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A Study on Land-Use Appraisal Model in Seoul Metropolitan Area

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Abstract

Seoul city is indisputably, one of the biggest cities in the world. With an extremely high density of population and growing incomes, the concentration of motor vehicles in the city in recent years has assumed a dramatic increase. For example, about 40 percent of all the motor vehicles in Korea and 63 percent of all passenger cars are concentrated in the city of Seoul (1). This fact, coupled with the old nature of most of the vehicles plying the roads of the city and the flexibility associated with the regulations on motor truck exhaust has resulted in a serious debasing of atmospheric quality. Thus, the role of motor vehicles in causing air pollution problems in Seoul Metropolitan Area cannot be over-emphasized. But since land use activity is an important factor in traffic generation, any attempt at addressing air pollution problem in the metropolis should inevitably be viewed from the angle of land use and traffic generation activities. It would also demand a clearer examination and scrutiny of past policies and their future impacts as well as the anticipated growth levels of these traffic generation activities.

The intensity of the air pollution in Seoul city today calls for earnest and sustained effort towards the development of feasible countermeasures that can help reduce this urban environmental problem. This is one of the major challenges facing researchers on environmental problems particularly in the rapidly urbanizing NIES and redressing this problem in Seoul city inevitably constitutes the thrust of the study.

Key Words: Nitrogen Oxides, Land Use, Seoul District, Seoul Suburbs District, Seoul Fringe District, Motor Truck, Trip Generation, Trip Distribution, Traffic Assignment, OD Table.

1. Introduction

The series of five-year economic development plans initiated and pursued by the Republic of Korea since the 1960's have resulted in rapid economic growth rates unrivalled in the history of economic development in any country. This trend has culminated in a change of the country's industrial structure as well as the rapid transformation of the economy from a rural and agricultural based into an urban and industrial one characterized by buoyancy and stability.

The accompanying effect of this drastic change has been the massive drift of people from the rural to the urban areas and the increased concentration of principal industrial facilities in the big cities. The latter case has in particular led to the worsening of atmospheric quality due to the widespread emission of obnoxious gases from these industrial plants into the atmosphere.

In addition, the role of motor vehicles in the worsening of the atmospheric quality cannot be over-emphasized. In a situation where about 40 percent of all vehicles owned in Korea are concentrated in Seoul which paradoxically occupies a mere 0.63 percent of the total land area and furthermore in a situation where motor truck, constituting 27.3 percent of all vehicle types in Seoul city, also accounts for about 51.81 percent of Nitrogen Oxide in the atmosphere, any countermeasure aimed at redressing this problem must focus an unbounded attention on the issue of land use rearrangements. This can result in changes in traffic generation and attraction associated with the metropolis.

In this study, an attempt has been made to build a motor truck exhaust appraisal model as a basis for assessing the abatement effectiveness of air pollution within Seoul city due to nitrogen oxides emitted from motor trucks.

Furthermore, the model is used to predict the city's traffic volume and its validity is ascertained by comparing it with the actual recorded traffic volume data.

Secondly, through a series of land use planning alternatives established in this study, the abatement effectiveness of Soeul city is assessed.

The study area, the Seoul Metropolitan area, has a coverage of 60 kilometers. For the purpose of this study, the region is delineated into three districts which are defined as follows:

Seoul District: a block covering an area of 20 kilometers and encompassing the Seoul city. For the rest of the study, this area is to be known as Seoul District.

Seoul Suburbs District: a block lying within an area of 20 kilometers and 40 kilometers from the center of Seoul city. This region is thereafter referred to as Seoul Suburbs District.

Seoul Fringe District: This area encompasses the region lying between 40 kilometers and 60 kilometers from the center of Seoul city. This area is thereafter known as Seoul Fringe District.

To define the type of land use to be employed in this study, a linear multiple regression analysis was conducted to assess the relative relationships between the various land uses and traffic generation and attraction within the Seoul Metropolitan Area. As a result of this analysis, Residential, Commercial and Industrial were selected and these three variables became the policy variable for the study.

Land use alternatives consisted of twelve cases which includes an equal extraction and equal apportionment to the Suburbs (two cases), equal extraction and equal approtionment to the Fringe (two cases), equal extraction and equal apportionment to the Suburbs and the Fringe on a 50 percent to 50 percent basis (two cases), selective extraction and selective apportionment to the Suburbs (two cases), selective extraction and selective apportionment to the Fringe (two cases), selective extraction and selective apportionment to the Suburbs and the Fringe on a 50 percent to 50 percent basis (two cases). The basis for the extraction and apportionment is a 10 percent and 30 percent respectively of all industrial land use activities within Seoul city (Seoul District) into the Seoul Suburbs District and Seoul Fringe District as detailed above.

Finally, based upon the results of the land use simulation, the amount of exhaust emitted from motor trucks are analyzed. Consequently, the effectiveness of each land use planning alternative is assessed by considering land use harmony relative to the volume of physical distribution and the transportion system.

2. Framework of the Study

2.1 *Study Area*

The study area covers a region of about 11412.3 square kilometers in size representing 11.53% of the total area of the Republic of Korea. This region is made up of Seoul city covering an area of 627.06 km^2 eighteen Guns extending to 10152.54 km^2 in size that is the 1982 statutory demarcated a dministrative district and six other cities coverning an area of 632.53 km^2. In brief, this region represents Seoul city and the Gyeonggi-do region excepting Onggin Gun.

The study area is characterized as Seoul District, Seoul Suburbs District and Seoul Fringe District depending on its measured distance from the CBD (Central Business District) of Seoul as shown in Figure 2-2. Seoul District takes up 17-Gu of the Seoul city covering a cricumferential area of about 20 kilometers from the CBD of Seoul city. Seoul Suburbs District covers the circumferential area lying

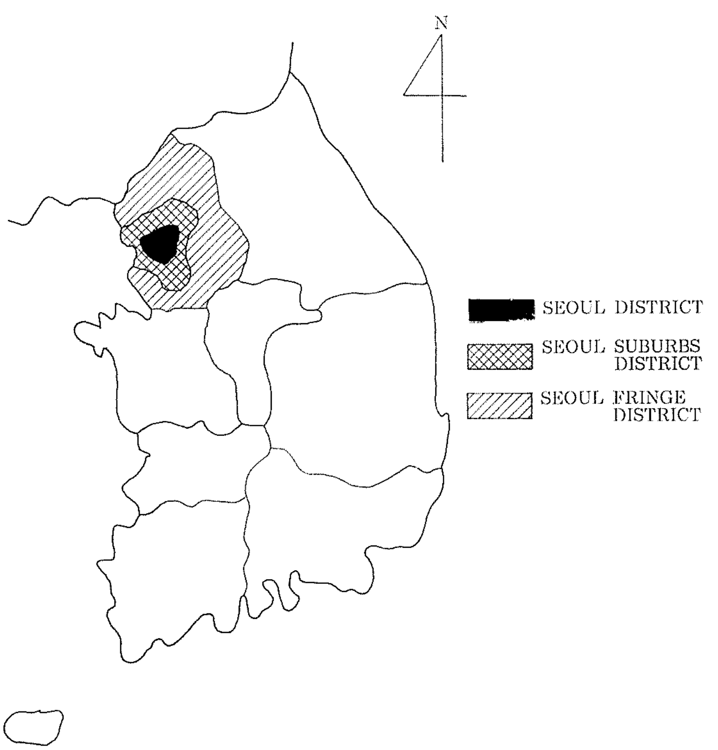


Figure 2-1. The Map Showing the Study Area.

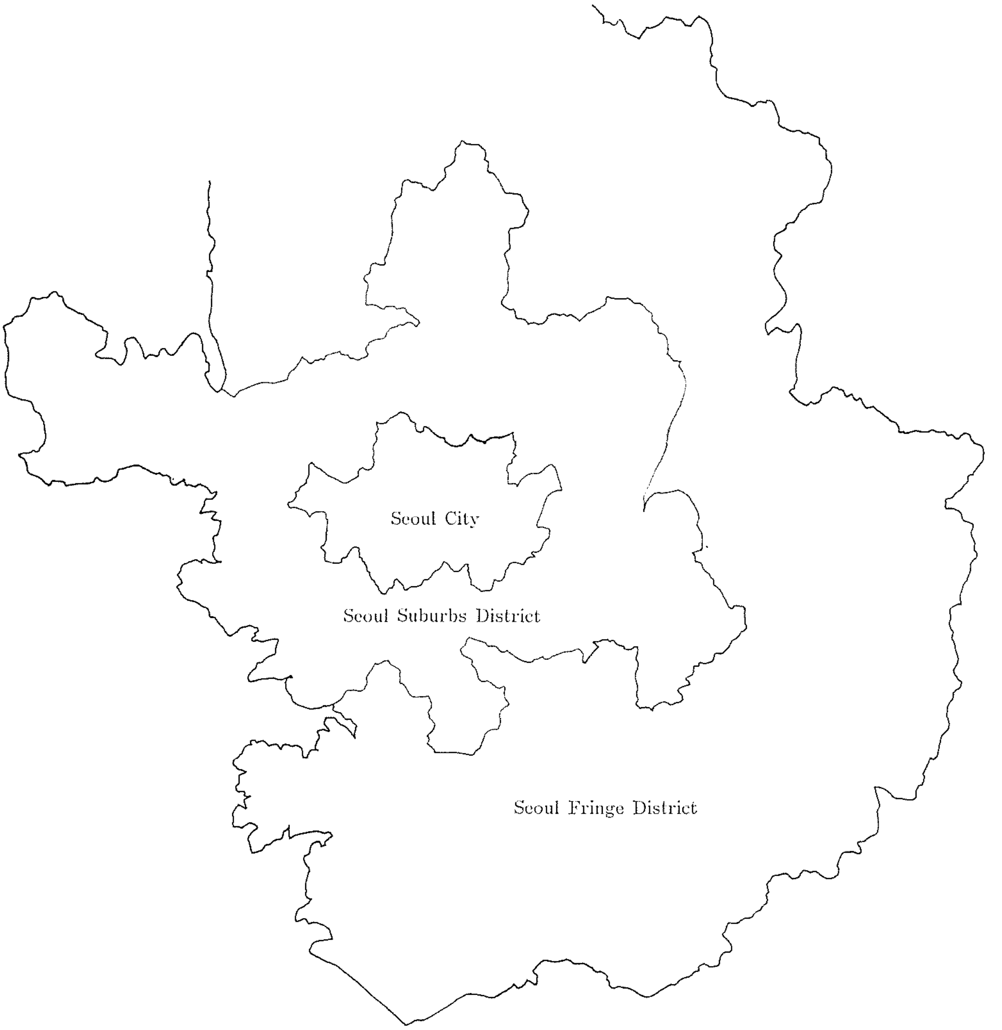


Figure 2-2. The Map of the 3 Designated Districts.

between a distance of about 20 km and 40 km. Seoul Fringe District which is the exterior region take up a circumferential area lying between a distance of about 40 kilometers and 60 kilometers from the CBD.

The study area is demarcated so that it represents a total of 38 zones with each zone representing a Gu, city or Gun. Seoul District takes up 17 zones, one Gu is equivalent to one zone, Seoul Suburbs District 12 zones and Seoul Fringe District 9 zones depending on the regional idiosyncrasy, traffic flow and so on, as shown in Figure 2-3. Table 2-1 shows the corresponding table of 38 zonal divisions and the adjusted administrative district of Seoul metropolitan area.

2. 2 *Traffic Selection*

The pursuance of a series of five year development plans, now in its fifth consecutive term has resulted in a marked improvement in the national living

Table 2-1. The Zonal Divisions

No. of Zone	Gu, City or Gun	Zonal Name
1	Jonglo Gu	Jonglogu
2	Jung Gu	Junggu
3	Yongsan Gu	Yongsangu
4	Seongdong Gu	Seongdonggu
5	Dongdaemum Gu	Dongdaemungu
6	Seongbuk Gu	Seongbukgu
7	Dobong Gu	Dobonggu
8	Eunpyeong Gu	Eunpyeonggu
9	Seodaemun Gu	Seodaemungu
10	Mapo Gu	Mapogu
11	Gangseo Gu	Gangseogu
12	Guro Gu	Gurogu
13	Yeongdeungpo Gu	Yeongdeungpogu
14	Dongjak Gu	Dongjakgu
15	Gwanak Gu	Ganakgu
16	Gangnam Gu	Gangnamgu
17	Gangdong Gu	Gangdonggu
18	Incheon City	Incheon
19	Bucheon City	Bucheon
20	Siheung Gun, Gwangmyeong City, Gunpo, Euiwang, Gwacheon	Siheung
21	Anyang City	Anyang
22	Suweon City	Suweon
23	Seongnam City	Seongnam
24	Gwangju Gun	Gwangju
25	Namyangju Gun	Namyangju
26	Euijeongbu City	Euijeongbu
27	Yangju Gun, Dongducheon City	Yangju
28	Goyang Gun	Goyang
29	Ganghwa Gun, Gimpo Gun	GanghwaGimpo
30	Hwaseong Gun	Hwaseong
31	Pyeongtek Gun, Songtan City	Pyeongtaek Songtan
32	Yongin Gun	Yongin
33	Anseong Gun	Anseong
34	Icheon Gun, Yeoju Gum	Icheon Yeoju
35	Yangpyeong Gun	Yangpyeong
36	Gapyeong Gun	Gapyeong
37	Yeoncheon Gun, Pocheon Gun	Yeoncheon Pocheon
38	Paju Gun	Paju

