Intra zonal trip rates of each zone derived from the person trip survey are shown in Appendix 12. These rates are applied for future demand forecasting, and are assumed to be constant.

(3) Verification of Trip Distribution Models

Figure12.4-1 shows trip length distribution between observed and modeled for model verifications.

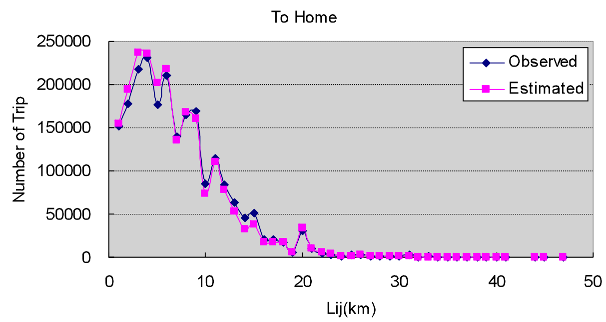
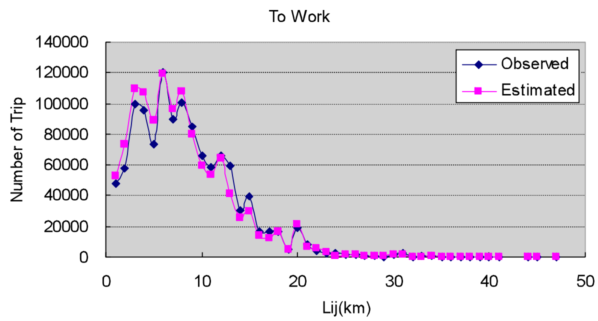
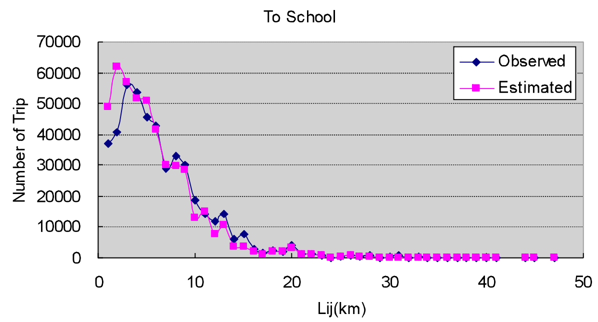
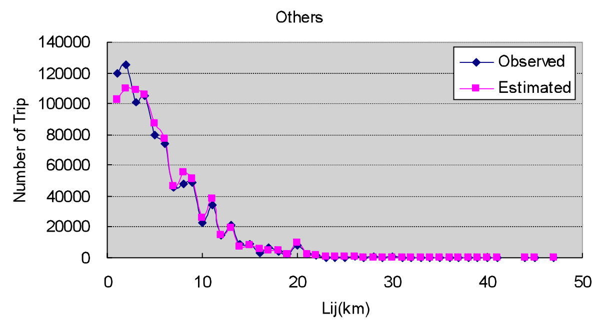
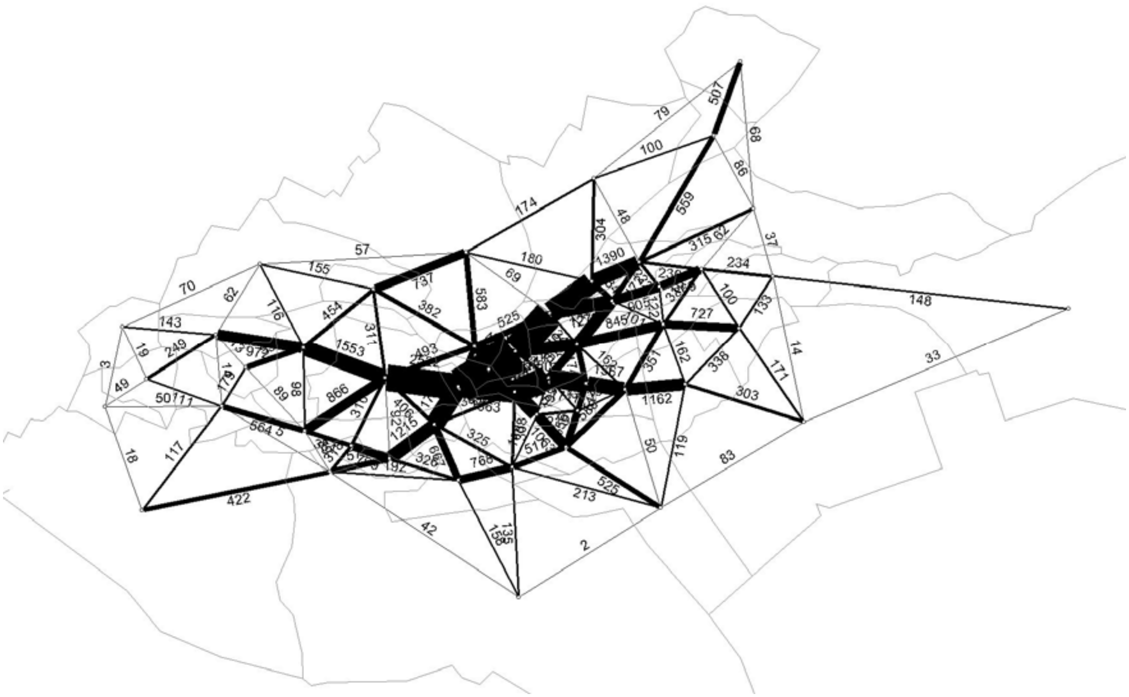
<table>
<tr><th>Trip Purpose</th><th>Trip Length Distribution</th></tr>
<tr><td>HOME</td><td>
</td></tr>
<tr><td>WORK</td><td>
</td></tr>
<tr><td>SCHOOL</td><td>
</td></tr>
<tr><td>OTHERS</td><td>
</td></tr>
</table>

