To the Graduate Council:

I am submitting herewith a thesis written by Sang Yool Lee entitled "The Development of a Microcomputer-based Integrated Location and Transportation Model." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Geography.

Bruce A. Ralston

Bruce A. Ralston
Major Professor

We have read this thesis
and recommend its acceptance:

Ronald Foresta

Thomas L. Bell

Accepted for the Council:

CW Minkel

Vice Provost and Dean of
The Graduate School

THE DEVELOPMENT OF A MICROCOMPUTER-BASED INTEGRATED LOCATION AND TRANSPORTATION MODEL

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Sang Yool Lee

May 1990

ACKNOWLEDGMENTS

I would like to express my sincere appreciation and gratitude to Dr. Bruce Ralston for his guidance, patience, and suggestions for this study. I am also grateful to my committee members, Dr. Thomas Bell and Dr. Ronald Foresta, for their consultation, criticism,and suggestion for this manuscript and graduate program guidance.

Most of all, I am grateful to my parents,and my brother, for their love and support. Also, I wish to express appreciation to my wife and my son.

ABSTRACT

The development of integrated urban models has been conducted in the past two decades. This study develops a microcomputer based integrated urban model which examine the interrelationships between location and transportation, based on the properties of the Putman's integrated urban models. First, the process of software development is illustrated, and the restrictions and assumptions necessary to modify such a model on a microcomputer environment are described. Secondly, this study illustrates how the microcomputer version can be used to forecast land use and transportation in a hypothetical urban area. Thirdly, the sensitivity of the version to changes of land use and transportation in the hypothetical urban area is tested to examine the behavior of the microcomputer based integrated urban model.

The microcomputer version developed in this study determines travel costs or times in the network, the simultaneous residential location and trip distribution, and the traffic volume on each link, according to the method of incremental full network reloading for the traffic assignment. This study finds that the simultaneous residential location and trip distribution are determined by the relative proportion of attractiveness and accessibility

characteristics, and the residential allocation is quite affected by the congestion effects on the network. A change in job generation and attractiveness of land use affects the distribution of residences in other zone, as well as the zone in which the change occurred. A change in the network structure and transportation function shows a rather complex impact on residential locations and loaded link volumes.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

FIGURE PAGE

CHAPTER 1

INTRODUCTION

1.1. Statement of Problem

Urban models[1] deal with the allocation and interaction of land use activities in cities and regions, and are used to evaluate the effects of changes in relation to certain land use activities.[2] From the early development of urban models begun in the 1950s, the mutual interrelationships between transportation and urban spatial phenomena were acknowledged. Research on transportation and urban land use was, however, often independently conducted with very little interchange between the two. The interrelationships were not clearly defined until Putman developed integrated urban

---

[1]Abdul Khakee, "Urban Models and Municipal Planning", Urban Geography, Vol.6, 1985, p.64. He illustrated several names of urban models: urban spatial structure model, urban development model, land use model, activity model, and location model. The term of urban model is generally used as more a comprehensive meaning than the above specific names.

[2]David Foot, Operational Urban Models, London, Methuen & Co., 1981, pp.3-6.

models.[3] The purpose of this thesis is to explore the properties of the integrated urban model, and to develop it as a microcomputer-based version to study the solutions and sensitivities to changes in input data.

Thus far, four types of integrated urban models have been developed to study the interrelationships between transportation and land use: (1) the interactive-iterative approach, (2) the combined model approach, (3) the programming model approach, (4) the market clearing simulation approach.[4] Berechman and Gordon examined the above four types of approaches and pointed out that none of them is superior in all aspects, but that the interactive-iterative model developed by S.H.Putman is the most easily implemented, because Putman's interactive-iterative approach can take the place of the much used the Urban Transportation Planning System(UTPS) type models. Only variations on Putman's approach will be discussed in the remainder of this thesis.

In general, the structure of the integrated urban model is easily understood, because its three sub models--employment location, residence location, and transportation--

---

[3]Stephen H. Putman, Integrated Urban Models, London, Pion Limited, 1983, p.3.

[4]Joseph Berechman and Peter Gordon, "Linked Models of Land Use-Transport Interactions: A Review", Advances in Urban Systems Modelling, ed. B. Hutchinson and M. Batty, New York, Elsevier Science Publishers B.V.,1986, pp.109-132.

are simply connected and largely based on existing operational models. However, the interrelationships between land use and transportation can be very complex. Efforts to integrate land use models with a suitable transportation network model can, therefore, be difficult. There is a need for further study of integrated urban models in order to examine the interrelationships between transportation and land use

1.2. Objectives and Organization of the Thesis

The purposes of this study are:

to examine the sub-models of the integrated urban model developed by Putman;

to develop a microcomputer-based version of the Putman's integrated urban model;

to illustrate how this model can be used to forecast land use and transportation in a hypothetical urban area; and,

to test the sensitivity of the model to changes of land use and transportation in the hypothetical urban area

This thesis is organized into five chapters. Chapter 1 provides a brief introduction to the research. Chapter 2 reviews the models related to Putman's integrated model. Before the three sub-models(employment location, residence location, and transportation) are discussed, Lowry's model, upon which Putman's development of the integrated urban model is based, is reviewed. Chapter 3 discusses the structure of the microcomputer version of the Putman's integrated urban model. Chapter 4 presents numerical analyses of land use and travel in a hypothetical city. Sensitivity analysis of the microcomputer version of the integrated urban model is also discussed. Chapter 5 provides a summary, draws conclusions concerning the use of integrated model, and discusses future research which might prove fruitful.

CHAPTER 2

INTEGRATED LOCATION AND TRANSPORTATION MODELS:

Literature Review

This chapter reviews previous studies related to integrated urban models. First, we consider the Lowry model, a pioneering attempt at comprehensive urban models. Then, employment location models, residence location models, and transportation network studies are examined in order to explore the properties of Putman's integrated urban model.

2.1. Lowry Model

The Lowry model, along with its numerous derivatives, comprises the largest class of urban models.[5] The procedure of the Lowry model was summarized by Putman.

> " In general the procedure involves use of the locations of 'basic' employment and assumptions about 'work-trip' behavior to generate a spatial distribution of the residences of the 'basic' employment employees. Both these spatial distributions, i.e.. 'basic' employment and their residences, along with assumptions about 'shopping-

---

[5]Stephen H. Putman, Urban Residential Location Models, Boston, Martinus Nijhoff Publishing, 1979, pp. 50-55.

> trip' behavior are used to generate a spatial distribution of 'non-basic' employment. The locations of the residences of the 'non-basic' employment employees are then generated by use of the 'work-trip' assumptions. "

As the summary indicates, this model consists of two sub-models: a residence location model for basic employment employees, and the model for non-basic employment location. The two sub-models are discussed, along with a review of trip function and attractiveness. In the Lowry model, the terms 'basic' and 'non-basic' employment are conceptually similar to the traditional classification of the urban economic activity which is divided into 'basic' or 'city-forming' sector and 'non-basic' or 'city-serving' sector. Among several measurement criteria of economic activity, employment is the most commonly employed criterion.[6] Basic employment is defined as economic activity that is insensitive to the spatial distribution of local markets, while non-basic employment refers to economic activity that is sensitive to the spatial distribution of local markets.[7]

Residence Location Model

The simple type of residence location sub-model in the

[6]Ray M. Northam, Urban Geography, Second Edition, New York, John Wiley & Sons, 1979, pp. 190-200.

[7]Putman, Integrated Urban Models, pp. 16-17.

Lowry framework assumes that the number of workers residing in a zone i is based on the workers traveling there, and the greater the length of a trip, the less the amount of travel.[8] The equation of the model is:

$$N_i = g\sum_j E_j P_{ij} \tag{2.1}$$

where, N_i: the number of persons living in zone i

E_j: the number of employees working in zone j

g: a scaling factor

P_{ij}: the probability of a trip between points i and j

From equation (2.1), a scaling factor, g, is first assumed to 1.0. Then, the trip probability, P_{ij}, derived from the Pittsburgh Area Transportation Study conducted by Lowry, is calculated.[9] The trip probability is:

$$P_{ij} = d_{ij}^{-1.330} \tag{2.2}$$

---

[8]Ibid., pp. 7-8.

[9]Putman, Urban Residential Location, p.52

where d_{ij} is the distance between points i and j, and

$d_{ij} >= 1.0$

The proper value of g is obtained by dividing the total number of employees by the total number of residents multiplied by g=1.0 as a trial value. Then, the number of residents in each zone is calculated by multiplying the scale factor g in equation (2.1). The sum of residents in all zones is equal to the total employees in the region. However, the number of employees in each zone will not be equal to the original number of employees working in each zone. That is, the Lowry model is inconsistent at the zonal level, though it preserves consistency at the regional level.[10] The inconsistencies are due to the lack of origin or destination constraints on the model.

Besides the simple declining power function which Lowry used in the trip probability of the model, there are two alternative forms of trip function: the declining exponential function and the Tanner function.[11] A declining power function or a exponential function is a one-parameter function of travel time or cost. The one parameter function, shown in (a) of Figure 2.1, is expressed as:

---

[10] Putman, Integrated Urban Models, p.9

[11] Ibid., pp. 213-218.

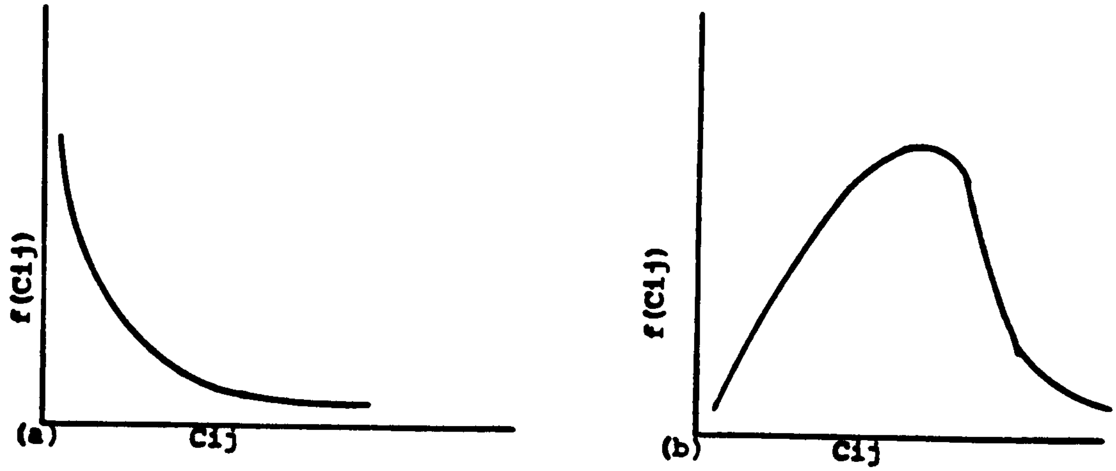


Figure 2.1. Trip Function Forms.
(a) Declining exponential or negative power trip function;(b) Tanner function with $\alpha>0$, $\beta<0$. From, "Integrated Urban Models", by S.H.Putman, 1983, p.178.

$$f(c_{ij})=\exp(-\beta c_{ij}) \tag{2.3}$$

or

$$f(c_{ij})=c_{ij}^{-\beta} \tag{2.4}$$

The Tanner function is a two-parameter function of travel time or cost, shown in (b) of Figure 2.1. This function is expressed as:

$$f(c_{ij})=c_{ij}^{\alpha}\exp(\beta c_{ij}) \tag{2.5}$$

where α and β are empirically derived parameters. In general, α is usually assumed to be greater than 0, and β less than 0.

From equation (2.1), the trip probability, P_{ij}, may be transformed into $W_i f(c_{ij})$ when some measure of attractiveness and a function for trip probability are introduced. Thus, the Lowry-type of residential location model can be expressed as:

$$N_i=g\sum_j E_j[W_i f(c_{ij})] \tag{2.6}$$

W_i is a measure of attractiveness of each potential residence zone, but the residential attractiveness in a zone is not a directly measurable attribute. Therefore, in actual model applications, measures such as public services, physical status, and socioeconomic composition of an area have been suggested as surrogates.[12]

Employment Location Model

Whereas basic employment location in the Lowry model

---

[12]Ibid., p.179.

was assumed exogenous, a model for non-basic employment location was developed within the Lowry model. Retail employment was assumed to be a typical type of non-basic employment, and further assumed to be a direct function of retail sales in the zone.[13] The form of the model is:

$$E_j^R = g(S_j) \tag{2.7}$$

where E_j^R : the retail employment in zone j

S_j : the retail sales in zone j

S_j in the equation 2.7 is expressed as:

$$S_j = \sum_i S_{ij} = \sum_i Y_i [W_j^R f(C_{ij}) / \sum_i W_j^R f(C_{ij})] \tag{2.8}$$

where Y_i: the purchasing power of consumers living in zone i

W_j^R: the retail 'attractiveness' of zone j

$f(C_{ij})$: the trip function

In this Lowry-type of employment location model, work-to-shopping trips coming from places of work can be added to equation (2.8). On the other hand, since this non-basic

---

[13] Ibid., p.151.

employment can be linked directly to the residence location model, the location of non-basic employment can be calculated simultaneously with the location of population.[14]

2.2. Employment Location Models

Employment location models are based on a number of employment location theories. These employment location theories are largely distinguished between market-sensitive(non-basic) and non-market-sensitive(basic) activities. Employment location models were also separately developed in accordance with such activities, rather than toward a comprehensive employment location model.[15] In addition, the employment location models did not receive primary emphasis in the overall urban land use models.[16]

In this review, employment location models are also examined according to market-sensitive and non-market-sensitive activities. Then, EMPAL, a model developed by Putman to simultaneously consider market-sensitive and non-

---

[14]Ibid., p.179.

[15]S.H. Putman, "Urban Land Use and Transportation Models: a state of the art summary", Transportation Research, 1975, Vol.9, p.189.

[16]S. Putman, "Future Directions for Urban Systems Models:Some Pointers from Empirical Investigations", Advances in Urban Systems Modelling, ed. B. Hutchinson and M. Batty, Elsevier Science Publishers B.V.,1986, pp.91-92.

market-sensitive activities, is reviewed as one of the sub-models of the integrated urban model.

2.2.1. Local-Market-Sensitive(LOMS) Employment Models

A number of non-basic employment location models have been developed. These models assume that intraurban non-basic employment depends highly on the spatial distribution of population. One of these approaches was examined by Putman.[17] The model is expressed as:

$$\Delta E_j{}^k{}_{,t}=a^k M_j{}^k{}_{,t}(\Delta E_*{}^k{}_{,t}/M_*{}^k{}_{,t})+b^k E_j{}^k{}_{,t-1}(\Delta E_*{}^k{}_{,t}/E_*{}^k{}_{,t-1}) \quad (2.9)$$

where $\Delta E_j{}^k{}_{,t}$ or $\Delta E_*{}^k{}_{,t}$: change of the employment of type k in zone j or regionwide forecast(*) at time t

$E_j{}^k{}_{,t-1}$ or $E_*{}^k{}_{,t-1}$: the employment of type k in zone j at time t-1 or regionwide type k employment at time t-1

$M_j{}^k{}_{,t}$ or $M_*{}^k{}_{,t}$: a measure of the markets for type k goods in zone j or in the regional level at time t

a^k, b^k: the parameters indicating the relative

[17] Putman, Integrated Urban Models, pp.18-20.

importance of the markets variable or the lagged variable

In this model the market variable and the lagged variable of non-basic employment form the basic structure of the model. The two independent variables, the market variable and the lagged variable, were derived from the hypotheses that the amount of LOMS employment in a zone at time t is directly proportional to the spatial distribution of the market for the employment, and the quantity of LOMS employment at time t-1. Meanwhile, the market in equation (2.9) is measured by the spatial distribution of the population multiplied by the probability of a shopping trip between zone i and zone j. Its suggested form is:

$$M_{j,t}^{k} = \sum_{i} P_{i,t} P^{s}_{ij} \qquad (2.10)$$

where $P_{i,t}$: the population living in zone i at time t

P^{s}_{ij}: the probability of a 'shopping' trip between zone i and zone j

The probability of a 'shopping' trip between zone i and zone j, P^{s}_{ij}, is transformed as follows.

$$P^s{}_{ij} = C_{ij}{}^{-2} / \sum_j C_{ij}{}^{-2} = C_{ij}{}^{-2} / C_{i*}{}^{-2} \qquad (2.11)$$

Thus, the LOMS employment model was expressed by the following equation.

$$\Delta E_j{}^k{}_{,t} = a^k \sum_i P_{i,t} (C_{ij}{}^{-2} / C_{i*}{}^{-2}) (\Delta E^k{}_{*,t} / \sum_j [\sum_i P_{i,t} (C_{ij}{}^{-2} / C_{j*}{}^{-2})]) + b^k E_j{}^k{}_{,t-1} (\Delta E^k{}_{*,t} / E^k{}_{*,t-1}) \qquad (2.12)$$

Later, Putman developed another non-basic employment model, suggesting that work-to-shop trips be allowed to originate anywhere in the region.[18] This model is expressed as follows:

$$E_i{}^{nb} = K(\sum_j P_j{}^r p^r{}_{ij} + \sum_j P_j{}^w p^w{}_{ij}) \qquad (2.13)$$

where,

$E_i{}^{nb}$: nonbasic employment in zone i

K: the regional ratio of nonbasic employees to total population

$P_j{}^r$ or $P_j{}^w$: the nonworking(resident) population in zone j or the working population(employees) employed

[18] Ibid., pp.159-160.

in zone j

P^r_{ij} or P^w_{ij}: the probabilities that a (nonworking) resident of zone j or an employee employed in zone j will shop in zone i

In equation (2.13), P^r_{ij} is constructed as follows:

$$P_{ij}{}^{r}=E_i{}^{nb}{}_{,t-1}C_{ij}{}^{-2}\exp(-\alpha^r/C_{ij})/\sum_k E_k{}^{nb}{}_{,t-1}C_{kj}{}^{-2}\exp(-\alpha^r/C_{kj}) \quad (2.14)$$

P^w_{ij} is defined by substituting α^w for α^r in equation (2.14). By substituting the relevant portion of equation (2.14) into equation (2.13), the model can be expressed as:

$$E_i{}^{nb}{}_{,t}=K\{\sum_j P_j{}^{r}[E_i{}^{nb}{}_{,t-1}C_{ij}{}^{-2}\exp(-\alpha^r/c_{ij})/\sum_k E_k{}^{nb}{}_{,t-1}C_{kj}{}^{-2}\exp(-\alpha^r/C_{kj})]+\sum_j P_j{}^{w}[E_k{}^{nb}{}_{,t-1}C_{ij}{}^{-2}\exp(-\alpha^w/C_{ij})/\sum_k E_k{}^{nb}{}_{,t-1}C_{kj}{}^{-2}\exp(-\alpha^w/C_{kj})]\} \quad (2.15)$$

This model uses the familiar gravity concept to estimate the probability that the (nonworking) resident in zone j or the employees employed in zone j will shop in zone i. That is, each probability is determined by the relative attractiveness and accessibility characteristics in each zone. Another retail employment model based on retail trade models was developed by Ducca and Wilson,[19] and modified by

---

[19] F.W.Ducca and R.H.Wilson,"A model of shopping center location", Environment and Planning A, Vol 8, 1976, p.615.

Putman.[20] This model sets the constraint that total demand is equal to total retail employment, and requires an equilibrium condition that the amount of demand to zone j is equal to the retail employment in zone j. These are expressed by

$$\sum_i D_i^R = \sum_j E_j^R$$

and,

$D_{*j}^R = E_{*j}^R$ for all j (where an asterisk denotes summation of all zones)

An expanded form of the model is:

$$E_j^R = \sum_i D_{ij}^R = \sum_n \epsilon_n \{ \sum_i [D_i^R, {}^nB_i (q_j + \delta A_j)^{\Gamma} C^{\beta}_{ij}] \} \qquad (2.16)$$

where E_j^R: the retail employment in zone j

D_{ij}^R: the demand for retail employment originating in zone i and arriving in zone j

ϵ_n: a weighting factor associated with each type n source of demand

[20] Putman, Integrated Urban Models, pp.160-161.

q_i:retail employment/zonal land use, in zone j

A_j:shopping center floor space in zone j

C_{ij}:travel time in minutes between zone i and zone j

$D_i^{R,r}$:demand due to nonworking population residing in zone j

$D_i^{R,w}$:demand due to employed persons employed in zone i

β, Γ, δ:empirically derived parameters

Putman indicated that the results of this model based on the Minneapolis-St Paul metropolitan area data appeared sensible for retail employment and service employment, but this model applied to data from the San Francisco area did not yield consistent results.[21]

2.2.2. <u>Non Local-Market-Sensitive(NLMS) Employment Models</u>

In many urban modelling attempts, some employment types whose intraurban location decision are not market-sensitive have been treated as being exogenously determined. Those types of employment are similar to basic employment.[22] A simple model for location of NLMS employment was also proposed by Putman, using the same general formulation for

[21] Ibid., pp.160-163.

[22] S.H.Putman, "Intraurban Employment Forecasting Models: a review and a suggested new model construct", <u>Journal of the American Institute of Planners</u>, 1972, Vol XXXVIII, No 1, pp. 218-220.

local market sensitive employment location model(LOMS model).[23] The hypothesis of this model is different from that of LOMS model in that the level of NLMS employment in a zone is directly proportional to the spatial distribution of production inputs, instead of population. In addition, the travel function is a work-trip function, rather than the shopping-trip function, and the relative magnitude of the lagged variable which reflects the quantity of the NLMS employment at a previous time would be greater than for the LOMS model.

The NLMS model was not, however, further developed within the context of the gravity model. Its development was based upon an exogenous forecast of basic employment location. When Putman sought a suitable model for forecasts of basic employment, BEMOD and EMPIRIC were considered.

BEMOD, developed by Nathanson, was further developed by the Bay Area Transportation Study of Putman in 1968.[24] The model, as described by Putman, is:

> "based upon certain attributes of each sub-area, a sector score or index is calculated for the sub-area. When scores have been computed, the region-wide growth or decline for each employment type is allocated to the sub-area as a function of the score and available land".

---

[23]Putman, Integrated Urban Models, pp.24-26.

[24]Putman, "Urban Land Use and Transportation Models", p.189.

EMPIRIC was devised by Donald M. Hill for a comprehensive development plan of Greater Boston in 1965.[25] This model is still widely used in transportation research, and also deals simultaneously with both residence location and employment location. The model, explained by Reif, is designed to distribute or allocate externally supplied growth forecasts of activities such as population and employment among the zones or subdivisions of the region under study. The model is expressed by the following equation:

$$\Delta R_i = \sum_{\substack{j=1 \\ j \neq i}}^{N} a_{ij} \Delta R_j + \sum_{k=1}^{M} b_{ik} (Z_k \text{ or } \Delta Z_k) \qquad (2.17)$$

where i or j =1,2,...i,j,...N: the number of located variables

k=1,1,... k,..M:the number of the locator variables such as intensities of land use, quality of water service, quality of sewage disposal service, automobile and transit

---

[25] Benjamin Reif, Models in Urban and Regional Planning, New York, Intertext Educational Publishers, 1973, pp.164-168.

accessibilities.

ΔR_i or ΔR_j=change in the level of the ith or jth located variable over the calibration or forecast time interval

Z_k=level of locator variable k at the beginning of the calibration or forecast time interval

ΔZ_k=change in the level of the kth locator variable over the calibration or forecast time interval

a_{ij}, b_{ij} =coefficients expressing the interrelationships among variables.

Lowry pointed out that this model does not have a set of land-use accounts through which the different activities compete for the same land, while Reif indicated that this model has merit because it covers all main activities of urban location.[26] Overall, in this model it is difficult to logically interpret the relationships between dependent variable and independent variables.

Putman first took advantage of the existing linear multiple regression models, BEMOD and EMPIRIC, in order to forecast basic employment. However, the results that he expected were not satisfactorily obtained from those

---

[26]Reif, op.cit., p.167.

models. This fact led him to develop EMPAL, which included basic and nonbasic employment.[27]

2.2.3. EMPAL

Nonbasic employment location in the Lowry model and its derivatives was estimated with residence location simultaneously, while basic employment was calibrated by a different analysis such as a linear multiple regression. However, it is known that basic employment location also follows the population movement to the suburbs.[28] Therefore, EMPAL, which can be applied to the intraurban employment locations of all types, was developed by Putman.[29] The basic equation of EMPAL is:

$$E_{j,t}=r\sum_{i}P_{i,t}A_{i,t}W_{j,t}C^{\alpha}_{i,j,t}\exp(\beta C_{i,j,t})+(1-r)E_{j,t-1} \qquad (2.18)$$

---

[27]Putman, Integrated Urban Models, pp. 154-158.

[28]Edwin S. Mills, Studies in the Structure of the Urban Economy, Baltimore and London, The John Hopkins Press, 1972, pp.14-29.

[29]Putman, Integrated Urban Models, pp.163-168.

where

$$A_{i,t}=[\sum_j W_{j,t}f(C_{ij,t})]^{-1}$$

$E_{j,t}$ or $E_{j,t-1}$=the employment of zone j at time t or t-1

$P_{i,t}$=population of zone i at time t

$W_{j,t}$=an attractiveness measure for zone j at time t

r = the weighting parameter

$C^{\alpha}_{i,j,t}\exp(\beta C_{i,j,t})$= the trip function

α and β= the two parameters in the trip function

In the case where the simultaneous location of employment and residence is not necessary, the form of the model for the retail employment sector was suggested as:

$$E_j{}^R{}_{,t}=r\sum_i P_{i,t-1}A_i{}^R{}_{,t-1}W_j{}^R{}_{,t-1}C^{\alpha}_{i,j,t}\exp(\beta C_{i,j,t}) \quad (2.19)$$

where,

$$W_j{}^R{}_{,t-1}=(E_j{}^R{}_{,t-1})^a L_i{}^b \quad (2.20)$$

where,

L_i=the total area of zone i

a,b=the empirically derived parameters

and

$$A_i{}^R{}_{,t-1} = [\sum_i (E_i{}^R{}_{,t-1})^a L_i{}^b C^\alpha{}_{i,j,t} \exp(\beta C_{i,j,t})]^{-1} \qquad (2.21)$$

The model substituting the relevant portion of equations (2.20) and (2.21) into equation (2.19) was tested with the data from the Minneapolis-St Paul and the Washington metropolitan areas by Putman.[30] The tests yielded consistent results and showed better explanation than some previous urban employment location models in term of residual variance.

2.3. Residential Location Models

There are a number of models of urban residential location. Putman classified the Lowry model and its derivatives as macro-descriptive behavioral models, because these models attempt to describe residential location behavior observed at a rather aggregate level of detail.[31] Although Lowry-type models formulated on the basis of the gravity concept were mainly developed in the 1960s, and

---

[30]Ibid., pp. 165-166.

[31]Putman, "Urban Land use and Transportation Models", pp.187-198.

applied to some metropolis, they were criticized because of their lack of firm theoretical basis.[32] However, since Lowry-type models were connected with entropy maximizing principles by A.G. Wilson in the 1970s, these models are widely used in urban residential location studies.[33] The models in which entropy maximizing principles are incorporated in the Lowry-type models are called constrained gravity models.

2.3.1. Constrained Gravity Models

As mentioned above, spatial interaction models based on the entropy maximizing principle were incorporated into the gravity concept. The models predict the number of trips between origins and destinations based on the attractiveness of zones and travel resistance between them, and can be used as residential location models.[34] Depending on where constraints are present, three forms of the constrained gravity model are possible.

---

[32] Khakee, op.cit., p.48.

[33] Foot, op.cit., pp.100-102.

[34] Foot, op.cit., p.78.

The Supply (or Production) Constrained Model

In the case that the number of trips originating in each zone, such as residents in each zone, is fixed while the number of trips ending in each destination, such as employees in each zone, is allowed to vary and is to be predicted, a supply-constrained model is used. The supply-constrained model can be formulated as follows:

$$T_{ij}=A_iO_iW_jf(c_{ij}) \tag{2.22}$$

$$\sum_j T_{ij}=O_i \tag{2.23}$$

where, T_{ij}= the number of trips from zone i to zone j

O_i= the number of trips originating at zone i

W_j= a measure of locational attraction at zone j

$f(c_{ij})$=the trip function between zones i and j

and A_i is given by:.

$$A_i=[\sum_j W_jf(c_{ij})]^{-1} \tag{2.24}$$

The Demand (or Attractiveness) Constrained Model

If the number of destinations, such as employees in each zone, is fixed, and the number of origins, such as residents in each zone, is allowed to vary and is to be predicted, a demand-constrained model is used. The model is expressed in the same form as the supply-constrained model, except that origin and destination are interchanged. The equation for the demand (or attractiveness)-constrained model is as follows:

$$T_{ij}=B_j W_i D_j f(c_{ij}) \qquad (2.25)$$

$$\sum_i T_{ij}=D_j, \qquad (2.26)$$

where, D_j= the number of trips terminating at zone j

$$B_j=[\sum_i W_i f(c_{ij})]^{-1} \qquad (2.27)$$

This model has very rarely been used as a singly constrained model, because it can be transformed into the supply-constrained model.[35] However, it is convenient to use

[35] Ibid., p.78

the demand-constrained model if notation i and j represent residence and work place in the residential location model, respectively.