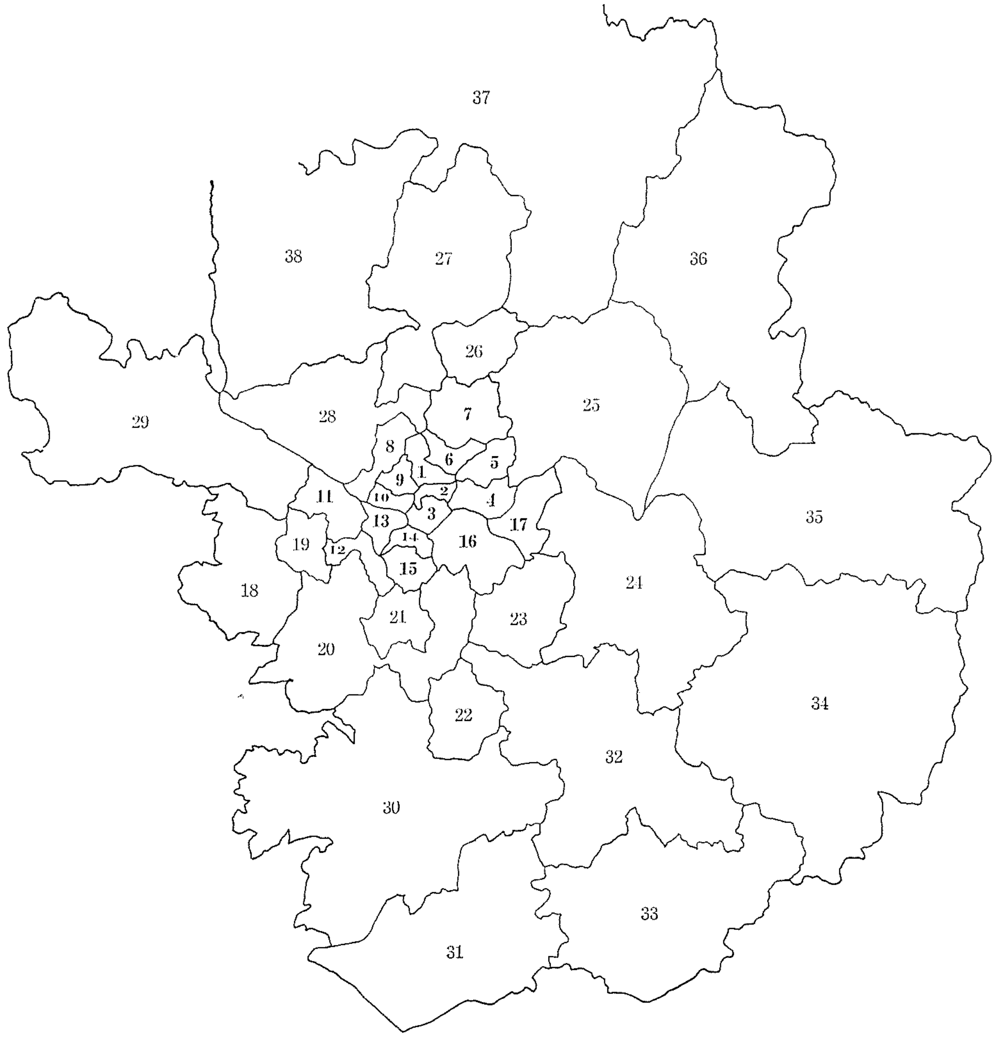


Figure 2-3. A Map of 38 Zonal Divisions.

standards in Korea. A remarkable and visible result accompanying this econemic improvement has been the drastic increase in vehicular ownership and usage. The number of motor vehicles operating within the country was 40,000 in 1965, rising to 126,000 in the 1970's, then to 527,700 in the 1980's and finally to 906,964 in 1984. The trends in the registration of motor vehicles in Seoul city is indicated in Table 2-2. Cars represented 63.7 percent of all motor vehicles under consideration while motor trucks made up 27.6 percent.

However, with regards to the amount of emission of nitrogen oxides (NO_x) in Seoul city, 57.70% comes from motor vehicles. Furthermore, motor trucks which are few in number compared to cars contributed 51.81 percent (2). Compared with similar studies for Tokyo, motor trucks contributed 66 percent and 74 percent in 1980 and 1985 respectively to all the nitrogen oxides (NO_x) emitted into the atmos-

Table 2-2. Registration of Motor Vehicles in Seoul (1982)

Kind of Vehicle			Number	Percentage	
Car	Taxi		30,167	11.9	63.7
	Others		131,327	51.8	
	Subtotal		161,494		
Bus	Small*		8,044	3.2	8.3
	Large**	City Bus	6,941	2.7	
		Others	6,052	2.4	
	Subtotal		21,037		
Truck	General Type	A***	30,845	12.1	27.6
		B****	36,506	14.4	
	Special Purpose		2,733	1.1	
	Subtotal		70,084		
Special Vehicle			1,032	0.4	0.4
Motor Cycle			57,434	22.6	
Total*****			253,647		100.0

* "has a capacity of 16 persons of fewer"
** "has a capacity of more than 16 persons"
*** "rated at 1 ton or less"
**** "rated at more than it"
***** "except motor cycle"

Source: A Survey on Vehicle Driving Pattern in Urban Area, National Environmental Protection Institute, 1983.

phere within the Tokyo Metropolitan Area (12). Based on the above reasons, motor trucks were chosen as the proxy for the vehicular type responsible for debasing atmospheric quality in Seoul city. In addition, trafic generation of motor trucks have been found to correlated much closer with the generation of physical distribution of goods and that large quantities of exhaust emitted by motor vehicles emanated from motor trucks (11).

2.3 *Exhaust Gas Selection*

The economic miracle that Korea has gone through in recent years has inevitably resulted in an increase in the consumption of fossil fuels of which petrol consumption has featured very prominently. Ever since the mid 1970's, this increased affinity for fossil fuel consumption has resulted in a nitrogen oxides (NO_x)-led atmospheric pollution in the urban areas, the principal source of which is motor atmospheric pollution in the urban areas, the principal source of which is motor vehicles. To counteract the problems caused by motor vehicle exhaust pollution (NO_x), various countries, for example EC, USA and Japan have established strict regulating standards and there exists a series of ongoing research activities to check the effectiveness of these standards. Similar standards were developed and enforced in Korea as detailed below.

1) Establishment of Regulating Standard

A clause for the regulation of motor vehicle emission standard was established in 1977 and enforced in earnest in 1980. The maximum permissible limit standard of motor vehicle exhaust gas (NO_x) was strengthened to the levels obtained in Eueope in 1984 as shown in Table 2-3.

Table 2-3. The Concentration Standard for Vehicles Exhaust Gas

Pollutant	Vehicle Type		Fuel	Test Method	Standards	
					A*	B*
Nitrogen Oxides	Normal Duty Vehicle or Light Duty Vehicle not exceeding 2.5 ton		Gasoline, Liquefied Petroleum Gas	10 Mode	3.0 g/km or less	2.5 g/km or less
	Normal Duty Vehicle or Light Duty Vehicle not exceeding 2.5 ton		Gasoline	6 Mode	2200 ppm or less	2200 ppm or less
	Normal Duty Vehicle	DI**	Diesel	6 Mode		1000 ppm or less
	Small Duty Vehicle	IDI		6 Mode		590 ppm or less

*; A "Enforcement till July 1st 1984"
B "Enforcement till July 1st 1984"
**; DI "Direct Injection Type"
IDI "Indirect Injection Type"
Source; Environment Agency, 1984.

In a bid to ensure a modification in the design technology employed by motor vehicle manufacturers as an attempt to reduce Nitrogen Oxides emissions of future vehicles, the Environmental Agency established a new maximum permissible limit standards for Nitrogen Oxides, Hydrocarbons and Carbon Dioxide emission to be complied with by manufacturers. Alongside this, a similar regulation was also established for diesel vehicles.

2) Enforcement of the maximum permissible limit standard for new vehicle

The maximum permissible limit standard for new vehicles was strengthened to the level of those prevailing in European countries. The enforcement of this new standard started in 1984. Based on the studies conducted by the Korean Environmental Agency in 1984, future forecasts indicated vast increases in the use of motor vehicles, fuel and a disproportionate increase in traffic volume. Consequently, the

Table 2-4. The Secondary Enforcement of the Maximum Permissible Limit Standard for New Vehicles

Vehicle Type	Pollutants	July 1st 1984	Aug. 1st 1987
Gasoline or LPG-Fueled Vehicle	CO	18 g/km	2.1~2.7 g/km
	HC	2.8 g/km	0.25~0.39 g/km
	NO_x	2.5 g/km	0.62~0.48 g/km
Diesel-Fueled Motor Vehicle	Smoke	50%	50%
	NO_x	1000/590 ppm (DI) (IDI)	850/450 ppm (DI) (IDI)
	CO	980 ppm	980 ppm
	HC	670 ppm	670 ppm

Source; Korean Enironment Agency, 1984.

agency decided to enforce rigid standard likened to those currently in force in Japan and America from the year 1987 as shown in Table 2-4.

Of all the Nitrogen Oxides (NO_x) emitted into the atmosphere in the Seoul city, non-stationary vehicles accounted for 57.7 percent. Motor trucks represented 57 percent of this vehicles, while 43 percent were accounted for by the cars.

Diesel-powered motor vehicles which are normally associated with high emissions of Nitrogen Oxides as compared to the gasoline-fueled ones constitutes more than 50 percent of all registered motor vehicles in Korea.

By reason of this, pollution caused by Nitrogen Oxides emitted by motor trucks constitutes the subject matter for this study.

2. 4 *Study Methodology*

The fundamental data frequently employed to estimated the amount of exhaust volume emitted by motor tricks in an urban area is the origin and destination table. However, the origin and destination table for motor trucks in Korea was not available. For the purpose of this study therefore, an origin and destination table was constructed using several secondary data (8) available from various Korean government agencies.

In addition, the origin and destination table of physical distribution volume in Seoul metropolitan area was available. An important setback of this table, however, was that the whole of the Seoul city area was designated as one zone. To remedy this situation, the annual average increasing rate of the volume of physical distribution in Seoul city was estimated from these sources, namely, the volume of the total physical distribution, the rate of distribution of internal-internal as well as internal-external physical distribution volume of goods within the Seoul city.

From this results, the volume representing the generation of physical distribution for both Seoul city and the Seoul Metropolitan area were estimated. By applying a redesigned OD Table estimating program to the above-generated volume of physical distribution generation data, the origin and destination volume for both the Seoul city and the Seoul Metropolitan were derived.

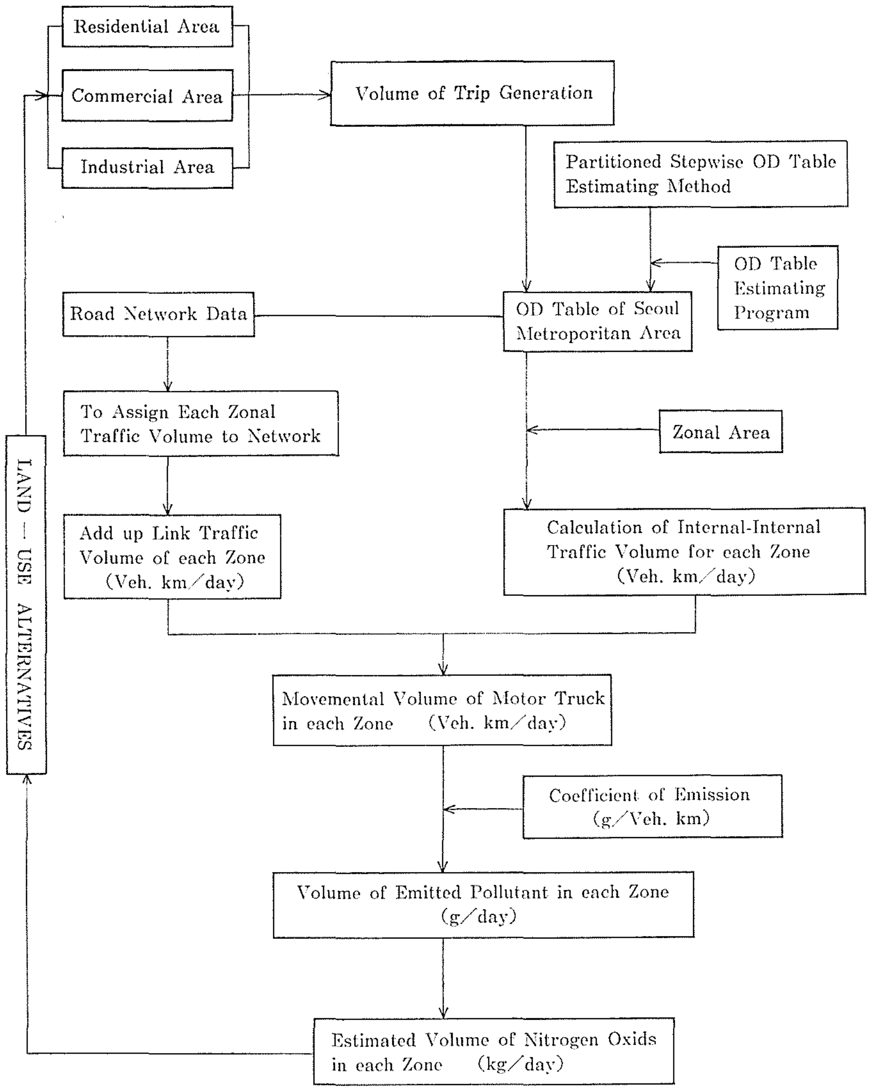


Figure 2-4. The Appraisal Model of Motor Truck Exhaust Gas.