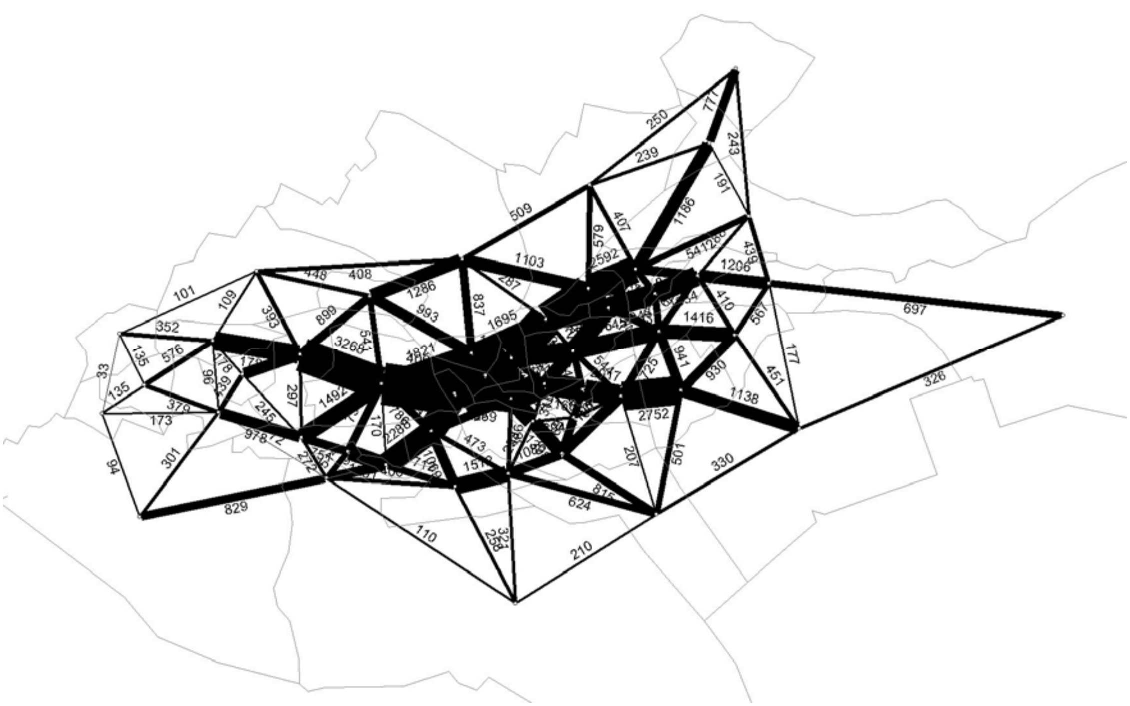
FIGURE 12.4-1 VERIFICATION OF TRIP DISTRIBUTION MODELS

(4) Future Trip Distribution

Based on the trip distribution in 2004 and 2025, the charts by spider network assignment method, which clarify the trip distribution and interaction among zone pairs, are presented in Figure12.4-2.



(Year 2004)



(Year 2025)

FIGURE 12.4-2 TRIP DISTRIBUTION OF TOTAL TRIPS IN 2004 AND 2025

12.5 FORECASTING MODAL SPLIT

Modal split models are applied to analyze and predict the choices of individuals or groups of individuals who chose the transportation modes when they make particular types of trips. Typically, the goal of this modeling is to predict the share or absolute number of trips by mode. The most commonly applied method to study modal split is the logit model.

