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NATIONAL MODELING FOR PASSENGER TRIPS IN KOREA

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Abstract: A National model for passenger trips is essential for transport planning and analyzing the effect of the various transport policy. Because of the importance of the national model it has been suggested that a Korea national model should be developed by the national planning authority for consistent and standardized methodology to be applied across all modes of transport. The purpose of this paper is to present the state of art of establishment of the first Korea national model. Firstly, the national travel survey is explained and the way to establish the base trip matrix is presented. Then, trip generation and distribution models are explained. In the mode choice models, car, bus and rail are considered as alternatives, and the impact of opening of the High-Speed rail is considered. This paper also briefly explains future plans on the development of the Korea national model.

Key Words: Trip generation, Distribution, Mode choice, National models, Korea

1. INTRODUCTION

A national model for passenger trips is essential for transport planning and analyzing the effect of the various transport policy. It plays an important role in the transport project appraisal and the result of transport appraisal heavily depends on the reliability of the national model. Because of the importance of the national model it has been suggested that A Korea national model should be developed by the national planning authority for consistent and standardized methodology to be applied across all modes of transport. However, high survey cost and the difficulty of performing a survey for national level had prevented the implementation of the suggestion until 1998. Interestingly economy crisis in 1997 became a motivation for the development of the Korea national model, and the Korea Transport Institute (KOTI) on the behalf of the Ministry of Construction and Transportation (MOCT) carried out a nationwide intercity trip survey in 1998, 2001 and 2002. Subsequently, based on the data, the first Korea national model have developed for consistent and standardized methodology to be applied across all modes of transport.

The purpose of this paper is to present the state of art of establishment of the first Korea national model. Firstly, the national travel survey is explained and the way to establish the base trip matrix is presented. Then, trip generation and distribution models, which model trips between origins and destinations, are explained. In particular, the trip generation and distribution models are developed according to the classification of zone groups to reflect intrinsic relations between zones. After the development of the trip distribution models, mode choice models are presented. In the mode choice models, car, bus and rail are considered as alternatives, while air transport is estimated exclusively. This paper also briefly explains future plans on the development of the Korea national model.

2. NATIONAL MODELS

This section presents reviews on the existing other countries' national models. National models have been developed in many countries. The models have generally been constructed by national planning authorities and developed to meet various future needs, which were linked to specific transport projects.

In U.K., the regional highways traffic model (RHTM) in 1978 was one of the first attempt to create a traffic model at national level and it has been very influential in shaping later modeling efforts. The objectives of the RHTM were to help government to allocate resources between proposed schemes in different regions in a consistent and systematic way. The model was restricted to car traffic, and to develop the model, 40,000 households and hundreds of thousands of roadside interviews were conducted.

The Netherlands nation models (NNM) were developed in 1985 and the model has been used since then. In 2000, the model was updated. The purpose of the model was to support the decision- making for transport policy issues by forecasting traffic flow on the major road and rail. Contrast to the RHTM, the model was developed using disaggregate data (households and individuals) and a modal split functions was used.

The Italian national model was developed to provide the Ministry of Transport with a consistent and standardized methodology to be applied across all modes of transport. Freight modeling was emphasized and the freight traffic was integrated with passenger traffic. In particular, weekend and seasonal differentiation were modeled explicitly because of the large tourist industry in Italy.

The Norwegian model was originally created to support a study of global air pollution, and subsequently, the model was developed to forecast traffic on specific infrastructure links. An important difference from the other national models was the separation of long-distance and short-distance traffic. The distinction was made at 100km, meaning that the transport modes considered in the models can be made more specific, slow modes not being relevant to the longer trips, while air and boat travel do not need to be considered for shorter trips.

It is clear that there are many similarities and differences. Model components for travel frequency, origin-destination connections, mode-split and route choice are presented in all the national models. Most of the models address a “normal” working day. On the other hand, some national models use EMME/2 commercial package for assignment and other models use specially developed software.

3. BASE DATA

In 1998, 2001 and 2002, the Korea Transport Institute (KOTI) on the behalf of the Ministry of Construction and Transportation (MOCT) carried out a nationwide intercity trip survey. Approximately eight billion won was invested for the surveys. Around one thousand external cordon points around 167 administrative districts were selected, and two hundreds of thousands roadside interviews were conducted. The intention was that traffic should be described by its origin and destination using 167 zones. Also all domestic 15 airports and 11 ferry terminals were selected for the rail and bus trips. The bus, rail and air trips have the same zone classification as the car trips data. While, a network was established using the National Geographic Information System data. The network contained 14,194 links, composing of 1,046 highway links and 5,812 national road links.