Finally, the origin and destination table for motor trucks in the Seoul Metropolitan area was estimated using the data on the volume of physical distribution per vehicle which was obtained through a survey conducted at eight points within a cordon in Seoul city.

Road network data was assembled from (8) (15) and the zonal traffic volume assigned was derived from it. Finally, the link traffic volume (Veh. km/day) of each zone is added up from this assignment result. As the internal-internal traffic volume was not assigned to road network, we assume the radius of each zonal area to be the average trip length of internal-internal traffic volume and from this, the volume of motor truck movements within each zone (Veh. km/day) was estimated.

By multiplying the volume of motor truck movements within each zone by its coefficient of emission (of Nitrogen Oxides), the air pollution due to exhaust for each zone is derived. By comparing the results of this calculation for the 12 land use alternatives established earlier on in this study with the values obtained for not enforcing these alternatives, a framework for consideration for subsequent analysis was obtained.

3. Land-use Appraisal Model for Metropolitan area

3.1 *Land-Use Index*

To determine the volume of trip generation and trip attraction, it is necessary to set up a land use index incorporating residential, industrial and commercial land uses.

These three land use indexes were chosen from an inventory on land use report prepared by the Korean Transportation Department 1983. The land-use patterns in Seoul Metropolitan area are classified in detail in Table 3-1. However, since data on commercial land use activities in the Seoul Suburbs District and the Seoul Fringe District were unavailable, some assumptions concerning its use had to be made.

It was assumed that the size of commercial land use in an area was directly related to the number of employees within that area. By using the relationship between the number of employees within the Seoul city and the size of its commercial land use, the correpsonding figures for the Suburbs and the Fringe were determined.

Table 3-1. Land-Use Classification

Classification Number	Land Use	Description
1	Residental Area	Dwellin
2	Commercial Area	Area for Retail or Wholescale Trade, Services, etc
3	Industrial Area	Area for Factories Tableland
4	Vacant Land	For Future Use and not under current use
5	Public Area	Public Facilities, Education-Culture Facilities Rivers, Park
6	Public Area of Urban District	Area outside Development Control District, Lands of Height more than 70 meters ASL and angle of inclination more than 15 degrees

Source: A Study on Traffic Improvement Scheme for Seoul, Department of Transportation, 1983, p. 59.

Table 3-2. Land-Use Index (UNIT: km²)

REGION	GU	RESIDENTIAL	COMMERCIAL	INDUSTRIAL
Seoul City	JONGRO	5.648	1.125	0.019
	JUNG	3.258	3.216	0.088
	YONGSAN	4.421	0.934	0.196
	SEONGDONG	8.252	1.273	1.501
	DONGDAEMUN	10.975	1.594	0.701
	SEONGBUG	9.87	1.628	1.05
	DOBONG	9.066	1.205	1.39
	EUNPYEONG	9.216	0.562	0.184
	SEODAEMUN	7.131	0.325	0.064
	MAPO	4.899	0.476	0.222
	GANGSEO	8.347	0.489	1.326
	GURO	7.213	0.646	4.37
	YEONGDEUNGPO	6.094	1.392	2.474
	DONGJAG	6.072	0.348	0.057
	GWANAG	6.09	0.818	0.029
	GANGNAM	10.225	0.916	0.368
	GANGDONG	8.763	0.625	0.408
SUBTOTAL		125.54	17.572	14.447
Suburbs	INCHEON	28.61	6.122	7.684
	BUCHEON	6.81	2.768	1.242
	SIHEUNG	12.165	2.453	2.974
	ANYANG	6.867	1.35	0.894
	SUWEON	10.826	1.373	1.345
	SEONGNAM	8.745	1.711	1.424
	GWANGJU	6.881	0.495	0.593
	NAMYANGJU	8.081	0.698	0.306
	EUIJEONGBU	3.722	0.360	0.215
	YANGJU	7.464	0.473	0.528
	GOYANG	7.031	0.293	0.599
	GANGHWA	14.499	0.518	0.406
SUBTOTAL		121.701	18.614	18.21
Fringe	HWASEONG	16.252	1.215	1.546
	PYEONGTAEG	11.556	0.383	0.887
	YONGIN	11.634	1.058	1.019
	ANSEONG	10.174	0.135	0.174
	ICHEON	16.218	0.63	1.184
	YANGPYENOG	8.216	0.045	0.036
	GAPYEONG	6.784	0.023	0.03
	POCHEON	16.176	0.158	0.126
	PAJU	11.949	0.246	0.133
SUBTOTAL		108.959	3.893	5.135
TOTAL		356.2	40.079	37.792

3.2 *Linear Multiple Regression Model for Trip Generation*

Three tables form the 1983 report published by the Korean Transportion Department was used to determine the volume of trip generation and attraction within Seoul Metropolitan Area.

One is the table on the volume of the generation and attraction of physical distribution of each Gu in Seoul city. This is shown in Table 3-3.

Table 3-3. Physical Distribution volume Generated and Attracted by each Gu

Gu	Volume Generated* (ton/day)	Volume Attracted* (ton/day)
Jonglo	3,670	3,959
Seongbuk	1,957	2,050
Dobong	4,786	5,045
Dongdaemun	6,546	18,747
Seongdong	5,953	9,177
Gangdong	3,455	3,560
Junggu	4.665	4,444
Yongsan	4,651	7,901
Gangnam	3,023	3,447
Dongjak	2,527	2,409
Gwanak	1,078	1,159
Yeongdeungpo	8,739	13,772
Guro	8,286	8,054
Gangseo	5,429	5,103
Mapo	1,605	1,673
Seodaemun	1,437	1,409
Eunpyeong	2,640	6,898
Total	70,448	98,907

*; The Physical Distribution Volume through Public Road came out from the Investigative Value of 1982.

The second is the origin and destination table of physical distribution volume of Seoul Metropolitan Area in 1982.

The third is the origin and destination table of person-trips in Seoul Metropolitan Area in 1982.

To replace the volume of physical distribution in the 38 zones under consideration with the volume of trip generation and attraction of motor truck, the following steps were taken.

Initially, the average load capacity (1.86 ton/vehicle) for a motor truck in Seoul Metropolitan Area was calculated from the table of load capacities for motor trucks as shown in Table 3-4. Therefore, a table of the volume of trip generation and attraction for the 38 zones in the metropolitan area was constructed as shown in

Table 3-4. Load Capacity

Routs of Survey \ Conveyance	Passenger Car (person)	Bus (person)	Truck (ton)
Seoul-Suwon	2.5	30	2.5
Seoul-Incheon	2.5	25	2.5
Seoul-Gimpo	1.85	30	1.5
Seoul-Munsan	2.2	30	1.0
Seoul-Euijeongbu	2.3	28	1.1
Seoul-Donong	2.6	23	2.2
Seoul-Gwangju	2.0	30	1.4
Seoul-Seongnam	2.35	33.4	2.7

Table 3-5. Trip Generation of Physical Distribution Volume and Motor Truck in Seoul Metropolitan Area

Gu	Trip Generation	
	Physical Distribution Volume (ton/day)	Motor Truck (Ver/day)
Jonglo	6896	3703
Jung	8754	4698
Yongsan	8751	4687
Seongdong	11270	6050
Dongdaemun	11328	6081
Seongbug	3709	1989
Donbong	9018	4844
Eunpyeong	4907	2638
Seodaemun	2653	1424
Mapo	3049	1639
Gangseo	10213	5485
Guro	15648	8401
Yeongdeungpo	16445	8827
Dongjag	4775	2564
Gwanag	1993	1069
Gangnam	5702	3064
Gangdong	6498	3487
Incheon	24566	13189
Bucheon	9700	5208
Siheung	6755	3626
Anyang	6656	5187
Suweon	8370	4492
Seongnam	11269	6054
Gwangju	1993	1069
Namyangju	13161	7065

Gu	Trip Generation	
	Physcal Distribution Volume (ton/day)	Motor Truck (Ver/day)
Euijeongbu	9202	4938
Yangju	450	246
goyang	6838	3672
Goyang	2764	1481
Ganghwa	882	473
Hwaseong	1850	993
Pyeongtaeg	3007	1614
Yongin	644	346
Anseong	750	406
Icheon	1202	645
Yangpyeong	457	247
Pocheon	1229	661
Paju	439	239
Total	246,796	132,511

Table 3-5.

In the estimation of the volume of trip generation and attraction from the above land-use index table, the analysis of multiple regression utilized and the linear equation generated was as follows:

$$\underset{(674.002)}{Y=3817.94}-\underset{(76.365)}{295.718\,X1}+\underset{(361.448)}{893.718\,X2}+\underset{(313.455)}{1506.79\,X3} \tag{3. 1}$$

$R^2=0.691476$

Y; Volume of Trip Generation
$X1$; Residential Area
$X2$; Commercial Area
$X3$; Industrial Area
R^2; Coefficient of Determination

The values in parentheses represent the standard errors. The analysis of variance shows negative correlation between the residential area and the volume of trip generation

$$F_0=25.4008>F^3_{34}(0.05)=2.922$$

From this we can deduce that the regression is significant at the levels of 0.05. The partial correlation coefficient were, as follows:

$$r_{1.23}=-0.553,\ r_{2.13}=0.39,\ r_{3.12}=0.636$$

3. 3 *Partitioned Stepwise OD Table Estimating Method and OD Table Estimating Program*

1) Partitioned Stepwise OD Table Estimation Method

(1) Estimating of Origin & Destination Table in Seoul City

The principal data used to estimate the origin and destination table for Seoul city was obtained from the following published materials:

a) A study on traffic improvement scheme in Seoul city, Korean Transportation Department, 1982

b) A study on the investigation of physical distribution and administrative improvement scheme for motor trucks, Koream Institute of Scientific Technology, 1979

The origin and destination table of the physical distribution in the Seoul Metropolitan Area (1982) designated the Seoul city area as one zone. To estimate an OD Table for the Seoul Metropolitan area, the origin and destination table for the Seoul Metropolitan area was divided into four parts as shown in Fig. 3-1 below.

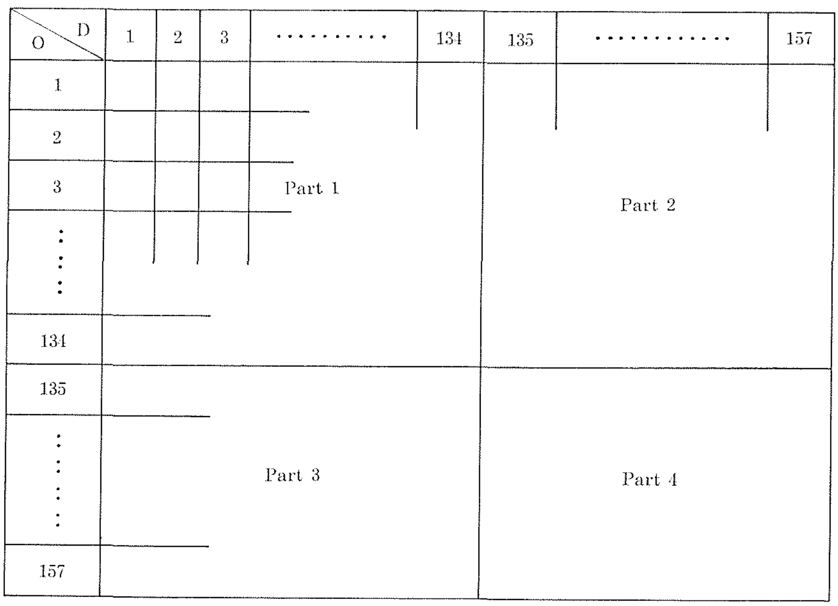


Figure 3-1. Procedures of Partitioned Stepwise OD Table Estimation Method in Seoul Metropolitan Area.

As shown in Figure 3-1, zone 1 to zone 134 represents the origin and destination table for the Seoul city while those ranging from zone 135 to zone 157 are for the Gyeonggi-do region. The flow chart for estimating the OD Table for Seoul city is as shown in Fig. 3-2.

The volume of physical distribution for Seoul city in 1977 was 28,652,800 ton/year while the daily volume of physical distribution stood at 78,501 ton/day as shown in Table 3-6 below.