The Doubly Constrained Model

In the case that the number of trips from origins to destinations is assumed to be given, and the number of trips from each origin to each destination is to be predicted, the doubly constrained model is used. That is, the T_{ij} values are subject to two constraints: $\sum_j T_{ij}=O_i$ and $\sum_i T_{ij}=D_j$. Its equation is:

$$T_{ij}=A_i B_j O_i D_j f(c_{ij}) \tag{2.28}$$

where, the balancing factors A_i and B_j are:

$$A_i=(\sum_j B_j D_j f(c_{ij}))^{-1} \tag{2.29}$$

$$B_j=(\sum_i A_i O_i f(c_{ij}))^{-1} \tag{2.30}$$

To calibrate the model, all A_i vectors are first assumed to 1.0, then the B_j vectors are calibrated. A_i vectors are then recalculated. This iterative procedure is continued until the values of the A_i and B_j show no further change.[36]

2.3.2 DRAM

Putman developed an urban residential location model, the Disaggregated Residential Allocation Model(DRAM), which maintains the basic form of the Lowry derivative model. He also used the formulation as one of sub-models in his integrated urban model. DRAM has two essential components: a trip function and an attractiveness component. A two-parameter function described in section 2.1 is used as the trip function, while income distribution and size and/or capacity of a zone are the measures of attractiveness.[37] A multivariate attractiveness measure in DRAM is:

$$W_i^n=(L_i^v)^{qn}(x\tilde{}_i)^{rn}(L_i^r)^{sn}(N\tilde{}_i^1)^{b1n}(N\tilde{}_i^2)^{b2n}(N\tilde{}_i^3)^{b3n}(N\tilde{}_i^4)^{b4n} \qquad (2.31)$$

where L_i^V= vacant, buildable land in zone i

$X\tilde{}_i$= one plus the proportion of buildable land in zone i that has already been built upon

---

[36]John R. Ottensmann, Basic Microcomputer Programs for Urban Analysis and Planning, New York, Chapman and Hall, 1985, p.109.

[37]Putman, Integrated Urban Models, pp.177-180.

L_i^r= residential land in zone i

N~i1,N~i2,N~i3, and N~i4= one plus the proportion of employed residents of zone i who are in the lowest, the lower, the upper-middle, and the upper income groups, 1,2,3,and 4

q,r,s,b= empirically derived parameters for each income group n(n=1,..,4)

The employment E_j in the Lowry model is converted from employees by type into employed residents by type in DRAM. This conversion is:

$$E_j = \sum_k a_{kn} E_j^k \tag{2.32}$$

where E_j^k= the number of employees of type k employed in zone j

a_{kn}= a regionwide ratio of the number of type n residents per type k employee

Thus, the final form of DRAM used in the integrated model is:

$$N_i^n = \sum_j(\sum_k a_{kn} E_j^k)(L_i^v)^{qn}(x^\sim_i)^{rn}(L_i^r)^{sn}(N^\sim_i{}^1)^{b1n}$$
$$(N^\sim_i{}^2)^{b2n}(N^\sim_i{}^3)^{b3n}(N^\sim{}_i{}^4)^{b4n} c_{ij}{}^\alpha \exp(^\beta c_{ij}) /$$
$$\{\sum_i (L_i^v)^{qn}(x^\sim_i)^{rn}(L_i^r)^{sn}(N^\sim_i{}^1)^{b1n}(N^\sim_i{}^2)^{b2n}$$
$$(N^\sim_i{}^3)^{b3n}(N^\sim{}_i{}^4)^{b4n} c_{ij}{}^\alpha \exp(\beta c_{ij})\} \quad (2.33)$$

Although this form of DRAM was suggested theoretically, it is difficult to apply. Several data sets, including disaggregated information on household incomes and/or land-use within zones would have to be obtained.[38] Such information is not readily available. Therefore, two simpler models were presented. These are:

$$N_i = \sum_j E_j [L_i{}^\sigma c_{ij}{}^\alpha \exp(\beta c_{ij}) / \sum_i L_i{}^\sigma c_{ij}{}^\alpha \exp(\beta c_{ij})] \quad (2.34)$$

and

$$N_i = \sum_j E_j [(L_i{}^v)^q (x^\sim_i)^r (L_i{}^r)^s c_{ij}{}^\alpha \exp(\beta c_{ij}) /$$
$$\sum_i (L_i{}^v)^q (x^\sim_i)^r (L_i{}^r)^s c_{ij}{}^\alpha \exp(\beta c_{ij})] \quad (2.35)$$

The model in equation (2.34) uses the total area of zone i as the attractiveness measure. The model in equation (2.35) has two additional variables: residential land and

---

[38] Ibid., pp.222-223.

percentage of developable land actually developed. The formulation to be used as the residential location model between the two simplified models depends on the availability of the necessary data sets.

2.4. Transportation Models: assignment technique

This section briefly describes traditional transportation generation and distribution procedures, and the simultaneous location and trip distribution procedure. Common methods of trip assignment are then reviewed.

2.4.1. Trip Generation and Trip Distribution

Traditional Trip Generation and Distribution

There are four sub-models in the conventional transportation model sequence. The four sub-models consist of separate trip generation, trip distribution, modal split, and trip assignment models. The sequence can proceed in a different order, but in most cases it follows the order listed above.[39]

Trip generation models were developed in an attempt to estimate the amount of traffic generated by zones. Two

---

[39] Eric Sheppard, "Modeling and Predicting Aggregate Flows", The Geography of Urban Transportation, ed. S. Hanson, New York, The Guilford Press, 1986, pp.95-96

approaches are usually considered in traffic generation modelling: multiple linear regression analysis and category (or cross-classification) analysis.[40] The former assumes that a number of land-use variables influence the amount of trip generation, so a linear relation is sought between the explanatory variables and dependent variable. Its general form is:

$$Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \ldots\ldots \beta_z X_z \qquad (2.36)$$

where Y = dependent variable

$X_1 \ldots X_2$ = explanatory variables

α = regression constant

$\beta_1 \ldots \beta_2$ = partial regression coefficients

Among the explanatory variables usually considered are (1) car ownership, (2) family income, (3) household size, (4) number of persons 5 years old and over in the household, (5) number of persons 16 years old and over who drive, (6) occupation of head of household, (7) distance from the central business district, (8) residential density, (9) structure type of house (single detached, single attached, combination, apartment, etc.), and (10) appraised house

[40] John Black, Urban Transport Planning, Baltimore, The John Hopkins University Press, 1981, pp.65-66.

value and/or median rent or value.[41]

Category analysis is based on "household trip making as its level of analysis".[42] Black goes on to explain that this method assumes the influences of home ownership, household size, and household income on household traffic generation. Households are then cross-classified by those variables, and the mean traffic production for each cross-classification is calculated from home interviews.

Whatever method of the above analyses is used, the analysis of trip generation estimates the number of trips produced by a zone or attracted to it. The next phase of transportation planning is trip distribution which determines where and how many of the generated trips will be attracted among each possible destination.[43] There are several methods of distributing trips. These are growth-factor methods[44], gravity models, intervening opportunity models, and entropy models.[45] The most widely used techniques are gravity models. The usual form of the

---

[41]John W. Dickey, Metropolitan Transportation Planning, New York, Hemisphere Publishing Co., 1983, p.187.

[42]Black, op.cit., p.67.

[43]Sheppard, op.cit., p.101.

[44]Dickey, op.cit., pp.197-202.

[45]Sheppard, op.cit., pp.102-112.

gravity models is:

$$T_{ij}=P_iA_jF(t)_{ij}/\sum_{j=1}^{n}A_jF(t)_{ij} \qquad (2.37)$$

where, T_{ij}= the number of trips produced in zone i and attracted to zone j

P_i= the trips produced from zone i

A_j= the trips attracted to zone j

$F(t)_{ij}$= the friction factor for interchange i, j (based on travel time between i and j)

n= number of zones in the study area

After the trip distribution phase, modal split analysis can be applied to determine the amount of travel using each available mode of transportation.[46] However, the analysis is not appropriate in smaller urban areas with no major transit systems.[47] Therefore, this step will be ignored in the micro-computer version developed for this study.

Simultaneous Location and Trip Generation and/ or Distribution

Putman proposed the idea that trip generation and distribution could be simultaneously extracted from the

[46]U.S.Department of Transportation, An Introduction to Urban Travel Demand Forecasting, Washington, D.C, Federal Highway Administration, 1977, p. 4-15.

[47]Ibid., p.5-13.

calculation of residence location.[48] That is, when residence location models based on the gravity concept are calibrated, a trip matrix, as if provided by use of a gravity model in the traditional transportation procedures, is produced. This method will be used in this study.

2.4.2. Trip Assignment

Trip assignment procedures are the processes by which traffic volume and paths are estimated over a transportation network. The assignment involves "the use of information about the characteristics of the network, along with a set of decision rules, and an algorithm for doing the assignment in an efficient fashion".[49] This phase was also used in the integrated model. Putman stated that the results of trip assignment is one of the essential inputs for the integrated urban models.[50]

> " On the completion of the assignment procedures, times and costs of travel through the network will have changed as a result of congestion. It will be then possible to calculate the zone-to-zone least time or least-cost paths. The results of this calculation yield the travel-cost matrix which is later input to the employment location and residence-location models".

---

[48] Putman, Integrated Urban Models, pp.109-115.

[49] Ibid., p.116.

[50] Ibid., p.27.

Thus far, a variety of trip assignment methods have been developed. Three general types of methods are reviewed here: all-or-nothing assignment, minimum path with capacity restraint, and multi-path assignment.

All-or-Nothing Assignment

This method is based on the assumption that travelers want to use the minimum travel time or cost path through the network. This method, which is an early trip assignment technique, has the property that once the trips between zones are loaded onto the links based on minimum travel time (or minimum cost), nothing is loaded on the other links.[51] This technique is unrealistic, because it does not consider the relationship between trip volume and travel time. This congestion/impedence problem led to the development of other types of trip assignment methods.[52]

Minimum Path with Capacity Restraint

Some methods of utilizing capacity restraint in a trip assignment were tested and described by Putman.[53] The

---

[51] U.S.Department of Transportation, *op.cit.*, pp.6-14,15, 16.

[52] Ibid., p.6-16.

[53] Putman, *Integrated Urban Models*, pp.117-124.

methods are iterative full network loading, incremental full network loading, incremental full network reloading, and incremental tree-by-tree loading procedures. These methods involve a congestion (or volume-delay) function, in order to deal with overloaded links in the network. A congestion function that has been used in transportation planning in the United States is as follows:

$$t_1 = t_o[1.0+0.15(V/V_o)^4] \qquad \text{for} \quad (V>V_o) \qquad (2.38a)$$

$$t_1 = t_o \qquad \text{for} \quad (V<=V_o) \qquad (2.38b)$$

where, t_1: the modified (congested) link travel time,

t_o: the uncongested (free flow) link travel time,

V : the volume of trips on the link,

V_o: the design capacity (volume of trips) of the link

Iterative full network loading first assigns all trips to be loaded on the shortest path, then applies the congestion function to each link on the network, and from the newly congested travel time, the process is iterated. The final solution is sought through the average of the congested link times over the successive iterations. Yet, the method is similar to all-or-nothing assignment in terms of loading on the single best path, and may result in ocillation problems.[54]

Incremental full network loading attempts to avoid oscillation problems by incrementally assigning trips on the network. For example, the first 40% of the volume between O-D pairs of all the trips is loaded, then the congestion function is applied to each link. Another 40% might be assigned next and, once more, the congestion level is calculated. This process is completed when the remaining volume of trips is loaded onto the network. Putman emphasized that the number of unused links, reflecting uneven loading of the trips on the network, is less in the incremental full networking loading than in the iterative full network loading.[55]

Incremental full network reloading is similar to the incremental full network loading. The initial 40% loading and the use of the congestion function is the same as in the incremental full network loading procedure. Then, 40% of the trip volume on the links are discarded, and the travel times on each link are stored. It means that 40% of trip volume is used to generate the travel times in the network, but actual trip volumes are not loaded onto the network yet. Next, 70% of the total trips are loaded and the congestion function recaluated in the same way. At this

---

[54] Ibid., p.117.

[55] Ibid., pp.120-122.

point 70% of the trip volume is discarded, and the final 100% is loaded.[56]

Incremental tree-by-tree loading is quite similar to incremental full network loading. The difference is in a random selection sequence for O-D pairs after an initial 40% loading on the network. The previous three procedures use a tree-by-tree method instead of random assignment. The reason for utilizing the random selection sequence is that it can reduce a bias which the tree-by-tree method causes due to the order of selecting zonal origins and destinations.[57] In a comparison of the incremental tree-by-tree loading and the incremental full network loading, the former has the advantage over the latter in terms of the reduction of total travel time and unused links.[58]

Multipath Assignment

Another consideration to be used in the integrated model was multipath assignment procedure. The main point of this method is to include the concept of perceived cost, as well as congestion effects. Although the method is similar to the incremental tree-by-tree loading, it involves a

---

[56]Ibid., p.118.

[57]Ibid., p.119.

[58]Ibid., pp.122-123.

double-pass procedure which is one of two types of stochastic assignment methods.[59] The performance of this assignment was also compared with the incremental tree-by-tree method by Putman. Generally, this method yielded better results than the latter, but the problems of computer execution time and some theoretical questions are obstacles to operationalizing this method.[60]

2.5 Summary

This chapter has reviewed employment location, residential location, and transportation assignment models related to the integrated urban models. Before the review of each model, the Lowry model was examined in some detail, because employment location models, especially non-basic employment location models, and residential location models are based on the Lowry formulation. Then, three non-basic employment location models, and two basic employment location models, BEMOD and EMPIRIC, were reviewed. The properties of EMPAL, the employment location model used in the integrated urban models, were explored. The constrained gravity models which incorporate entropy maximizing principles with the Lowry model were also examined with

---

[59] Ibid., p.131.

[60] Ibid., p.134; Sheppard, op.cit., p.114-116.

respect to residential location models. The residential location model of Putman, DRAM, was examined. Finally, traditional trip generation and trip distribution procedures were compared with the simultaneous location and trip distribution procedure. Then, the four methods of trip assignment were reviewed.

From this review, some problems are revealed in developing a microcomputer version of the integrated urban model. These problems will be discussed, and the implementation of the microcomputer version will be explained in Chapter 3.

CHAPTER 3

IMPLEMENTATION OF THE INTEGRATED URBAN MODEL

This chapter deals with the development of a software package to implement a microcomputer version of the integrated urban model described in the previous chapters. Although the basic structure of the software package is based on Putman's flow chart in Figure 3.1[61], some aspects are modified so that the model will run on a microcomputer. Restrictions and assumptions of the microcomputer version are discussed first. Then, the process of the software package development to implement the microcomputer version is presented.

3.1. The Problems of the Integrated Models in the Microcomputer Version

In implementing the microcomputer version, the full use of the integrated urban model is restricted for the following reasons. First, a version of the EMPAL, which includes the simultaneous consideration of basic and non-basic employment is not attempted in the microcomputer

[61] Putman, <u>Integrated Urban Models</u>, p.45.

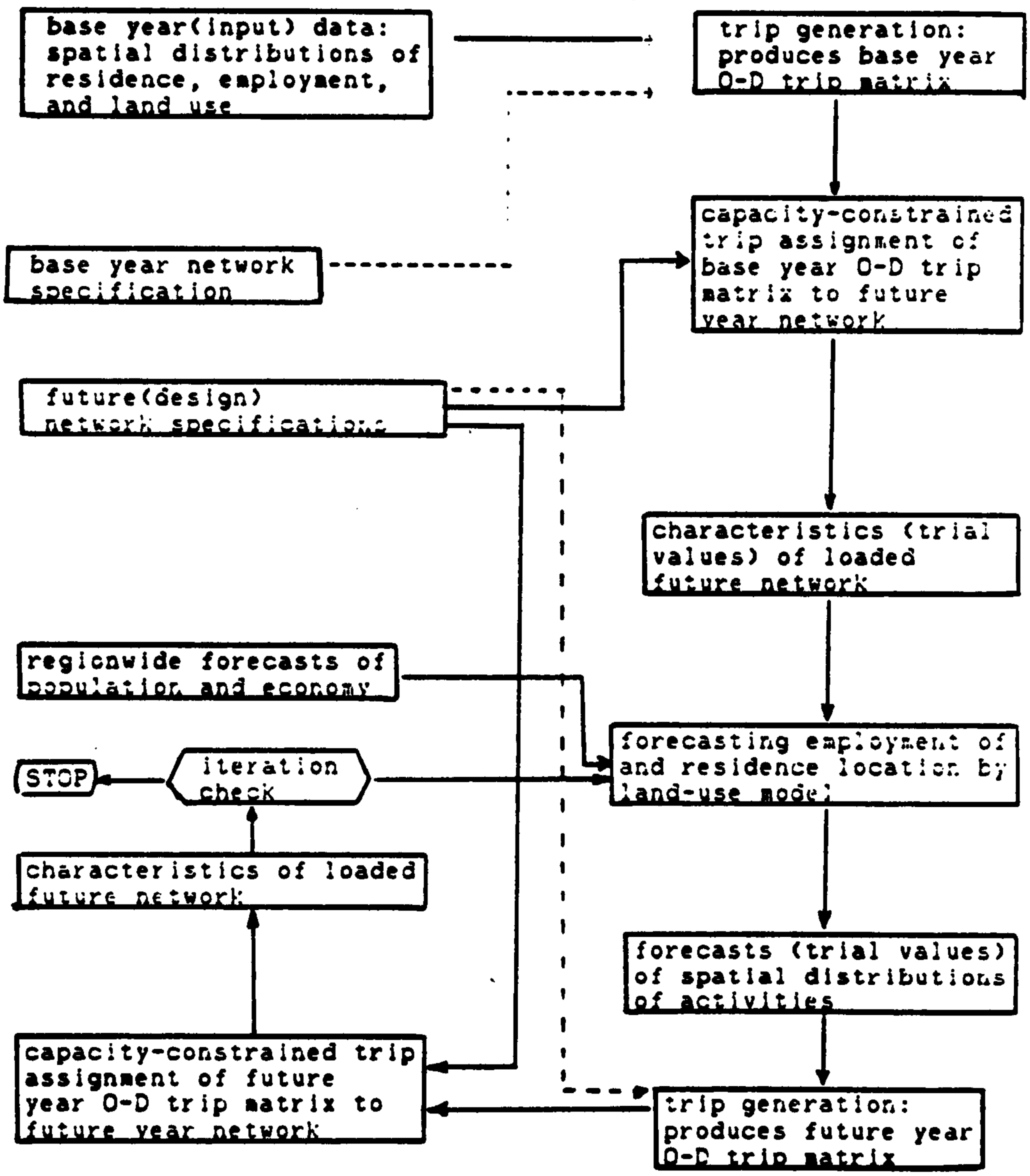


Figure 3.1. Integrated transportation and land use model package. From "Integrated Urban Models" by S.H.Putman, 1983, p.45.

version. EMPAL requires calibration of too many parameters. In the case of the Minneapolis-St Paul data to which the EMPAL was applied, a total of 25 parameters for five employment sectors (manufacturing; transportation, communication, utilities;retail trade; services; and miscellaneous) were estimated.[62] A data collection task of this magnitude is beyond the scope of this thesis.

Secondly, EMPAL is treated exogenously in the integrated urban models of Putman. That is, EMPAL and DRAM are not solved simultaneously, nor is there a feedback loop from DRAM to EMPAL. Therefore, the results of EMPAL can be treated as exogenous inputs into DRAM. Separate and exogenous treatment of EMPAL is also followed in the microcomputer version. I further assume that employment data are given exogenously in this study.

Thirdly, the microcomputer version is restricted to the assumed employment pattern. Transportation planning deals largely with the transportation problem of afternoon peak congestion which includes work-to-shop and home-to-shop trips, as well as work-to-home trips. However, since employment is assumed, the first two purpose trips are ignored, and only work-to-home trips are treated in this study.

Fourthly, problems in developing the microcomputer

---

[62] Ibid., p.167.

version arise when the transportation model is introduced into the modeling process. The trip matrix containing the results of the simultaneous location and trip distribution procedures should be converted to the number of vehicle trips. The conversion procedure was illustrated by Putman in research based on the San Francisco metropolitan area.[63] The research showed that the occupancy rate of vehicle trip for home-based work is 1.18. However, in the microcomputer-based version developed here, the rate is assumed to be 1.0. This value is used in order that the allocation of residence may be compared, given the assumption that the total number of residence is equal to the total trip distribution in the demand constrained gravity model: $\sum_i T_{ij}=D_j$.

Finally, specific information on the transportation network, such as directional counts, number of lanes, link location, area type, etc.[64], should be considered in a complete urban model. However, only two way flows of one lane are assumed here. The storage capacity of a microcomputer-based system is not enough to deal with all of this information about the structure of the transportation network. This storage problem restricts the use of many

---

[63] Ibid., p.108.

[64] U.S.Department of Transportation, op.cit., pp.6-8.

zones and locations in the microcomputer version.

3.2. The Construction of Microcomputer Version

The whole process of the software package development proceeds as follows. First, future employment in each zone is assumed. These data are then used to predict residence locations by using the gravity model concept. The prediction of residence location is treated simultaneously with trip distribution procedures. Then, trip assignment is accomplished, along the shortest path connecting origin and destination zones. Since the all-or-nothing method is used, unrealistic assignments can result. Therefore, a congestion function is applied on each link. Before the application of the congestion function, the paths must be unpacked in order to calculate the volume on each link. Through the congestion function, a new matrix of trip distance or cost is obtained. Finally, incremental full network reloading is applied.

In light of the modifications specified, the Putman's original flow chart of the integrated modelling is modified as illustrated in Figure 3.2.

Data and Parameters

Several data files are required as input to the microcomputer version. The user is allowed to input a file

Flow Chart

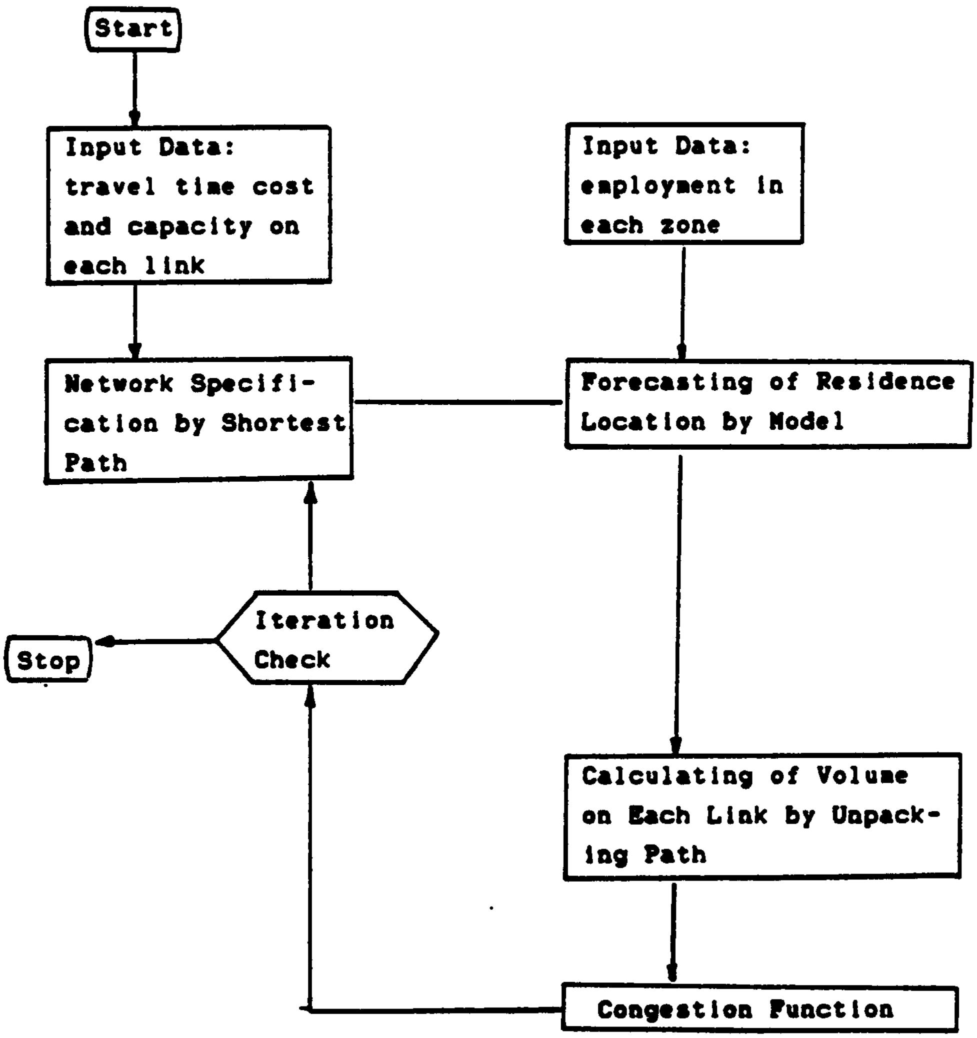


Figure 3.2 Flow Chart for the Microcomputer-Based Version

of costs between nodes and capacity of each link, a file of employment in each zone, and three attractiveness files which show the amounts of vacant and buildable land, one plus the proportion of buildable land actually developed, and residential land in each zone. Several parameters are also needed to calibrate the trip function, and the attractiveness measures. The values of previously surveyed parameters are taken from Putman, and are shown in Table 3.1 and Table 3.2.[65]

Simultaneous Residence Location and Trip Distribution

The programs for four types of gravity models discussed in Chapter 2 as potentially useful in the development of residence location models are available to the user. The programs for supply-constrained and doubly-constrained models which were developed by Ottensman are modified, and the programs for the other two types of gravity models: the unconstrained case and the demand-constrained case, are developed. However, in the actual application of the microcomputer version, the demand-constrained model is used. In the demand-constrained gravity model, the employment data file and three attractiveness data files based on equation (2.35) are used to simultaneously calculate the residence

---

[65]Putman, Integrated Urban Models, pp.217-224.

Table 3.1

Trip-function Parameters for Urban Areas with Incomplete Data Sets

Area	Number of zones	Year	Parameter α	β
Gosford-Wyong,Australia	22	1971	0.09	-0.03
Melbourne, Australia	41	1970	1.04	-0.06
Natal, Brazil	18	1976	0.93	-0.01
Rio de Janerio,Brazil	50	1968	1.08	-0.01
Reading, England	130	1962	1.31	-0.06
Tokyo, Japan	25	1970	0.69	-0.01
Mexico City, Mexico	111	1976	-0.47	-4.89
Monclova-Frontera,Mexico	67	1977	2.73	-0.14
Ankara, Turkey	36	1970	0.64	-0.14
Gazoantep, Turkey	53	1970	0.64	-0.14
Izmit, Turkey	23	1968	0.90	-0.03
Colorado Springs,CO	81	1970	1.95	-1.90
Hazleton,PA	90	1960	-0.18	0.15
Ljubliana,Yugoslavia	98	1961	-2.10	-0.003

Tables 3.1, from "Integrated Urban Models", by S.H.Putman, 1983, pp.223.

Table 3.2

Land-variable Parameters for Urban Areas with Incomplete Data Sets

Area	Land variable(s)	Parameters	Value
Gosford-Wyong	developable	σ	-2.31
Melbourne	developable	σ	0.13
Natal	urbanized	σ	0.48
Rio de Janerio	urbanized	σ	0.60
Reading	vacant developable	q	1.19
	proportion developable	r	8.71
Tokyo	vacant developable	q	0.04
	proportion urbanized	r	0.50
Mexico City	vacant developable	q	0.02
	proportion developable	r	0.90
	developed residential	s	0.85
Monclova-Frontera	total zonal area	σ	0.24
Ankara	total zonal area	σ	-0.31
Gaziantep	total zonal area	σ_1	0.25
	residential building area	σ_2	0.07
Izmit	total zonal area	σ	0.80
Colorado Springs	vacant developable	q	0.06
	proportion developable	r	1.57
	developed residential	s	0.68
Hazleton	vacant developable	q	-0.09
	proportion developable	r	1.00
	developed residential land	s	0.95
Ljubljana	total zonal area	σ	1.05

Tables 3.2, from "Integrated Urban Models", by S.H.Putman, 1983, pp.224.

location and trip distribution. Then, the user may choose one of three types of decay functions as the travel function: inverse power, negative exponential, and Gamma functions.

Shortest Path

The program to find the shortest paths was adapted from D.K. Smith, who used Floyd's algorithm.[66] This algorithm is useful in finding the shortest path between all possible nodes. The implimentation of Floyd algorithm by Smith was:

step 0 Create the $n * n$ matrix D_o whose elements are:

$d_o(i,j)=d(i,j)$(the length of arc(i,j),if this exists),

$=0$(if $i=j$),

$=\infty$(if no arc(i,j) exists).

Create the $n * n$ matrix P with elements:

$p(i,j)=i$.

Set $k=0$.

step 1 Define the $n * n$ matrix D_{k+1} with elements

$d_{k+1}(i,j)= \min\{d_k(i,j),\ d_k(i,k+1)+d_k(k+1,j)\}$.

If the latter value is chosen, then change $p(i,j)$

[66]David K.Smith, Network Optimisation Practice: A Computational Guide, Chester, Ellis Horwood Limited, 1982, pp.74-82.

to be p(k+1,j).

step 2 Increase k by 1. If k=n, stop, otherwise return to step 1.

Through this method, the shortest path is first found in the network, and the process is repeated during the incremental reloading.

Unpacking the Paths

After the trip distribution procedure, the volume on each link traversed by the trip is computed in order that the congestion on each link may be evaluated. The calculation of such volume in the program is called 'unpacking the paths'. The program to unpack the path was developed specifically with the micro-computer version.

Congestion (or volume-delay) Function

Using the results of the unpacking program, congestion on each link is calculated. The data file that includes the information on the capacity of each link and its nodes is used in the congestion function. Then, new travel times or costs from the application of the function are created in the new data file and used to replace the previous cost data file.