(1) Modal Split Hierarchy

The modal split models in this study comprise of three models, that is, “Walk Split Model”, “Private-Public Split Model” and “Bus-Rail Split Model” as shown in Figure 12.5-1 below. Walk Split Model provides the modal share between WALK and all other modes. Private-Public Split Model is to split person trips other than walking into private modes (car and taxi) and public modes (rail and bus). Bus-Rail Split Model provides the modal splits of person trips by public modes between bus and rail modes. The modal split models are established by trip purpose, using the person trip survey data.

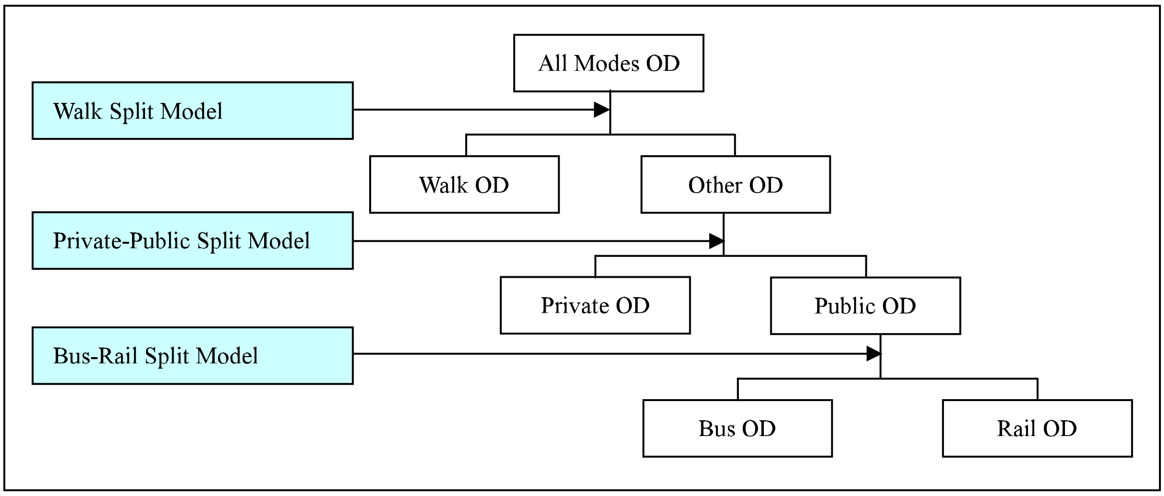
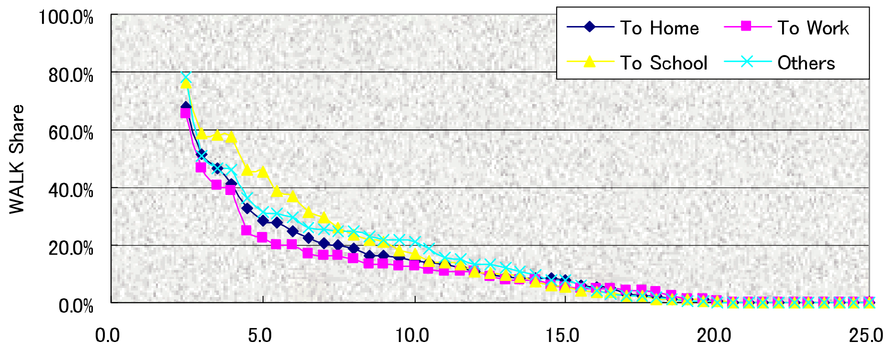