To build a base trip matrix, which is essential for developing a national model, the following procedures were adopted. For the case of bus, rail and air trip matrix, official government publications coming from the national bus federation, the national air federation and the office of Korean National Railroads were used. For the establishment of the base trip matrix for car trips, one day car traffic volume, which is entering, and leaving from the 167 administrative districts (zones) was identified. To do this, a ratio of passing by zone was estimated firstly using the roadside interview data. The passing ratio for the car trips is calculated by the following as

$$R_k(attraction) = \frac{(T_k(attraction) - D_k(attraction))}{T_k(attraction)} \tag{1}$$

$$R_k(production) = \frac{(T_k(production) - O_k(production))}{T_k(production)} \tag{2}$$

Where,

$R_k(production)$: The passing ratio of the zone at *k* point for production

$R_k(attraction)$: The passing ratio by of the zone at *k* point for attraction

$O_k(production)$: The car traffic which leave from only the zone

$D_k(attraction)$: The car traffic which enter only the zone

$T_k(production)$: The car traffic which product not only from the zone but also other zones

$T_k(attraction)$: The car traffic which enter not only the zone but also other zones

After the estimation of the one-day car traffic volume, which was entering to and leaving from only the zone, a sample origin and destination trip table was constructed. In here, to consider the possibility that one vehicle was counted more than one time; only one interviewed vehicle data was used if the time, vehicle type, occupancy and departing time was equal to be each other. While, to correct the zero cell in the sample origin and destination trip matrix, a double constrained gravity model was estimated from the established trip matrix, and the zero cells were estimated by the gravity model. The estimated gravity model was following as.

$$T_{ij} = A_i B_j O_i D_j \exp(-0.036791 C_{ij}) \tag{3}$$

Where,

T_{ij} : observed auto trips from zone i to zone j

C_{ij} : free flow travel time from zone i to zone j

O_i : production of zone i D_j : attraction of zone j

A_i , B_j : balancing factor for zone *i* and *j*, respectively.

Using the production and attraction of each zone and the updated origin and destination trip table, the origin and destination table was expanded by the balancing procedure. The balancing procedure was carried out using EMME2 software. After the base trip matrix for car trips were established, it was examined by various existing data sources including TCS (Toll collecting system) highway data. For example, a network analysis was carried out using the base trip table by comparison of the assigned and observed TCS traffic flows. Table 1 shows the difference percentage between observed traffic and assigned traffic at designated links. 82 % of the Highway links are included in 30% difference, while 50% of the national road links are included in 30% difference. User equilibrium assignment was accomplished and trips are changed to pcu using conversion factors. One of reasons for higher match percentage in highway links is the intra-zonal trips are respectively smaller than those in the national road links. Figure 1 also shows the assigned traffic volume using the established base matrix and the network. Demand is increased along the Seoul-Busan corridor and there are large traffic around Seoul metropolitan area. After careful validation procedure, it was concluded that the base origin and destination trip table was reliable to develop a national model for forecasting the future travel demand.

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Table 1. The Difference Percentage between Observed Traffic and Assigned Traffic (PCU)

<table>
<tr><th colspan="2" rowspan="2">Range (%)</th><th colspan="3">Highway</th><th colspan="3">National Road</th></tr>
<tr><th>Link Points</th><th colspan="2">%</th><th>Link Points</th><th colspan="2">%</th></tr>
<tr><td rowspan="6">Over Estimation</td><td>300 +</td><td>0</td><td colspan="2">0</td><td>6</td><td colspan="2">1</td></tr>
<tr><td>100～300</td><td>0</td><td colspan="2">0</td><td>47</td><td colspan="2">6</td></tr>
<tr><td>60～100</td><td>3</td><td colspan="2">2</td><td>38</td><td colspan="2">4</td></tr>
<tr><td>30～60</td><td>20</td><td colspan="2">12</td><td>88</td><td colspan="2">10</td></tr>
<tr><td>10～30</td><td>51</td><td>31</td><td rowspan="4">82</td><td>114</td><td>13</td><td rowspan="4">50</td></tr>
<tr><td>0～10</td><td>26</td><td>16</td><td>66</td><td>8</td></tr>
<tr><td rowspan="4">Under Estimation</td><td>-10～-0</td><td>30</td><td>18</td><td>76</td><td>9</td></tr>
<tr><td>-30～-10</td><td>30</td><td>18</td><td>169</td><td>20</td></tr>
<tr><td>-60～-30</td><td>6</td><td colspan="2">4</td><td>149</td><td colspan="2">17</td></tr>
<tr><td>-100～-60</td><td>1</td><td colspan="2">1</td><td>101</td><td colspan="2">12</td></tr>
<tr><td colspan="2">Comparison Link Points</td><td>167</td><td colspan="2">100</td><td>854</td><td colspan="2">100</td></tr>
</table>