Incremental Full Network Reloading

This method, one of a number of possible transportation assignment methods, begins with 40% of total employment in the each zone. Forty percent of the trips are also forecast in the residence location model, and assigned to the network. Congestion on each link is then calculated and saved. After one iteration, another 40% plus the previous 40% based on employment is used to compute residence locations and network flows. Congestion costs are again updated. The remaining 20% of the trips follows the same procedure.

3.3. Summary

This chapter illustrated the process of software development of a microcomputer version of an integrated urban model. The restrictions and assumptions necessary to modify such a model in a microcomputer environment are described. Because employment location is assumed exogenous to this study, only work-to-home trips are treated. Due to storage problems, the transportation network is also simplified. Based on those restrictions on the integrated urban model, the process of the microcomputer version is presented. The following order in development of the software package is specified: data and parameters, simultaneous residential location and trip distribution, shortest paths, unpacking the paths, the application of a congestion function, and incremental full network reloading assignment. Chapter 4 will use these model components to illustrate how the microcomputer version is used to forecast land use and transportation in a hypothetical urban area. Then, sensitivity tests will be run to examine the effects of changed inputs.

CHAPTER 4

THE RESULTS AND SENSITIVITY TEST OF THE MICROCOMPUTER VERSION

The software package described in the previous chapter is used to study the model's behavior in a hypothetical city. A hypothetical city is chosen so that the effects of changes in basic input data and model parameters can be studied. In this way, the appropriateness of various model assumptions can be evaluated.

Two forms of model verification have usually been implemented.[67] One is to fit the equations of the model to various cross-sectional data sets. The other is to apply sensitivity tests that examine the response of the model to variations in input data. There is a problem with the former method because of the limited empirical data used in this study. Because of this, verification of the microcomputer version developed for this study only employs sensitivity tests.

First, hypothetical data sets are employed to examine the results of the microcomputer version. Then, sensitivity tests proceed in the following order: job generation,

---

[67]Putman, Integrated Urban Models, p.211.

attractiveness of zones, new roads and closure in the network structure, capacity change, and travel time changes in the transport cost function.

4.1. Hypothetical Data Sets Used in the Microcomputer Version

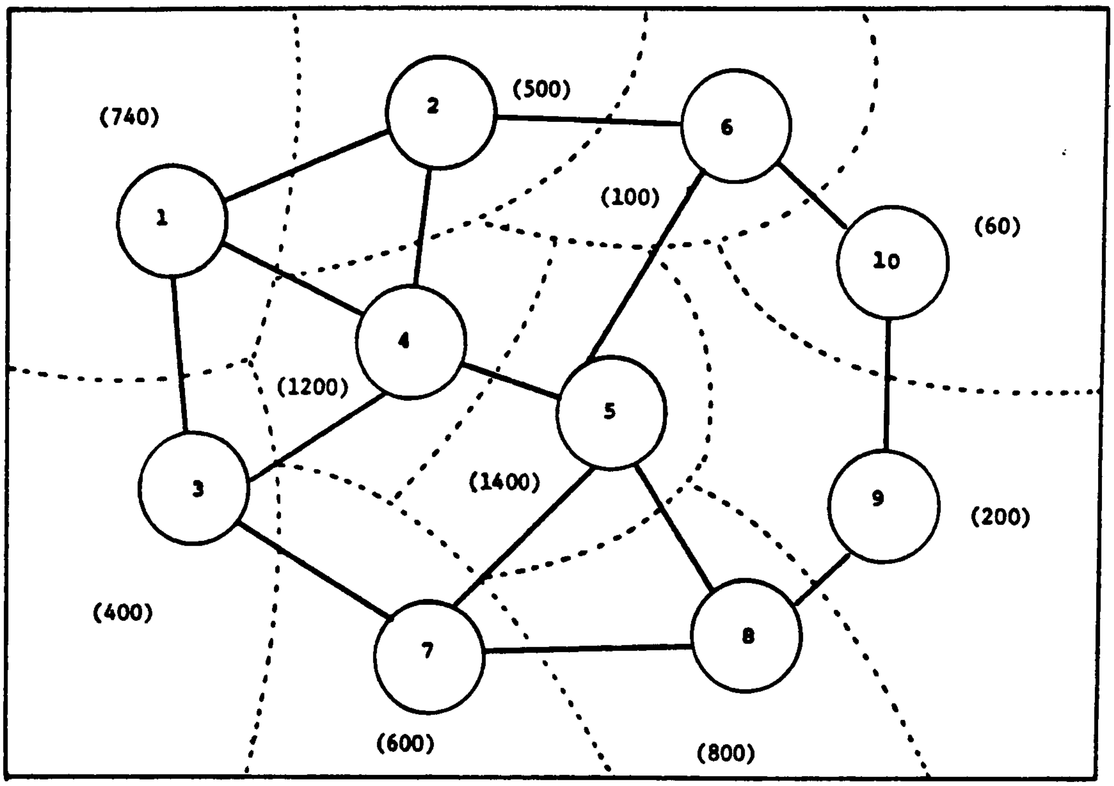
The following data sets are assumed exogenous to the model: a transportation network, and employment within the ten zones of the hypothetical urban area are depicted in Figure 4.1.

a) employment in the zones

Table 4.1 shows the number of employees in ten zones. There are 6,000 total employees. Zones 4 and 5 contain of the most employees,and zone 10 the least.

b) travel length (cost or time) between nodes, link capacity, and the shortest paths on the network

Table 4.2 shows travel costs or times and the capacity of the link between two directly connected nodes. Flows are allowed in both directions with the same travel length incurred on the road in each direction. Intrazonal trips within same zones are assumed to take 1 unit of time and to have 1000 design capacity of the link. Table 4.3 shows the shortest paths found between nodes in terms of travel costs



* Broken line is the boundary of each zone.
* The number in parenthesis is the number of employees in each zone.

Figure 4.1, Hypothetical Transportation Network in a Ten-Node City and The Number of Employees in Each Zone

Table 4.1

Employment in the Zones

zone	employment	zone	employment
1	740	6	100
2	500	7	600
3	400	8	800
4	1200	9	200
5	1400	10	60

Table 4.2

Trip Length and Capacity

Zone	1	2	3	4	5	6	7	8	9	10
1	1(1000)	1.7(100)	1.9(100)	1.2(60)						
2	1.7(100)	1(1000)		2.0(50)		2.3(100)				
3	1.9(100)		1(1000)	1.4(70)			1.8(100)			
4	1.2(60)	2.0(50)	1.4(70)	1(1000)	1.3(85)					
5				1.3(85)	1(1000)	2.1(55)	2.2(85)	2.4(85)		
6		2.3(100)			2.1(55)	1(1000)				2.6(100)
7			1.8(100)		2.2(85)		1(1000)	2.0(100)		
8					2.4(85)		2.0(100)	1(1000)	1.9(100)	
9								1.9(100)	1(1000)	2.7(100)
10						2.6(100)			2.7(100)	1(1000)

a The numbers within parenthesis are the amount of capacity of the link by row and column.

Table 4.3

<u>The Shortest Paths</u>

			To					To		
From	1	2	3	4	5	6	7	8	9	10
1	(1)	(1-2)	(1-3)	(1-4)	(1-4-5)	(1-2-6)	(1-3-7)	(1-4-5-8)	(1-4-5-8-9)	(1-2-6-10)
2	(2-1)	(2)	(2-4-3)	(2-4)	(2-4-5)	(2-6)	(2-4-3-7)	(2-4-5-8)	(2-6-10-9)	(2-6-10)
3	(3-1)	(3-4-2)	(3)	(3-4)	(3-4-5)	(3-4-5-6)	(3-7)	(3-7-8)	(3-7-8-9)	(3-4-5-6-10)
4	(4-1)	(4-2)	(4-3)	(4)	(4-5)	(4-5-6)	(4-3-7)	(4-5-8)	(4-5-8-9)	(4-5-6-10)
5	(5-4-1)	(5-4-2)	(5-4-3)	(5-4)	(5)	(5-6)	(5-7)	(5-8)	(5-8-9)	(5-6-10)
6	(6-2-1)	(6-2)	(6-5-4-3)	(6-5-4)	(6-5)	(6)	(6-5-7)	(6-5-8)	(6-10-9)	(6-10)
7	(7-3-1)	(7-3-4-2)	(7-3)	(7-3-4)	(7-5)	(7-5-6)	(7)	(7-8)	(7-8-9)	(7-8-9-10)
8	(8-5-4-1)	(8-5-4-2)	(8-7-3)	(8-5-4)	(8-5)	(8-5-6)	(8-7)	(8)	(8-9)	(8-9-10)
9	(9-8-5-4-1)	(9-10-6-2)	(9-8-7-3)	(9-8-5-4)	(9-8-5)	(9-10-6)	(9-8-7)	(9-8)	(9)	(9-10)
10	(10-6-2-1)	(10-6-2)	(10-6-5-4-3)	(10-6-5-4)	(10-6-5)	(10-6)	(10-9-8-7)	(10-9-8)	(10-9)	(10)

or times on the network.

c) attractiveness in the each zones

Table 4.4 shows three measures of attractiveness for each zone, including vacant developable land in acres, the proportion of buildable land already developed, and the amount of residential land per zone.

d) parameters in trip function and attractiveness

The parameters used in the trip function and the attractiveness of a residential location are derived from a study of Colorado Springs, CO.[68] The reason that the parameters derived from this city were selected(see Tables 3.1 and 3.2) is that the hypothetical city of this study was assumed to be small or medium sized. Colorado Springs, CO, is also that type of city, and three kinds of attractiveness parameters, based on equation (2.35), have already been determined. The values in trip function and attractiveness are:

(1) α:1.95, β:-1.90(trip function)

(2) q:0.06, r: 1.57, s:0.68(vacant buildable, one plus proportion of buildable, and residential land)

---

[68]Putman, <u>Integrated Urban Models</u>, p.223.

Table 4.4

Three Measures of Attractiveness

	vacant buildable land(unit acre)	one plus proportion of buildable land	residential land(unit acre)
zone 1	35	1.75	20
2	40	1.65	30
3	40	1.8	15
4	20	1.9	5
5	15	1.85	10
6	55	1.5	40
7	50	1.45	40
8	60	1.4	35
9	80	1.3	25
10	90	1.3	20

4.2. The Results of the Microcomputer Version

The microcomputer version of Putman's integrated urban model uses the information of the above data sets and parameters. The process described in Chapter 3 is used to forecast the residential location and trip distribution, and to assign the trips. The results which are obtained through three iterations of the model show: 1) the travel times or costs in the network; 2) the simultaneous residential location and trip distribution; and, 3) loaded volumes on each link. These results are discussed below.

The first iteration

During the first iteration, the initial shortest paths from zone to zone in the network were found in terms of travel times or costs (see Tables 4.3 and 4.5). Along the shortest paths found in Table 4.3, 40 percent of the employees working in the respective employment locations are allocated to the possible residential locations (see Table 4.6 and Figure 4.2). The distribution to the possible residential locations was determined by the attractiveness and accessibility characteristics of the each residential location (see table 4.7). For example, ninety people of the total 296 employed at zone 1 were allocated to the same zone 1. The ninety people represent thirty percent of the total employees, which is the relative proportion of

Table 4.5

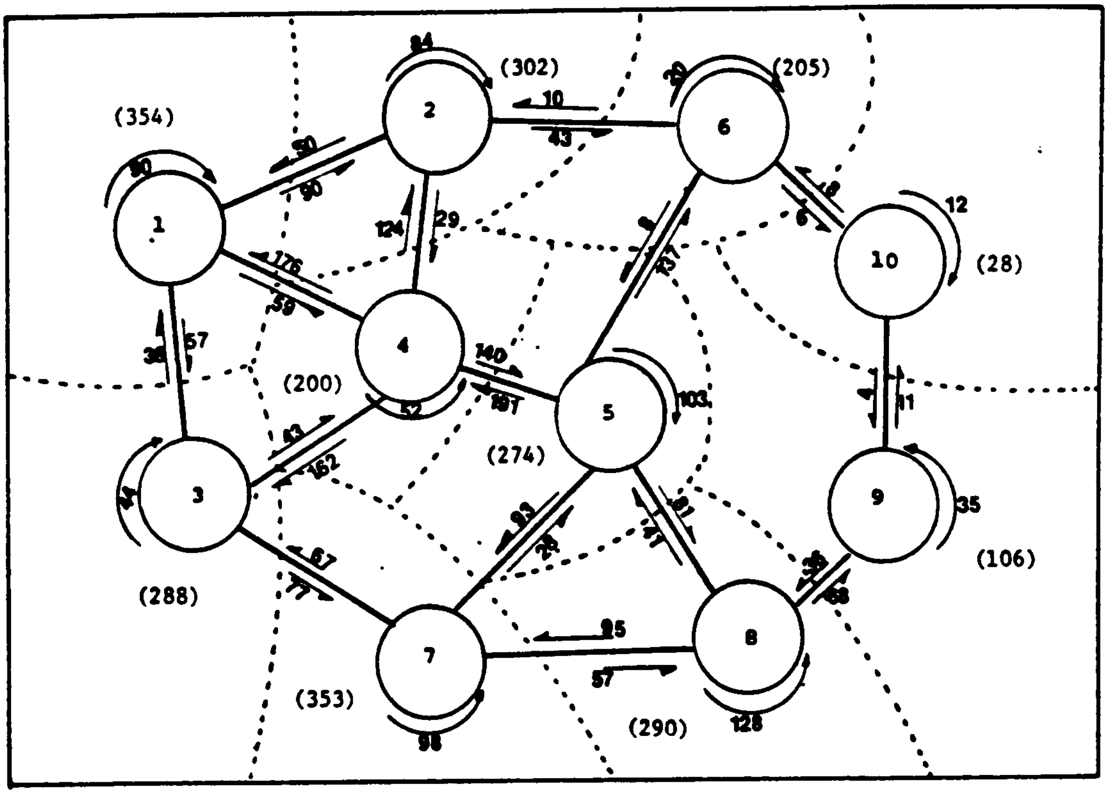
Travel Times or Costs in the Network
(first iteration)

Zone	1	2	3	4	5	6	7	8	9	10
1	1	1.7	1.9	1.2	2.5	4	3.7	4.9	6.8	6.6
2	1.7	1	3.4	2	3.3	2.3	5.2	5.7	7.6	4.9
3	1.9	3.4	1	1.4	2.7	4.8	1.8	3.8	5.7	7.4
4	1.2	2	1.4	1	1.3	3.4	3.2	3.7	5.6	6
5	2.5	3.3	2.7	1.3	1	2.1	2.2	2.4	4.3	4.7
6	4	2.3	4.8	3.4	2.1	1	4.3	4.5	5.3	2.6
7	3.7	5.2	1.8	3.2	2.2	4.3	1	2	3.9	6.6
8	4.9	5.7	3.8	3.7	2.4	4.5	2	1	1.9	4.6
9	6.8	7.6	5.7	5.6	4.3	5.3	3.9	1.9	1	2.7
10	6.6	4.9	7.4	6	4.7	2.6	6.6	4.6	2.7	1

Table 4.6

Simultaneous Residential Location and Trip
Matrix from Origin to Destination
(first iteration)

	Destination										
origin	1	2	3	4	5	6	7	8	9	10	total
1	90	85	49	37	20	6	8	1	0	0	296
2	49	84	7	16	6	37	1	0	0	1	200
3	32	7	44	20	9	1	43	4	0	0	160
4	119	89	95	52	74	18	22	10	0	0	480
5	55	26	38	65	103	108	93	66	4	2	560
6	1	8	0	1	5	20	1	0	0	3	40
7	6	1	48	5	25	4	98	50	4	0	240
8	2	1	7	4	30	4	85	128	58	2	320
9	0	0	0	0	1	0	3	31	36	8	80
10	0	0	0	0	0	7	0	1	3	12	24
total	354	302	288	200	274	205	353	290	106	28	2400



* Broken line is the boundary of each zone.

* The number in parenthesis is the number of residents in each zone.

Figure 4.2, The Number of Residents in Each Zone and Transportation Flow on Each Arc (First Iteration)

Table 4.7

Values of Attractiveness and Accessiblity
(first iteration)

	1	2	3	4	5	6	7	8	9	10	total
1	3.42	3.23	1.87	1.43	0.76	0.22	0.32	0.05	0.00	0.00	11.30
2	2.54	4.34	0.34	0.85	0.29	1.90	0.04	0.01	0.00	0.03	10.33
3	2.16	0.49	2.96	1.32	0.61	0.07	2.87	0.24	0.01	0.00	10.73
4	3.34	2.51	2.67	1.47	2.09	0.50	0.62	0.28	0.01	0.01	13.47
5	1.18	0.56	0.81	1.38	2.21	2.32	1.98	1.40	0.08	0.04	11.98
6	0.17	1.86	0.05	0.16	1.16	4.41	0.14	0.09	1.92	0.70	8.77
7	0.26	0.04	2.04	0.22	1.05	0.14	4.16	2.10	0.15	0.00	10.17
8	0.05	0.02	0.20	0.11	0.85	0.11	2.41	3.64	1.66	0.04	9.08
9	0.00	0.00	0.01	0.01	0.07	0.03	0.24	2.30	2.62	0.62	5.91
10	0.00	0.05	0.00	0.00	0.04	1.36	0.00	0.08	0.72	2.27	4.54

attractiveness and accessibility characteristics in employment zone 1. From Table 4.6, it can be seen that most people working in each zone j reside in the same zone, except for zone 4. Although zone 4 has high accessibility, the attractiveness is relatively lower than the other zones because of the limited amount of vacant and residential land. After the simultaneous residential and trip distribution, the loaded volumes on each link are shown in Table 4.8 and Figure 4.2. All 40 links are used at this time, but some links, especially those originating from zones 4 and 5, experience a good deal of congestion.

Table 4.8

Loaded Volumes on Each Link(first iteration)

	1	2	3	4	5	6	7	8	9	10
1	90	90	57	59						
2	50	84		29		43				
3	38		44	43			77			
4	176	124	162	52	140					
5				191	103	137	93	81		
6		10			8	20				6
7			67		28		98	57		
8					41		95	128	68	
9								36	35	11
10						8			4	12

The second iteration

At the second iteration, the travel times or costs were updated based on the previous step. The results are shown in Table 4.9. The travel times (or costs) from zones 4 and 5 to the other zones are longer (or more expensive) than during the initial iteration because of congestion. Therefore, the residential allocation from the employment zones 4 and 5 mostly remained in these same zones. This fact brought the rapid increase of the residence locations 4 and 5 (see Table 4.10 and Figure 4.3). At this stage in the iterative modeling process, some links are unused because of the high congestion. Five links in the first iteration, (links 4-1, 4-2, 4-3, 5-4, and 5-6), are unused. Overall, however, the links on the network are more congested (see Table 4.11 and Figure 4.3).

Table 4.9

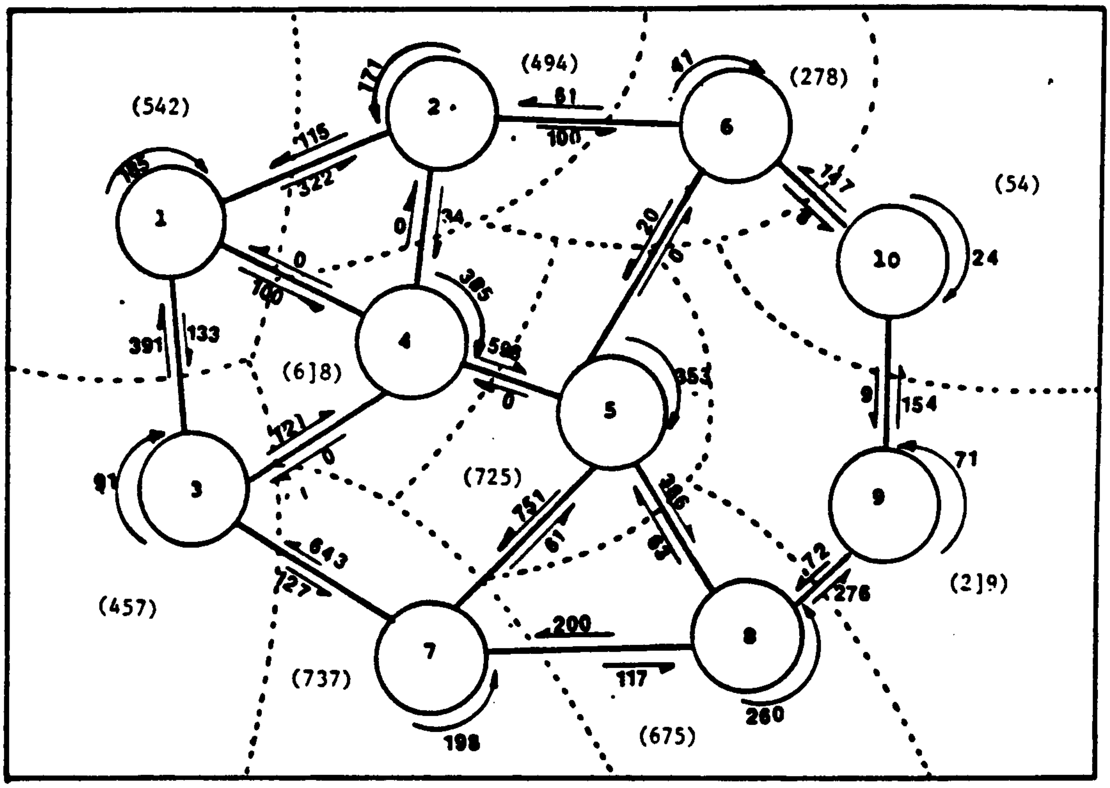
Travel Times or Costs in the Network
(Second iteration)

	1	2	3	4	5	6	7	8	9	10
1	1	1.7	1.9	1.2	3.9	4	3.7	5.7	7.6	6.6
2	1.7	1	3.6	2	4.4	2.3	5.4	6.8	7.6	4.9
3	1.9	3.6	1	1.4	4	5.9	1.8	3.8	5.7	8.4
4	9.1	10.8	7.2	1	2.7	12.3	5.4	5.1	7.0	9.7
5	6.4	8.1	4.5	5.9	1	9.6	2.7	2.4	4.3	7
6	4	2.3	5.9	4.3	2.1	1	4.8	4.5	5.3	2.6
7	3.7	5.4	1.8	3.2	2.2	7.7	1	2	3.9	6.6
8	5.7	7.4	3.8	5.2	2.4	7.2	2	1	1.9	4.6
9	7.6	7.6	5.7	7.1	4.3	5.3	3.9	1.9	1	2.7
10	6.6	4.9	8.4	6.9	4.7	2.6	6.6	4.6	2.7	1

Table 4.10

Simultaneous Residential Location and Trip Matrix from Origin to Destination (Second iteration)

origin	Destination 1	2	3	4	5	6	7	8	9	10	total
1	185	175	101	77	23	12	17	2	0	0	592
2	100	171	12	33	7	75	1	0	0	1	400
3	67	13	91	41	11	1	88	7	0	0	320
4	119	89	95	385	207	18	28	18	1	0	960
5	56	26	46	65	353	108	225	224	14	2	1120
6	1	17	0	1	11	41	1	1	0	6	80
7	12	2	97	10	50	4	198	100	7	0	480
8	2	1	14	4	61	4	172	260	118	3	640
9	0	0	0	0	2	1	6	62	71	17	160
10	0	1	0	0	0	14	0	1	8	24	48
total	542	494	457	618	725	278	737	675	219	54	4800



* Broken line is the boundary of each zone.

* The number in parenthesis is the number of residents in each zone.

Figure 4.3, The Number of Residents in Each Zone and Transportation Flow on Each Arc (Second Iteration)

Table 4.11

Loaded Volumes on Each Link(second iteration)

	1	2	3	4	5	6	7	8	9	10
1	185	322	133	100						
2	115	171		34		100				
3	391		91	121			127			
4	0	0	0	385	598					
5				0	353	0	751	386		
6		21			20	41				8
7			643		61		198	117		
8					63		200	260	276	
9								72	71	154
10						147			9	24

* The zero value is different from the blank column by row here. It means that the links were previously used, but are unused at this time.

The third iteration

The new travel times or costs are much longer or more expensive than during the previous iteration, because the links are getting congested as more employment is loaded on the network (see Table 4.12). The final total accumulated residential locations show that the number of people residing in each residential location is more dispersed than those working in each employment location (see Table 4.13 and Figure 4.4). Meanwhile, thirty four links were reused during this third and final iteration (see Table 4.14 and Figure 4.4). Although the unused links during the previous iteration are used at this time again, another six used links during second iteration were unused. Those six links are links 1-3, 3-1, 4-5, 5-1, 5-7,and 6-3.

Table 4.12

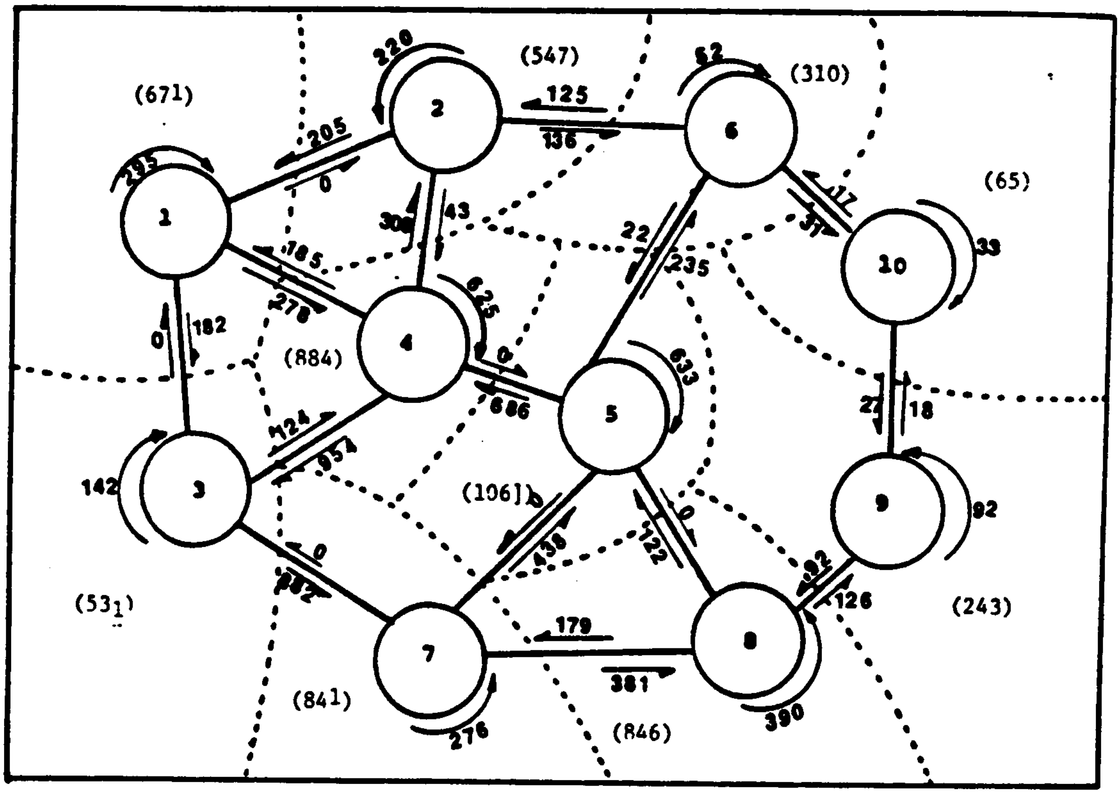
Travel Times or Costs in the Network
(third iteration)

	1	2	3	4	5	6	7	8	9	10
1	1	16.1	2.8	2.6	7.5	18.4	5.3	7.9	23.7	21.0
2	2.1	1	4.9	2	4.4	2.3	7.4	9.5	7.6	4.9
3	17.7	16.8	1	3.2	4.7	18.8	2.5	5.1	23.6	21.4
4	14.4	13.5	7.5	1	12.2	15.8	10.0	12.5	21.1	18.4
5	18.6	16.4	13.8	6.3	1	14.1	16.3	18.8	19.4	16.7
6	4.4	2.3	7.2	4.3	2.1	1	9.7	7.2	5.3	2.6
7	20.8	18.6	16.0	8.5	2.2	16.3	1	2.6	21.1	18.9
8	21.0	18.8	16.2	8.7	2.4	16.5	6.8	1	18.5	19.1
9	13.8	11.7	16.6	10.6	4.3	9.4	8.7	1.9	1	5.0
10	8.8	6.7	11.6	8.7	6.5	4.4	11.4	4.6	2.7	1

Table 4.13

Simultaneous Residential Location and Trip Matrix from Origin to Destination (third iteration)

	Destination										
origin	1	2	3	4	5	6	7	8	9	10	total
1	295	174	124	91	23	12	18	2	0	0	740
2	119	220	12	43	8	96	1	0	0	1	500
3	67	13	142	44	12	1	113	8	0	0	400
4	119	89	95	625	207	18	28	18	1	0	1200
5	56	26	47	65	633	109	225	224	14	2	1400
6	1	21	0	1	14	52	1	1	0	8	100
7	12	2	97	10	70	3	276	122	7	0	600
8	2	1	14	5	91	4	172	390	119	3	800
9	0	0	0	0	3	1	6	80	92	16	200
10	0	1	0	0	0	14	0	1	10	33	60
total	671	547	531	884	1061	310	841	846	243	65	6000



* Broken line is the boundary of each zone.

* The number in parenthesis is the number of residents in each zone.