From the above results, the percentage of internal-internal distribution volume (inter-city ratio) is 53.7 percent while the corresponding figure for the internal-external distribution is 46.3 percent. For period ranging from 1977 to 1981 and

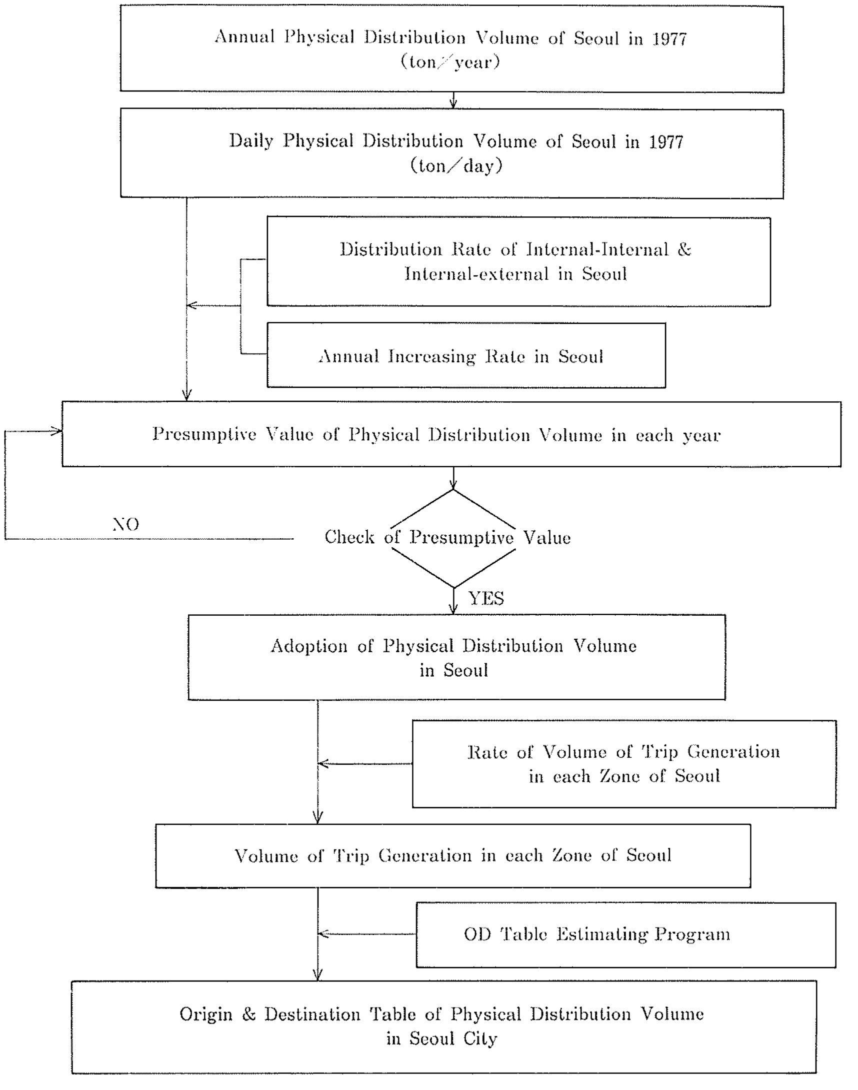


Figure 3-2. Flow Chart for Estimating OD Table in Seoul City.

Table 3-6. The volume of Physical Distribution in Seoul City and Gyeonggi-do Region

Region	Physical Distribution volume	
Seoul	28,652,800 (ton/year)	78,501 (ton/day)
Gyeonggi	22,514,700 (ton/year)	61,684 (ton/day)

Source: KIST, 1979.

1982 to 1986, the volume of physical distribution increased by 10.4 percent and 16.3 percent respectively. This is shown in Table 3-7 below.

The volume of physical distribution for 1982 was obtained as shown in Table

Table 3-7. Ratio of Physical Distribution Volume

Region	Internal-Internal	Internal-External	Average Increasing Ratio	
			1977～1981	1982～1986
Seoul	53.7%	46.3%	10.4%	16.3%
Gyeonggi	48.7%	51.3%		

Table 3-8. Physical Distribution Volume of Part 1 by Each Year

(ton/day)

Classification \ Year	1977	1978	1979	1980	1981	1982
Internal-Internal	42,155	46,539	51,379	56,723	62,622	69,134
External-External	36,346	40,126	44,299	48,906	53,992	62,793

Table 3-9. Volume of trip Generation of Internal-Internal Physical Distribution Volume by each Gu in Seoul City

Zone No.	Physical Distribution Volume (ton/day)	Share (%)
1	3595	5.2
2	4566	6.6
3	4563	6.6
4	5874	8.5
5	6427	9.3
6	1935	2.8
7	4702	6.8
8	2560	3.7
9	1383	2.0
10	1589	2.3
11	5329	7.7
12	8159	11.8
13	8575	12.4
14	2490	3.6
15	1037	1.5
16	2978	4.3
17	3387	4.9
Total	69,142	100

3-8 (This is derived from Tables 3-6 and 3-7). The internal-internal physical distribution volume in 1977 was 42,155 ton/day while the corresponding value for the internal-external volume was 36,346 ton/day. For 1982, the values obtained were 69,134 ton/day for the internal-internal volume and 62,793 ton/day for the internal-external volume.

By comparing the above-derived value (62,793 ton/day) for physical distribution volume with the physical distribution volume (63,452 ton/day) obtained from the origin and destination table, the latter value was adopted.

The value of the internal — internal physical distribution volume for 1982, which is our base year is 69,134 ton/day. To derive the corresponding proportional value of this volume for each of the individual zones or Gu within the Seoul city, the volume of trip generation of internal-internal physical distribution volume of each Gu or zone in Seoul city (as shown below on Table 3-9) was used.

By using an OD Table Estimating Program for the estimating of motor truck OD Table on physical distribution volume as shown in Table 3-9, the OD Table for the volume of physical distribution for Seoul city was obtained.

(2) Estimation of the Part* 2, 3, and 4

The value obtained from the OD Table for the Seoul Metropolitan Area were used to determine the physical distribution volume for parts 2 and 3.

Part 4 represents the internal-internal physical distribution volume for Gyeonggi-do region. For the year 1977, the physical distribution volume for the region totaled 22,514,700 ton/year while the daily physical distribution volume stood at 61,684 ton/year. The internal-internal physical distribution volume for the region as shown in Table 3-10 was 30,040 ton/day.

Table 3-10. Physical Distribution Volume of Gyeonggi-do Region in 1977

Region	Physical Distribution Volume		Internal-Internal (ton/day)	Internal-External (ton/day)
Gyeonggi	22,514,700 (t/y)	61,684 (t/d)	30,040	31,644

Of the above totals, internal-internal physical distribution volume represents 48.7 percent while internal-external volume makes up 51.3 percent (Table 3-7). From 1977 to 1981, The volume of physical distribution in the region showed an increase of 10.4 percent. Between 1982 and 1986 the increase rate was 16.3 percent. This trend is shown in Table 3-7. The value of physical distribution volume as indicated in Table 3-11 was obtained from Tables 3-7 and 3-10 respectively. The internal-internal physical distribution volume of 1977 was 30,040 ton/day while the corresponding figure for 1982 was 51,899 ton/day.

The volume of trip generation of physical distribution in Seoul Metropolitan Area was obtained as shown in Table 3-5. By applying the OD Table Estimation Program to the above trip generation data, the OD Tables of physical distribution volume and of motor trucks in Seoul Metropolitan area was obtained.

2) Trip Distribution Model

The OD Table of physical distribution volume and of motor trucks for the

*: For the Definition of Parts 2, 3 and 4 see Figure 3-1.

Table 3-11. Physical Distribution volume of Part 4 by each year

(unit : ton/day)

Region \ Year	1977	1978	1979	1980	1981	1982
Gyeonggi	30,040	33,164	36,613	40,421	44,625	51,899

Seoul Metropolitan area was constructed using Partitioned Stepwise OD Table Estimating Method explained earlier on. The various land-use alternatives employed in the study resulted in various OD Tables. The essence of the above idea is to design a trip distribution model that can reflect changes in the OD Table resulting from land use changes.

For the purpose of this study, the OD Table Estimation Program was designed using the Frator method based on present pattern method. This made it possible to obtain trip distribution volume (T_{ij}) to be proportional to the persent distribution volume (t_{ij}) resulting from changes in land uses.

The Frator method is employed as follows:
The volume of trip distribution between zone i and zone j (focusing on trip generation) is,

$$X_{ij}^{(g)} = g_i F_{gi} \times \frac{x_{ij} \cdot F_{aj}}{\sum_{j=1}^{n} x_{ij} \cdot F_{aj}} \tag{3.2}$$

while the volume of trip distribution between zone i and zone j (considering trip attraction) is,

$$X_{ij}^{(a)} = a_j F_{aj} \times \frac{x_{ij} \cdot F_{gi}}{\sum_{i=1}^{n} x_{ij} \cdot F_{gi}} \tag{3.3}$$

$X_{ij}^{(g)}$: Volume of Trip Distribution between Zone i and j (with Consideration due to Trip Generation)

$X_{ij}^{(a)}$: Volume of Trip Distribution between Zone i and j (with Consideration due to Trip Attraction)

x_{ij} : Volume of Trip Distribution between Zone i and j

F_{gi} : Rate of Increase of Trip Generation in zone i, $F_{gi}=G_i/g_i$

F_{aj} : Rate of Increase of Trip Generation in zone j, $F_{aj}=A_j/a_j$

g_i : Volume of Trip Distribution in Zone i, $g_i=\sum_{j=1}^{n} x_{ij}$

a_j : Volume of Trip Distribution in Zone j, $a_j=\sum_{i=1}^{n} x_{ij}$

Since $X_{ij}^{(g)}$ and $X_{ij}^{(a)}$ are equivalents originally, and they are formulations to be made on both the generation-side and attraction-side, the volume (X_{ij}) of trip distribution between zone i and zone j via the land-use alternatives is given by means of $X_{ij}^{(g)}$ and $X_{ij}^{(a)}$. That is,

$$X_{ij}=\frac{X_{ij}^{(g)}+X_{ij}^{(a)}}{2} \tag{3.4}$$

Substituting equations (3. 2) and (3. 3) into (3. 4),

$$X_{ij}=\sum x_{ij}\,F_{gi}\,F_{aj}\times\frac{L_{gi}+L_{aj}}{2} \tag{3.5}$$

is obtained. Here,

$$L_{gi}=\frac{g_i}{\sum_{j=1}^{n}x_{ij}\cdot F_{aj}},$$

$$L_{aj}=\frac{a_j}{\sum_{i=1}^{n}x_{ij}\cdot F_{gj}} \tag{3.6}$$

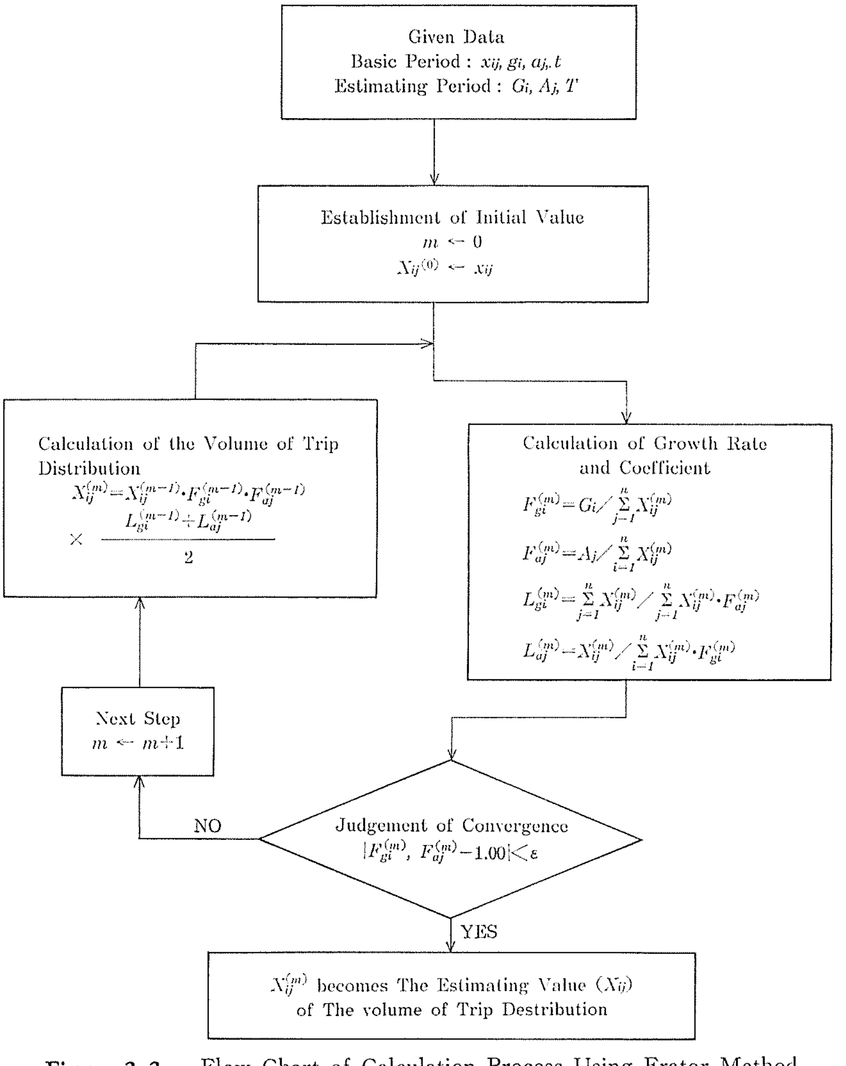


Figure 3-3. Flow Chart of Calculation Process Using Frator Method.

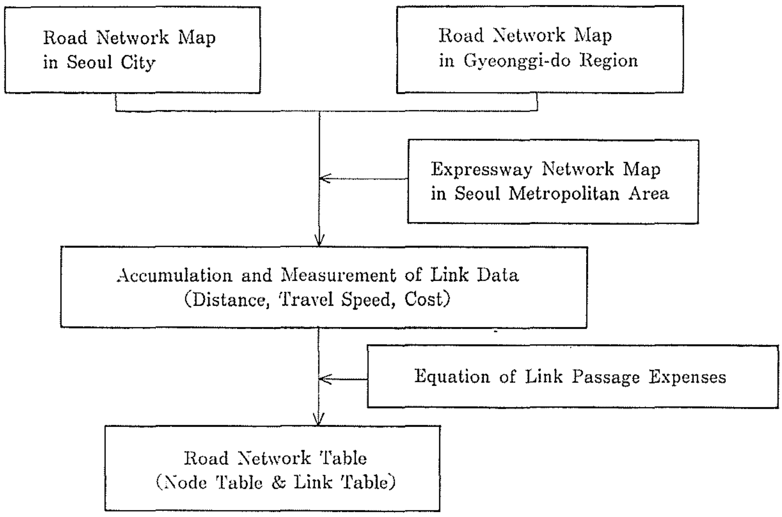


Figure 3-4. The Flow Chart of Road Network Table Derivation.