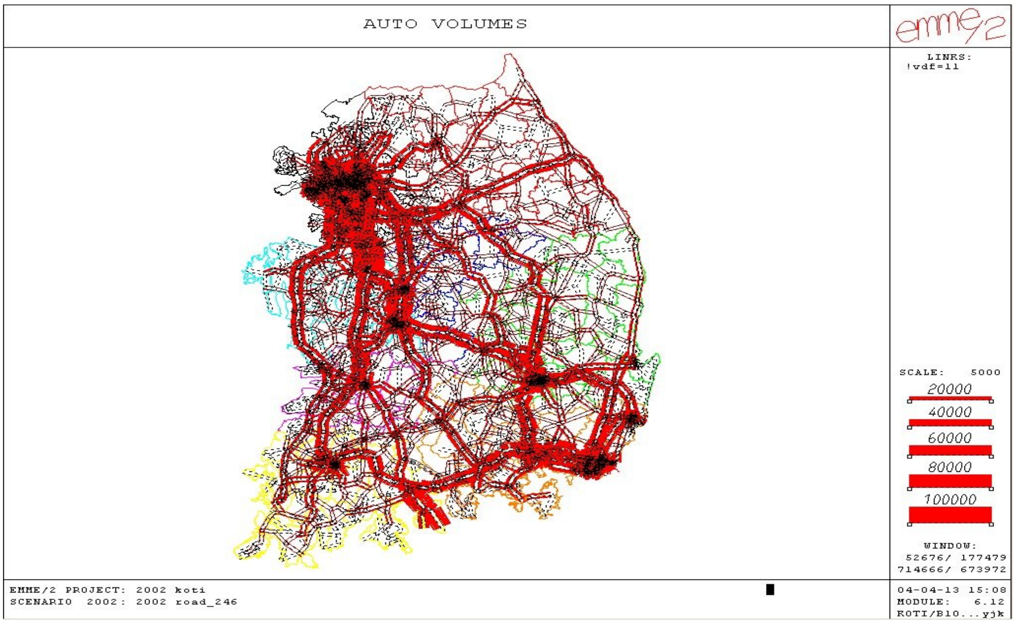

Figure 1. Assigned Traffic Volume in 2002

4. DEVELOPMENT OF THE NATIONAL MODEL

4.1 Trip Generation and Distribution model; Abstract Models

This section explains the development of the Korea National Model. An abstract model is used for development to forecast distribution trips. In other words, trips from zone i to zone j are explained by the social economic variables of zone i and /or zone j.

Firstly the zones are grouped by statistical techniques to consider the intrinsic relations between zones that cannot be explained by the social variables. The grouping also helps to avoid the possibility of overestimation/underestimation of trips, which is coming from the zone size problem. The criteria variables for the grouping are population, car ownership, the number of employment, and GRP. Then, correlation analysis is carried out between the observed trips and the social economic variables within the grouped zones to choose adequate explanatory variables.

Table 2 shows the grouping results and the 167 zones are divided into five groups. Group 1 has only Seoul city, which is a capital of Korea, and Group 2, is consist of 5 big cities.

Table 2. Analysis Groups and Zones

	Zones	Number of Zones	Number of O-D pairs
Group 1	Seoul city	1	318
Group 2	Busan, Taegu, Incheon, Kwangju, Daejeon	5	1,560
Group 3	Kounggi-do	30	8,556
Group 4	Ulsan and 23 cities	24	5,304
Group 5	Remaining zones	100	9,702