FIGURE 12.5-1 BASIC STRUCTURE OF MODAL SPLIT MODEL

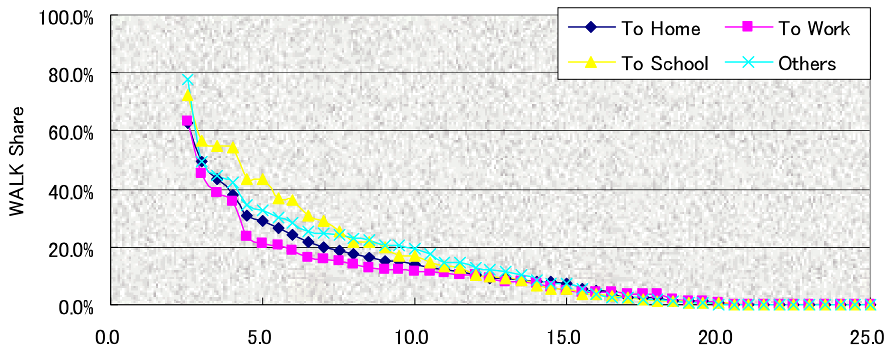
(2) Inter Zonal Walk Split Model

The diversion curve models are selected for Walk Split Model in the study. The independent variable employed in the model is travel length (km) of the shortest pass on the road network. The analysis of WALK share shows that it is mainly affected by trip length and also personal characteristics, defined from trip purpose and household car ownership. Considering the expansion of car ownership in future framework, Walk Split curves by trip length are modeled by trip purpose considering the ratio of car ownership rate. The model derived from the Person Trip Survey data is shown in Figure 12.5-2.