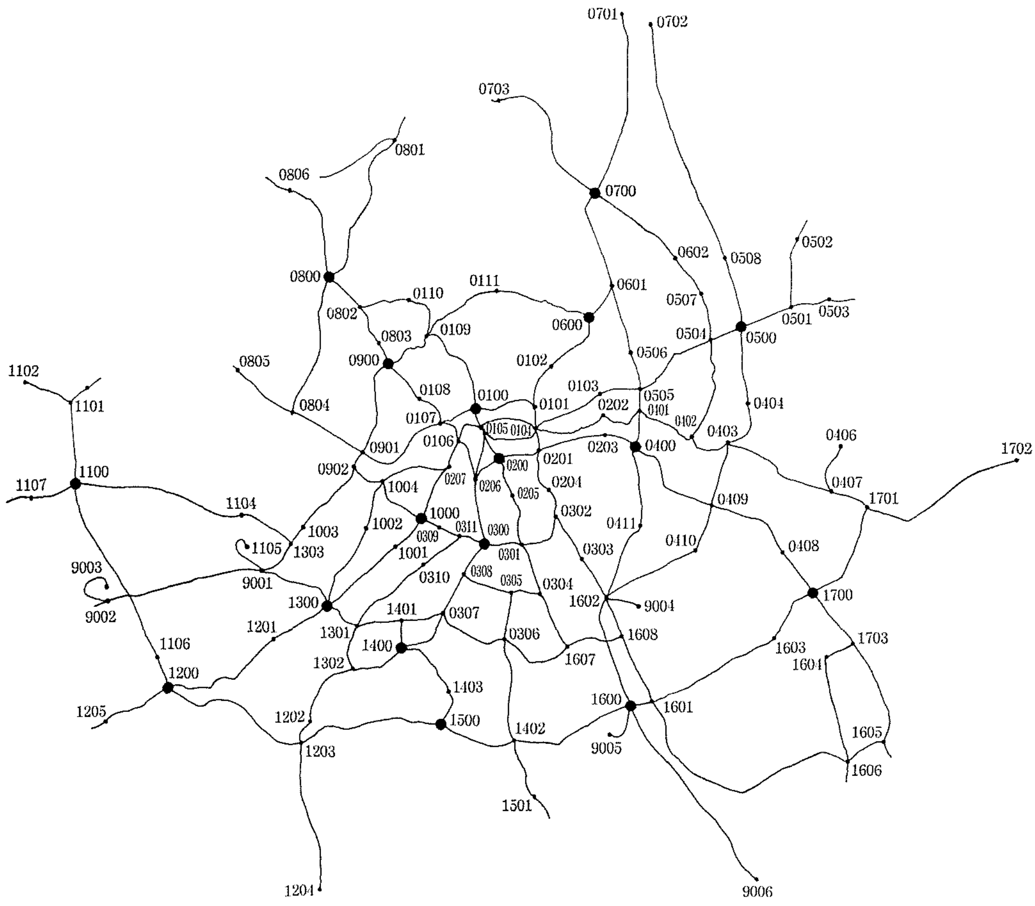


Figure 3-5. The Network and Node Map in Seoul City.

L_{gi} ; the reciprocal of average attraction for all zones relative to generation zone i.

L_{aj} ; the reciprocal of average generation for all zones relative to attraction zone j.

As the volume of trip generation $\left(\sum_{j=1}^{n} X_{ij}\right)$ and the volume of trip attraction $\left(\sum_{i=1}^{n} X_{ij}\right)$ of each zone which is calculated from X_{ij} (3. 5) are not consistent with the volume

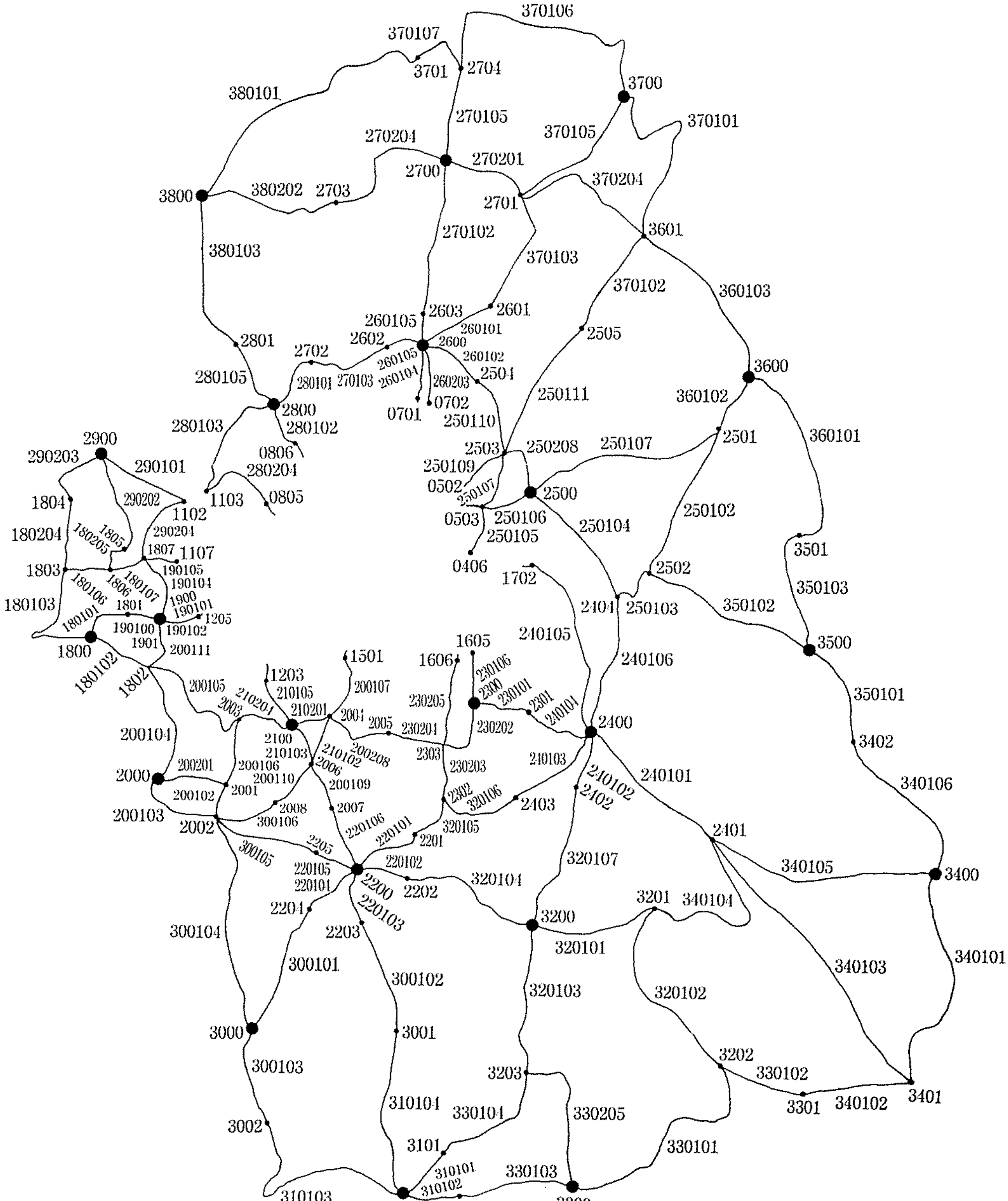


Figure 3-6. The Network and Node Map in Gyeonggi-do Region.

of trip generation (G_i) and the volume of trip attraction (A_j), the repetitious calculation is done till both F_{gi} and F_{aj} converges to 1.00. This calculation process is depicted in Figure 3-3.

3.4 *Road Network*

The study area, as previously stated, consists of a 11412.13 square kilometers of land area representing the Seoul Metropolitan area. This land area also represents 11.53 percent of the total land area of the Republic of Korea. In addition, there are six cities of about 632.53 square kilometers in size and eighteen Guns of 10152.54 square kilometers. This vast area constitutes the Seoul Metropolitan area under this study. The network map is the central source of data for the determination of the assignment of trip distribution. It is composed of the link (road selection) and node (road crossing, trip generation points). The flow chart of the procedure for the road network table derivation is shown in Figure 3-4 below.

To simplify issues, the road network map of the Seoul Metropolitan area was desegregated into two, one for Seoul city and the other for Gyeonggi-do region. Experssway network, however, constituted one set of map. Based on the above, the system was classified into national roads, local roads and expressways. All roads in the Seoul city were designated as national roads while those in the Gyeonggi-do region constituted national and local roads.

The number of nodes available on general roads (national and local) were 188 while those for the expressways were 18. With regards to links, the Seoul city

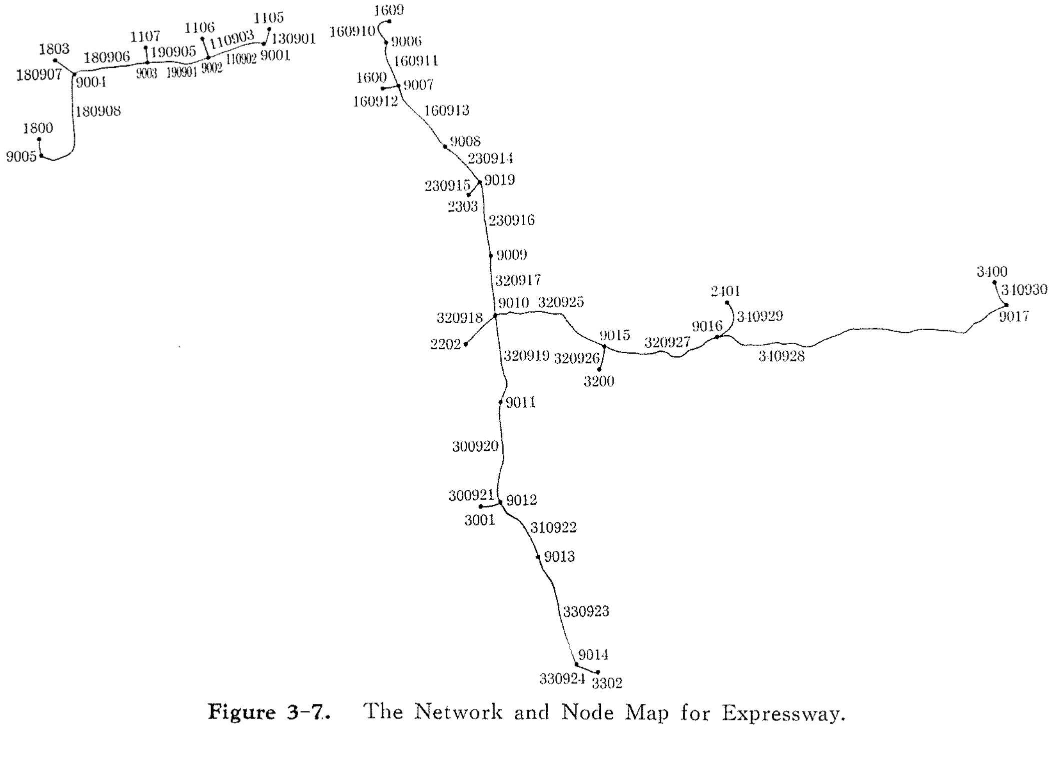


Figure 3-7. The Network and Node Map for Expressway.

Table 3-12. Classification of Link Number

○ ○	○ ○	○ ○
Zone Number	Road Number	Link Number

area had 154, with the Suburbs and Fringe districts having 77 and 44 links respectively. The corresponding link number for the expressway was 30. Thus in all, the Seoul Metropolitan Area had 206 nodes and 305 links. The network maps for the Seoul city, the Seoul Metropolitan area as well as for the expressways are shown in Figures 3-5, 3-6, 3-7.

The link numbers employed in this study were characterized by a six-digit number and its classification is as shown in Table 3-12.

The foremost two numbers represent the number for the zone in which the link is situated.

In all there are 38 zones in the study area. The next two digits refer to the system of road classification. 01 represents national roads, 02 represents local roads and finally 09 represents expressways.

This is illustrated in the Table 3-13 below.

Road Network Table is as shown in Figure 3-8.

Table 3-13. Classification of Road

Road Number	Road Name
01	National Road
02	Road of City or Gun
09	Expressway

3.5 *Traffic Assignment Model by Cost Distance Equilibrium*

1) Link Passage Expenses

As a criterion for the determination of traffic assignment embodies a high level of sensitivity.

Therefore, link passage expenses have to reflect accurately a driver's route choice. It has been established that a driver chooses a route based on the shortest distance to be traveled, the comfort of using the road and the ease with which to use the road. In other words a drivers criterion for choosing a particular route is based on a standpoint of driving distance, driving cost and the pleasantness associated with the route.

To obtain the link passage expenses based on the above reasoning, three methods exist.

(1) A Method Based on Actual Distance
(2) A Method Based on Time Distance
(3) A Method Based on Cost Distance

For the purpose of this study, the third method was adopted.