Note: Ulroong-gun, Jeju-do (4 zones), Yeochun-gun, Yeochun-city are exlude

After the grouping the zones, the equation 4 was adapted finally as the trip distribution model for zone i to zone j. In here, *Tij* is the travel time by car, however it is actually minimum travel time between zones. Instead, difference of travel time between modes has been considered as explanatory variables. However, it was proved not to be good. The effects of the population size and length of travel time is considered as Dummy variables. The introduction of the Dummy variables helps to fit the model estimation results with the base trip matrix. However, to predict the future demand, it is assumed that the groups are not changed. Also, the 30min, 45min, 60 min and 65min were used for dummy variables to reflect the short and medium and long distance effects. The groups are also divided according to the size of the population (3million) to keep the homogeneity in groups as possible.
Table 3 shows the estimation results of the trip distribution model. It should be noted that the distribution models are estimated according to the divided zone groups. As the population of the zone increases, the intercity trips become less sensitive to the travel time. Car travel time represents the smallest travel time between origin and destinations. To forecast trip matrix, the future car travel time is obtained from the established the network data.

$$lnTRIP_{ij} = a + b_l \, lnTijp + b_2 \, lnPOP_{ij} + b_3 \, lnCAR_{ij} + b_4 \, D_1 + b_5 \, D_2 \quad (4)$$

Where
$TRIP_{ij}$ = Passenger Trips between zone i and zone j per day (air trips are excluded)
Tij = Car travel time between zone i and zone j (mins)
POP_{ij}= population of zone i multiplied by population of zone j
CAR_{ij} = car ownership of zone i multiplied by car ownership of zone j

D_1 = Dummy variable for travel time. If *Tijp* is less than 30 mins in Group 2, the D_1 is equal to 1, otherwise 0. If *Tijp* is less than 45 mins in Group 3, the D_1 is equal to 1, otherwise 0.
If *Tijp* is more than 65 mins in Group 4, the D_1 is equal to 1, otherwise 0. If *Tijp* is more than 60 mins in Group 5, the D_1 is equal to 1, otherwise 0.
D_2 = Dummy variable for population. If POP_{ij} is more than 3million people, the D_2 is equal to 1, otherwise 0.

Table 3. Estimation Results of the Trip Distribution Model according to the Groups

		a	b_1	b_2	B_3	b_4	B_5	R^2
Group 1	coeff	-8.294	-1.634	0.870	-	-	-	0.838
	t	-6.419	-26.580	20.830	-	-	-	-
Group 2	coeff	-1.860	-2.667	0.788	-	-0.858	-	0.633
	t	-2.119	-44.039	24.813	-	-2.658	-	-
Group 3	coeff	3.912	-3.208	0.688	0.528	-1.742	0.149	0.698
	t	7.069	-99.176	31.960	9.450	-17.934	2.882	-
Group 4	coeff	-3.616	-3.390	1.001	-	0.508	-	0.614
	t	-5.101	-67.519	37.168	-	3.964	-	-
Group 5	coeff	4.780	-4.826	0.942	0.181	1.559	-	0.740
	t	8.058	-142.559	44.399	2.391	15.945	-	-

To check the validation of the developed trip generation and distribution models, various tests are carried out. The signs of b_1 and b_2 are negative and positive, respectively for all groups, which are intuitive. Furthermore, variance inflation factor test also prove that the estimated all mode has no problem of multi-correlations between the explanatory variables, and F and t tests tell that the estimated models and coefficients are significant.

4.2 Mode Choice Model; Aggregated Logit Models

The forecasted trips between zone i and zone j from the estimated trip distribution model are allocated to various mode trips by the following modal split models. Two kinds aggregated mode choice models are developed. The first mode choice model is an aggregated logit mode and covers the area where is not linked by Kyungbu High-Speed Rail (HSR). The second mode choice model is a combined RP and SP aggregated logit model and it is for the area where the Kyungbu HSR linked. In the second model, the competitiveness between air and the HSR is considered in the SP logit model, and the model also has been used to consider the impact of HSR on the national transport system.

The travel time and cost between zones, which is essential data for the development of the mode choice models, are obtained from the established network. Because the present and future networks give only distance and travel time from between zone i to zone j by modes, the estimated travel time are converted into cost using the base units. See more details about the base units in Kim (2004).