Figure 4.4, The Number of Residents in Each Zone and Transportation Flow on Each Arc (Third Iteration)

Table 4.14

Loaded Volumes on Each Link
(third iteration)

	1	2	3	4	5	6	7	8	9	10
1	295	0	182	278						
2	205	220		43		136				
3	0		142	124			882			
4	185	308	954	625	0					
5				686	633	235	0	0		
6		125			22	52				31
7			0		438		276	381		
8					122		179	390	126	
9								92	92	18
10						17			27	33

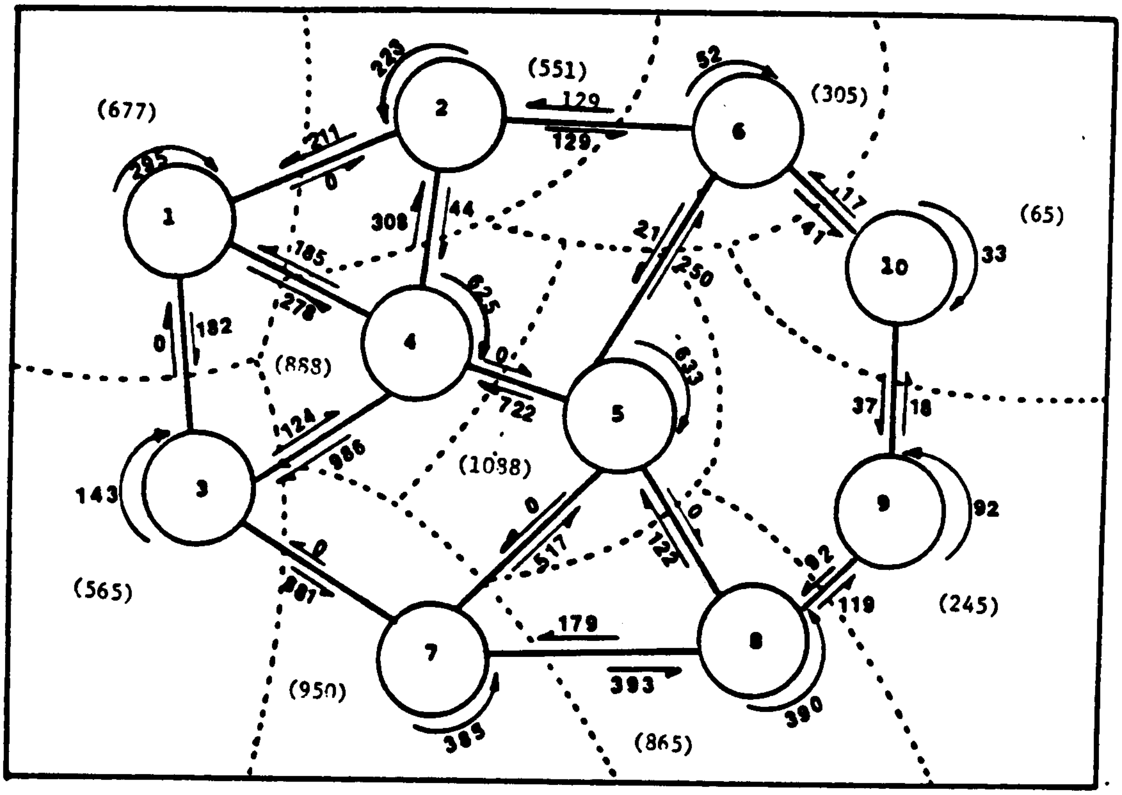
4.3. Sensitivity Tests of the Microcomputer Version

The following sensitivity tests were conducted to examine how the version of the Putman's integrated urban model responds to changes in input data. The results of the version upon which the data sets used in the hypothetical urban area were based are compared against the results of the data sets which used different inputs. The number of residents in each zone and the loaded volume on each link after third iteration are depicted at each discussion below(from Figure 4.5 to Figure 4.13), and all the results by the changed inputs are shown in the tables of Appendix B.

Job Generation

In examining the effects of job generation and closure, it was assumed that a new factory in zone 7 employs 200 people. The results of test run show that zone 7 and the adjacent zones 3, 5, and 8 contain most of the 200 new employees (see Appendix B.1.3.2). The new workers in zone 7 were allocated to each residential location, depending on the percentage of the relative attractiveness and accessibility characteristics in each residential location.

Meanwhile, congestion effects on some links causes travel times or costs to increase. Congestion was present in the case of an increase in zone 7. The link 2-6 was overloaded during the second 40 percent loading of



* Broken line is the boundary of each zone.

* The number in parenthesis is the number of residents in each zone.

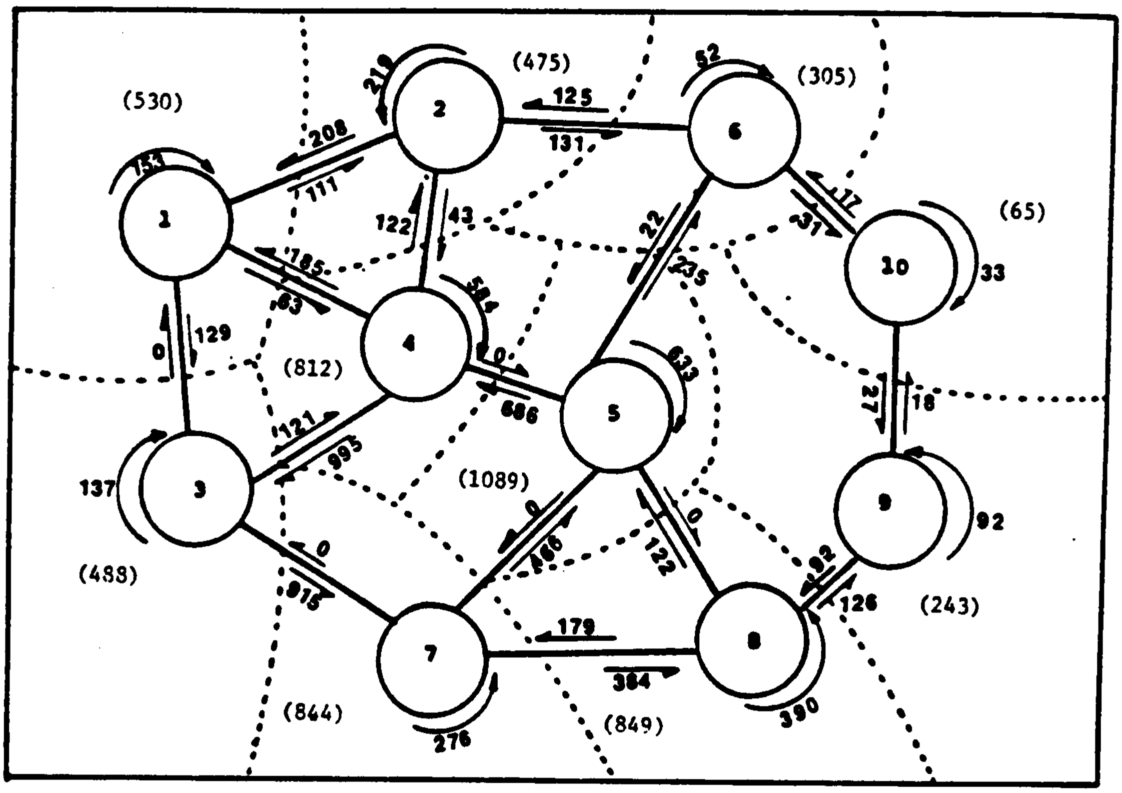
Figure 4.5, The Number of Residents in Each Zone and Transportation Flow on Each Arc (The Case of Job Generation) employment (see Appendix B.1.2.3). The time or cost from zone 2 to 6 was, therefore, changed from 2.3 to 2.7 time (or cost) units (see Appendix B.1.3.1). Thus, the trip distribution from zone 2 to zone 6 was affected by the relatively lower accessibility of zone 2 (see Appendix B.1.3.2). This relatively lower accessibility from zones 2 to 6 was directly reflected in the number of people residing in zone 6.

As another case, it is supposed that an existing factory that employed 300 people in zone 1 closed. This situation is noted because, in general, urban models are just designed to operate in terms of growth.[69] The effects of the closure in the microcomputer version are decreases of 142 residents in zone 1, 73 in zone 4, 72 in zone 2, 43 in zone 3, 6 in zone 6, and small decrease in zones 7 and 8 (see Appendix B.2.3.2). Those changes are attributed to the change of the trip distribution from employment zones 2, 3, and 4 to the other zones, as well as the reduction of 300 workers from zone 1.

The changes of trip distribution from employment zones 2, 3, and 4 also resulted from the reduction of the amount of travel on some links which caused the change of travel times (or costs) in the third iteration (see Appendix B.2.2.3 and 2.3.1).

---

[69] Khakee, op.cit., pp.61-62.



* Broken line is the boundary of each zone.
* The number in parenthesis is the number of residents in each zone.

Figure 4.6, The Number of Residents in Each Zone and Transportation Flow on Each Arc (The Case of Job Closure)

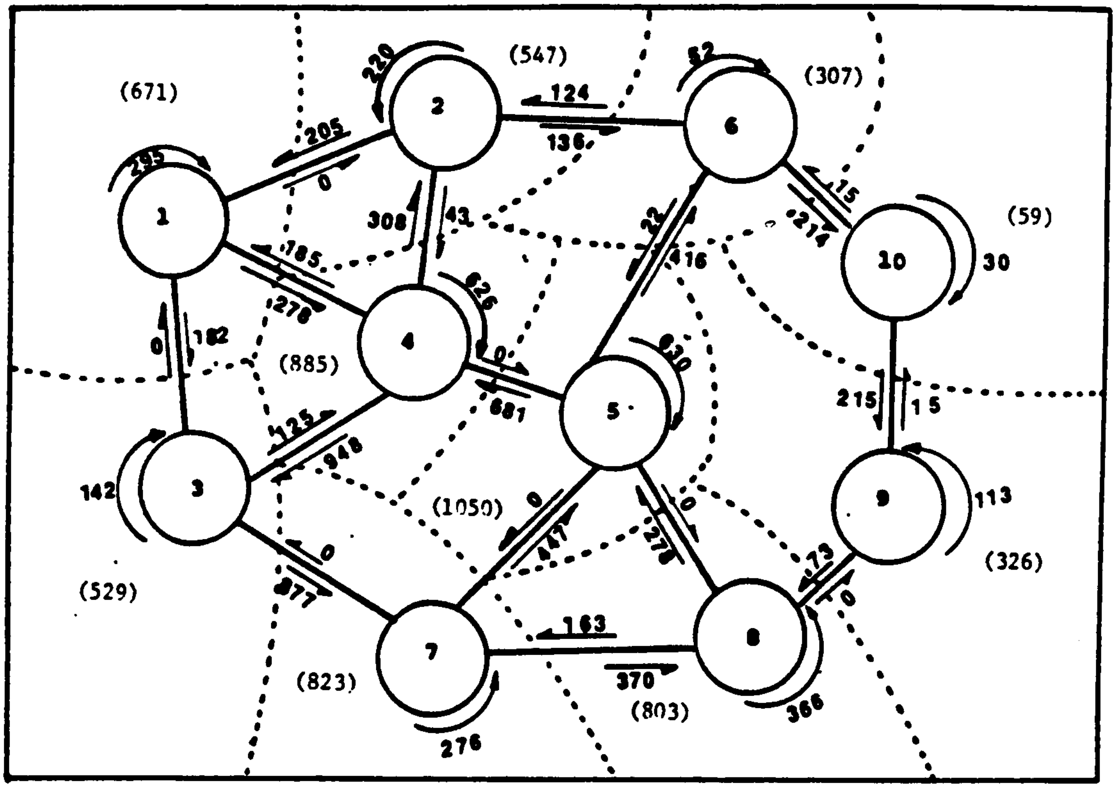
A change of job is likely to affect change in residential location, according to the relative percentage of attractiveness and accessibility characteristics. However, the effects of job changes were not just limited to the residential allocation of the people working in the changed employment zone. Job changes also affected the residential allocation and trip distribution in the other employment zones because of the effects of congestion on some links not directly connected with the changed employment zone.

Attractiveness of Zones

Three types of attractiveness in each zone were used in the microcomputer version of the Putman's model: the vacant buildable land, one plus the proportion of buildable land which has already been built upon, and the residential land. The second attractiveness measure was associated with the availability of infrastructure.[70] This means that the higher level of infrastructure prepared, the more development can be induced.

The following two cases on attractiveness were tested. First, the buildable land was improved from 30 to 70 percent of the total vacant buildable land in zone 9. The change represents the change of W_i, specifically $x^{\sim}_i$ from

[70]Putman, Integrated Urban Models, p.179.

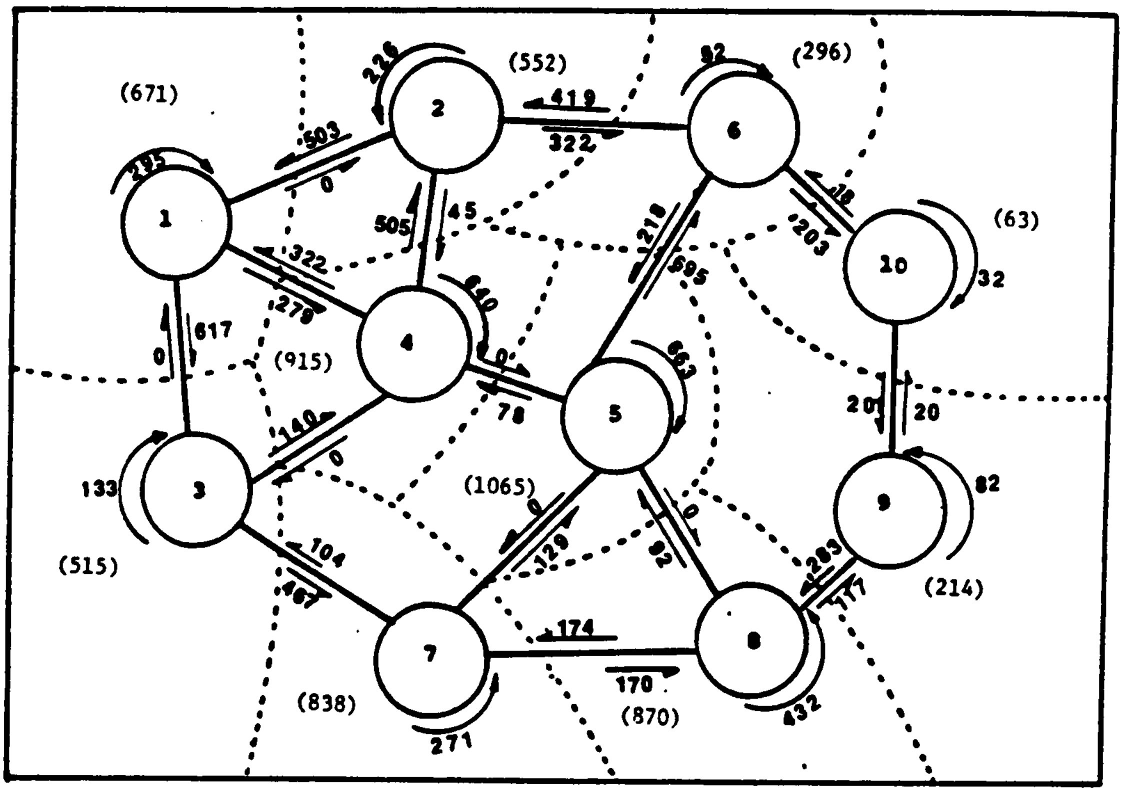


* Broken line is the boundary of each zone.
* The number in parenthesis is the number of residents in each zone.

Figure 4.7, The Number of Residents in Each Zone and Transportation Flow on Each Arc (The Case of Improvement of Vacant Buildable Land)

$(L_i^{\,v})^q(x^{\sim}_i)^r(L_i^{\,r})^s$ in equation (2.35). The results show that the improvement increased the total number of residents from 243 to 325 in residential zone 9, while residents decreased to 803, 823, 1050, and 59 in the respective residential zones 8, 7, 5, and 10(see Appendix B.3.3.2). On the other hand, the loaded volume on each link show that the most used link to reach the residential zone 9 was link 8-9 at the second 40 percent loading, but the link was unused due to severe congestion during the last 20 percent loading. Instead, link 10-9 is highly used (see Appendix B.3.2.3 and 3.3.3).

Second, it is supposed that a developer attempts to extend residential land of zone 8 from 35 units to 50 units, utilizing just the existing land zoned for residential purposes. The results show that the largest increases in residents were generated for zones 4 and 8, while the most decreases took place in residential zones 9, 3, and 6 (see Appendix B.4.3.2). The degree of increase in zone 8 is not great, however, despite the fact that the increase in attractiveness was directly apportioned to zone 8. The reason for the modest change in zone 8 is that the values of attractiveness and accessibility in each employment zone toward zone 8 were not greatly changed because of the high cost of travel to that zone. The increase in residential zone 4 mainly resulted from the increase of the residential location and trip distribution from employment zone 4 to the



* Broken line is the boundary of each zone.
* The number in parenthesis is the number of residents in each zone.

Figure 4.8, The Number of Residents in Each Zone and Transportation Flow on Each Arc (The Case of Extension of Residential Land) same zone, and from zone 3 to zone 4. The increase in zone 4 is attributed to accessibility. That is, the links connected with zone 4 were already congested at the first 40 percent loading (see Appendix B.4.1.3). Since link capacity in intrazonal travel was assumed to be 1000 of the link, the relative accessibility became higher than the initial one when links connecting other zones are congested (see Appendix B.4.1.4). This explains the increased number of people in residence zone 4. The increase from employment zone 3 to residence zone 4 also occurs for the same reason (see Appendix B.4.2.3).

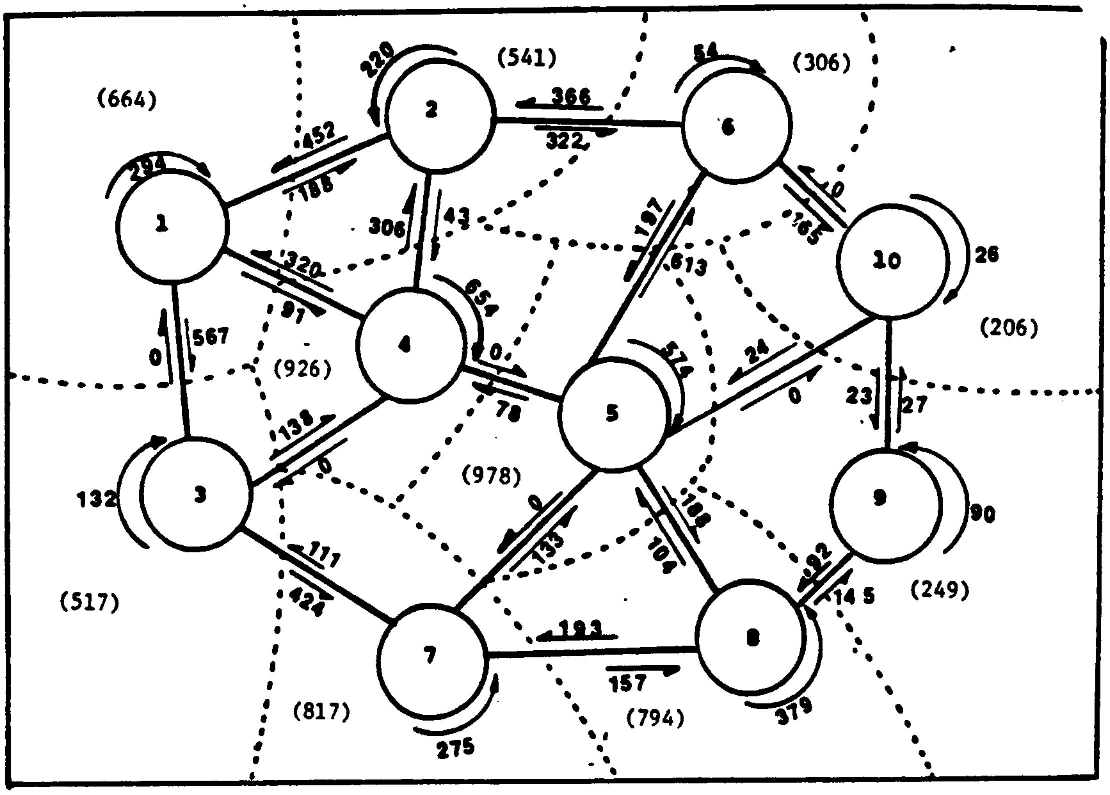
When a factor of attractiveness is added to a residential location, more workers are supposed to choose that zone. In addition, the effects of congestion on links effect considerably the change of residential location and trip distribution.

Network Structure

It is hypothesized that the network would be better improved if a new road is constructed directly between node 5 and node 10. New link 5-10 and 10-5 would have a unit of 2.3 travel time length and 60 units of volume capacity. As expected, the test run shows that the new flow takes place mainly between zone 5 and 10. Therefore, the number of residents is reduced in all the other zones (see Appendix B.5.3.2).

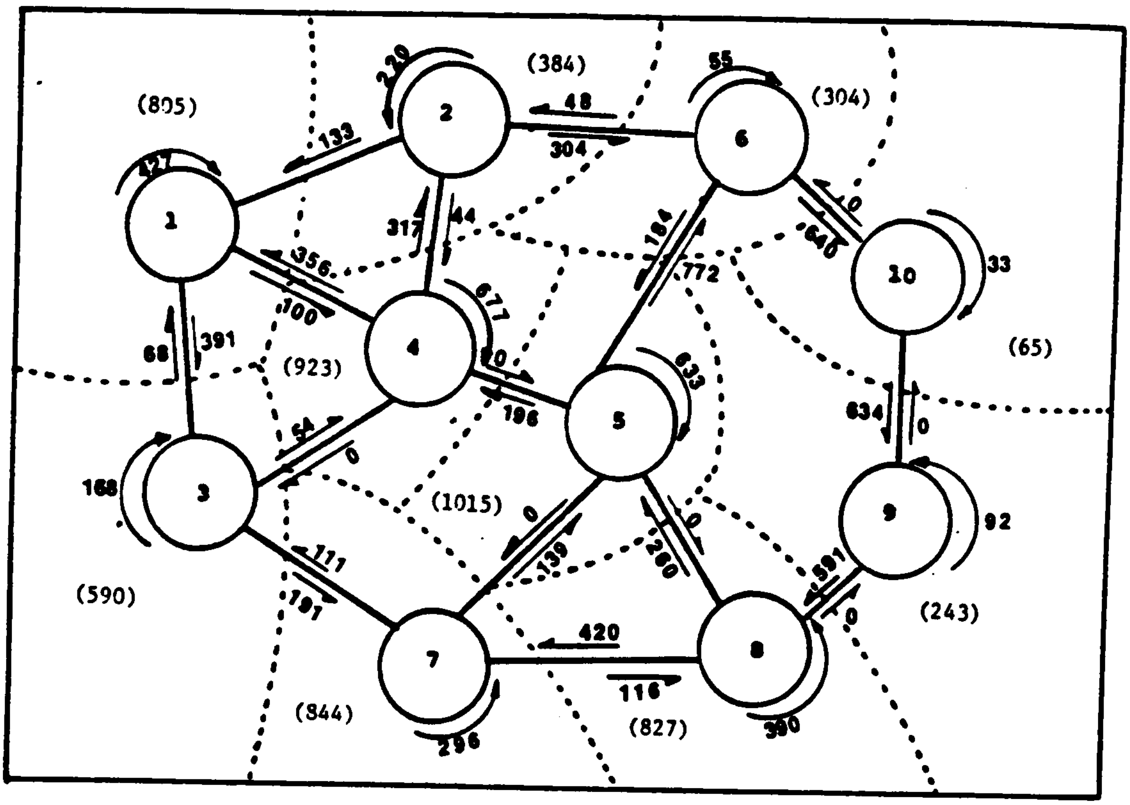
The results from the construction of new links were compared with the previous results in terms of the total times (or costs) in the network. The total times or costs due to new links are 904.01 units of travel length, while the previous results show 1051.9 units of travel length. Those values were calculated from the matrix of travel times (or costs) in the last shortest paths. If one unit of travel length is equivalent to 5 minutes, a total of 12 hours and 32 minutes can be saved as the result of the new links in the network. Meanwhile, comparison of the last loaded volume on each link with the results in the hypothetical urban area reveals that the changes tend to be concentrated in the near links of the new links (see Appendix B.5.3.3).

Suppose, now, that link 1-2 is closed. The results show that the total residents in zone 2 decreases to 384 from 547, and from 846 to 827 in zone 8. In zones 1, 3, and 4, on the other hand, population increases (see Appendix B.6.3.2). The change is largely due to the lowered accessibility to residential zone 2. Congestion effects also affect the trip distribution and residential location. Particularly, the links originating from employment zone 4 were congested early in the iterative procedure. Thus, the relative accessibility became higher in the same zone. Then, during the second 40 percent loading, the congestion effects changed the accessibility from the employment zones



* Broken line is the boundary of each zone.
* The number in parenthesis is the number of residents in each zone.

Figure 4.9, The Number of Residents in Each Zone and Transportation Flow on Each Arc (The Case of a New Road Construction)



* Broken line is the boundary of each zone.
* The number in parenthesis is the number of residents in each zone.

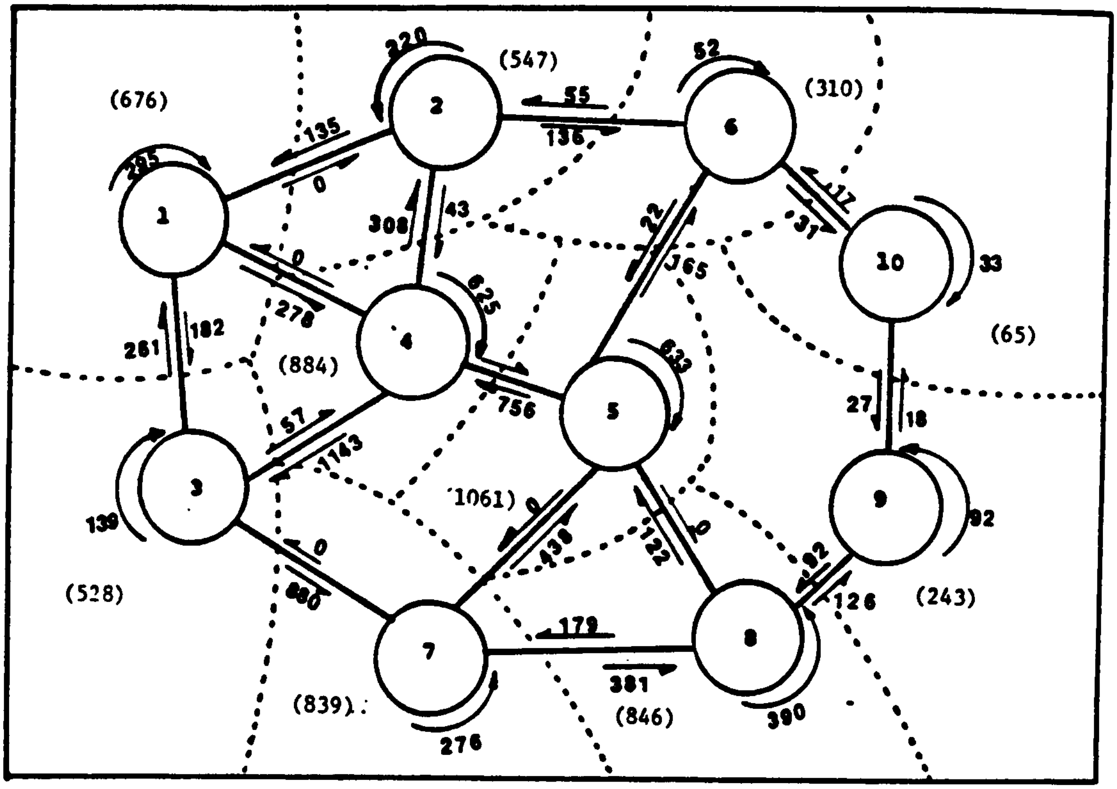
Figure 4.10, The Number of Residents in Each Zone and Transportation Flow on Each Arc (The Case of Road Closure)

3 and 7 to the other zones.

Change in Transportation Function

1) Capacity on Links

According to Table 4.14, there was no volume loaded on link 3-1. The link was not used because the capacity of the link was not enough to allow the flows. Thus, its capacity is increased from 100 to 250 per unit of time to test the capacity change of the link. The results of the capacity change show that only 5 people were added in residential zone 1, while 3 and 2 people moved from residential zones 3 and 7, respectively (see Appendix B.7.3.2). The slight changes are attributed to congestion effects after the second 40 percent loading. That is, the loaded volume on link 3-1 are the same as the previous results until the second 40 percent loading, because the link was not congested. However, after the second 40 percent loading, link 3-1 was still used even though the loaded volume had begun to exceed the capacity of the link. Since the link in the hypothetical urban area was too overloaded, the link was unused (see Table 4.14). Therefore, the difference of accessibility from employment zone 3 to the other zones resulted in the above slight change of the residential locations.



* Broken line is the boundary of each zone.
* The number in parenthesis is the number of residents in each zone.