The equation of link passage expenses based on cost distance is expressed as follows (3. 7).

$$E_{ij}=D_{ij}\left(FE+\frac{DE+PE+S+TIE}{V}\right) \tag{3. 7}$$

E_{ij}: Expenses incurred by a Motor Truck Traveling from Nodes i to j (Yen/Veh.)
D_{ij}: Distance between Nodes i to j (Km)
FE: Fuel Expenses incurred for a Traveling one kilometer (Yen/Km)
DE: Depreciation Expense incurred for Traveling an hour (Yen/hr)
PE: Premium Expenses for an hour (Yen/hr)
S: Driver's Income for ah hour (Yen/hr)
TIE: Motor Truck Inspection Expenses for an hour (Yen/hr)
V: Velocity (Km/hr)

Table 3-14 shows the total number of motor vehicles in Korea in 1985, the daily average driving distance and the vehicle kilometers traveled etc. The depreciation expenses, the premium expenses as well as the fuel expenses are estimated using the table below.

a	b		c	d	e
Link Nubmer	Node Number		Distance (km^2)	Travel Speed (km^2/h)	Cost (Veh/Veh.)
	Node	Node			
010201	0100	0101	1.9	22.5	28.70
010202	0101	0102	1.5	19.7	23.86
010103	0103	0104	2.4	22.1	36.49
010204	0105	0104	0.7	19.7	11.13
010105	0105	0104	1.8	22.1	27.37
010106	0100	0105	0.7	30.9	9.50

Figure 3-8. An Example of Road Network Table.

a : Link Number.
b : Node Number of Link both ends.
c : Actual Survey of the Map (1/50,000) of Seoul Metropolis and Map (1/100,000).
d : "A study on Traffic Improvement Scheme for Seoul Metropolis", Department of Transportation, 1983.
"A survey on Vehicle Driving Pattern in Urban Area", Korean National Environmental Protection Institute, 1983.
"A Stndy on Smoke Control Technology of Diesel Vehicles (1)", Korean National Environmental Protection Institute, 1986.
e : Road Appraisal Equation (see the 3. 2. 1).

Table 3-14. Status of Driving Distance and Vehicle Kilometers Traveled

Kinds of Vhicle		No. of Vheicle		Driving Distance	Fuel Economy	Vehicle Kilometers traveled ×10³ (Veh. km/day)	
		Seooul	Korea	(km/day)	(km/l)	Seoul	Korea
Taxi		37012	99090	310	9.91	11474	30718
Passenger Car		258108	452663	46	9.86	11873	20822
Jeep		1728	4906	64	7.5	111	314
Bus	City	8261	20433	338	2.84	2792	6906
	Inter City		10082	344	3.33		3468
	Rental & Sightseeing	1448	4547	191	3.45	277	868
	Express Bus	8	1829	592	2.74	5	1083
	Small Bus	28541	62737	64	9.9	1827	4015
	Others	5994	28681	40	3.19	240	1147
	Sub Total	44252	128309			5141	17487
Motor Truck	1 ton or less	53876	128309	75	10.72	4041	16450
	1.1 ton to 3 ton	37486	115682	77	6.31	2886	8908
	3.1 ton to 7.9 ton	4290	35018	105	3.05	450	3677
	8 ton or more	9055	58429	162	2.20	1467	9465
	Sub Total	104707	428462			8844	38500
Motor Cycle		80945	711439	13.7	38.25	1109	9747
Total*		445807	1113430			37443	107841
Grand Total**		526752	1824869			38552	117588

* Motor Cycle Excluded.
** Cycle Included.
Source: "A Study on Smoke Control Technology of Diesel Vehicles (1)" NEPI, 1986.

In addition, the explanation of the sources of the data as well as the method for their derivation is also provided as follow:

(1) Feul Expenses (FE)

Table 3-15 shows the weighted average diesel used for making a distance of one kilometer. The number of motor trucks used in the analysis was obtained from the report published on Korean Automobiles in 1983.

Percentages in terms of vehicle kliometers traveled by the various types of motor trucks is as follows:

(a) Motor Trucks Weighing one ton or less ········ 40.76 percent
(b) Motor Trucks Weighing between 1.1 to 3 tons ········ 37.38 percent
(c) Motor Trucks Weighing between 3.1 to 8 tons ········ 10.36 percent
(d) Motor Trucks Weighing 8.1 tons and over ········ 11.5 percent

The fuel economy as a representative of the above classification scheme at that time (1986) was 10.72 km/l, 6.31 km/l, 3.05 km/l and 2.5 km/l respectively.

1 represents one litre.

The price of a liter of diesel oil in Korea in 1983 was approximately 51.5 yen. The diesel oil expenses for making a trip of one kilometer for the different motor truck subgroups as lited above (a, b, c, d) were 4.8 yen, 8.2 yen, 16.9 yen and 23.4 yen respectively. The weighted average at the time was 1.96 yen, 3.07 yen, 1.75 yen, and 2.69 yen respectively resulting in a representative fuel expenses (FE) of 9.74 yen/km.

(2) Depreciation Expenses (DE)

Table 3-16 shows the weighted average of depreciation expenses incurred in an hour in Korea. The approximate purchase price of a motor truck (based on our classification above) in Korea is given below.

(a) 1 ton or less .... 1,000,000 yen
(b) Between 1.1 and 3 tons .... 1,400,000 yen
(c) Between 3.1 and 8 tons .... 3,850,000 yen
(d) 8.1 tons and above .... 7,180,000 yen

Table 3-15. Fuel Expenses

Kinds of Motor Truck	No. of Motor Truck***	Driving Distance (km/day)	Vehicle kilometers Traveled (Veh. km/day)	Fuel Economy (km/l)	Expenses for a liter (Yen/l)	Weighted Average (Yen/Veh. km)
1.0 ton or less*	34650	75	2598750 (40.76%)	10.72	4.8	1.96
1.1 ton to 3 ton	30953	77	2383381 (37.38%)	6.31	8.2	3.07
3.1 ton to 8 ton	6291	105	660555 (10.36%)	3.05	16.9	1.75
8.1 tod or more	4526**	162	733212 (11.5%)	2.2	23.4	2.69
						9.47

* Light duty trucks included.
** Special Trucks included.
*** in the year 1983.

Table 3-16. Depreciation Expenses

Kinds of Motor Truck	No. of Motor Truck***	Driving Distance (km/day)	Vehicle kilometers Traveled (Veh. km/day)	Expenses for an hour (Yen/h)	Weighted Average (Yen/h)
1.0 ton or less*	34650	75	2598750 (40.76%)	19.0	7.74
1.1 ton to 3 ton	30953	77	2383381 (37.38%)	26.6	9.94
3.1 ton to 8 ton	6291	105	660555 (10.36%)	73.2	7.58
8.1 ton or more	4526**	162	733212 (11.5%)	136.6	15.71
					40.97

* Light duty trucks included.
** Special Trucks included.
*** in the year 1983.

Table 3-17. Premium Expenses

Kinds of Motor Truck	No. of Motor Truck***	Percentage of No. of Motor Truck	Expenses for a hour (Yen/h)	Weighted Average (Yen/h)
1.0 ton or less*	34650	45.34	1.44	0.65
1.1 ton to 3 ton	30953	40.5	2.41	0.98
3.1 ton to 8 ton	6291	8.2	2.41	0.2
8.1 ton or more	4526**	5.9	3.43	0.2
				2.03

* Light duty.
** Special truck.
*** in the year 1983.

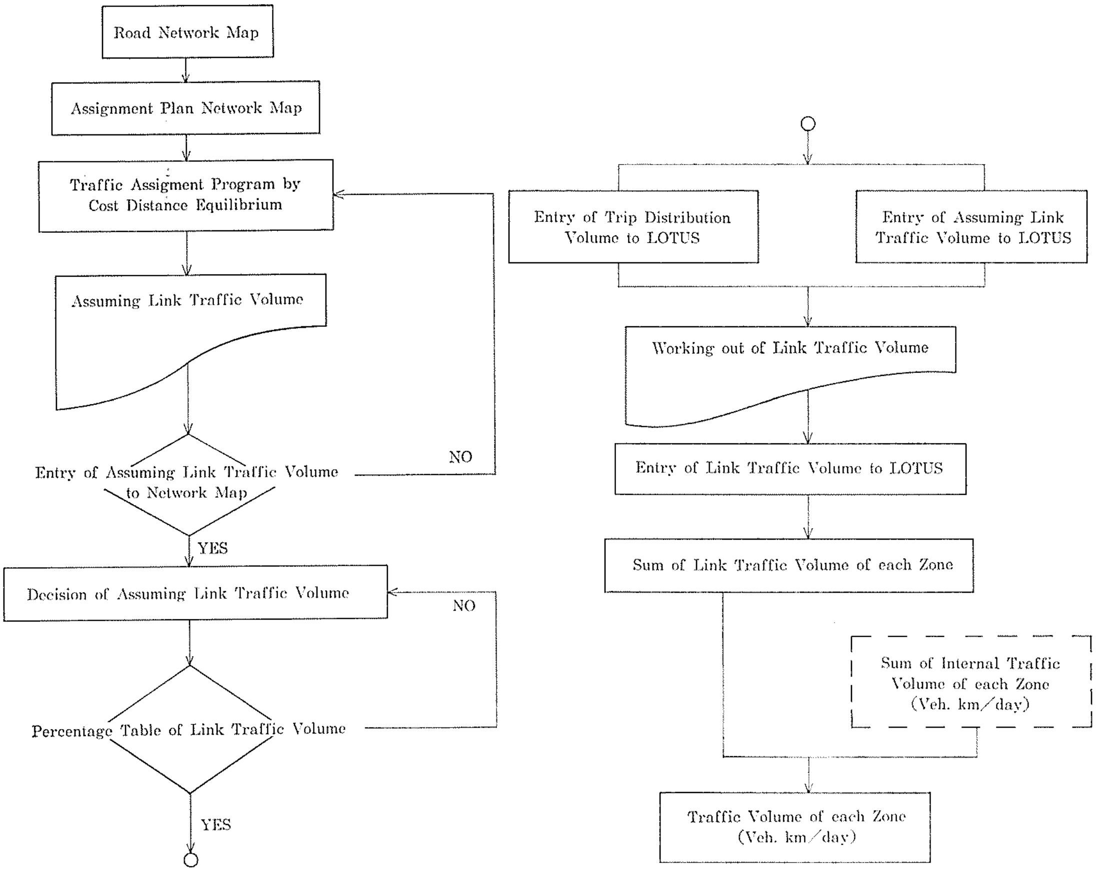


Figure 3-9. The Process for Calculating the Traffic Volume of Each Zone.

The life-span of a motor truck vary greatly depending on the type of vehicle, the driving pattern etc. This study, however, assumes a duration of six years.

Based on this, the depreciation expenses incurred in an hour for the usage of the different brands of motor trucks are 19 yen, 26.6 yen, 73.2 yen and 136.6 yen respectively. The weighted average for the depreciation expenses is thus 7.74 yen/h, 9.94 yen/h, 7.58 yen and 15.71 yen/h respectively.

The representative Depreciation Expense (DE) becomes 40.97 yen/h.

(3) Premium Expenses (PE)

Table 3-17 shows the weighted average of premium expenses for an hour. Normally, premium expenses vary between private and business use. This study however, adopts the business-type premium. Thus, the annual premium on the various motor truck types is given as follows:

(a) Less than 1 ton ··············· 12,580 yen
(b) Between 1.1 and 8 tons ··············· 21,120 yen
(c) 8.1 or more tons ··············· 30,020 yen

The corresponding hourly premium is 1.44 yen, 2.41 yen, 2.41 yen, and 3.43 yen respectively.

The weighted average premium are 0.65 yen/h, 0.98 yen/h, 0.2 yen/h respectively.

The representative Premium Expenses (PE) becomes 2.03 yen/h.

A driver's income per hour is approximately 83.3 yen and the motor truck inspection expenses for an hour is 0.44 yen.

Thus, the equation for the link passage expenses is shown below (3. 8) after substituting the data above into the equation (3. 7).

$$C_{ij} = D_{ij}\left(9.47 + \frac{40.97 + 2.03 + 83.3 + 0.44}{V}\right) \tag{3. 8}$$

2) Traffic Assignment Program based on Cost-Distance Equilibrium

This analysis on the volume of traffic assignment, unlike the previous ones which utilized large memory computers, uses only a personal computer.

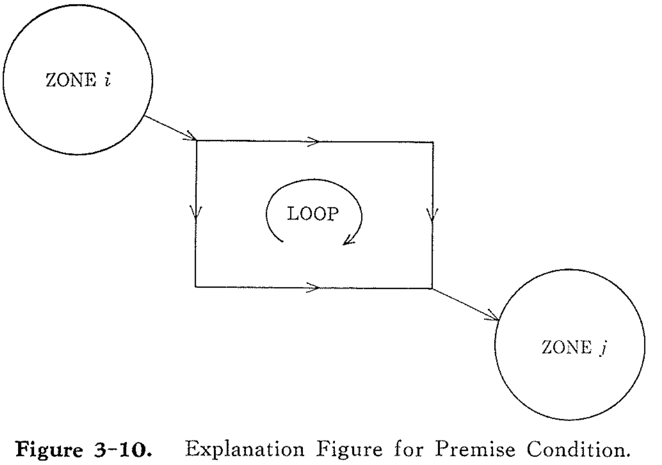


Figure 3-10. Explanation Figure for Premise Condition.

The assignment theory used in this study is based on the one developed Yamamura Satou Assignment Theory (1967). Flow chart connecting the road network to the sum of the link traffic volume of each zone is shown in Figure 3-9.