To develop the aggregated logit model, which covers the non-service area of the Kyungbu HSR, firstly, the mode choice models are tried to be estimated according to the divided zone groups. However, the segmentations have not been justified. Furthermore, the consideration of the mode choice model according to the travel distance also has been tried, but they have not been significant. In the end, it is conclude that the following aggregated multinomial logit model has been suggested for the national mode choice model. In here, total number of observations is 25,440 and rho-squared is 0.7444.

$$U_{ijm} = a_l\ TIMEijm + a_2\ COSTjicar + a_3\ COST_{ijbus} + a_4\ COST_{ijrail} + a_5\ D_m \tag{5}$$

Where
U_{ijm} = Utility of mode m between zone i to zone j
TIMEijm = Total travel time of mode m between zone i to zone j (mins)
COSTjim = Total cost of mode m between zone i to zone j (won)
D_{m} = Dummy variable for mode m

Table 4. The Estimation Result of the Multinomial Choice Model

		a_l	a_2	A_3	a_4	a_5
Car	coeff	-0.009424	-0.00006528			
	t	-9.6	-7.0			
Bus	coeff	-0.009424	-	-0.0003532		-0.1601
	t	-9.6	-	-12.4		-2.2
Rail	coeff	-0.009424	-		-0.0001398	-2.468
	t	-9.6	-		-7.3	-20.5

While, for the area where the Kyungbu HSR linked, the combined RP and SP model is estimated. To do this, a set of coefficients is estimated by SP data. Then, using the results of this estimation, the total utility for each alternative available in reality is computed. Finally a correct scale factor for SP coefficients is obtained by estimating a logit model using observed (RP) choice as a dependent variable and the computed preference utilities as an independent variable. Equation 6 is the utility function for SP model and Table 5 presents the estimation result of the SP model. The results are combined with the estimation result of the aggregated logit model.

$$U_m = \alpha_1 COST_{air} + \alpha_2 COST_{hrail} + \alpha_3 COST_{bus} + \alpha_4 COST_{car} + \alpha_5 AT_m + \alpha_6 T_m + \alpha_7 DM\text{-}A + \alpha_8 DM\text{-}HR + \alpha_9 DM\text{-}B \quad (6)$$

Where

$COST_{mr}$ = *Cost for* mode m, AT_m= *Access Time for* mode m, T_m= *Travel Time for* mode m

DM-A= Dummy Variable for Ai, DM-HR= Dummy Variable for High-Speed Rail, DM-B= Dummy Variable for Bus

Table 5. The Estimation Result of the SP Choice Model

Modes		α_1	α_2	α_3	α_4	α_5	α_6	α_7	α_8	α_9
Air	coeff	-0.00007581	-	-	-	-0.01627	-0.01433	0.3566	-	-
	t	-21.8	-		-	-25.6	-33.4	1.7	-	-
HSRl	coeff	-	-0.00007295	-	-	-0.01627	-0.01433	-	0.5238	-
	t	-	-30.0	-	-	-25.6	-33.4	-	4.4	-
Bus	coeff	-	-	-0.0001016	-	-0.01627	-0.01433	-	-	0.4983
	t	-	-	-21.1	-	-25.6	-33.4	-	-	3.8
Car	coeff	-	-	-	-0.00008479	-	-0.01433	-	-	-
	t	-	-	-	-21.8	-	-33.4	-	-	-
Rho-Squared		No of Obs = 10143 $\rho^2(0)$= 0.3476 rho-squared(0) $\rho^2(C)$= 0.2471								

To check the validation of the estimated mode choice model, values of travel time are compared with previous value of time studies. The estimated model presents the 8,662won/hour for car users, 4,045won/hour for rail users, and 1,601won/hour for bus users. These values are quite similar with other value of time studies for the case of intercity trip. Furthermore, signs of time and cost are negative and they are significant with confidence 95% level.

5. FORECASTING THE FUTURE TRANSPORT DEMAND

This section briefly summarizes the results of the future demand in Korea using the developed national modes. More detailed analyses including the network analysis are presented in Kim (2004). Table 6 shows the forecasting results of the future transport demand. In 2002, the modal split of car is 79.4%, however it is declined continuously. In 2031, the percentage is dropped to 75.8%. While, the share of air and rail is increased steadily. It becomes 2.0%, 11.0% respectively in 2031. The number of trips also is increased continuously, however, the increase rate is decreased as the going to the future. Fig 2 shows the assigned road volume in 2031. The network includes all national transport investment plans. Seoul metropolitan area and the Kyoungbu corridor still remain congested though considerable investment plan is going to be implemented.