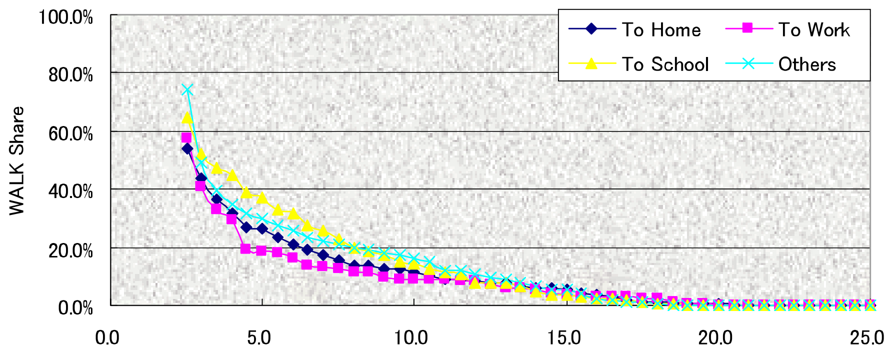
2004



2010



2015



2025

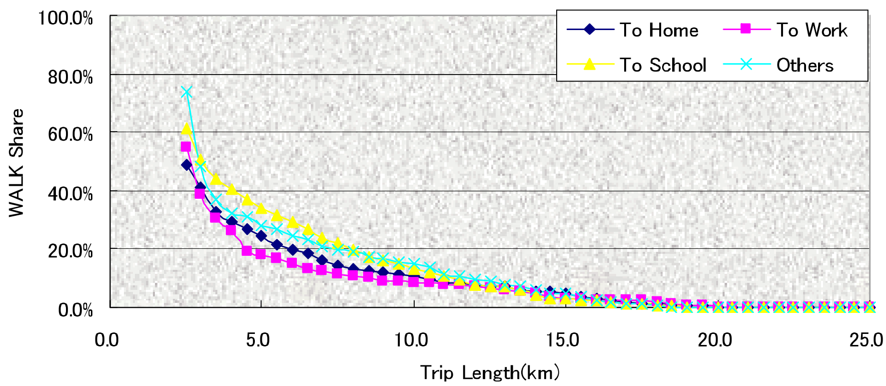


FIGURE 12.5-2 INTER-ZONAL WALK SPLIT MODEL

P_Lij = (Pijwalk_W/Ocar * Pop_W/Ocar + Pijwalk_W/car * Pop_W/car) / Pop_Total

Where;

P_Lij: Walk share by trip length (=Lij (km))

Pijwalk_W/Ocar: Walk share by no-car owning household

Pijwalk_W/car: Walk share by car owning household

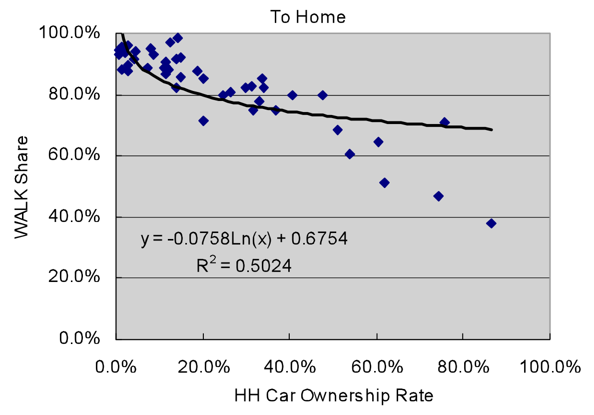
Pop_W/Ocar: Population in no-car owning household

Pop_W/car: Population in car owning household

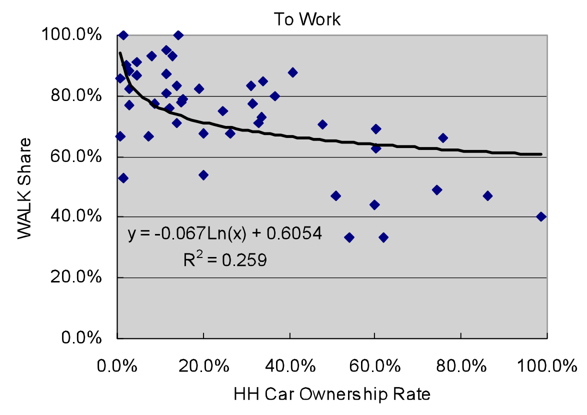
Pop Total: Total population (= Pop_W/Ocar + Pop_W/car)

(3) Intra Zonal Walk Split Model

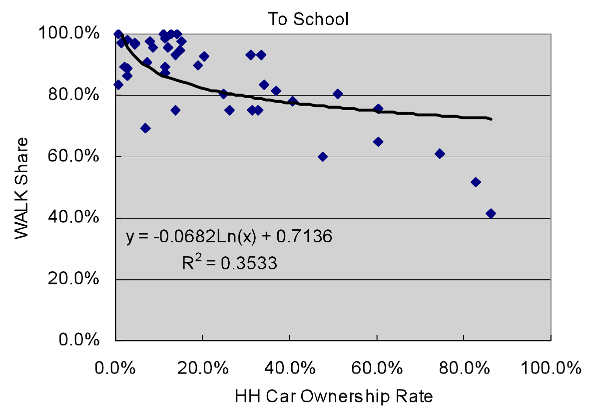
Based on the analysis of the person trip survey data, WALK share in intra zonal trip correlate negatively with car ownership rate depicting increasing car ownership rate, against decreasing WALK share. The relationships between WALK share in intra zones and car ownership rate are modeled as shown in Figure12.5-3.