Figure 4.11, The Number of Residents in Each Zone and Transportation Flow on Each Arc (The Case of Capacity Extension on the Link)

2) accessibility on links

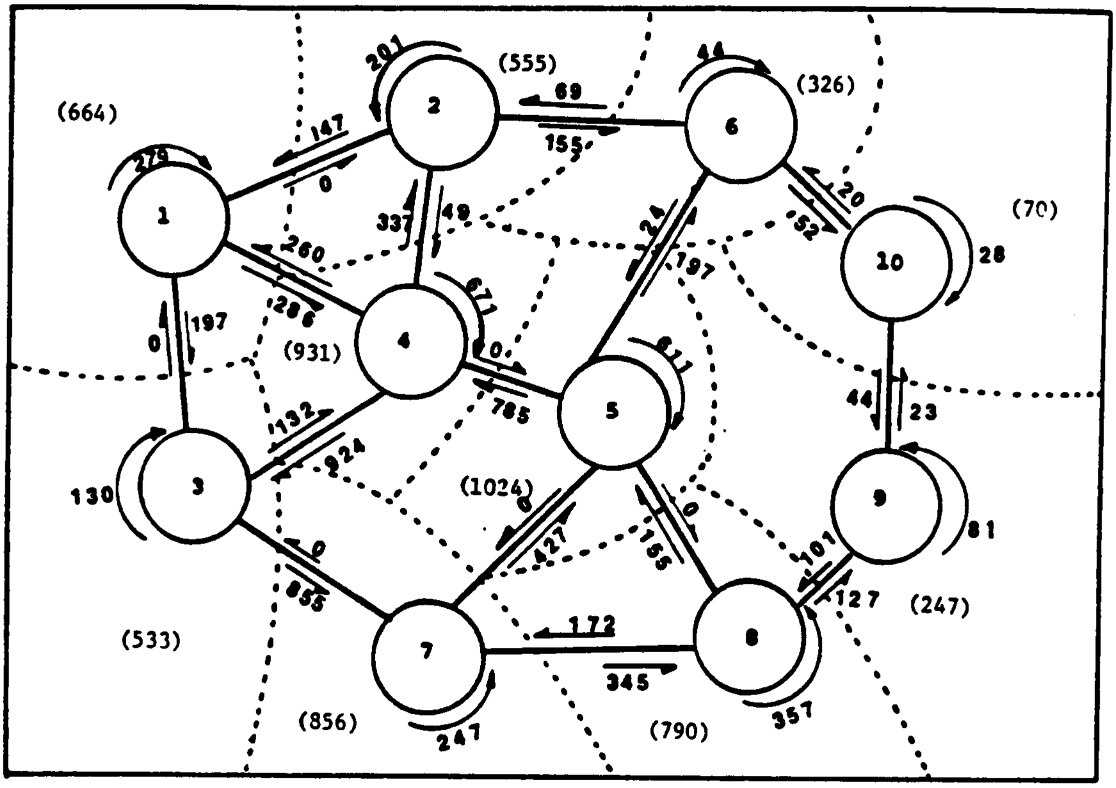
Two types of change in accessibility were tested in the integrated urban model. Those were regionwide change and zone-specific change in accessibility. Regionwide decreases and increases in transportation costs might affect regional growth and decline.[71]

Regionwide decreases in travel times or costs were assumed in the microcomputer version. By multiplying the zone-to-zone travel cost matrix based on the shortest paths by 0.9, a scenerio of a 10 percent across-the-board increase of regionwide accessibility was tested. The results show that the residential zones experiencing the greatest increases were the zones 4, 6 and 7, and the most decreased zones were zones 8 and 5 (see Appendix B.8.3.2). However, the dispersal of development was not identified, because the zones in the hypothetical urban area are small in number.

When the regionwide accessibility was increased, the changes of the trip distribution and residential location were not consistent, because the decrease of C_{ji} does not correspond to the decrease at $F(C_{ji})$ of the two parameter trip function. The final loaded volume on each link was quite different from the previous results (see Appendix B.8.3.3). This means that regionwide changes of accessibility cause a considerable change on every link.

---

[71]Ibid., pp.234-237.



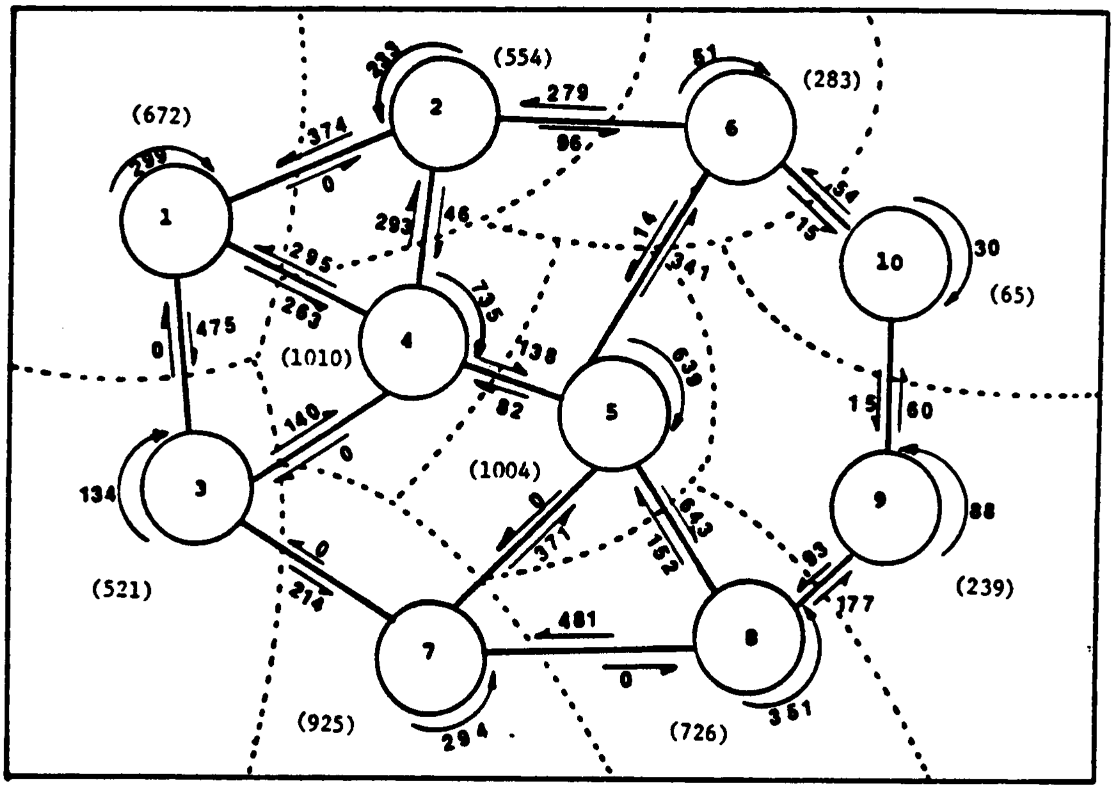
* Broken line is the boundary of each zone.
* The number in parenthesis is the number of residents in each zone.

Figure 4.12, The Number of Residents in Each Zone and Transportation Flow on Each Arc (The Case of Regionwide Change in Accessibility)

The effects of zone-specific change were tested on link 5-8 and 8-5. The accessibility has been changed from 2.4 units of time (or cost) to 1.4 units. The effects are decreases in the population in residential zones 8, 5, 6, 3, and 9, while the other zones (7, 4,and 2) increased. This phenomenon is explained by the fact that as soon as the accessibility was higher between zones 5 and 8, the links were heavily used from the first 40 percent loading (see Appendix B.9.1.3). Therefore, the accessibility was lower between two zones.

4.4. Summary

This chapter illustrated the results of the microcomputer version of the Putman's integrated urban model applied to a hypothetical 10 node city and the response of changed inputs in that hypothetical city. The results were obtained through three iterations of the version. Each iteration revealed travel costs or times in the network, the simultaneous residential location and trip distribution, and loaded volumes on each link. At each iteration, the simultaneous residential location and trip distribution from each zone was determined by the relative proportion of attractiveness and accessibility characteristics. In addition, it was found that the residential allocation from employment was quite affected by the congestion effects



* Broken line is the boundary of each zone.
* The number in parenthesis is the number of residents in each zone.

Figure 4.13, The Number of Residents in Each Zone and Transportation Flow on Each Arc (The Case of Zone-Specific Change in Accessibility) which alter travel times or costs.

Based on the results of the version, sensitivity tests were calculated to examine the effects of changed inputs. Sensitivity tests were used to simulate the effects of changes in job generation, attractiveness of land use, network structure, and change in transportation function. From the sensitivity tests, the change of job generation and attractiveness of land use in a specific zone was not just limited to a change of residential location in that zone, but also brought change in the number of residence in other zones as well. During this process, the congestion effects considerably affected such a change of residence. Change of transportation, as measured by both network structure and transportation function, showed rather complex impact on residential locations and loaded volumes on links. The reason was generally found in the direct and indirect effects of transportation to location and land use.

CHAPTER 5

SUMMARY AND CONCLUSIONS

The purpose of this study was to develop a microcomputer version of the integrated location and transportation models developed by S.H. Putman and to study the behavior of that model. The microcomputer version developed examined the interrelationship between land use and transportation in a hypothetical urban area.

The procedure of the microcomputer version begins by determining the shortest path in terms of travel costs or times in the network. Employment(only work-to-home trips were assumed) was exogenously forecast. The zone-to-zone travel characteristics of the network and the employment in each zone were then used as inputs to simultaneously forecast trip distribution and residential location. A congestion function was applied to the loaded volumes on each link used during the trip distribution and residential location phase of the model sequence. Congestion effects created new travel times or costs in the network. This process was iterated three times, according to the method of incremental full network reloading described in Chapter 2.

Activity location, land use, and transportation were first forecast in a hypothetical urban area. The results of the forecast suggests that "(a) transportation changes can affect activity location and land use; (b) activity location and land use can affect transportation; (c) activity location and land use can affect activity location and land use." [72] Therefore, the effects of activity location, land use, and transportation on each other were examined, and can summarized as follows.

Change of Activity

The probability of residential change in the location of job growth or decline is directly proportional to a measure of the attractiveness and the accessibility of the possible residential locations from the employment zone. The response not directly attributable to change in the measure of attractiveness and accessibility was caused by the effects of congestion on some links. As some links become congested at some places and not at others, the growth or the decline of residence was a concomitant.

Change of Land Use

The change of land use was represented as the change of attractiveness in the microcomputer version of the Putman's model. The land uses measured as attractiveness indices were vacant buildable land, buildable land already constructed, and residential land. Since the allocation of

---

[72] Ibid., p.313.

residence is directly proportional to attractiveness, residential change was quite affected by the change of land use in particular area. Also, congestion effects were present when a change of land use occurred in the microcomputer version.

Change of Transportation

The effects of transportation on location and land use were examined by the change of network structure and transportation function (i.e. capacity and accessibility).

First, a road construction or closure brought about a considerable change to the volume loaded onto each link, and then caused a change in the allocation of residence. Although the results of this study do not distinctively confirm the range of influence from the changed network, residential changes were particularly noted in areas near the network change.

Secondly, the expansion of capacity on some links allowed more transportation flows. It also brought about a change of volume loaded onto the adjacent links. However, the allocation of residence was not greatly affected by the expansion of capacity on a specific link, because some links onto which too much volume exceeding capacity had been loaded were unused by the complete conversion of volume loaded to the near links expanded. Of course, those results might not reflect a general effects of the expansion of capacity on a link. The big difference of volume loaded between links by the capacity change is due to the method of incremental full network reloading.

Thirdly, regionwide change(or specific change) of accessibility brought a considerable change of the volume loaded at most links. Meanwhile, an identifiable and consistent spatial pattern such as concentration or dispersion was not distinctively revealed in this study because of the small number of zones utilized in the hypothetical city.

The effects of transportation on location and land use were rather complex, because the effects involved direct and indirect effects, and feedbacks through a complex process.

There are two major advantages of this microcomputer version of the Putman's model. One is to allow the examination of the interrelationship between location, land use, and transportation. Putman's operational urban models easily allow one to study these interrelationships. The other is related to policy simulations. Policy simulations may be needed to evaluate the impacts of future transportation on location and land use, or vice versa. The process would be similar to the sensitivity tests developed within the scope of this study. The evaluation of alternative scenario can proceed quickly, using the microcomputer version developed here.

Putman's work has been criticized for its lack of requilibrium and non-unique solutions.[73] This implementation of Putman's work is subject to the same criticism. Nonetheless, the program allows for the study of the non-linear relationship between location and transportation. Further, Putman's model has been applied in a number of planning contexts. This indicates that computational feasibility is often preferred to more theoretically advanced approaches. In this context, this thesis can be considered a first step in the development and application of urban models on microcomputers.

In fact, there are some restrictions in using the microcomputer version as detailed in Chapter 3. Those problems include the exogenous determination of employment locations, only work-to-home trips, the lack of detailed transportation planning delimiting an appropriate surrogate of attractiveness, and the limitations on the capacity of computer storage. Overall, the lack of empirical trip data to be used in the model is the greatest barrier to a realistic forecast of location, land use, and transportation.

Future research should focus on the use of EMPAL in

---

[73] Alex Anas, "Book Reviews", <u>Annals of the Association of American Geographers</u>, 1985, Vol.75, pp. 617-619.

such a modeling effort. The EMPAL model as a base for a microcomputer model would allow for better integration of location and transportation elements. Related to EMPAL, the following two directions can be suggested. First, begin the EMPAL procedure with the input of population at time t-1, or at time t. Then, load 40 percent of employment onto the network to forecast population at time t and determine trip distribution. Then, iterate the process until the 40 percent of employment and the residence in each zone reach equilibrium. After this process, another 40 percent and the rest 20 percent of employment are iterated until the percent of employment reaches its respective equilibrium. In addition, another direction for further research is to separate the calculation of non-basic and basic employment location. From the separate procedures described in Chapter 2, the results of the separate employment locations can be used in DRAM.

BIBLIOGRAPHY

BIBLIOGRAPHY

Alex Anas, "Book Reviews", Annals of the Association of American Geographers, 1985, Vol.75.

Batty, Michael. "Urban Models in the Planning Process", Geography and the Urban Environment, Vol.1, 1978.

Berechman, J. and Gordon, P. "Linked Models of Land Use-Transport Interactions: A Review", Advances in Urban Systems Modelling, ed. B. Hutchinson and M. Batty, New York, Elsevier Science Publishers B.V.,1986.

Black, John. Urban Transport Planning, Baltimore, The John Hopkins University Press, 1981.

Dickey, John. W. Metropolitan Transportation Planning, New York, Hemisphere Publishing Co., 1983.

Ducca, F.W. and Wilson, R.H. "A model of shopping center location", Environment and planning A Vol.8, 1976.

Foot, David. Operational Urban Models, London, Methuen & Co., 1981

Giualiano, Genevieve. "Land Use Impacts of Transportation Investments: Highway and Transit", The Geography of Urban Transportation, ed. S. Hanson, New York, The Guilford Press, 1986.

Khakee, Abdul. "Urban Models and Municipal Planning", Urban Geography, Vol.6, 1985.

Mills, Edwin S. Studies in the Structure of the Urban Economy, Baltimore and London, The John Hopkins Press, 1972.

Northam, Ray M. Urban Geography, Second Edition, New York, John Wiley & Sons, 1979.

O'Sullivan, Patrick. "Regions of a Transport Network", Annals. Association of American Geographers, Vol.68, No.3, 1978.

Ottensmann, John. R. Basic Microcomputer Programs for Urban Analysis and Planning, New York, Chapman and Hall, 1985.

Pas, Eric. I. "The Urban Transportation Planning Process", The Geography of Urban Transportation, ed. S. Hanson, New York, The Guilford Press, 1986.

Putman, Stephen. H. "Intraurban Employment Forecasting Models: a Review and a Suggested New Model Construct", Journal of the American Institute of Planners, Vol XXXVIII, 1972.

Putman, S. H. Empirical Model of Regional Growth: Monograph Series Number Six, Philadelphia, Regional Science Research Institute, 1975.

Putman, S. H. "Urban Land Use and Transportation Models: a State of the Art Summary", Transportation Research, Vol.9, No.1, 1975.

Putman, S. H. Urban Residential Location Models: Studies in Applied Regional Science, Vol.13, Martinus Nijhoff Publishing, 1979.

Putman, S. H. Integrated Urban Models, London, Pion Limited, 1983.

Reif, Benjamin. Models in Urban and Regional Planning, New York, Intertext Educational Publishers, 1973.

Sheppard, Eric. "Modeling and Predicting Aggregate Flows", The Geography of Urban Transportation, ed. S. Hanson, New York, The Guilford Press, 1986.

Smith, David. K. Network Optimisation Practice: A Computational Guide, Chester, Ellis Horwood Limited, 1982.

U.S. Department of Transportation, An Introduction to Urban Travel Demand Forecasting, Washington D.C, The Federal Highway Administration, 1977.

APPENDICES

APPENDIX A: THE PROGRAM FOR THE INTEGRATED LOCATION AND TRANSPORTATION MODELS IN BASIC PROGRAMMING LANGUAGE

```
10 REM Micro-Computer Program for Integrated Urban Model
20 REM  by Sang Yool Lee
30 REM  A(J)- Attractiveness of Destination J
40 REM  F(I,J)- Function of Distance from I to J
50 REM  R(I)- Origins at I
60 REM  X(I,J)- Sum of j of a(j) *f(i,j)
70 REM  Z(I,J)- Distance from I to J
80 REM A2(k)-Temporal variable to store the number of volume
90 REM B2(k)-Temporal variable to store j to j1
100 REM D(i,j)-travel length on links
110 REM P1(i,j)-The variables for predecessors between i and j
120 REM V1(i,j)-The number of volume on link i-j
130 REM Q(i,j)-The column and row of the sum over trip matrix
140 REM U(j)-employment data in zone j
150 REM U1(j)-.2 or .4* employment data
160 REM V(i)-The variable for vacant data file
170 REM  B- Function Parameter
180 REM W1-The variable for the 1+proportion of buildable land file
190 REM W2-The variable for the residential land file
200 REM D1(i,j)-The variable for travel length in congestion function
210 REM D2(i,j)-The variable for capacity in congestion function
220 REM G(i,j),H(j),K(j),M(j),L(j),N(I,j)-The variables in the no constrained
        model
230 REM P(i,j)-The sum over j of V)i)*F(i,j) in demand-constrained model
240 REM W(i)-The Attractiveness in Supply and Demand Constrained Model
250 REM c1,c2,.. choice variable
260 REM  N1- Number of Origins
270 REM  N2-Number of Destinations
280 REM T(i,j)- trip matrix from origin to destination
290 DIM A(21),D(21,21),F(21,21),R(21), X(21,21),P1(21,21),V1(21,21),A2(21)
300 DIM Z(21,21), T(21,21),Q(21,21),W(21),L(21),B2(21),D1(21,21),D2(21,21)
310 DIM G(21,21),H(21),K(21),M(21),V(21),P(21,21),U(21),U1(21),N(21,21)
320 DIM W1(21),W2(21),F1(21,21)
330 REM F specifies number of fields in table segments
340   F=5
350 REM Distance Data Input and Output
360 PRINT
370 PRINT "Gravity Model"
380 REM DISTANCE INPUT
390 GOSUB  610
400 GOTO 390
410 PRINT
420 REM options for general forms of gravity model
440 REM NO CONSTAINTS GRAVITY MODEL
```

```
450 GOSUB 1400
460 GOTO 430
470 REM SUPPLY CONSTRAINTS GRAVITY MODEL
480 GOSUB 1750
490 GOTO 430
500 REM DEMAND CONSTRAINTS GRAVITY MODEL
510 GOSUB 2000
520 GOSUB 6000
530 GOSUB 680
535 GOTO 510
540 REM SUPPLY AND DEMAND CONSTRAINTS MODEL
550 GOSUB 3360
560 GOTO 430
570 PRINT
580 PRINT
590 PRINT
600 REM INITIAL DISTANCE INPUT ROUTINE  ****************************
610 PRINT
620 PRINT "NUMBER OF ORIGINS (MAXIMUM 20)";
630 INPUT N1
640 PRINT "NUMBER OF DESTINATIONS (MAXIMUM 20)";
650 INPUT N2
660 PRINT
670 S2=0
680 GOSUB 5000
690 IF S1>=2 THEN 920
700 PRINT " OPTIONS FOR GENERAL FORMS OF GRAVITY MODEL"
710 PRINT TAB(5); "1- NO CONSTRAINTS"
720 PRINT TAB(5); "2- SUPPLY CONTSRAINTS"
730 PRINT TAB(5); "3- DEMAND CONSTRAINTS"
740 PRINT TAB(5); "4- SUPPLY AND DEMAND CONSTRAINTS"
750 PRINT TAB(5); "5-stop"
760 PRINT
770 PRINT "CHOICE OF OPTION";
780 INPUT C1
790 IF C1 < >1 THEN 820
800 GOSUB 920
810 GOTO 450
820 IF C1 < >2 THEN 850
830 GOSUB 920
840 GOTO 480
850 IF C1 < >3 THEN 880
```

```
860 GOSUB 920
870 GOTO 510
880 IF C1 < >4 THEN 910
890 GOSUB 920
900 GOTO 550
920 REM OPTIONS FOR DISTANCE FUNCTION SUBROUTINE **********
930 IF S1>=2 THEN 1280
940 PRINT
950 PRINT "OPTIONS FOR DISTANCE FUNCTION:"
960 PRINT TAB(5); "1-INVERSE POWER FUNCTION:"
970 PRINT TAB(5); "2- NEGATIVE EXPONENTIAL FUNCTION"
980 PRINT TAB(5); "3-Gamma Function"
990 PRINT
1000 PRINT "CHOICE OF OPTION";
1010 INPUT C2
1020 IF C2=3 THEN 1280
1030 PRINT
1040 PRINT "DISTANCE FUNCTION PARAMETER"
1050 PRINT "(POSITIVE NUMBER)";
1060 INPUT B
1070 PRINT
1080 REM calculate inverse power or negative exponential function *****
1090 IF C1=3 THEN 1190
1100 FOR I=1 TO N1
1110 FOR J=1 TO N2
1120 IF C2 < >1 THEN 1150
1130 F(I,J)=1/Z(I,J)^B
1140 GOTO 1160
1150 F(I,J)=EXP(-B*Z(I,J))
1160 NEXT J
1170 NEXT I
1180 GOTO 1380
1190 FOR J=1 TO N2
1200 FOR I=1 TO N1
1210 IF C2< >1 THEN 1240
1220 F(J,I)=1/Z(I,J)^B
1230 GOTO 1250
1240 F(J,I)=EXP(-B*Z(I,J))
1250 NEXT I
1260 NEXT J
1270 GOTO 1380
1280 IF S1>=2 THEN 1330
```

```
1290 PRINT SPC(5); "WHAT IS ALPHA PERIMETER";
1300 INPUT B2
1310 PRINT SPC(5); "WHAT IS BETHA PERIMETER";
1320 INPUT B3
1330 FOR J=1 TO N2
1340  FOR I=1 TO N1
1350   F(J,I)=Z(J,I)^B2*EXP(B3*Z(J,I))
1360  NEXT I
1370 NEXT J
1380 RETURN
1390 PRINT
1400 REM **no constraints gravity model *****
1410 PRINT SPC(5);"What is the origin data file";
1420 INPUT E$
1430 OPEN E$ FOR INPUT AS #1
1440 FOR I=1 TO N1
1450 INPUT #1, R(I)
1460 NEXT I
1470 CLOSE #1
1480  H(1)=0
1490 L=1
1500 FOR J=1 TO N2
1510 G(J,1)=0
1520  FOR I=1 TO N1
1530  G(J,1)=G(J,1)+  L* R(I)*F(I,J)
1540  NEXT I
1550 PRINT
1560  H(1)=H(1) +G(J,1)
1570 NEXT J
1580 PRINT
1590 K(1)=0
1600 FOR I=1 TO N1
1610 K(1)=K(1) +R(I)
1620 NEXT I
1630 L=K(1)/H(1)
1640 M(1)=0
1650  FOR I=1 TO N1
1660  N(I,1)=0
1670  FOR J=1 TO N2
1680  N(I,1)=N(I,1) +L*R(I)*F(I,J)
1690  NEXT J
1700 PRINT
1710 M(1)=M(1) + N(I,1)
1720  NEXT I
1730 GOSUB 3910
1740 RETURN
1750 REM ***SUPPLY CONSTRAINTS GRAVITY MODEL ****************
```

```
1760 PRINT SPC(5);"what is the origin data file";
1770 INPUT F$
1780 OPEN F$ FOR INPUT AS #1
1790 FOR I=1 TO N1
1800 INPUT #1, R(I)
1810 NEXT I
1820 CLOSE #1
1830 PRINT SPC(5);"What  is the attractiveness data file";
1840 INPUT G$
1850 OPEN G$ FOR INPUT AS #2
1860 FOR J=1 TO N2
1870 INPUT #2, A(J)
1880 NEXT J
1890 CLOSE #2
1900 REM CALCULATE SUM OVER J OF A(J) * F(I,J)
1910 FOR I=1 TO N1
1920  X(I,1)=0
1930   FOR J=1 TO N2
1940   X(I,1)=X(I,1) +A(J)*F(I,J)
1950   NEXT J
1960 NEXT I
1970  PRINT
1980 GOSUB 3910
1990 RETURN
2000 REM DEMAND CONSTRAINTS GRAVITY MODEL
2010 IF S1>=2 THEN 2040
2020 PRINT SPC(5);"What is the employment data file";
2030 INPUT H$
2040 OPEN H$ FOR INPUT AS #1
2050 IF S1>=2 THEN 2080
2060 PRINT SPC(5);"What is the data file of vacant buildable land";
2070 INPUT I$
2080 OPEN I$ FOR INPUT AS #2
2090 FOR J=1 TO N2
2100 INPUT #1,U(J)
2110 IF S1=3 THEN 2140
2120 U1(J)=.4*U(J)
2130 GOTO 2150
2140 U1(J)=.2*U(J)
2150 NEXT J
2160 CLOSE #1
2170 FOR I=1 TO N1
2180 INPUT #2,V(I)
2190 NEXT I
2200 CLOSE #2
```

```
2210 IF S1>=2 THEN 2240
2220 PRINT SPC(5); "what is the file of one plus proportion of buildable land";
2230 INPUT J$
2240 OPEN J$ FOR INPUT AS #1
2250 FOR I=1 TO N1
2260 INPUT #1,W1(I)
2270 NEXT I
2280 CLOSE #1
2290 IF S1>=2 THEN 2320
2300 PRINT SPC(5); "what is the file of residential land";
2310 INPUT L$
2320 OPEN L$ FOR INPUT AS #1
2330 FOR I=1 TO N1
2340 INPUT #1, W2(I)
2350 NEXT I
2360 CLOSE #1
2370 IF S1>=2 THEN 2440
2380 PRINT SPC(5);"what is the q parameter(vacant developable)";
2390 INPUT B5
2400 PRINT SPC(5);"what is the r parameter(proportion developable)";
2410 INPUT B6
2420 PRINT SPC(5);"what is the s parameter(residential)";
2430 INPUT B7
2440 REM CALCULATE SUM OVER J OF v(I)*F((I,J)
2450 FOR J=1 TO N2
2460 P(J,1)=0
2470 FOR I=1 TO N1
2480 P(J,1)=P(J,1)+V(I)^B5*W1(I)^B6*W2(I)^B7*F(J,I)
2481 F1(J,I)=V(I)^B5*W1(I)^B6*W2(I)^B7*F(J,I)
2490 NEXT I
2495 PRINT
2497 PRINT
2498 PRINT
2500 NEXT J
2501 PRINT
2510 PRINT
2520 REM compute predicted trips
2530 IF S1>=2 THEN 2600
2540 FOR J=1 TO N2+1
2550  T(J,N1+1)=0
2560 NEXT J
2570  FOR I=1 TO N1+1
2580  T(N2+1,I)=0
2590  NEXT I
2600 FOR J=1 TO N2
```

```
2610 FOR I=1 TO N1
2620 T1=U1(J)*V(I)^B5*W1(I)^B6*W2(I)^B7*F(J,I)/P(J,1)
2621 IF S1<3 THEN 2640
2630  T1=INT(T1+ .5)
2640 IF S1>=2 THEN 2670
2650  T(J,I)=T1
2660 GOTO 2680
2670 T(J,I)=T1+T(J,I)
2680  T(J,N1+1)=T(J,N1+1)+T1
2690  T(N2+1,I)=T(N2+1,I)+T1
2700  T(N2+1,N1+1)=T(N2+1,N1+1)+T1
2710 NEXT I
2720 NEXT J
2730 CLS
2740 PRINT "TRIP MATRIX FROM ORIGIN TO DESTINATION; Tji(Demand-constrained)"
2760 PRINT "Simultaneous Residential Location and Trip Matrix from Origin to"
2770 PRINT "Destination:(by the demand-constrained gravity model)"
2780 IF N1=5 THEN 2850
2790 IF N1=10 THEN 2850
2800 IF N1=15 THEN 2850
2810 IF N1=20 THEN 2850
2820 F1=INT(N1/F+ .99)
2830 IF F1 < >1 THEN 2850
2840 GOTO 2860
2850 F1=INT(N1/F)+1
2860 PRINT
2870 PRINT
2880 FOR F2=1 TO F1
2890 PRINT
2900 PRINT
2910 PRINT "origin"
2940 F3=(F2-1)*F +1
2950 F4=F3 +F-1
2960 IF F4<=N1+1 THEN  2980
2970 F4=N1+1
2980 F5=11
2990 FOR I=F3 TO F4
3000 IF I=N1+1 THEN 3050
3010 PRINT TAB(F5); "dest";I;
3040 GOTO 3080
3050 PRINT TAB(F5); "total";
3080 F5=F5 +14
3090 NEXT I
3100 PRINT
```

```
3110 PRINT
3120 FOR J=1 TO N2+1
3130 F5=11
3140 IF J=N2+1 THEN 3190
3150 PRINT J;
3180 GOTO 3220
3190 PRINT "total";
3220 FOR I=F3 TO F4
3230 PRINT TAB(F5); T(J,I);
3260 F5=F5 +14
3270 NEXT I
3280 PRINT
3290 PRINT
3300 NEXT J
3310 GOSUB 4560
3320 NEXT F2
3330 PRINT
3340 PRINT
3350 RETURN
3360 REM DEMAND AND SUPPLY CONSTRAINTS GRAVITY MODEL
3370 PRINT
3380 PRINT SPC(5);"What is the origin data file";
3390 INPUT J$
3400 OPEN J$ FOR INPUT AS #1
3410 PRINT SPC(5);"What is the destination data file";
3420 INPUT K$
3430 OPEN K$ FOR INPUT AS #2
3440 Q(N1 +1,N2 +1)=0
3450 FOR I=1 TO N1
3460 INPUT #1,Q(I,N2+1)
3470 Q(N1+1,N2+1)=Q(N1+1,N2+1) +Q(I,N2+1)
3480 NEXT I
3490 CLOSE #1
3500 PRINT
3510 T1=0
3520 FOR J=1 TO N2
3530 INPUT #2,Q(N1+1,J)
3540 T1=T1+Q(N1+1,J)
```

```
3550 NEXT J
3560 CLOSE #2
3570 PRINT
3580 REM  "Balancing factors" ***********
3590 PRINT "This may take a while"
3600 EP=.001
3610 Q(N1+1,N2+1)=0
3620 FOR I=1 TO N1
3630 W(I)=1
3640 Q(N1+1,N2+1)=Q(N1+1,N2+1) +Q(I,N2+1)
3650 NEXT I
3660 REM determine k and l factors
3670 E1=0
3680 REM complete l from k
3690 FOR J=1 TO N2
3700 L1=0
3710 FOR I=1 TO N1
3720 L1=L1+W(I) *Q(I,N2+1)*F(I,J)
3730 NEXT I
3740 L1=1/L1
3750 IF (L(J)-L1)<EP THEN 3770
3760 E1=1
3770 L(J)=L1
3780 NEXT J
3790 REM compute k from l
3800 FOR I=1 TO N1
3810 K1=0
3820 FOR J=1 TO N2
3830 K1=K1+L(J)*Q(N1+1,J)*F(I,J)
3840 NEXT J
3850 K1=1/K1
3860 IF (W(I)-K1) <EP THEN 3880
3870 E1=1
3880 W(I)=K1
3890 NEXT I
3900 IF E1=1 THEN 3670
3910 REM compute predicted trips
3920 FOR I=1 TO N1+1
3930 T(I,N2+1)=0
3940 NEXT I
3950 FOR J=1 TO N2+1
3960 T(N1+1,J)=0
3970 NEXT J
3980 FOR I=1 TO N1
3990 FOR J=1 TO N2
4000 IF C1 < >1 THEN 4030
4010 T1=L*R(I)*F(I,J)
4020 GOTO 4070
4030 IF C1 < >2 THEN 4060
```

```
4040 T1=R(I)*A(J)*F(I,J)/X(I,1)
4050 GOTO 4070
4060 T1= W(I)*L(J)*Q(I,N2+1)*Q(N1+1,J)*F(I,J)
4070 T1=INT(T1 +.5)
4080 T(I,J)=T1
4090 T(I,N2+1)=T(I,N2+1)+T1
4100 T(N1+1,J)=T(N1+1,J)+T1
4110 T(N1+1,N2+1)=T(N1+1,N2+1)+T1
4120 NEXT J
4130 NEXT I
4140 CLS
4150 PRINT "Predicted Trips from Origins to Destinations"
4160 IF N2=5 THEN 4230
4170 IF N2=10 THEN 4230
4180 IF N2=15 THEN 4230
4190 IF N2=20 THEN 4230
4200 F1=INT(N2/F+ .99)
4210 IF F1 < >1 THEN 4230
4220 GOTO 4240
4230 F1=INT(N2/F) +1
4240 PRINT
4250 FOR F2=1 TO F1
4260 PRINT
4270 PRINT "origin"
4280 F3=(F2-1)*F+1
4290 F4=F3+F-1
4300 IF F4<=N2+1 THEN 4320
4310 F4=N2+1
4320 F5=11
4330 FOR J=F3 TO F4
4340 IF J=N2 +1 THEN 4370
4350 PRINT TAB(F5); "dest"; J;
4360 GOTO 4380
4370 PRINT TAB(F5); "total";
4380 F5=F5 +14
4390 NEXT J
4400 PRINT
4410 FOR I=1 TO N1 +1
4420 F5=11
4430 IF I=N1+1 THEN  4460
4440 PRINT I;
4450 GOTO 4470
4460 PRINT "total";
4470 FOR J=F3 TO F4
4480 PRINT TAB(F5); T(I,J);
4490 F5=F5+14
4500 NEXT J
4510 PRINT
```

```
4520 NEXT I
4530 GOSUB 4560
4540 NEXT F2
4550 RETURN
4560 REM pause output subroutine(extra)*****
4570 PRINT
4580 PRINT "continue"
4590 INPUT A$
4600 RETURN
4610 END
5000 REM FLOYD'S ALGORITHM ******
5010 REM PROG3P6
5020 T5=20
5030 REM MATRICX USED ARE d: INITIAL DISTANCE MATIRX
5040 REM   : AND "OLD" MATRIX
5050 REM    e: "NEW" MATRIX
5060 REM VARIABLES USED FOR WORKING ARE TO-T8
5070 FOR I=1 TO T5
5080 FOR J=1 TO T5
5090   D(I,J)=99999999#
5100 NEXT J
5110  D(I,I)=1
5120 NEXT I
5130  PRINT  " SHORTEST PATH ALGORITHM(FLOYD) "
5140 PRINT
5150 S1=S2+1
5160  N=N1
5170 IF S1>=2 THEN 5200
5180 PRINT " WHAT IS YOUR ZERO FLOW ARC DATA FILE";
5190 INPUT K$
5200 OPEN K$ FOR INPUT AS #1
5210 IF EOF(1) THEN 5250
5220  INPUT #1, I,J,T7,T8
5230 D(I,J)=T7
5240 GOTO 5210
5250 CLOSE #1
5260 REM      ---------------------
5270 REM *** the  matrix has`been input as below****
5280 FOR I=1 TO N
5290 FOR J=1 TO N
5300 P1(I,J)=I
5310 NEXT J
5320 NEXT I
5330 REM           STEP 0
5340 REM      ---------------------
5350 REM D HAS BEEN ALREADY SET UP
5360 K=0
5370 REM       --------------------
5380 REM           STEP 1
```

```
5390 REM       --------------------
5400 T2=K+1
5410 FOR I=1 TO N
5420 FOR J=1 TO N
5430  IF I=T2 THEN 5480
5440 IF J=T2 THEN 5480
5450 IF I=J THEN 5480
5460 T1=D(I,T2)+D(T2,J)
5470 IF T1<D(I,J) THEN 5500
5480 Z(I,J)=D(I,J)
5490 GOTO 5520
5500 Z(I,J)=T1
5510 P1(I,J)=P1(T2,J)
5520 NEXT J
5530 NEXT I
5540 REM       ----------------------
5550 REM            STEP 2
5560 REM       --------------------
5570 K=K+1
5580 IF K=N THEN 5650
5590 FOR I=1 TO N
5600 FOR J=1 TO N
5610  D(I,J)=Z(I,J)
5620 NEXT J
5630 NEXT I
5640 GOTO 5370
5650 PRINT " the matrix of shortest paths is:"
5660  FOR I=1 TO N
5670  FOR J=1 TO N
5680  PRINT Z(I,J);
5690  NEXT J
5700   PRINT
5710  NEXT I
5715 PRINT
5716 PRINT
5717 PRINT
5720 PRINT " the matrix of predecessors is:"
5730  FOR I=1 TO N
5740 FOR J=1 TO N
5750 PRINT P1(I,J);
5760 NEXT J
5770 PRINT
5780 NEXT I
5790 RETURN
6000 REM *** unpack the paths ***
6010   FOR I=1 TO N
6020 FOR J=1 TO N
```

```
6030   V1(I,J)=0
6040   NEXT J
6050 NEXT I
6060  FOR I=1 TO N
6070   FOR J=1 TO N
6080    J1=J
6090    K=1
6100    T3=K+1
6110     B2(K)=J1
6120     A2(K)=P1(I,J1)
6130 IF I=J THEN 6190
6140 IF A2(K)=I THEN 6190
6150   V1(A2(K),B2(K))=T(I,J)+V1(A2(K),B2(K))
6160   J1=A2(K)
6170    K=K+1
6180   GOTO 6100
6190 V1(I,J1)=V1(I,J1)+T(I,J)
6200 NEXT J
6210 NEXT I
6220 J=J1
6230  FOR I=1 TO N
6240    FOR J=1 TO N
6250   PRINT V1(I,J);
6260    NEXT J
6265 PRINT
6270 PRINT
6280 NEXT I
7000 REM congestion function and the revision of new data file
7010 FOR I=1 TO N
7020  FOR J=1 TO N
7030   D1(I,J)=99999999#
7040   D2(I,J)=99999999#
7050 NEXT J
7060 NEXT I
7070 OPEN K$ FOR INPUT AS #1
7080 IF EOF(1) THEN 7130
7090 INPUT #1, I,J,T7,T8
7100 D1(I,J)=T7
7110 D2(I,J)=T8
7120 GOTO 7080
```

```
7130 CLOSE #1
7140 OPEN K$ FOR OUTPUT AS #1
7150 FOR I=1 TO N
7160 FOR J=1 TO N
7170 IF I=J THEN 7240
7180 IF D1(I,J)=99999999# THEN 7270
7190 IF V1(I,J)<=D2(I,J) THEN 7240
7200 T7=D1(I,J)*(1+.15*(V1(I,J)/D2(I,J))^4)
7210 T8=D2(I,J)
7220 PRINT #1, I,J, T7,T8
7230 GOTO 7270
7240 T7=D1(I,J)
7250 T8=D2(I,J)
7260 GOTO 7220
7270 NEXT J
7280 NEXT I
7290 CLOSE #1
7300 S2=S2+1
7310 IF S2=3 THEN 7400
7320 RETURN
7400 END
```