(1) Traffic Assignment Theory based on Cost-Distance Equilibrium

The traffic assignment theory by Cost-Distance Equilibrium Method states that the aggregate of the compensative link traffic volume of each loop (Yamamura, Satou, 1967) obtained from the link passage expense should be equal to the assumed traffic volume from zone i to zone j.

The premise condition of this traffic assignment theory is as follows:

A. The efflux traffic volume at zone i is identical with the influx traffic volume at j.
   The efflux traffic volume from zone i does not disappear on the its way, that is, and all efflux traffic volume flows into zone j.

B. The most suitable traffic assignment from zone i to zone j is the traffic volume obtained when total link driving expenses of each loop becomes equal.
   This means that the aggregation of compensative traffic volume of each loop is to be 0.00001.

(2) Flow Chart of Traffic Assignment Program by Cost-Distance Equilibrium

We built the traffic assignment basic program by Cost-Distance Equilibrium based on the premise shown in Figure 3-11.

To determine the traffic assignment volume, we assumed that the trip generation volume flowing from zone i to zone j is 100 vehicles and this is attracted solely to zone j. This assumed traffic volume ($Q_l(i)$) of each link was presented in a form of a table.

From the output on the equation of the link passage expense (3. 8) the link passage expense table was built. These two tables became the input data of Figure 3-10.

The driving expense ($AK_l(i)$) of each link is calculated from this assumed link traffic volume and the link passage expense at that time. A loop driving expense (B_l) is obtained by adding up the link driving expenses within the loop. Similarly, the link passage expenses (C_l) is obtained by adding up the link passage expenses ($T_l(i)$) at that time, in each loop.

The compensative loop traffic volume (D_l) is obtained from the next equation.

$$D_l = -B_l/C_l \tag{3. 9}$$

B_l: Loop Diriving Expense
C_l: Link Passage Expense

Every compensative loop traffic volume is expected to be 0.00001 assuming link traffic volume is printed.

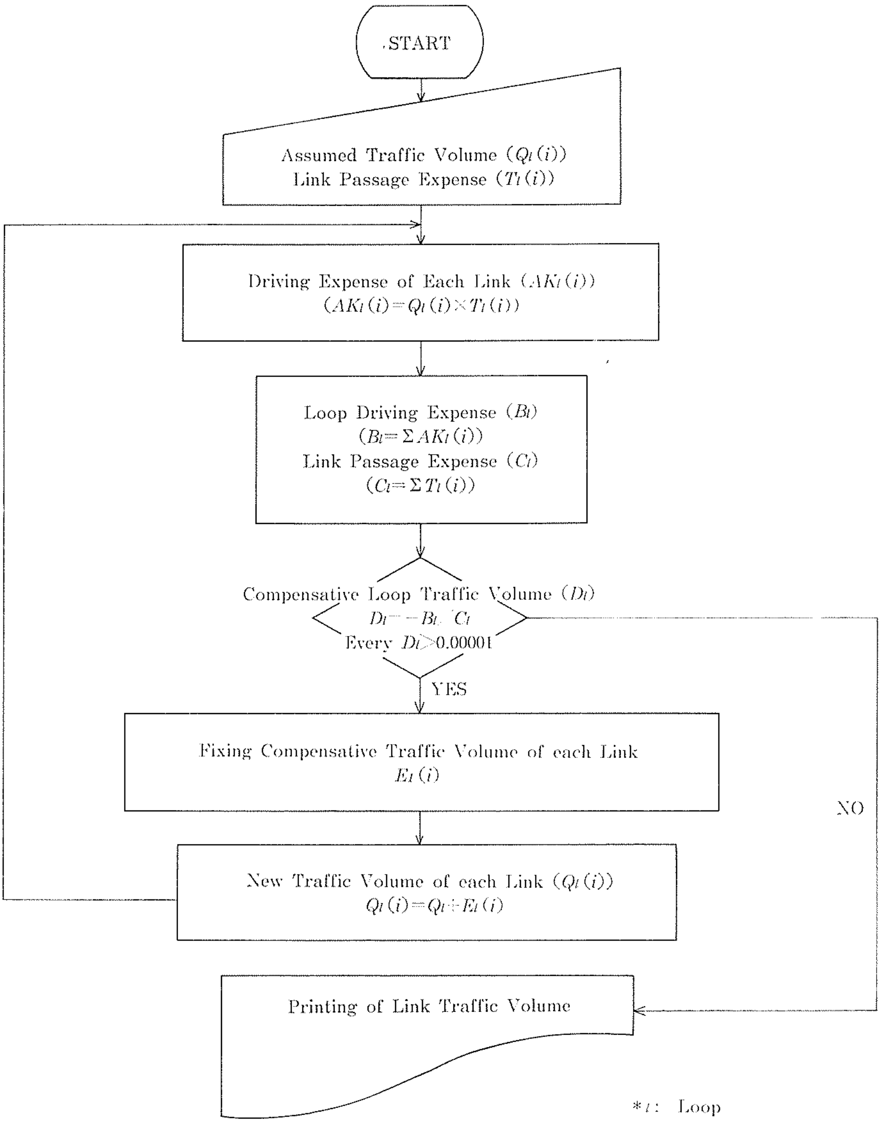


Figure 3-11. Flow Chart of Traffic Assignment Program Based on Cost Distance Equilibrium.

However, if this volume is a greater than 0.00001, then the calculation process determines the fixing compensative traffic volume ($E_l(i)$) of each link and works out a new traffic volume ($Q_l(i)$) for each link. This 'adjusted' traffic volume then re-enters the data as a fresh input.

To determine the assumed traffic volume ($Q_l(i)$) as an input data for the traffic assignment program and link passage expense ($T_l(i)$), 1369 network map had to be established.

The network maps make it possible to determine the number of loops between one zone i and the other zone j. From this, the tables for the assumed link

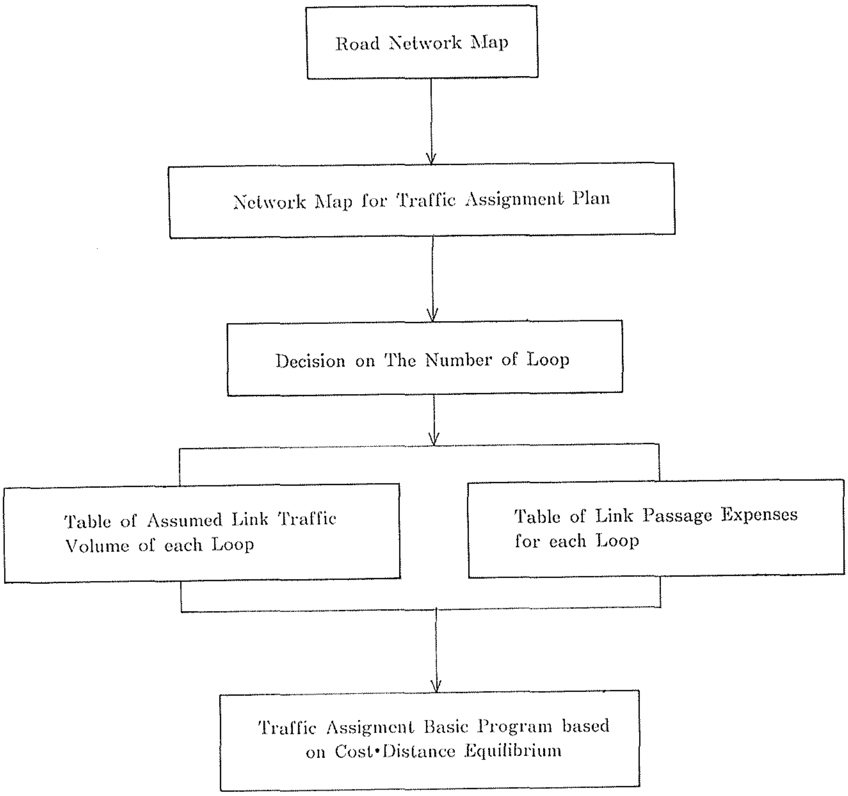


Figure 3-12. Flow Chart of Input Data for Traffic Assignme nt Program.

traffic volume and link passage expenses are derived via the trip generation of 100 vehicles from zone *i* to zone *j*.

These two tables then become the input data for the traffic assignment program based on cost distance equilibrium.

(3) Percentage of Table of Each Link Traffic Volume

The purpose here is to construct a table showing the percentages for each link traffic volume by utilizing the interzonal link traffic volume.

This flow chart is as shown in Figure 3-13.

The assumed link traffic volume is worked out from the traffic assignment program by using the cost distance equilibrium method from zone *i* to *j*. By superimposing this on the network map for traffic assignment plan, the assumed traffic volume can be estimated through the analysis of the assumed link traffic volume. The table displaying the percentage value of the 38 interzonal traffic volume based on the above treatise is shown in Figure 3-14.

The values obtained from the above table together with data on the volume of trip distribution is punched into a LOTSU 1-2-3 and the link traffic volume is subsequently obtained.

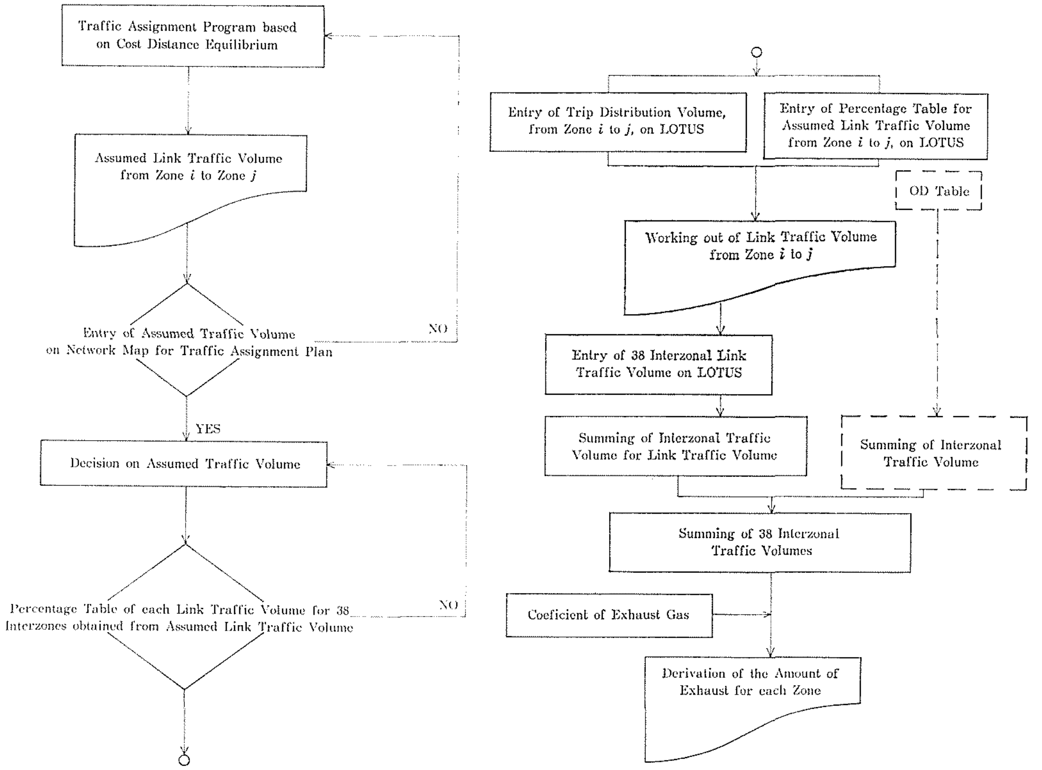


Figure 3-13. Flow Chart of Traffic Volume for Interzonal Link Traffic.

Link Number / from Zone i to j	010201	010202	010103	010204	• • • • • •
0100 — 0200	0.167			0.167	
0100 — 0300					
0100 — 0400	0.303		0.261	0.303	
0100 — 0500	0.530		0.382	0.530	

Figure 3-14. Percentage Table of each Link Traffic Volume of 38 Interzone.

4. Land-Use Alternatives

In recent year, the dispersive policy of population and industries in big cities of the developing countries especially those of the NIES (Newly Industrializing Economies) in which the agglomeration of population and industries is alarmingly disproportionate has been a focus of intense research activity. Most of these studies, however, have been undertaken from myopic perspectives making their implementation air impossibility. To ensure a long-term solution, this study deviates from the previous line of research by approaching the problem in a comprehensive manner. This involves the idea of land use re-located.

The three land use variables considered under the study are as follows:

(1) Residential Area
(2) Commercial Area
(3) Industrial Area

Three districts comprising of Seoul District (Seoul city's 20 kilometer block), Seoul Suburbs District 20-40 kilometer block) and lastly Seoul Fringe District (40-60 kilometer block) were demarcated.

Next, a series of policy variable were evolved and simulated to assess their effectiveness on resolving the motor truck exhaust problem of Seoul city.

Initially, 10 percent and 30 percent respectively of the total industrial land use of the Seoul District were reapportioned to the Suburbs District and the Fringe District respectively and the abatement effectiveness of motor truck exhaust pollution was observed.