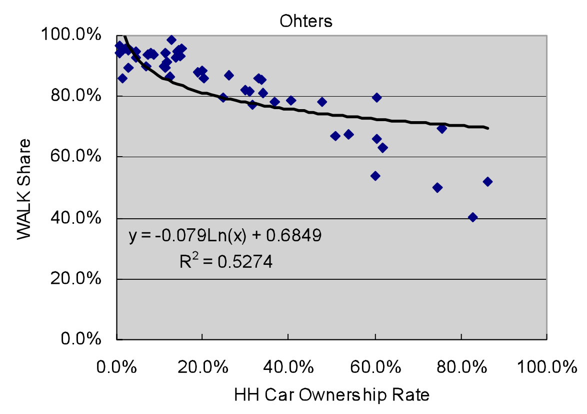
(To Home)



(To Work)



(To School)



(Others)

FIGURE 12.5-3 RELATIONSHIP BETWEEN INTRA ZONAL WALK SHARE AND CAR OWNERSHIP RATE

Using the models above, average WALK shares in the future are estimated as shown in Table12.5-1. WALK shares in each zone are available in Section 12.2 of Appendix 12.

TABLE 12.5-1 INTRA ZONAL WALK SHARE (AVERAGE IN THE STUDY AREA)

Year	HH Car Ownership Rate (%)	Trip Purpose			
		HOME	WORK	SCHOOL	OTHERS
2004	23.3%	83.6%	76.3%	87.4%	85.1%
2010	31.1%	82.2%	75.1%	86.2%	83.7%
2015	41.3%	80.9%	74.0%	85.0%	82.3%
2025	49.2%	78.8%	72.1%	83.2%	80.1%

(4) Modeling Modal Split from NMT (WALK) to MT (Private or Public Mode)

Considering the modal shift from walking to private or public mode by implementation of transportation policies, total walking split rate are developed using the logit model indicated below. This model is applied only in forecasting alternatives, which have change in transportation conditions deviating from existing condition. (See Table 12.5-2)

Pij walk = U_walk / (U_walk + U_car + U_public)

U_walk = f1 * Lij + f2 * Car_rate_i + f3 * Car_rate_j

Where; Lij: Trip length from I zone to j zone

Car_rate: Car ownership rate in origin or destination zone

f1, f2, f3: model parameter

TABLE 12.5-2 NMT MODAL SHIFT MODEL PARAMETERS

	HOME	WORK	SCHOOL	OTHERS
Lij	-2.0765	-2.2246	-2.1584	-2.0958
Car_Rate at Origin Zone	-	-13.1474	-11.3551	-12.2861
Car_Rate at Destination Zone	-11.5039	-	-	-

(5) Inter Zonal Private - Public Split Model

Model Formulation

With wide usability and the proven application, the logit models are chosen for inter zonal modal split models as following equations:

Pij car = Ucar / (U car + U bus)

U_car = a1 * Car_rate_i + b1 * Car_rate_j + c1 * Park_car + d1 * Tij_car + e1 * Cij_car

U_public = + d2 * Tij_public + e2 * Cij_public

Where; Pij: modal share

U: Utility function

Car_rate: Car ownership rate in origin or destination zone

Tij_car : travel time by car mode

Tij_public: travel time by bus or rail mode (= min (Tij_bus, Tij_Rail))

Park: parking cost only in CBD area (=70Ksh)

Cij_car: travel cost by car mode (VOC: Vehicle Operation Cost = 20Ksh/km)

Cij_public: travel cost by bus or rail mode (= min (Tij_bus, Tij_Rail))

a, b, c, d, e: parameters

In this model, two explanatory variables by zone pair and zonal attribute are introduced. The former constitute of the travel time and travel cost between private and public modes. The latter consist of car ownership rate and parking cost in the origin or destination zone.