APPENDIX B: THE RESULTS OF SENSITIVITY TESTS

APPENDIX B: The Results of Sensitivity Tests

1.1.1

Times or Costs in the Network(first iteration)

	1	2	3	4	5	6	7	8	9	10
1	1	1.7	1.9	1.2	2.5	4	3.7	4.9	6.8	6.6
2	1.7	1	3.4	2	3.3	2.3	5.2	5.7	7.6	4.9
3	1.9	3.4	1	1.4	2.7	4.8	1.8	3.8	5.7	7.4
4	1.2	2	1.4	1	1.3	3.4	3.2	3.7	5.6	6
5	2.5	3.3	2.7	1.3	1	2.1	2.2	2.4	4.3	4.7
6	4	2.3	4.8	3.4	2.1	1	4.3	4.5	5.3	2.6
7	3.7	5.2	1.8	3.2	2.2	4.3	1	2	3.9	6.6
8	4.9	5.7	3.8	3.7	2.4	4.5	2	1	1.9	4.6
9	6.8	7.6	5.7	5.6	4.3	5.3	3.9	1.9	1	2.7
10	6.6	4.9	7.4	6	4.7	2.6	6.6	4.6	2.7	1

1.1.2

$W_i F(C_{ji})$ and total, $\sum_i W_i F(C_{ji})$ (first iteration)

	1	2	3	4	5	6	7	8	9	10	total
1	3.42	3.23	1.87	1.43	0.76	0.22	0.32	0.05	0.00	0.00	11.30
2	2.54	4.34	0.34	0.85	0.29	1.90	0.04	0.01	0.00	0.03	10.33
3	2.16	0.49	2.96	1.32	0.61	0.07	2.87	0.24	0.01	0.00	10.73
4	3.34	2.51	2.67	1.47	2.09	0.50	0.62	0.28	0.01	0.01	13.47
5	1.18	0.56	0.81	1.38	2.21	2.32	1.98	1.40	0.08	0.04	11.98
6	0.17	1.86	0.05	0.16	1.16	4.41	0.14	0.09	1.92	0.70	8.77
7	0.26	0.04	2.04	0.22	1.05	0.14	4.16	2.10	0.15	0.00	10.17
8	0.05	0.02	0.20	0.11	0.85	0.11	2.41	3.64	1.66	0.04	9.08
9	0.00	0.00	0.01	0.01	0.07	0.03	0.24	2.30	2.62	0.62	5.91
10	0.00	0.05	0.00	0.00	0.04	1.36	0.00	0.08	0.72	2.27	4.54

1.1.3

Simultaneous Residential Location and Trip Matrix from Origin to Destination(first iteration)

origin	dest 1	dest 2	dest 3	dest 4	dest 5
1	90	85	49	37	20
2	49	84	7	16	6
3	32	7	44	20	9
4	119	89	95	52	74
5	55	26	38	65	103
6	1	8	0	1	5
7	8	1	64	7	33
8	2	1	7	4	30
9	0	0	0	0	1
10	0	0	0	0	0
total	356	302	304	202	282

origin	dest 6	dest 7	dest 8	dest 9	dest 10
1	6	8	1	0	0
2	37	1	0	0	1
3	1	43	4	0	0
4	18	22	10	0	0
5	108	93	66	4	2
6	20	1	0	0	3
7	4	131	66	5	0
8	4	85	128	58	2
9	0	3	31	36	8
10	7	0	1	3	12
total	206	386	307	107	28

origin	total
1	296
2	200
3	160
4	480
5	560
6	40
7	320
8	320
9	80
10	24
total	2480

1.1.4

Loaded Volumes on Each Link(first iteration)

	1	2	3	4	5	6	7	8	9	10
1	90	90	57	59						
2	50	84		29		43				
3	40		44	45			77			
4	176	125	162	52	140					
5				191	103	137	93	81		
6		10			8	20				6
7			87		37		131	75		
8					41		95	128	70	
9								36	35	11
10						8			4	12

1.2.1

Travel Times or Costs in the Network(second iteration)

	1	2	3	4	5	6	7	8	9	10
1	1	1.7	1.9	1.2	3.9	4	3.7	5.7	7.6	6.6
2	1.7	1	3.6	2	4.4	2.3	5.4	6.8	7.6	4.9
3	1.9	3.6	1	1.4	4	5.9	1.8	3.8	5.7	8.4
4	9.1	10.8	7.2	1	2.7	12.3	5.4	5.1	7.0	9.7
5	6.4	8.1	4.5	5.9	1	9.6	2.7	2.4	4.3	7
6	4	2.3	5.9	4.3	2.1	1	4.8	4.5	5.3	2.6
7	3.7	5.4	1.8	3.2	2.2	7.7	1	2	3.9	6.6
8	5.7	7.4	3.8	5.2	2.4	7.2	2	1	1.9	4.6
9	7.6	7.6	5.7	7.1	4.3	5.3	3.9	1.9	1	2.7
10	6.6	4.9	8.4	6.9	4.7	2.6	6.6	4.6	2.7	1

1.2.2

$W_i F(C_{ji})$ and total, $\Sigma W_i F(C_{ji})$ (second iteration)

	1	2	3	4	5	6	7	8	9	10	total
1	3.42	3.23	1.87	1.43	0.12	0.22	0.32	0.01	0.00	0.00	10.62
2	2.54	4.34	0.26	0.85	0.06	1.90	0.02	0.00	0.00	0.03	10.00
3	2.16	0.38	2.96	1.32	0.11	0.01	2.87	0.24	0.01	0.00	10.06
4	0.00	0.00	0.00	1.47	0.58	0.00	0.02	0.03	0.00	0.00	2.11
5	0.00	0.00	0.07	0.00	2.21	0.00	1.17	1.40	0.08	0.00	4.96
6	0.17	1.86	0.01	0.05	1.16	4.41	0.07	0.09	0.02	0.70	8.54
7	0.26	0.02	2.04	0.22	1.05	0.00	4.16	2.10	0.15	0.00	10.01
8	0.01	0.00	0.20	0.01	0.85	0.00	2.41	3.64	1.66	0.04	8.83
9	0.00	0.00	0.01	0.00	0.07	0.03	0.24	2.30	2.62	0.62	5.90
10	0.00	0.05	0.00	0.00	0.04	1.36	0.00	0.08	0.72	2.27	4.53

1.2.3
Simultaneous Residential Location and Trip
Matrix from Origin to Destination(second iteration)

origin	dest 1	dest 2	dest 3	dest 4	dest 5
1	184	175	101	77	23
2	100	171	12	33	7
3	67	13	91	41	11
4	119	89	95	385	207
5	56	26	46	65	353
6	2	17	0	1	10
7	16	2	129	14	67
8	2	1	14	4	61
9	0	0	0	0	2
10	0	1	0	0	0
total	546	495	490	621	742

origin	dest 6	dest 7	dest 8	dest 9	dest 10
1	12	17	2	0	0
2	75	1	0	0	1
3	1	88	7	0	0
4	18	28	18	1	0
5	108	225	224	14	2
6	41	1	1	0	6
7	5	264	133	10	0
8	4	172	260	119	3
9	1	6	62	71	17
10	14	0	1	8	24
total	279	803	709	222	55

origin	total
1	592
2	400
3	320
4	960
5	1120
6	80
7	640
8	640
9	160
10	48
total	4960

1.2.4

Loaded Volumes on Each Link(second iteration)

	1	2	3	4	5	6	7	8	9	10
1	185	324	133	101						
2	115	171		34		101				
3	397		91	124			127			
4	0	0	0	385	598					
5				0	353	0	750	386		
6		21			20	41				8
7			684		78		264	153		
8					63		200	260	279	
9								72	71	154
10						147			9	24

1.3.1

Travel Times or Costs in the Network(third iteration)

	1	2	3	4	5	6	7	8	9	10
1	1	16.2	2.8	2.6	7.5	18.9	5.3	8.9	24.2	21.5
2	2.1	1	4.9	2	4.8	2.7	7.4	9.9	8.0	5.3
3	17.9	17.1	1	3.5	4.7	19.2	2.5	6.1	24.5	21.8
4	14.4	13.6	7.5	1	12.1	16.3	10.0	13.6	21.6	18.9
5	19.0	16.8	13.8	6.3	1	14.5	16.3	19.9	19.8	17.1
6	4.4	2.3	7.2	4.3	2.1	1	9.7	7.2	5.3	2.6
7	21.2	19.0	15.6	8.5	2.2	16.7	1	3.6	22.0	19.3
8	21.4	19.2	16.1	8.7	2.4	16.9	6.8	1	19.1	19.5
9	13.8	11.7	16.6	10.6	4.3	9.4	8.7	1.9	1	4.7
10	8.8	6.7	11.6	8.7	6.5	4.4	11.4	4.6	2.7	1

1.3.2

$W_i F(C_{ji})$ and total, $\Sigma W_i F(C_{ji})$ (third iteration)

	1	2	3	4	5	6	7	8	9	10	total
1	3.42	0.00	0.72	0.44	0.00	0.00	0.03	0.00	0.00	0.00	4.61
2	1.72	4.34	0.03	0.85	0.03	1.28	0.00	0.00	0.00	0.02	8.27
3	0.00	0.00	2.96	1.15	0.04	0.00	1.44	0.00	0.00	0.00	4.60
4	0.00	0.00	0.00	1.47	0.00	0.00	0.00	0.00	0.00	0.00	1.47
5	0.00	0.00	0.00	0.00	2.21	0.00	0.00	0.00	0.08	0.00	2.21
6	0.00	1.86	0.00	0.05	1.16	4.41	0.00	0.00	0.02	0.70	8.30
7	0.00	0.00	0.00	0.00	1.05	0.00	4.16	0.31	0.00	0.00	5.52
8	0.00	0.00	0.00	0.00	0.85	0.00	0.00	3.64	0.00	0.00	4.50
9	0.00	0.00	0.00	0.00	0.07	0.00	0.00	2.30	2.62	0.03	5.02
10	0.00	0.00	0.00	0.00	0.00	0.12	0.00	0.08	0.72	2.27	3.19

1.3.3
Simultaneous Residential Location and Trip
Matrix from Origin to Destination(third iteration)

origin	dest 1	dest 2	dest 3	dest 4	dest 5
1	294	175	124	91	23
2	121	222	12	43	7
3	67	13	143	44	12
4	119	89	95	625	207
5	56	26	46	65	633
6	2	21	0	1	13
7	16	2	129	14	97
8	2	1	14	4	90
9	0	0	0	0	3
10	0	1	0	0	0
total	677	551	565	888	1088

origin	dest 6	dest 7	dest 8	dest 9	dest 10
1	12	18	2	0	0
2	90	1	0	0	1
3	1	113	7	0	0
4	18	28	18	1	0
5	108	225	224	14	2
6	51	1	1	0	8
7	5	385	142	10	0
8	4	172	390	119	3
9	1	6	80	92	17
10	14	0	1	10	33
total	305	950	865	245	65

origin	total
1	740
2	500
3	400
4	1200
5	1400
6	100
7	800
8	800
9	200
10	60
total	6200

1.3.4

Loaded Volumes on Each Link(third iteration)

	1	2	3	4	5	6	7	8	9	10
1	295	0	182	278						
2	211	223		44		129				
3	0		143	124			881			
4	185	308	986	625	0					
5				722	633	250	0	0		
6		129			21	52				41
7			0		517		385	393		
8					122		179	390	119	
9								92	92	18
10						17			37	33

2.1.1

Times or Costs in the Network(first iteration)

	1	2	3	4	5	6	7	8	9	10
1	1	1.7	1.9	1.2	2.5	4	3.7	4.9	6.8	6.6
2	1.7	1	3.4	2	3.3	2.3	5.2	5.7	7.6	4.9
3	1.9	3.4	1	1.4	2.7	4.8	1.8	3.8	5.7	7.4
4	1.2	2	1.4	1	1.3	3.4	3.2	3.7	5.6	6
5	2.5	3.3	2.7	1.3	1	2.1	2.2	2.4	4.3	4.7
6	4	2.3	4.8	3.4	2.1	1	4.3	4.5	5.3	2.6
7	3.7	5.2	1.8	3.2	2.2	4.3	1	2	3.9	6.6
8	4.9	5.7	3.8	3.7	2.4	4.5	2	1	1.9	4.6
9	6.8	7.6	5.7	5.6	4.3	5.3	3.9	1.9	1	2.7
10	6.6	4.9	7.4	6	4.7	2.6	6.6	4.6	2.7	1

2.1.2

$W_i F(C_{ji})$ and total, $\sum_i W_i F(C_{ji})$ (first iteration)

	1	2	3	4	5	6	7	8	9	10	total
1	3.42	3.23	1.87	1.43	0.76	0.22	0.32	0.05	0.00	0.00	11.30
2	2.54	4.34	0.34	0.85	0.29	1.90	0.04	0.01	0.00	0.03	10.33
3	2.16	0.49	2.96	1.32	0.61	0.07	2.87	0.24	0.01	0.00	10.73
4	3.34	2.51	2.67	1.47	2.09	0.50	0.62	0.28	0.01	0.01	13.47
5	1.18	0.56	0.81	1.38	2.21	2.32	1.98	1.40	0.08	0.04	11.98
6	0.17	1.86	0.05	0.16	1.16	4.41	0.14	0.09	1.92	0.70	8.77
7	0.26	0.04	2.04	0.22	1.05	0.14	4.16	2.10	0.15	0.00	10.17
8	0.05	0.02	0.20	0.11	0.85	0.11	2.41	3.64	1.66	0.04	9.08
9	0.00	0.00	0.01	0.01	0.07	0.03	0.24	2.30	2.62	0.62	5.91
10	0.00	0.05	0.00	0.00	0.04	1.36	0.00	0.08	0.72	2.27	4.54

2.1.3

Simultaneous Residential Location and Trip Matrix from Origin to Destination(first iteration)

origin	dest 1	dest 2	dest 3	dest 4	dest 5
1	53	50	29	22	11
2	49	84	7	16	6
3	32	7	44	20	9
4	119	89	95	52	74
5	55	26	38	65	103
6	1	8	0	1	5
7	6	1	48	5	25
8	2	1	7	4	30
9	0	0	0	0	1
10	0	0	0	0	0
total	317	268	268	185	266

origin	dest 6	dest 7	dest 8	dest 9	dest 10
1	3	5	1	0	0
2	37	1	0	0	1
3	1	43	4	0	0
4	18	22	10	0	0
5	108	93	66	4	2
6	20	1	0	0	3
7	3	98	50	4	0
8	4	85	128	58	2
9	0	3	31	36	8
10	7	0	1	3	12
total	202	350	290	106	28

origin	total
1	176
2	200
3	160
4	480
5	560
6	40
7	240
8	320
9	80
10	24
total	2280

2.1.4

Loaded Volumes on Each Link(first iteration)

	1	2	3	4	5	6	7	8	9	10
1	53	54	34	35						
2	50	84		29		41				
3	38		44	43			74			
4	176	125	162	52	131					
5				191	103	137	93	81		
6		9			8	20				6
7			67		28		98	57		
8					41		95	128	68	
9								36	35	11
10						8			4	12

2.2.1

Travel Times or Costs in the Network(second iteration)

	1	2	3	4	5	6	7	8	9	10
1	1	1.7	1.9	1.2	3.6	4	3.7	5.7	7.6	6.6
2	1.7	1	3.6	2	4.4	2.3	5.4	6.8	7.6	4.9
3	1.9	3.6	1	1.4	3.8	5.9	1.8	3.8	5.7	8.4
4	8.8	10.5	6.8	1	2.4	12.0	5.1	4.8	6.7	9.4
5	6.4	8.1	4.5	5.9	1	9.6	2.7	2.4	4.3	7
6	4	2.3	5.9	4.3	2.1	1	4.8	4.5	5.3	2.6
7	3.7	5.4	1.8	3.2	2.2	7.7	1	2	3.9	6.6
8	5.7	7.4	3.8	5.2	2.4	7.2	2	1	1.9	4.6
9	7.6	7.6	5.7	7.1	4.3	5.3	3.9	1.9	1	2.7
10	6.6	4.9	8.4	6.9	4.7	2.6	6.6	4.6	2.7	1

2.2.2

$W_i F(C_{ji})$ and total, $\Sigma W_i F(C_{ji})$ (second iteration)

	1	2	3	4	5	6	7	8	9	10	total
1	3.42	3.23	1.87	1.43	0.19	0.22	0.32	0.01	0.00	0.00	10.69
2	2.54	4.34	0.26	0.85	0.06	1.90	0.02	0.00	0.00	0.03	10.00
3	2.16	0.38	2.96	1.32	0.14	0.01	2.87	0.24	0.01	0.00	10.09
4	0.00	0.00	0.00	1.47	0.84	0.00	0.04	0.05	0.00	0.00	2.41
5	0.00	0.00	0.07	0.00	2.21	0.00	1.17	1.40	0.08	0.00	4.96
6	0.17	1.86	0.00	0.05	1.16	4.41	0.07	0.09	0.02	0.70	8.54
7	0.26	0.02	2.04	0.22	1.05	0.00	4.16	2.10	0.15	0.00	10.01
8	0.01	0.00	0.20	0.31	0.85	0.00	2.41	3.64	1.66	0.04	8.83
9	0.00	0.00	0.01	0.00	0.07	0.03	0.24	2.30	2.62	0.62	5.90
10	0.00	0.05	0.00	0.00	0.04	1.36	0.00	0.08	0.72	2.27	4.53

2.2.3
Simultaneous Residential Location and Trip
Matrix from Origin to Destination(second iteration)

origin	dest 1	dest 2	dest 3	dest 4	dest 5
1	110	103	60	46	15
2	100	171	12	33	7
3	67	13	91	41	11
4	119	89	95	344	242
5	56	26	46	65	353
6	2	17	0	1	11
7	12	2	97	10	50
8	2	1	14	4	61
9	0	0	0	0	2
10	0	1	0	0	0
total	467	423	416	545	753

origin	dest 6	dest 7	dest 8	dest 9	dest 10
1	7	10	1	0	0
2	75	1	0	0	1
3	1	88	7	0	0
4	18	30	21	1	0
5	108	225	224	14	2
6	41	1	1	0	6
7	3	198	100	7	0
8	4	172	260	119	3
9	1	6	62	71	17
10	14	0	1	8	24
total	273	733	678	219	54

origin	total
1	352
2	400
3	320
4	960
5	1120
6	80
7	480
8	640
9	160
10	48
total	4560

2.2.4

Loaded Volumes on Each Link(second iteration)

	1	2	3	4	5	6	7	8	9	10
1	110	246	84	61						
2	115	171		34		95				
3	391		91	132			108			
4	0	0	0	344	642					
5				0	353	0	753	389		
6		21			20	41				8
7			643		50		198	116		
8					63		200	260	276	
9								72	71	154
10						147			9	24

2.3.1

Travel Times or Costs in the Network(third iteration)

	1	2	3	4	5	6	7	8	9	10
1	1	11.1	1.9	1.4	6.3	13.4	4.1	6.6	18.7	16.0
2	2.1	1	4.0	2	4.4	2.3	6.2	8.8	7.6	4.9
3	18.5	17.5	1	4.0	4.0	18.5	2.2	4.7	23.3	21.1
4	14.4	13.5	7.5	1	11.9	15.8	9.7	12.2	21.1	18.4
5	18.6	16.4	13.8	6.3	1	14.1	16.0	18.5	19.4	16.7
6	4.4	2.3	6.3	4.3	2.1	1	8.5	7.2	5.3	2.6
7	20.8	18.6	16.0	8.5	2.2	16.3	1	2.5	21.1	18.9
8	21.0	18.8	16.2	8.7	2.4	16.5	6.8	1	18.6	19.1
9	13.8	11.7	15.7	10.6	4.3	9.4	8.7	1.9	1	5.0
10	8.8	6.7	10.7	8.7	6.5	4.4	11.4	4.6	2.7	1