Furthermore, considering the numerous zones in the Seoul District, the following two extractive methods were applied as follows:

(1) equal extraction from each zone of Seoul city
(2) proportional extraction from zones exceeding environmental judgment criterion value in Seoul city

In approtioning these industrial activities to the Suburbs District and the Fringe District, consideration was given to

(1) equal extraction and equal apportionment to the Suburbs or the Fringe
(2) equal extraction and equal apportionment to the Suburbs and the Fringe on 50 percent to 50 percent basis
(3) selective extraction and selective apportionment to the Suburbs or the Fringe
(4) selective extraction and selective apportionment to the Suburbs or the Fringe on a 50 percent to 50 percent basis

This land use plan resulted in 12 cases paraphrased as follows:

(1) case 1: Equal Extraction of 10 percent of industrial land use activities of Seoul District and Equal Apportionment of that 10 percent to the Seoul Suburbs District
(2) case 2: Equal Extraction of 10 percent of industrial land use activities

of Seoul District and Equal Apportionment of that 10 percent to the Seoul Fringe District

(3) case 3: Equal Extraction of 10 percent of industrial land use activities of Seoul District and Equal Apportionment of that 10 percent to the Suburbs and the Fringe on a 50 percent to 50 percent basis

(4) case 4: Selective Extraction of 10 percent of industrial land use activities of Seoul District and selective apportionment of that 10 percent to the Seoul Suburbs District

(5) case 5: Selective Extraction of 10 percent of industrial land use activities of Seoul District and selective apportionment of that 10 percent to the Seoul Fringe District

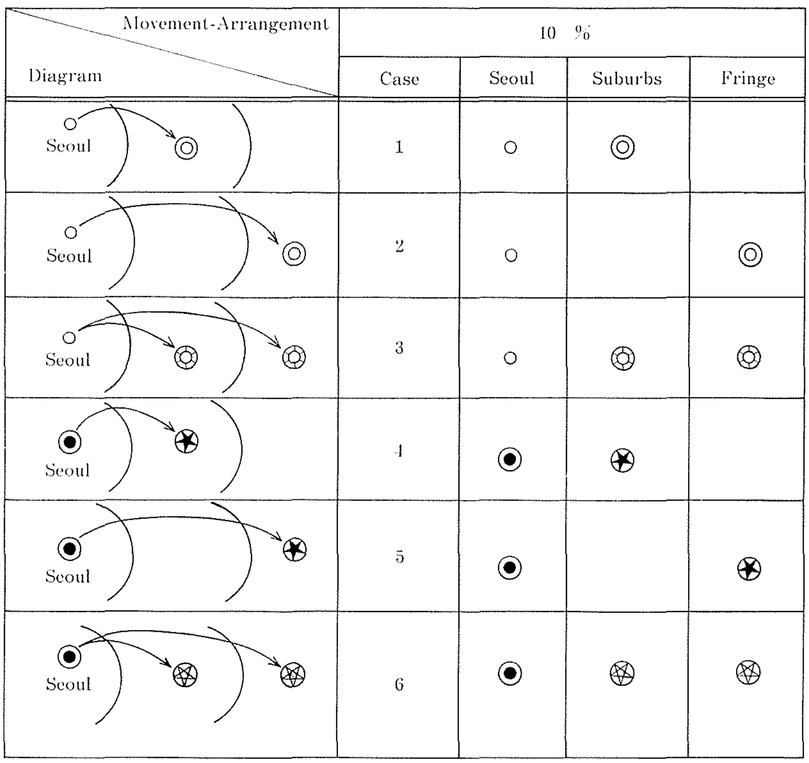


Figure 4-1. Land-Use Alternatives Using 10%.

Note; 1. The Method Extracting the Industrial Area.

○ ; Equal Extraction

◉ ; Selective Extraction

2. The Method Apportioning the Industrial Area.

◎ ; Equal Apportionment

(symbol) ; Selective Apportionment

(symbol) ; Equal Apportionment to Both on 50% to 50% Basis

(symbol) ; Selective Apportionment to Both on 50% to 50% Basis

(6) case 6 : Selective Extraction of 10 percent of industrial land use activities of Seoul District and selective apportionment of that 10 percent to the Seoul Suburbs District and the Seoul Fringe District on 50 percent to 50 percent basis

(7) case 7 : Equal Extraction of 30 percent of industrial land use activities of Seoul District and Equal Apportionment of that 30 percent to the Seoul Suburbs District

(8) case 8 : Equal Extraction of 30 percent of industrial land use activities of Seoul District and Equal Apportionment of that 30 percent to the Seoul Fringe District

(9) case 9 : Equal Extraction of 30 percent of industrial land use activities

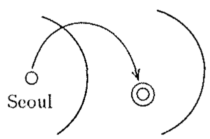
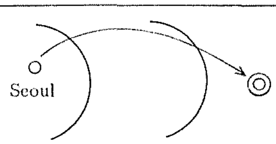
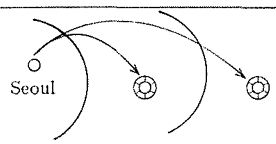
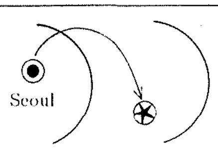
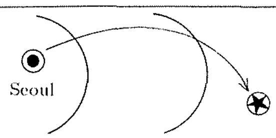
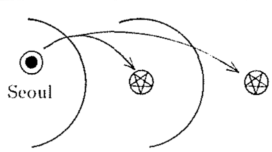
Movement-Arrangement / Diagram	30 %			
	Case	Seoul	Suburbs	Fringe
	7	○	◎	
	8	○		◎
	9	○	⊚	⊚
	10	⦿	⊛	
	11	⦿		⊛
	12	⦿	✪	✪

Figure 4-2. Land-Use AlternativesUsing 30%.

of Seoul District and Equal Apportionment of that 30 percent to the Suburbs and the Fringe on a 50 percent to 50 percent basis

(10) case 10 : Selective Extraction of 30 percent of industrial land use activities of Seoul District and selective apportionment of that 30 percent to the Seoul Suburbs District

(11) case 11 : Selective Extraction of 30 percent of industrial land use activities of Seoul District and selective apportionment of that 30 percent to the Seoul Fringe District

(12) case 12 : Selective Extraction of 30 percent of industrial land use activities of Seoul District and selective apportionment of that 30 percent to the Seoul Suburbs District and the Seoul Fringe District on a 50 percent to 50 percent basis

5. Analysis and Consideration of Land Use

5. 1 *Abatement Effectiveness using Equal Extraction and Equal Apportionment*

If we extract 10 percent or 30 percent of the industrial area from each of the 17 zones of Seoul city and apportion equally to the Suburbs, the Fringe, or to both on 50 percent to 50 percent basis, we can obtain the simulation results of abatement effectiveness of the amount of exhaust per area in Seoul city as shown in Table 5-1.

Apportioning equally 10 percent of the industrial area from the 17 zones of Seoul city to the Suburbs, the Fringe, or to both on 50 percent to 50 percent basis, we can obtain the abatement effectiveness of 1.16 percent, 1.96 percent and 2.14 percent respectively.

Apportioning equally 30 percent of the industrial area from the 17 zones of Seoul city to the Suburbs, the Fringe, lr to both on 50 percent to 50 percent basis, we can also obtained the abatement effectiveness of 5.70 percent, 6.51 percent and 5.17 percent respectively.

Table 5-1. Abatement Effectiveness of the Amount of Motor Truck Exaust in Seoul City using Apportionment of 10% or 30%

(kg/km²/day)

LOCATION / PERCENTAGE RELOCATED	TO SUBURBS		TO FRINGE		TO BOTH ON 50% TO 50%	
	EQUAL	SELECTIVE	EQUAL	SELECTIVE	EQUAL	SELECTIVE
10%	11.09 (−1.16%)	11.09 (−1.16%)	11.00 (−1.96%)	11.13 (−0.80%)	10.98 (−2.14%)	11.09 (−1.16%)
30%	10.58 (−5.70%)	10.92 (−2.67%)	10.49 (−6.51%)	10.74 (−4.28%)	10.64 (−5.17%)	10.80 (−3.74%)

5. 2 *Abatement Effectiveness Using Selective Apportionment*

If we extract selectively 10 percent or 30 percent of the industrial area from 14 zones of Seoul city being over the Environmental Judgement Criterion Value and apportion selectively to 8 zones of the Suburbs and 5 zones of the Fringe having low value as compared with the Environmental Judgement Criterion Value, we can obtain the simulation results as shown in Table 5-1.

Apportioning selectively 10 percent of the industrial area of 14 zones of Seoul city to the Suburbs, the Fringe, or both on 50 percent to 50 percent basis, we can obtain the abatement effectiveness of 1.16 percent, 0.80 percent and 1.16 percent respectively.

Apportioning selectively 30 percent of the industrial area of 14 zones of Seoul city to the Suburbs, the Fringe, or both on 50 percent to 50 percent basis, we can obtain the abatement effectiveness of 2.67 percent, 4.28 percent and 3.74 percent respectively.

Apportioning 10 percent of the industrial area from Seoul city to the Suburbs, we can obtain the abatement effectiveness of 1.16 percent using equal apportionment and of 1.16 percent using selective apportionment. That is, when we apportioned 10% of the industrial area from Seoul city to the Suburbs, the abatement effectiveness using equal apportionment and using selective apportionment did not show no difference.

However, apportioning 10 percent of the industrial area from Seoul city to the Fringe, we can obtain the abatement effectiveness of 1.96 percent using equal apportionment and of 0.80 percent using selective apportionment. Again, apportioning 10 percent of the industrial area from Seoul city to the Suburbs and the Fringe on 50 percent to 50 percent basis, we can obtain the abatement effectiveness of 2.14 percent using equal apportionment and of 1.16 percent using selective apportionment.

That is, if we apportion 10 percent of the industrial area to the Suburbs, to the Fringe, or to both on 50 percent to 50 percent basis, the abatement effectiveness using equal apportionment and using selective apportionment showed the abatement effectiveness of about twice as much as using the selective apportionment excepting the Fringe District.

Apportioning 30 percent of the industrial area from Seoul city to the Suburbs, we can obtain the abatement effectiveness of 5.70 percent using equal apportionment and of 2.67 percent using selective apportionment. Again, apportioning 30 percent of the industrial area from Seoul city to the Fringe, we can obtain the abatement effectivenesss of 6.51 percent using equal apportionment and of 4.28 percent using selective apportionment. Furthermore, apportioning 30 percent of the industrial area from Seoul city to the Suburbs and the Fringe on 50 percent to 50 percent basis, we can obtain the abatement effectiveness of 5.17 percent using equal apportionment and of 3.74 percent using selective apportionment.

That is, if we apportion 30 percent of the industrial area to the Suburbs, to the Fringe, or to both on 50 percent to 50 percent basis, equal apportionment showed the abatement effectiveness of about one and a half times as much as selective apportionment.

6. Conclusion

A summary of the results are as follows:

1) In this study, an appraisal model for measuring the abatement effectiveness of air pollutant (NO_x) due to motor truck exhaust in Seoul city was built and it became clear that it is functionally operative.

2) Apportioning 10 percent of the industrial area from Seoul city to the Suburbs, we can obtain the abatement effectiveness of 1.16 percent using equal apportionment and also of 1.16 percent using selective apportionment.

That is, when we apportioned 10 percent of the industrial area from Seoul city to the Suburbs, the abatement effectiveness using equal apportionment and using selective apportionment show no difference.

However, apportioning 10% of the industrial area from Seoul city to the Fringe, we can obtain the abatement effectiveness of 1.96 percent using equal apportionment and of 0.80 percent using selective apportionment. Also, apportioning 10 percent of the industrial area from Seoul city to the Suburbs and the Fringe on 50 percent to 50 percent, we can obtain the abatement effectiveness of 2.14 percent using equal apportionment and of 1.16 percent using selective apportionment.

That is, if we apportion 10 percent of the industrial area to the Suburbs, to the Fringe, or to both on 50 percent to 50 percent, equal apportionment showed the abatement effectiveness of about twice as much as selective apportionment excepting the Fringe District.

3) Apportioning 30 percent of the industrial area from Seoul city to the Suburbs, we can obtain the abatement effectiveness of 5.70 percent using equal apportionment and of 2.67 percent using selective apportionment.

Again, apportioning 30 percent of the industrial area from Seoul city to the Fringe, we can obtain the abatement effectiveness of 6.51 percent using equal apportionment and of 4.28 percent using selective apportionment. Furthermore, apportioning 30 percent of the industrial area from Seoul city to the Suburbs and the Fringe on 50 percent to 50 percent, we can obtain the abatement effectiveness of 5.17 percent using equal apportionment and of 3.74 percent using selective apportionment.

That is, if we apportion 30 percent of the industrial area to the Suburbs, to the Fringe, or to both on 50 percent to 50 percent, equal apportionment showed the abatement effectiveness of about one and a half times as much as selective apportionment.

4) The abatement effectiveness of Seoul city in each of cases 1, 2, 3, 7, 8 and 9, using equal extraction and equal apportionment, was obtained as 1.16 percent, 1.96 percent, 2.14 percent, 5.70 percent, 6.51 percent and 5.17 percent respectively.

The abatement effectiveness of Seoul city in each of cases 4, 5, 6, 10, 11, 12, using selective extraction and selective apportionment, was obtained as 1.16 percent, 0.80 percent, 1.16 percent, 2.67 percent, 4.28 percent and 3.74 percent respectively.

Thus, it became clear that for the abatement effectiveness of motor truck exhaust volume in Seoul city the land use plan using equal extraction and equal apportionment was more effective than the land use plan using selective extraction and selective apportionment.

5) Using the traditional four-step travel demand forecasting process well-known as the standard technique for estimating link traffic volume, we have to choose whether we build the computer program serving each step's purpose or buy the computer program software after paying an enormous amount.

However, if we use the appraisal model of motor truck exhaust built in this study, we can obtain that simulation results easily by only one personal computer and thus, it does not cost a great deal.

Therefore, it seems to us that the appraisal model of motor truck exhaust is a suitable model for developing countries and most especially for the Newly Industrializing Economics (NIES).

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