<u>Assumption of Travel Time and Cost Estimate</u>

Travel time and cost among all zone pairs are estimated using TRANSCAD assignment module with the assumption of the following mode condition. These conditions and values are finally fixed after the verification of equivalency to the observed travel data in the person trip survey and the travel speed survey. (See Table 12.5-3 and Table 12.5-4)

Travel Time $Tij = Tij\_simulation * F + Tij\_access + Tij\_egress + Tw$

Travel Cost $Cij = a \quad Lij =< c$

$Cij = a + b*(Lij - c) \quad Lij > c$

Where; Ti_ simulation: Travel Time from i to j by TRANSCAD assignment module

Tij_ access: Travel time from origin zone to transport network / station

Tij_ egress: Travel time from transport network / station to destination zone

Tw: Waiting time at station/bus stop

Lij: Travel length from i to j (km)

F: Adjustment factor derived from the travel speed survey

a, b, c: parameters

TABLE 12.5-3 ASSUMPTION OF TRAVEL TIME SIMULATION

	F Adjustment factor	Tij_ access/egress Zone Access	Tw Waiting Time
Car	0.75	5 min	0 min
Bus	0.65	5 min	10 min
Rail	1.00	(by simulation)	10 min

TABLE 12.5-4 ASSUMPTION OF TRAVEL COST SIMULATION

Unit: Ksh

		A(constant)	B(slope)	c (km)
Car	Parking	70	0	0
	VOC	0	20	0
Bus		20	2	5
Rail		20	2	5

Calibration Results

The following parameters were calibrated and identified by the method of maximum likelihood, which attempts to find a set of parameters that is most likely to have resulted in the choices observed in the person trip survey data. (See Table 12.5-5)

TABLE 12.5-5 MODEL PARAMETERS OF PRIVATE-PUBLIC SPLIT MODEL

	HOME	WORK	SCHOOL	OTHERS
Car_rate_i	-	4.63304	2.08556	2.95276
Car_rate_j	3.51773	-	-	-
Tij_car	-0.43825	-0.45084	-0.49146	-0.48145
Tij_public	-0.35609	-0.34888	-0.31760	-0.33797
Park_ij	-0.00318	-0.00358	-0.00094	-0.00608
Cij_car	-0.23944	-0.24152	-0.20721	-0.16765
Cij_public	-0.02731	-0.05673	-0.10710	-0.07019

(6) Bus-Rail Split Model

The diversion curve model considering access/egress trip length ratio against total trip length, is selected for Bus-Rail Split Model in the Study. The independent variable employed in the model was travel length (km) and access/egress trip length of the shortest pass by rail network simulation. The RAIL shares derived from the Person Trip Survey data are shown in Table 12.5-6.

TABLE 12.5-6 DIVERSION CURVE OF RAIL SHARE MODEL

Lij_Total (km)	LR<0.25	LR>=0.25
	Rail Share	Rail Share
0.00 – 2.99	0.0%	0.0%
3.00 – 5.99	4.5%	0.0%
6.00 – 8.99	5.5%	0.0%
9.00 – 11.99	6.5%	0.0%
12.00 – 14.99	7.5%	0.0%
15.00 – 19.99	8.5%	0.0%
20.00 – 24.99	10.0%	0.0%
25.00 – 29.99	12.0%	0.0%
30.00 – 34.99	14.0%	0.0%
35.00 – 39.99	16.0%	0.0%
40.00 -	18.0%	0.0%

Note: LR = (Lij_Access + Lij_egress) / Lij_Total