2.3.2

$W_iF(C_{ji})$ and total, $\Sigma W_iF(C_{ji})$ (third iteration)

	1	2	3	4	5	6	7	8	9	10	total
1	3.42	0.00	1.87	1.33	0.00	0.00	0.19	0.00	0.00	0.00	6.81
2	1.72	4.34	0.14	0.85	0.06	1.90	0.00	0.00	0.00	0.03	9.04
3	0.00	0.00	2.96	0.07	0.06	0.00	2.04	0.06	0.00	0.00	5.20
4	0.00	0.00	0.00	1.47	0.00	0.00	0.00	0.00	0.00	0.00	1.47
5	0.00	0.00	0.00	0.00	2.21	0.00	0.00	0.00	0.00	0.00	2.21
6	0.09	1.86	0.00	0.05	1.16	4.41	0.00	0.00	0.02	0.70	8.30
7	0.00	0.00	0.00	0.00	1.05	0.00	4.16	1.20	0.00	0.00	6.41
8	0.00	0.00	0.00	0.00	0.85	0.00	0.00	3.64	0.00	0.00	4.49
9	0.00	0.00	0.00	0.00	0.07	0.00	0.00	2.30	2.62	0.03	5.02
10	0.00	0.00	0.00	0.00	0.00	0.12	0.00	0.08	0.72	2.27	3.19

2.3.3
Simultaneous Residential Location and Trip
Matrix from Origin to Destination(third iteration)

origin	dest 1	dest 2	dest 3	dest 4	dest 5
1	154	103	84	63	15
2	119	219	14	42	8
3	66	13	137	42	12
4	119	89	95	584	242
5	56	26	46	65	633
6	2	21	0	1	14
7	12	2	97	10	70
8	2	1	14	4	91
9	0	0	0	0	3
10	0	1	0	0	0
total	530	475	488	812	1089

origin	dest 6	dest 7	dest 8	dest 9	dest 10
1	7	12	1	0	0
2	96	1	0	0	1
3	1	119	8	0	0
4	18	30	21	1	0
5	109	225	224	14	2
6	52	1	1	0	9
7	3	276	122	7	0
8	4	172	390	119	3
9	1	6	80	92	17
10	14	0	1	11	33
total	305	844	849	243	65

origin	total
1	440
2	500
3	400
4	1200
5	1400
6	100
7	600
8	800
9	200
10	60
total	5700

2.3.4

Loaded Volumes on Each Link(third iteration)

	1	2	3	4	5	6	7	8	9	10
1	153	111	129	63						
2	208	219		43		131				
3	0		137	121			915			
4	185	122	995	584	0					
5				686	633	235	0	0		
6		125			22	52				31
7			0		466		276	384		
8					122		179	390	126	
9								92	92	18
10						17			27	33

3.1.1

Times or Costs in the Network(first iteration)

	1	2	3	4	5	6	7	8	9	10
1	1	1.7	1.9	1.2	2.5	4	3.7	4.9	6.8	6.6
2	1.7	1	3.4	2	3.3	2.3	5.2	5.7	7.6	4.9
3	1.9	3.4	1	1.4	2.7	4.8	1.8	3.8	5.7	7.4
4	1.2	2	1.4	1	1.3	3.4	3.2	3.7	5.6	6
5	2.5	3.3	2.7	1.3	1	2.1	2.2	2.4	4.3	4.7
6	4	2.3	4.8	3.4	2.1	1	4.3	4.5	5.3	2.6
7	3.7	5.2	1.8	3.2	2.2	4.3	1	2	3.9	6.6
8	4.9	5.7	3.8	3.7	2.4	4.5	2	1	1.9	4.6
9	6.8	7.6	5.7	5.6	4.3	5.3	3.9	1.9	1	2.7
10	6.6	4.9	7.4	6	4.7	2.6	6.6	4.6	2.7	1

3.1.2

$W_i F(C_{ji})$ and total, $\sum_i W_i F(C_{ji})$ (first iteration)

	1	2	3	4	5	6	7	8	9	10	total
1	3.42	3.23	1.87	1.43	0.76	0.22	0.32	0.05	0.00	0.00	11.30
2	2.54	4.34	0.34	0.85	0.29	1.90	0.04	0.01	0.00	0.03	10.33
3	2.16	0.49	2.96	1.32	0.61	0.07	2.87	0.24	0.01	0.00	10.73
4	3.34	2.51	2.67	1.47	2.09	0.50	0.62	0.28	0.01	0.01	13.47
5	1.18	0.56	0.81	1.38	2.21	2.32	1.98	1.40	0.13	0.04	12.03
6	0.17	1.86	0.05	0.16	1.16	4.41	0.14	0.09	0.02	0.70	8.77
7	0.26	0.04	2.04	0.22	1.05	0.14	4.16	2.10	0.23	0.00	10.25
8	0.05	0.02	0.20	0.11	0.85	0.11	2.41	3.64	2.53	0.05	9.95
9	0.00	0.00	0.01	0.01	0.07	0.03	0.24	2.30	3.99	0.62	7.28
10	0.00	0.05	0.00	0.00	0.04	1.36	0.00	0.08	1.10	2.27	4.91

3.1.3

Simultaneous Residential Location and Trip
Matrix from Origin to Destination(first iteration)

origin	dest 1	dest 2	dest 3	dest 4	dest 5
1	90	85	49	37	20
2	49	84	7	16	6
3	32	7	44	20	9
4	119	89	95	52	74
5	55	26	38	64	103
6	1	8	0	1	5
7	6	1	47	5	25
8	2	1	7	4	27
9	0	0	0	0	1
10	0	0	0	0	0
total	353	302	287	200	270

origin	dest 6	dest 7	dest 8	dest 9	dest 10
1	6	8	1	0	0
2	37	1	0	0	1
3	1	43	4	0	0
4	18	22	10	1	0
5	108	92	65	6	2
6	20	1	0	0	3
7	4	98	49	5	0
8	4	77	117	81	2
9	0	3	25	44	7
10	7	0	0	5	11
total	203	344	273	143	26

origin	total
1	296
2	200
3	160
4	480
5	560
6	40
7	240
8	320
9	80
10	24
total	2400

3.1.4

Loaded Volumes on Each Link(first iteration)

	1	2	3	4	5	6	7	8	9	10
1	90	90	57	59						
2	50	84		29		43				
3	38		44	43			77			
4	175	124	162	52	140					
5				190	103	136	93	84		
6		10			8	20				6
7			66		28		97	59		
8					37		87	117	95	
9								29	44	9
10						8			6	11

3.2.1

Travel Times or Costs in the Network(second iteration)

	1	2	3	4	5	6	7	8	9	10
1	1	1.7	1.9	1.2	3.9	4	3.7	5.7	7.6	6.6
2	1.7	1	3.6	2	4.4	2.3	5.4	6.8	7.6	4.9
3	1.9	3.6	1	1.4	4	5.9	1.8	3.8	5.7	8.4
4	9.1	10.8	7.2	1	2.7	12.3	5.4	5.1	7.0	9.7
5	6.4	8.1	4.5	5.9	1	9.6	2.7	2.4	4.3	7
6	4	2.3	5.9	4.3	2.1	1	4.8	4.5	5.3	2.6
7	3.7	5.4	1.8	3.2	2.2	7.7	1	2	3.9	6.6
8	5.7	7.4	3.8	5.2	2.4	7.2	2	1	1.9	4.6
9	7.6	7.6	5.7	7.1	4.3	5.3	3.9	1.9	1	2.7
10	6.6	4.9	8.4	6.9	4.7	2.6	6.6	4.6	2.7	1

3.2.2

$W_i F(C_{ji})$ and total, $\Sigma W_i F(C_{ji})$ (second iteration)

	1	2	3	4	5	6	7	8	9	10	total
1	3.42	3.23	1.87	1.43	0.12	0.22	0.32	0.01	0.00	0.00	10.62
2	2.54	4.34	0.26	0.85	0.06	1.90	0.03	0.00	0.00	0.03	10.00
3	2.16	0.38	2.96	1.32	0.11	0.01	2.87	0.24	0.01	0.00	10.07
4	0.00	0.00	0.00	1.47	0.58	0.00	0.03	0.03	0.00	0.00	2.11
5	0.00	0.00	0.08	0.00	2.21	0.00	1.18	1.40	0.13	0.00	5.01
6	0.17	1.86	0.01	0.05	1.16	4.41	0.07	0.09	0.03	0.70	8.55
7	0.26	0.03	2.04	0.22	1.05	0.00	4.16	2.10	0.23	0.00	10.09
8	0.01	0.00	0.20	0.01	0.85	0.00	2.41	3.64	2.53	0.05	9.70
9	0.00	0.00	0.01	0.00	0.07	0.03	0.24	2.30	3.99	0.62	7.27
10	0.00	0.06	0.00	0.00	0.04	1.36	0.00	0.08	1.10	2.27	4.91

3.2.3

Simultaneous Residential Location and Trip Matrix from Origin to Destination(second iteration)

origin	dest 1	dest 2	dest 3	dest 4	dest 5
1	185	175	101	77	23
2	100	171	12	33	7
3	67	13	91	41	11
4	119	89	95	386	206
5	56	26	46	65	350
6	2	17	0	1	11
7	12	2	96	10	50
8	2	1	13	4	56
9	0	0	0	0	2
10	0	1	0	0	0
total	541	494	455	617	715

origin	dest 6	dest 7	dest 8	dest 9	dest 10
1	12	17	2	0	0
2	75	1	0	0	1
3	1	88	7	0	0
4	18	28	18	1	0
5	108	224	222	21	2
6	41	1	1	0	6
7	3	197	99	11	0
8	4	157	237	165	3
9	1	5	51	88	14
10	13	0	1	11	22
total	275	718	638	296	49

origin	total
1	592
2	400
3	320
4	960
5	1120
6	80
7	480
8	640
9	160
10	48
total	4800

3.2.4

Loaded Volumes on Each Link(second iteration)

	1	2	3	4	5	6	7	8	9	10
1	185	322	133	101						
2	115	171		34		100				
3	391		91	120			127			
4	0	0	0	386	597					
5				0	350	0	749	391		
6		21			20	41				8
7			639		61		197	120		
8					57		182	237	332	
9								59	88	149
10						145			12	22

Table 3.3.1

Travel Times or Costs in the Network(third iteration)

	1	2	3	4	5	6	7	8	9	10
1	1	16.1	2.8	2.6	7.5	18.4	5.3	7.9	23.7	21.0
2	2.1	1	4.9	2	4.4	2.3	7.4	9.5	7.6	4.9
3	17.5	16.6	1	3.2	4.7	18.6	2.5	5.1	23.9	21.2
4	14.3	13.4	7.5	1	12.2	15.7	10.0	12.6	21.0	18.3
5	18.3	16.2	13.6	6.2	1	13.9	16.1	18.7	19.2	16.5
6	4.4	2.3	7.2	4.3	2.1	1	9.7	7.2	5.3	2.6
7	21.0	18.4	15.8	8.4	2.2	16.1	1	2.6	21.4	18.7
8	21.0	18.6	16.0	8.6	2.4	16.3	5.3	1	21.6	18.9
9	13.5	11.3	16.3	10.5	4.3	9.0	7.2	1.9	1	4.7
10	8.7	6.6	11.6	8.6	6.4	4.3	9.9	4.6	2.7	1

3.3.2

$W_i F(C_{ji})$ and total, $\Sigma W_i F(C_{ji})$ (third iteration)

	1	2	3	4	5	6	7	8	9	10	total
1	3.42	0.00	0.72	0.44	0.00	0.00	0.03	0.00	0.00	0.00	4.61
2	1.72	4.34	0.04	0.85	0.06	1.90	0.00	0.00	0.00	0.03	8.93
3	0.00	0.00	2.96	0.22	0.04	0.00	1.43	0.00	0.00	0.00	4.69
4	0.00	0.00	0.00	1.47	0.00	0.00	0.00	0.00	0.00	0.00	1.47
5	0.00	0.00	0.00	0.00	2.21	0.00	0.00	0.00	0.08	0.00	2.21
6	0.09	1.86	0.00	0.05	1.16	4.41	0.00	0.00	0.03	0.70	8.31
7	0.00	0.00	0.00	0.00	1.05	0.00	4.16	1.10	0.00	0.00	6.31
8	0.00	0.00	0.00	0.00	0.85	0.00	0.03	3.64	0.00	0.00	4.52
9	0.00	0.00	0.00	0.00	0.07	0.00	0.00	2.30	3.99	0.04	6.41
10	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.08	1.10	2.27	3.59

3.3.3

Simultaneous Residential Location and Trip
Matrix from Origin to Destination(third iteration)

origin	dest 1	dest 2	dest 3	dest 4	dest 5
1	295	175	124	91	23
2	119	220	12	42	8
3	67	13	142	45	12
4	119	89	95	626	206
5	55	26	46	65	630
6	2	21	0	1	14
7	12	2	96	10	70
8	2	1	13	4	86
9	0	0	0	0	2
10	0	1	0	0	0
total	671	547	529	885	1050

origin	dest 6	dest 7	dest 8	dest 9	dest 10
1	12	18	2	0	0
2	96	1	0	0	1
3	1	112	8	0	0
4	18	28	18	1	0
5	108	224	222	21	2
6	52	1	1	0	8
7	3	276	120	11	0
8	4	158	366	165	3
9	1	5	65	113	14
10	13	0	1	15	30
total	307	823	803	326	59

origin	total
1	740
2	500
3	400
4	1200
5	1400
6	100
7	600
8	800
9	200
10	60
total	6000

3.3.4

Loaded Volumes on Each Link(third iteration)

	1	2	3	4	5	6	7	8	9	10
1	295	0	182	278						
2	205	220		43		136				
3	0		142	125			877			
4	185	308	948	626	0					
5				681	630	416	0	0		
6		124			22	52				214
7			0		447		276	370		
8					278		163	366	0	
9								73	113	15
10						15			215	30

4.1.1

Times or Costs in the Network(first iteration)

	1	2	3	4	5	6	7	8	9	10
1	1	1.7	1.9	1.2	2.5	4	3.7	4.9	6.8	6.6
2	1.7	1	3.4	2	3.3	2.3	5.2	5.7	7.6	4.9
3	1.9	3.4	1	1.4	2.7	4.8	1.8	3.8	5.7	7.4
4	1.2	2	1.4	1	1.3	3.4	3.2	3.7	5.6	6
5	2.5	3.3	2.7	1.3	1	2.1	2.2	2.4	4.3	4.7
6	4	2.3	4.8	3.4	2.1	1	4.3	4.5	5.3	2.6
7	3.7	5.2	1.8	3.2	2.2	4.3	1	2	3.9	6.6
8	4.9	5.7	3.8	3.7	2.4	4.5	2	1	1.9	4.6
9	6.8	7.6	5.7	5.6	4.3	5.3	3.9	1.9	1	2.7
10	6.6	4.9	7.4	6	4.7	2.6	6.6	4.6	2.7	1

4.1.2

$W_i F(C_{ji})$ and total, $\sum_i W_i F(C_{ji})$ (first iteration)

	1	2	3	4	5	6	7	8	9	10	total
1	3.42	3.23	1.87	1.43	0.76	0.22	0.32	0.06	0.00	0.00	11.32
2	2.54	4.34	0.34	0.85	0.29	1.90	0.04	0.02	0.00	0.03	10.33
3	2.16	0.49	2.96	1.32	0.61	0.07	2.87	0.31	0.01	0.00	10.80
4	3.34	2.51	2.67	1.47	2.09	0.50	0.62	0.35	0.01	0.01	13.55
5	1.18	0.56	0.81	1.38	2.21	2.32	1.98	1.80	0.09	0.04	12.37
6	0.17	1.86	0.05	0.17	1.16	4.41	0.14	0.11	0.02	0.70	8.79
7	0.26	0.04	2.04	0.22	1.05	0.14	4.16	2.68	0.15	0.00	10.74
8	0.05	0.02	0.20	0.11	0.85	0.11	2.41	4.64	1.66	0.05	10.08
9	0.00	0.00	0.01	0.01	0.07	0.03	0.24	2.93	2.62	0.62	6.54
10	0.00	0.06	0.00	0.00	0.04	1.36	0.10	0.72	1.10	2.27	4.56

4.1.3

Simultaneous Residential Location and Trip
Matrix from Origin to Destination(first iteration)

origin	dest 1	dest 2	dest 3	dest 4	dest 5
1	89	85	49	37	20
2	49	84	7	16	6
3	32	7	44	20	9
4	118	89	95	52	74
5	53	26	37	63	100
6	1	8	0	1	5
7	6	1	46	5	24
8	2	1	6	4	27
9	0	0	0	0	1
10	0	0	0	0	0
total	350	300	283	197	266

origin	dest 6	dest 7	dest 8	dest 9	dest 10
1	6	8	2	0	0
2	37	1	0	0	1
3	1	43	5	0	0
4	18	22	12	0	0
5	105	90	81	4	2
6	20	1	1	0	3
7	3	93	60	3	0
8	3	76	147	53	2
9	0	3	36	32	8
10	7	0	1	4	12
total	201	336	344	96	27

origin	total
1	296
2	200
3	160
4	480
5	560
6	40
7	240
8	320
9	80
10	24
total	2400

4.1.4

Loaded Volumes on Each Link(first iteration)

	1	2	3	4	5	6	7	8	9	10
1	89	90	57	59						
2	50	84		30		43				
3	38		44	43			77			
4	173	123	161	52	142					
5				185	100	133	90	100		
6		10			8	20				6
7			63		27		93	68		
8					37		86	147	62	
9								41	32	10
10						8			4	12

4.2.1

Travel Times or Costs in the Network(second iteration)

	1	2	3	4	5	6	7	8	9	10
1	1	1.7	1.9	1.2	4.0	4	3.7	5.7	7.6	6.6
2	1.7	1	3.6	2	4.4	2.3	5.4	7.4	7.6	4.9
3	1.9	3.6	1	1.4	4	5.9	1.8	3.8	5.7	8.4
4	9.1	10.8	7.2	1	2.8	13.1	5.5	5.9	7.8	10.5
5	6.3	8.0	4.4	5.7	1	10.3	2.6	3.1	5.0	7.7
6	4	2.3	5.9	4.3	2.1	1	4.7	5.2	5.3	2.6
7	3.7	5.4	1.8	3.2	2.2	7.7	1	2	3.9	6.6
8	5.7	7.4	3.8	5.2	2.4	7.2	2	1	1.9	4.6
9	7.6	7.6	5.7	7.1	4.3	5.3	3.9	1.9	1	2.7
10	6.6	4.9	8.4	6.9	4.7	2.6	6.6	4.6	2.7	1

4.2.2

$W_i F(C_{ji})$ and total, $\Sigma W_i F(C_{ji})$ (second iteration)

	1	2	3	4	5	6	7	8	9	10	total
1	3.42	3.23	1.87	1.43	0.10	0.22	0.32	0.01	0.00	0.00	10.61
2	2.54	4.34	0.26	0.85	0.06	1.90	0.03	0.00	0.00	0.03	10.00
3	2.16	0.38	2.96	1.32	0.11	0.01	2.87	0.31	0.01	0.00	10.13
4	0.00	0.00	0.00	1.47	0.52	0.00	0.02	0.01	0.00	0.00	2.02
5	0.00	0.00	0.08	0.00	2.21	0.00	1.25	0.78	0.03	0.00	4.37
6	0.17	1.86	0.01	0.05	1.16	4.41	0.07	0.04	0.01	0.70	8.50
7	0.26	0.03	2.04	0.22	1.05	0.00	4.16	2.67	0.15	0.00	10.59
8	0.01	0.00	0.20	0.01	0.85	0.00	2.41	4.64	1.66	0.05	9.83
9	0.00	0.00	0.01	0.00	0.07	0.03	0.24	2.93	2.62	0.62	6.53
10	0.00	0.06	0.00	0.00	0.04	1.36	0.00	0.09	0.72	2.27	4.55

4.2.3
Simultaneous Residential Location and Trip
Matrix from Origin to Destination(second iteration)

origin	dest 1	dest 2	dest 3	dest 4	dest 5
1	185	175	101	77	23
2	100	171	12	33	7
3	66	13	91	40	11
4	118	89	95	400	197
5	54	26	47	63	384
6	2	17	0	1	11
7	12	1	92	10	47
8	2	1	13	4	55
9	0	0	0	0	2
10	0	1	0	0	0
total	539	493	450	629	736

(continued)

origin	dest 6	dest 7	dest 8	dest 9	dest 10
1	12	17	2	0	0
2	75	1	0	0	1
3	1	88	9	0	0
4	18	28	15	1	0
5	105	250	181	8	2
6	41	1	1	0	7
7	3	187	121	7	0
8	4	155	298	107	3
9	1	6	72	64	15
10	14	0	1	8	24
total	273	733	701	194	52

origin	total
1	592
2	400
3	320
4	960
5	1120
6	80
7	480
8	640
9	160
10	48
total	4800

4.2.4

Loaded Volumes on Each Link(second iteration)

	1	2	3	4	5	6	7	8	9	10
1	185	339	134	100						
2	115	171		34		117				
3	404		91	54			129			
4	0	0	320	400	263					
5				63	383	0	405	313		
6		21			20	41				8
7			264		58		187	140		
8					57		180	298	236	
9								81	64	130
10						125			8	24

4.3.1

Travel Times or Costs in the Network(third iteration)

	1	2	3	4	5	6	7	8	9	10
1	1	15.6	2.8	2.6	7.6	18.5	5.4	8.5	19.2	21.1
2	2.1	1	5.0	2	5.0	2.9	7.5	10.1	8.2	5.5
3	15.1	14.4	1	1.4	4.7	17.3	2.5	5.7	16.4	19.9
4	13.7	13.0	16.5	1	18.0	15.9	19.0	22.2	21.2	18.5
5	17.2	15.0	20.0	5.7	1	12.7	22.6	19.9	18.0	15.3
6	4.4	2.3	7.3	4.3	2.1	1	9.8	7.2	5.3	2.6
7	19.4	17.2	14.9	7.9	2.2	14.9	1	3.1	13.8	17.5
8	19.6	17.0	20.1	8.1	2.4	15.1	5.2	1	10.7	14.6
9	11.8	9.7	14.7	10.0	4.3	7.4	7.1	1.9	1	3.9
10	8.0	5.8	10.8	7.8	5.6	3.5	9.8	4.6	2.7	1

4.3.2

$W_iF(C_{ji})$ and total, $\Sigma W_iF(C_{ji})$ (third iteration)

	1	2	3	4	5	6	7	8	9	10	total
1	3.42	0.00	0.71	0.45	0.00	0.00	0.03	0.00	0.00	0.00	4.60
2	1.71	4.34	0.04	0.85	0.02	0.90	0.00	0.00	0.00	0.01	7.87
3	0.00	0.00	2.96	1.32	0.04	0.00	1.36	0.01	0.00	0.00	5.70
4	0.00	0.00	0.00	1.47	0.00	0.00	0.00	0.00	0.00	0.00	1.47
5	0.00	0.00	0.00	0.01	2.21	0.00	0.00	0.00	0.00	0.00	2.22
6	0.09	1.86	0.00	0.05	1.16	4.41	0.00	0.00	0.02	0.70	8.30
7	0.00	0.00	0.00	0.00	1.05	0.00	4.16	0.74	0.00	0.00	5.95
8	0.00	0.00	0.00	0.00	0.85	0.00	0.04	4.64	0.00	0.00	5.53
9	0.00	0.00	0.00	0.00	0.07	0.00	0.00	2.93	2.62	0.14	5.77
10	0.00	0.01	0.00	0.00	0.00	0.41	0.00	0.09	0.72	2.27	3.52

4.3.3

Simultaneous Residential Location and Trip Matrix from Origin to Destination(third iteration)

origin	dest 1	dest 2	dest 3	dest 4	dest 5
1	295	175	124	92	23
2	122	226	12	44	7
3	66	13	133	59	12
4	118	89	95	640	197
5	54	26	47	64	663
6	2	21	0	1	14
7	12	1	92	10	68
8	2	1	13	4	79
9	0	0	0	0	2
10	0	1	0	0	0
total	671	552	515	915	1065

(continued)

origin	dest 6	dest 7	dest 8	dest 9	dest 10
1	12	18	2	0	0
2	86	1	0	0	1
3	1	107	10	0	0
4	18	28	16	1	0
5	105	250	181	8	2
6	52	1	1	0	8
7	3	271	136	7	0
8	4	156	432	107	3
9	1	6	92	82	16
10	15	0	1	10	32
total	296	838	870	214	63

origin	total
1	740
2	500
3	400
4	1200
5	1400
6	100
7	600
8	800
9	200
10	60
total	6000

4.3.4

Loaded Volumes on Each Link(third iteration)

	1	2	3	4	5	6	7	8	9	10
1	295	0	617	279						
2	503	226		45		322				
3	0		133	140			467			
4	322	505	0	640	0					
5				78	663	695	0	0		
6		419			218	52				203
7			104		129		271	170		
8					92		174	432	117	
9								283	82	20
10						18			201	32

5.1.1

Times or Costs in the Network(first iteration)

	1	2	3	4	5	6	7	8	9	10
1	1	1.7	1.9	1.2	2.5	4	3.7	4.9	6.8	4.8
2	1.7	1	3.4	2	3.3	2.3	5.2	5.7	7.6	4.9
3	1.9	3.4	1	1.4	2.7	4.8	1.8	3.8	5.7	5
4	1.2	2	1.4	1	1.3	3.4	3.2	3.7	5.6	3.6
5	2.5	3.3	2.7	1.3	1	2.1	2.2	2.4	4.3	2.3
6	4	2.3	4.8	3.4	2.1	1	4.3	4.5	5.3	2.6
7	3.7	5.2	1.8	3.2	2.2	4.3	1	2	3.9	4.5
8	4.9	5.7	3.8	3.7	2.4	4.5	2	1	1.9	4.6
9	6.8	7.6	5.7	5.6	4.3	5.3	3.9	1.9	1	2.7
10	4.8	4.9	5	3.6	2.3	2.6	4.5	4.6	2.7	1

5.1.2

$W_i F(C_{ji})$ and total, $\Sigma_i W_i F(C_{ji})$ (first iteration)

	1	2	3	4	5	6	7	8	9	10	total
1	3.42	3.23	1.87	1.43	0.76	0.22	0.32	0.05	0.00	0.04	11.33
2	2.54	4.34	0.34	0.85	0.29	1.90	0.04	0.01	0.00	0.03	10.33
3	2.16	0.49	2.96	1.32	0.61	0.07	2.87	0.24	0.01	0.03	10.75
4	3.34	2.51	2.67	1.47	2.09	0.50	0.62	0.28	0.01	0.20	13.67
5	1.18	0.56	0.81	1.38	2.21	2.32	1.98	1.40	0.09	0.97	12.92
6	0.17	1.86	0.05	0.17	1.16	4.42	0.14	0.09	0.02	0.70	8.77
7	0.26	0.04	2.04	0.22	1.05	0.14	4.16	2.10	0.15	0.06	10.22
8	0.05	0.02	0.20	0.11	0.85	0.11	2.41	3.64	1.66	0.05	9.08
9	0.00	0.00	0.01	0.01	0.07	0.03	0.24	2.30	2.62	0.62	5.91
10	0.05	0.06	0.00	0.00	0.95	1.36	0.10	0.08	0.72	2.27	5.75

5.1.3

Simultaneous Residential Location and Trip Matrix from Origin to Destination(first iteration)

origin	dest 1	dest 2	dest 3	dest 4	dest 5
1	89	84	49	37	20
2	49	84	7	16	6
3	32	7	44	20	9
4	117	88	94	52	73
5	51	24	35	60	96
6	1	8	0	1	5
7	6	1	48	5	25
8	2	1	7	4	30
9	0	0	0	0	1
10	0	0	0	1	4
total	348	298	284	195	269

origin	dest 6	dest 7	dest 8	dest 9	dest 10
1	6	8	1	0	1
2	37	1	0	0	1
3	1	43	4	0	0
4	18	22	10	0	6
5	101	86	61	4	42
6	20	1	0	0	3
7	3	98	49	4	1
8	4	85	128	58	2
9	0	3	31	36	8
10	6	0	0	3	10
total	195	346	285	105	75

origin	total
1	296
2	200
3	160
4	480
5	560
6	40
7	240
8	320
9	80
10	24
total	2400

5.1.4

Loaded Volumes on Each Link(first iteration)

	1	2	3	4	5	6	7	8	9	10
1	89	90	57	60						
2	50	84		29		43				
3	38		44	43			77			
4	170	121	158	51	147					
5				179	96	127	87	77		52
6		10			7	20				4
7			67		29		97	57		
8					41		95	128	68	
9								36	35	11
10					5	6			3	9

5.2.1

Travel Times or Costs in the Network(second iteration)