Table 6 The Forecasting Results of the Future Transport Demand

		Car	Bus	Rail	Air	Total
2002	Trips /day	9,358,833	1,350,373	1,014,060	59,053	11,782,320
	%	79.4	11.5	8.6	0.5	100.0
2006	Trips /day	9,684,510	1,466,674	1,248,221	71,567	12,470,971
	%	77.7	11.8	10.0	0.6	100.0
2011	Trips /day	10,538,697	1,590,745	1,478,743	103,420	13,711,606
	%	76.9	11.6	10.8	0.8	100.0
2016	Trips /day	10,947,109	1,666,729	1,546,635	145,487	14,305,960
	%	76.5	11.7	10.8	1.0	100.0
2021	Trips /day	11,700,066	1,779,181	1,664,986	197,186	15,341,418
	%	76.3	11.6	10.9	1.3	100.0
2026	Trips /day	12,116,302	1,798,372	1,726,314	256,721	15,897,709
	%	76.2	11.3	10.9	1.6	100.0
2031	Trips /day	12,051,282	1,781,512	1,740,924	321,080	15,894,797
	%	75.8	11.2	11.0	2.0	100.0

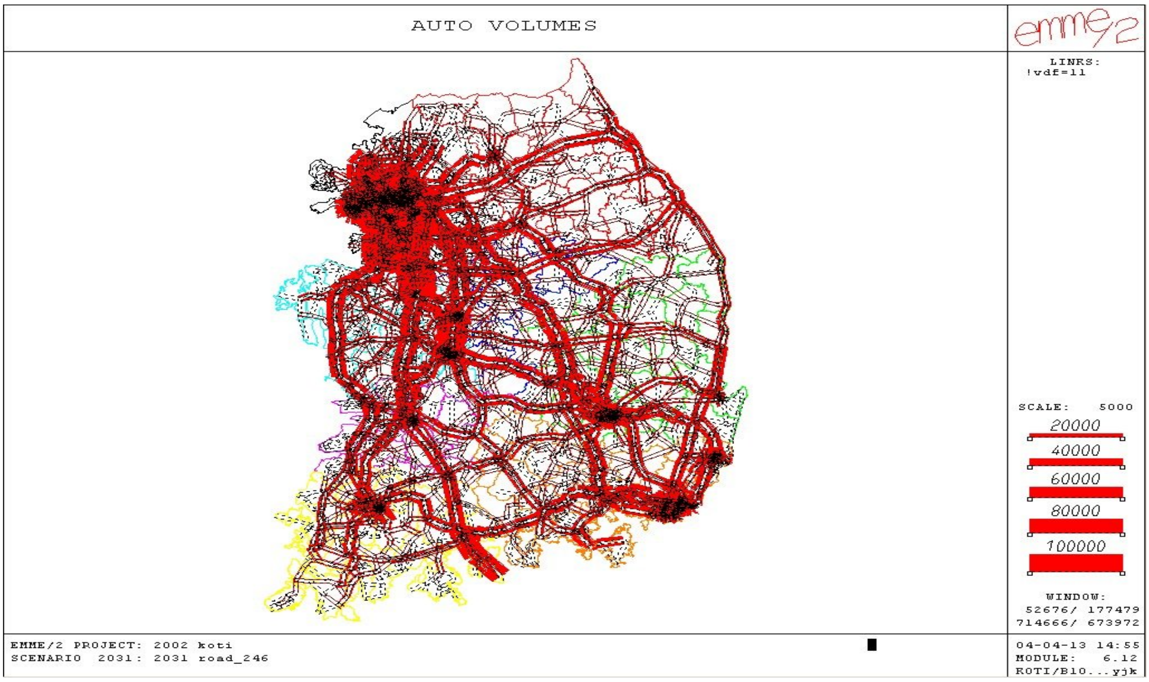

Figure 2. Assigned Traffic Volume(PCU) in 2031

6. CONCLUSIONS

A national model for passenger trip is essential for transport planning and analyzing the effect of the various transport policy. It plays an important role in the transport project appraisal and the result of transport appraisal heavily depends on the reliability of the national model. Because of the importance of the national model it has been suggested that the Korea national model should be developed by the national planning authority for consistent and standardized methodology to be applied across all modes of transport.

This paper presented the state of art of establishment of the first Korea national model. The developed models has been provided for forecasting trip demand for all transport related projects according to transport investment guidance which is prepared by the Ministry of Construction and Transportation, and the models are expected to play an important role for standardized manner of transport investment appraisal. For the future plans, the national travel survey will be carried out in 2005 and this will be a good chance to update and validate the Korea national models.

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