	1	2	3	4	5	6	7	8	9	10
1	1	1.7	1.9	1.2	4.2	4	3.7	5.7	7.6	6.5
2	1.7	1	3.6	2	4.4	2.3	5.4	6.8	7.6	4.9
3	1.9	3.6	1	1.4	4	5.9	1.8	3.8	5.7	6.3
4	8.8	10.2	6.9	1	3.0	7.9	5.6	5.4	7.3	5.3
5	6.3	7.2	4.4	5.1	1	4.9	2.6	2.4	4.3	2.3
6	4	2.3	5.9	4.3	2.1	1	4.7	4.5	5.3	2.6
7	3.7	5.4	1.8	3.2	2.2	7.1	1	2	3.9	4.5
8	5.7	7.4	3.8	5.2	2.4	7.2	2	1	1.9	4.6
9	7.6	7.6	5.7	7.1	4.3	5.3	3.9	1.9	1	2.7
10	6.6	4.9	6.6	6.9	2.3	2.6	4.9	4.6	2.7	1

5.2.2

$W_i F(C_{ji})$ and total, $\Sigma W_i F(C_{ji})$ (second iteration)

	1	2	3	4	5	6	7	8	9	10	total
1	3.42	3.23	1.87	1.43	0.08	0.22	0.32	0.01	0.00	0.00	10.58
2	2.54	4.34	0.26	0.85	0.06	1.90	0.03	0.00	0.00	0.03	10.00
3	2.16	0.38	2.96	1.32	0.11	0.01	2.87	0.24	0.01	0.00	10.06
4	0.00	0.00	0.00	1.47	0.41	0.00	0.02	0.02	0.00	0.02	1.94
5	0.01	0.00	0.09	0.01	2.21	0.06	1.34	1.40	0.09	0.97	6.18
6	0.17	1.86	0.01	0.05	1.16	4.41	0.07	0.08	0.02	0.70	8.55
7	0.26	0.03	2.04	0.22	1.05	0.00	4.16	2.10	0.15	0.06	10.07
8	0.01	0.00	0.20	0.01	0.85	0.00	2.41	3.64	1.66	0.05	8.83
9	0.00	0.00	0.01	0.00	0.07	0.03	0.24	2.30	2.62	0.62	5.90
10	0.00	0.06	0.00	0.00	0.95	1.36	0.06	0.08	0.72	2.27	5.50

5.2.3
Simultaneous Residential Location and Trip
Matrix from Origin to Destination(second iteration)

origin	dest 1	dest 2	dest 3	dest 4	dest 5
1	185	175	101	77	22
2	100	171	12	33	7
3	67	13	91	41	11
4	117	88	94	414	175
5	52	25	43	61	296
6	2	17	0	1	11
7	12	2	96	10	50
8	2	1	14	4	61
9	0	0	0	0	2
10	0	1	0	1	8
total	537	491	453	643	643

origin	dest 6	dest 7	dest 8	dest 9	dest 10
1	12	17	2	0	1
2	75	1	0	0	1
3	1	88	7	0	0
4	18	27	15	1	11
5	106	207	188	11	130
6	41	1	1	0	6
7	3	197	100	7	3
8	4	172	260	119	3
9	1	7	62	71	17
10	12	1	1	6	19
total	272	718	636	215	193

origin	total
1	592
2	400
3	320
4	960
5	1120
6	80
7	480
8	640
9	160
10	48
total	4800

5.2.4

Loaded Volumes on Each Link(second iteration)

	1	2	3	4	5	6	7	8	9	10
1	185	203	133	101						
2	115	171		35		96				
3	267		91	55			127			
4	0	0	211	414	357					
5				61	296	0	331	216		385
6		134			20	41				8
7			237		67		197	116		
8					63		200	260	145	
9								72	71	25
10					9	257			7	19

5.3.1

Travel Times or Costs in the Network(third iteration)

	1	2	3	4	5	6	7	8	9	10
1	1	6.1	2.8	2.6	7.5	8.4	5.3	7.8	11.0	11.0
2	2.1	1	4.9	2	4.4	2.3	7.5	9.5	7.6	4.9
3	14.3	13.8	1	1.4	4.7	15.6	2.5	5.1	8.2	10.9
4	12.9	12.4	15.6	1	16.8	14.7	18.2	20.7	20.0	17.3
5	16.5	14.3	19.3	5.1	1	11.0	21.8	17.5	16.2	13.5
6	5.6	3.4	8.4	5.4	2.1	1	10.9	7.2	5.3	2.6
7	18.7	16.5	10.3	7.3	2.2	13.1	1	2.5	5.7	8.4
8	18.9	16.7	17.1	7.5	2.4	13.3	6.8	1	3.2	5.9
9	20.8	18.6	19.0	9.4	4.3	15.2	8.7	1.9	1	2.7
10	18.8	16.6	21.6	7.4	2.3	13.2	11.4	4.6	2.7	1

5.3.2

$W_i F(C_{ji})$ and total, $\Sigma W_i F(C_{ji})$ (third iteration)

	1	2	3	4	5	6	7	8	9	10	total
1	3.42	0.00	0.72	0.44	0.00	0.00	0.03	0.00	0.00	0.00	4.62
2	1.71	4.34	0.04	0.85	0.06	1.90	0.00	0.00	0.00	0.03	8.93
3	0.00	0.00	2.96	1.32	0.04	0.00	1.43	0.04	0.00	0.00	5.79
4	0.00	0.00	0.00	1.47	0.00	0.00	0.00	0.00	0.00	0.00	1.47
5	0.00	0.00	0.00	0.01	2.21	0.00	0.00	0.00	0.00	0.00	2.23
6	0.02	0.49	0.00	0.01	1.16	4.41	0.00	0.00	0.02	0.70	6.81
7	0.00	0.00	0.00	0.00	1.05	0.00	4.16	1.19	0.01	0.00	6.42
8	0.00	0.00	0.00	0.00	0.85	0.00	0.00	3.64	0.40	0.01	4.90
9	0.00	0.00	0.00	0.00	0.07	0.00	0.00	2.30	2.62	0.62	5.62
10	0.00	0.00	0.00	0.00	0.95	0.00	0.00	0.07	0.72	2.27	4.01

5.3.3

Simultaneous Residential Location and Trip Matrix from Origin to Destination(third iteration)

origin	dest 1	dest 2	dest 3	dest 4	dest 5
1	294	175	124	91	22
2	119	220	12	42	8
3	67	13	132	59	12
4	117	88	94	654	175
5	52	25	43	63	574
6	2	18	0	1	14
7	12	2	96	10	70
8	2	1	14	4	89
9	0	0	0	0	3
10	0	1	0	1	11
total	664	541	517	926	978

origin	dest 6	dest 7	dest 8	dest 9	dest 10
1	12	18	2	0	1
2	96	1	0	0	1
3	1	108	8	0	0
4	18	27	15	1	11
5	106	207	188	11	130
6	54	1	1	0	8
7	3	275	122	7	3
8	4	172	379	131	3
9	1	6	78	90	21
10	12	1	1	8	26
total	306	817	794	249	206

origin	total
1	740
2	500
3	400
4	1200
5	1400
6	100
7	600
8	800
9	200
10	60
total	6000

5.3.4

Loaded Volumes on Each Link(third iteration)

	1	2	3	4	5	6	7	8	9	10
1	294	188	567	91						
2	452	220		43		322				
3	0		132	138			424			
4	320	306	0	654	0					
5				78	574	613	0	188		0
6		366			197	54				165
7			111		133		275	157		
8					104		193	379	145	
9								92	90	27
10					24	0			23	26

6.1.1

Times or Costs in the Network(first iteration)

	1	2	3	4	5	6	7	8	9	10
1	1	3.2	1.9	1.2	2.5	4.6	3.7	4.9	6.8	7.2
2	1.7	1	3.4	2	3.3	2.3	5.2	5.7	7.6	4.9
3	1.9	3.4	1	1.4	2.7	4.8	1.8	3.8	5.7	7.4
4	1.2	2	1.4	1	1.3	3.4	3.2	3.7	5.6	6
5	2.5	3.3	2.7	1.3	1	2.1	2.2	2.4	4.3	4.7
6	4	2.3	4.8	3.4	2.1	1	4.3	4.5	5.3	2.6
7	3.7	5.2	1.8	3.2	2.2	4.3	1	2	3.9	6.6
8	4.9	5.7	3.8	3.7	2.4	4.5	2	1	1.9	4.6
9	6.8	7.6	5.7	5.6	4.3	5.3	3.9	1.9	1	2.7
10	6.6	4.9	7.4	6	4.7	2.6	6.6	4.6	2.7	1

6.1.2

$W_i F(C_{ji})$ and total, $\sum_i W_i F(C_{ji})$ (first iteration)

	1	2	3	4	5	6	7	8	9	10	total
1	3.42	0.64	1.87	1.43	0.76	0.09	0.32	0.05	0.00	0.00	8.59
2	2.54	4.34	0.34	0.85	0.29	1.90	0.04	0.01	0.00	0.03	10.33
3	2.16	0.49	2.96	1.32	0.61	0.07	2.87	0.24	0.01	0.00	10.73
4	3.34	2.51	2.67	1.47	2.09	0.50	0.62	0.28	0.01	0.01	13.47
5	1.18	0.56	0.81	1.38	2.21	2.32	1.98	1.40	0.09	0.04	11.98
6	0.17	1.86	0.05	0.17	1.16	4.42	0.14	0.09	0.02	0.70	8.77
7	0.26	0.04	2.04	0.22	1.05	0.14	4.16	2.10	0.15	0.00	10.17
8	0.05	0.02	0.20	0.11	0.85	0.11	2.41	3.64	1.66	0.05	9.08
9	0.00	0.00	0.01	0.01	0.07	0.03	0.24	2.30	2.62	0.62	5.91
10	0.00	0.06	0.00	0.00	0.04	1.36	0.00	0.08	0.72	2.27	4.54

6.1.3

Simultaneous Residential Location and Trip
Matrix from Origin to Destination(first iteration)

origin	dest 1	dest 2	dest 3	dest 4	dest 5
1	118	22	65	49	26
2	49	84	7	16	6
3	32	7	44	20	9
4	118	89	95	52	74
5	55	26	38	65	103
6	1	8	0	1	5
7	6	1	48	5	25
8	2	1	7	4	30
9	0	0	0	0	1
10	0	0	0	0	0
total	382	239	304	212	280

origin	dest 6	dest 7	dest 8	dest 9	dest 10
1	3	11	2	0	0
2	37	1	0	0	1
3	1	43	4	0	0
4	18	22	10	0	0
5	108	93	66	4	2
6	20	1	0	0	3
7	3	98	50	4	0
8	4	85	128	58	2
9	0	3	31	36	8
10	7	0	0	4	12
total	202	356	291	106	28

origin	total
1	296
2	200
3	160
4	480
5	560
6	40
7	240
8	320
9	80
10	24
total	2400

6.1.4

Loaded Volumes on Each Link(first iteration)

	1	2	3	4	5	6	7	8	9	10
1	118		75	103						
2	50	84		29		37				
3	38		44	43			80			
4	176	147	162	52	150					
5				191	103	140	93	82		
6		10			8	20				6
7			67		28		98	57		
8					41		95	128	68	
9								36	36	11
10						8			4	12

6.2.1

Travel Times or Costs in the Network(second iteration)

	1	2	3	4	5	6	7	8	9	10
1	1	15.2	1.9	2.7	5.9	12.9	3.7	5.7	7.6	10.3
2	1.7	1	3.6	2	4.4	2.3	5.4	6.8	7.6	4.9
3	1.9	13.3	1	1.4	4	11	1.8	3.8	5.7	8.4
4	9.4	15.1	7.5	1	3.2	12.8	5.9	5.6	7.5	10.2
5	6.4	11.9	4.5	5.9	1	9.6	2.7	2.4	4.3	7
6	4	2.3	5.9	4.3	2.1	1	4.8	4.5	5.3	2.6
7	3.7	11.5	1.8	3.2	2.2	9.2	1	2	3.9	6.6
8	5.7	9.5	3.8	5.2	2.4	7.2	2	1	1.9	4.6
9	7.6	7.6	5.7	7.1	4.3	5.3	3.9	1.9	1	2.7
10	6.6	4.9	8.4	6.9	4.7	2.6	6.6	4.6	2.7	1

6.2.2

$W_i F(C_{ji})$ and total, $\Sigma W_i F(C_{ji})$ (second iteration)

	1	2	3	4	5	6	7	8	9	10	total
1	3.42	0.00	1.87	0.38	0.01	0.00	0.32	0.01	0.00	0.00	6.01
2	2.54	4.34	0.26	0.85	0.06	1.90	0.03	0.00	0.00	0.03	10.00
3	2.16	0.00	2.96	1.32	0.11	0.00	2.87	0.24	0.01	0.00	9.67
4	0.00	0.00	0.00	1.47	0.33	0.00	0.01	0.02	0.00	0.00	1.83
5	0.00	0.00	0.07	0.00	2.21	0.00	1.17	1.40	0.09	0.00	4.96
6	0.17	1.86	0.01	0.05	1.16	4.41	0.07	0.09	0.02	0.70	8.54
7	0.26	0.00	2.04	0.22	1.05	0.00	4.16	2.10	0.15	0.00	9.99
8	0.01	0.00	0.20	0.01	0.85	0.00	2.41	3.64	1.66	0.05	8.83
9	0.00	0.00	0.01	0.00	0.07	0.03	0.24	2.30	2.62	0.62	5.90
10	0.00	0.06	0.00	0.00	0.04	1.36	0.00	0.07	0.72	2.27	4.53

6.2.3

Simultaneous Residential Location and Trip
Matrix from Origin to Destination(second iteration)

origin	dest 1	dest 2	dest 3	dest 4	dest 5
1	286	22	156	68	27
2	100	171	12	33	7
3	68	7	93	42	11
4	119	89	95	437	162
5	56	26	46	65	353
6	2	17	0	1	11
7	12	1	97	10	50
8	2	1	14	4	61
9	0	0	0	0	2
10	0	1	0	0	0
total	645	335	515	661	683

origin	dest 6	dest 7	dest 8	dest 9	dest 10
1	3	27	2	0	0
2	75	1	0	0	1
3	1	90	8	0	0
4	18	25	14	1	0
5	109	225	224	14	2
6	41	1	1	0	7
7	3	198	100	7	0
8	4	172	260	119	3
9	1	6	62	71	17
10	14	0	1	8	24
total	269	746	673	219	54

origin	total
1	592
2	400
3	320
4	960
5	1120
6	80
7	480
8	640
9	160
10	48
total	4800

6.2.4

Loaded Volumes on Each Link(second iteration)

	1	2	3	4	5	6	7	8	9	10
1	286		251	68						
2	115	171		34		83				
3	257		93	121			199			
4	0	0	214	437	309					
5				0	353	0	418	498		
6		167			20	41				8
7			308		88		198	156		
8					63		200	260	430	
9								72	71	308
10						300			9	24

6.3.1

Travel Times or Costs in the Network(third iteration)

	1	2	3	4	5	6	7	8	9	10
1	1	27.6	13.2	3.4	21.8	29.9	19.3	23.0	35.2	32.5
2	2.1	1	15.3	2	4.4	2.3	16.3	9.5	7.6	4.9
3	14.3	27.4	1	3.3	8.6	23.9	6.1	9.8	29.2	26.5
4	14.4	24.1	27.6	1	28.5	26.4	33.7	33.6	31.7	29.0
5	20.7	20.3	33.9	6.3	1	15.3	29.3	22.5	20.6	17.9
6	7.1	5.0	20.3	7.0	2.1	1	14.0	7.2	5.3	2.6
7	23.3	22.9	26.0	8.9	2.6	17.9	1	3.8	23.2	20.5
8	23.1	22.7	32.8	8.7	2.4	17.7	6.8	1	23.0	20.3
9	25.0	24.6	34.7	10.6	4.3	19.6	8.7	1.9	1	22.2
10	27.7	27.3	37.4	13.3	7	22.3	11.4	4.6	2.7	1

6.3.2

$W_i F(C_{ji})$ and total, $\Sigma W_i F(C_{ji})$ (third iteration)

	1	2	3	4	5	6	7	8	9	10	total
1	3.42	0.00	0.00	0.16	0.00	0.00	0.00	0.00	0.00	0.00	3.58
2	1.72	4.34	0.00	0.85	0.06	1.90	0.00	0.00	0.00	0.03	8.89
3	0.00	0.00	2.96	0.19	0.00	0.00	0.00	0.00	0.00	0.00	3.16
4	0.00	0.00	0.00	1.47	0.00	0.00	0.00	0.00	0.00	0.00	1.47
5	0.00	0.00	0.00	0.00	2.21	0.00	0.00	0.00	0.00	0.00	2.21
6	0.00	0.05	0.00	0.00	1.16	4.41	0.00	0.00	0.02	0.70	6.35
7	0.00	0.00	0.00	0.00	0.70	0.00	4.16	0.25	0.00	0.00	5.12
8	0.00	0.00	0.00	0.00	0.85	0.00	0.00	3.64	0.00	0.00	4.49
9	0.00	0.00	0.00	0.00	0.07	0.00	0.00	2.30	2.62	0.00	4.99
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.72	2.27	3.06

6.3.3

Simultaneous Residential Location and Trip Matrix from Origin to Destination(third iteration)

origin	dest 1	dest 2	dest 3	dest 4	dest 5
1	427	22	157	75	27
2	119	220	12	43	8
3	68	7	168	47	11
4	119	89	95	677	162
5	56	26	46	65	633
6	2	17	0	1	15
7	12	1	97	10	66
8	2	1	14	4	91
9	0	0	0	0	3
10	0	1	0	0	0
total	805	384	590	923	1015

origin	dest 6	dest 7	dest 8	dest 9	dest 10
1	3	26	2	0	0
2	96	1	0	0	1
3	1	90	8	0	0
4	18	25	14	1	0
5	109	225	224	14	2
6	55	1	1	0	8
7	3	296	106	7	0
8	4	172	390	119	3
9	1	6	80	92	17
10	14	0	1	11	33
total	304	844	827	243	65

origin	total
1	740
2	500
3	400
4	1200
5	1400
6	100
7	600
8	800
9	200
10	60
total	6000

6.3.4

Loaded Volumes on Each Link(third iteration)

	1	2	3	4	5	6	7	8	9	10
1	427		391	100						
2	133	220		44		304				
3	68		168	54			191			
4	356	317	0	677	0					
5				196	633	772	0	0		
6		48			184	55				640
7			111		139		296	116		
8					260		420	390	0	
9								591	92	0
10						0			634	33

7.1.1

Times or Costs in the Network(first iteration)

	1	2	3	4	5	6	7	8	9	10
1	1	1.7	1.9	1.2	2.5	4	3.7	4.9	6.8	6.6
2	1.7	1	3.4	2	3.3	2.3	5.2	5.7	7.6	4.9
3	1.9	3.4	1	1.4	2.7	4.8	1.8	3.8	5.7	7.4
4	1.2	2	1.4	1	1.3	3.4	3.2	3.7	5.6	6
5	2.5	3.3	2.7	1.3	1	2.1	2.2	2.4	4.3	4.7
6	4	2.3	4.8	3.4	2.1	1	4.3	4.5	5.3	2.6
7	3.7	5.2	1.8	3.2	2.2	4.3	1	2	3.9	6.6
8	4.9	5.7	3.8	3.7	2.4	4.5	2	1	1.9	4.6
9	6.8	7.6	5.7	5.6	4.3	5.3	3.9	1.9	1	2.7
10	6.6	4.9	7.4	6	4.7	2.6	6.6	4.6	2.7	1

7.1.2

$W_i F(C_{ji})$ and total, $\sum_i W_i F(C_{ji})$ (first iteration)

	1	2	3	4	5	6	7	8	9	10	total
1	3.42	3.23	1.87	1.43	0.76	0.22	0.32	0.05	0.00	0.00	11.30
2	2.54	4.34	0.34	0.85	0.29	1.90	0.04	0.01	0.00	0.03	10.33
3	2.16	0.49	2.96	1.32	0.61	0.07	2.87	0.24	0.01	0.00	10.73
4	3.34	2.51	2.67	1.47	2.09	0.50	0.62	0.28	0.01	0.01	13.47
5	1.18	0.56	0.81	1.38	2.21	2.32	1.98	1.40	0.08	0.04	11.98
6	0.17	1.86	0.05	0.16	1.16	4.41	0.14	0.09	1.92	0.70	8.77
7	0.26	0.04	2.04	0.22	1.05	0.14	4.16	2.10	0.15	0.00	10.17
8	0.05	0.02	0.20	0.11	0.85	0.11	2.41	3.64	1.66	0.04	9.08
9	0.00	0.00	0.01	0.01	0.07	0.03	0.24	2.30	2.62	0.62	5.91
10	0.00	0.05	0.00	0.00	0.04	1.36	0.00	0.08	0.72	2.27	4.54

7.1.3

Simultaneous Residential Location and Trip
Matrix from Origin to Destination(first iteration)

origin	dest 1	dest 2	dest 3	dest 4	dest 5
1	90	85	49	37	20
2	49	84	7	16	6
3	32	7	44	20	9
4	119	89	95	52	74
5	55	26	38	65	103
6	1	8	0	1	5
7	6	1	48	5	25
8	2	1	7	4	30
9	0	0	0	0	1
10	0	0	0	0	0
total	354	302	288	200	274

origin	dest 6	dest 7	dest 8	dest 9	dest 10
1	6	8	1	0	0
2	37	1	0	0	1
3	1	43	4	0	0
4	18	22	10	0	0
5	108	93	66	4	2
6	20	1	0	0	3
7	3	98	49	4	0
8	4	85	128	58	2
9	0	3	31	36	8
10	7	0	0	4	12
total	204	353	290	106	28

origin	total
1	296
2	200
3	160
4	480
5	560
6	40
7	240
8	320
9	80
10	24
total	2400

7.1.4

Loaded Volumes on Each Link(first iteration)

	1	2	3	4	5	6	7	8	9	10
1	90	90	57	59						
2	50	84		29		43				
3	38		44	43			77			
4	176	124	162	52	140					
5				191	103	137	93	81		
6		10			8	20				6
7			67		28		98	57		
8					41		95	128	68	
9								36	35	11
10						8			4	12

7.2.1

Travel Times or Costs in the Network(second iteration)

	1	2	3	4	5	6	7	8	9	10
1	1	1.7	1.9	1.2	3.9	4	3.7	5.7	7.6	6.6
2	1.7	1	3.6	2	4.4	2.3	5.4	6.8	7.6	4.9
3	1.9	3.6	1	1.4	4	5.9	1.8	3.8	5.7	8.4
4	9.1	10.8	7.2	1	2.7	12.3	5.4	5.1	7.0	9.7
5	6.4	8.1	4.5	5.9	1	9.6	2.7	2.4	4.3	7
6	4	2.3	5.9	4.3	2.1	1	4.8	4.5	5.3	2.6
7	3.7	5.4	1.8	3.2	2.2	7.7	1	2	3.9	6.6
8	5.7	7.4	3.8	5.2	2.4	7.2	2	1	1.9	4.6
9	7.6	7.6	5.7	7.1	4.3	5.3	3.9	1.9	1	2.7
10	6.6	4.9	8.4	6.9	4.7	2.6	6.6	4.6	2.7	1

7.2.2

$W_i F(C_{ji})$ and total, $\Sigma W_i F(C_{ji})$ (second iteration)

	1	2	3	4	5	6	7	8	9	10	total
1	3.42	3.23	1.87	1.43	0.12	0.22	0.32	0.01	0.00	0.00	10.62
2	2.54	4.34	0.26	0.85	0.06	1.90	0.02	0.00	0.00	0.03	10.00
3	2.16	0.38	2.96	1.32	0.11	0.01	2.87	0.24	0.01	0.00	10.06
4	0.00	0.00	0.00	1.47	0.58	0.00	0.02	0.03	0.00	0.00	2.11
5	0.00	0.00	0.07	0.00	2.21	0.00	1.17	1.40	0.08	0.00	4.96
6	0.17	1.86	0.01	0.05	1.16	4.41	0.07	0.09	0.02	0.70	8.54
7	0.26	0.02	2.04	0.22	1.05	0.00	4.16	2.10	0.15	0.00	10.01
8	0.01	0.00	0.20	0.01	0.85	0.00	2.41	3.64	1.66	0.04	8.83
9	0.00	0.00	0.01	0.00	0.07	0.03	0.24	2.30	2.62	0.62	5.90
10	0.00	0.05	0.00	0.00	0.04	1.36	0.00	0.08	0.72	2.27	4.53

7.2.3

Simultaneous Residential Location and Trip Matrix from Origin to Destination(second iteration)

origin	dest 1	dest 2	dest 3	dest 4	dest 5
1	184	175	101	77	23
2	100	171	12	33	7
3	67	13	91	41	11
4	119	89	95	385	207
5	56	26	46	65	353
6	2	17	0	1	11
7	12	2	97	10	50
8	2	1	14	4	61
9	0	0	0	0	2
10	0	1	0	0	0
total	542	494	457	618	725

origin	dest 6	dest 7	dest 8	dest 9	dest 10
1	12	17	2	0	0
2	75	1	0	0	1
3	1	88	7	0	0
4	18	28	18	1	0
5	108	225	224	14	2
6	41	1	1	0	6
7	3	198	100	7	0
8	4	172	260	119	3
9	1	6	62	71	17
10	14	0	1	8	24
total	278	737	675	219	54

origin	total
1	592
2	400
3	320
4	960
5	1120
6	80
7	480
8	640
9	160
10	48
total	4800

7.2.4

Loaded Volumes on Each Link(second iteration)

	1	2	3	4	5	6	7	8	9	10
1	185	322	133	100						
2	115	171		34		100				
3	391		91	121			127			
4	0	0	0	385	598					
5				0	353	0	751	386		
6		21			20	41				8
7			642		60		198	117		
8					63		200	260	276	
9								72	71	154
10						147			9	24

7.3.1

Travel Times or Costs in the Network(third iteration)

	1	2	3	4	5	6	7	8	9	10
1	1	16.2	2.8	2.6	7.5	18.4	5.3	7.9	23.7	21.0
2	2.1	1	4.9	2	4.4	2.3	7.4	9.5	7.6	4.9
3	3.6	16.8	1	3.2	4.7	18.8	2.5	5.1	23.6	21.4
4	11.1	13.5	7.5	1	12.2	15.8	10.0	12.5	21.1	18.4
5	17.4	16.4	13.8	6.3	1	14.1	16.3	18.8	19.4	16.7
6	4.4	2.3	7.2	4.3	2.1	1	9.7	7.2	5.3	2.6
7	19.6	18.6	16.0	8.5	2.2	16.3	1	2.6	21.1	18.9
8	19.8	18.8	16.2	8.7	2.4	16.5	6.8	1	18.5	19.1
9	13.8	11.7	16.6	10.6	4.3	9.4	8.7	1.9	1	5.0
10	8.8	6.7	11.6	8.7	6.5	4.4	11.4	4.0	2.7	1

7.3.2

$W_i F(C_{ji})$ and total, $\Sigma W_i F(C_{ji})$ (third iteration)

	1	2	3	4	5	6	7	8	9	10	total
1	3.42	0.00	0.72	0.44	0.00	0.00	0.03	0.00	0.00	0.00	4.61
2	1.72	4.34	0.04	0.85	0.06	1.90	0.00	0.00	0.00	0.03	8.93
3	0.29	0.00	2.96	0.20	0.04	0.00	1.44	0.04	0.00	0.00	4.97
4	0.00	0.00	0.00	1.47	0.00	0.00	0.00	0.00	0.00	0.00	1.47
5	0.00	0.00	0.00	0.00	2.21	0.00	0.00	0.00	0.08	0.00	2.21
6	0.09	1.86	0.00	0.05	1.16	4.42	0.00	0.00	0.02	0.70	8.30
7	0.00	0.00	0.00	0.00	1.05	0.00	4.16	1.18	0.00	0.00	6.39
8	0.00	0.00	0.00	0.00	0.85	0.00	0.00	3.64	0.00	0.00	4.49
9	0.00	0.00	0.00	0.00	0.07	0.00	0.00	2.30	2.62	0.03	5.02
10	0.00	0.00	0.00	0.00	0.00	0.12	0.00	0.08	0.72	2.27	3.19

7.3.3
Simultaneous Residential Location and Trip
Matrix from Origin to Destination(third iteration)

origin	dest 1	dest 2	dest 3	dest 4	dest 5
1	295	175	124	91	23
2	119	220	12	42	8
3	72	13	139	44	12
4	119	89	95	625	207
5	56	26	46	65	633
6	2	21	0	1	14
7	12	2	97	10	70
8	2	1	14	4	91
9	0	0	0	0	3
10	0	1	0	0	0
total	676	547	528	884	1061

origin	dest 6	dest 7	dest 8	dest 9	dest 10
1	12	18	2	0	0
2	96	1	0	0	1
3	1	111	8	0	0
4	18	28	18	1	0
5	108	225	224	14	2
6	52	1	1	0	8
7	3	276	122	7	0
8	4	172	390	119	3
9	1	6	80	92	17
10	14	0	1	11	33
total	310	839	846	243	65

origin	total
1	740
2	500
3	400
4	1200
5	1400
6	100
7	600
8	800
9	200
10	60
total	6000

7.3.4

Loaded Volumes on Each Link(third iteration)

	1	2	3	4	5	6	7	8	9	10
1	295	0	182	278						
2	135	220		43		136				
3	261		139	57			880			
4		308	1143	625						
5				756	633	165	0	0		
6		55			22	52				31
7			0		438		276	381		
8					122		179	390	126	
9								92	92	18
10						17			27	33

8.1.1

Times or Costs in the Network(first iteration)

	1	2	3	4	5	6	7	8	9	10
1	0.9	1.5	1.7	1.1	2.3	3.6	3.3	4.4	6.1	5.9
2	1.5	0.9	3.1	1.8	3.0	2.1	4.7	5.1	6.8	4.4
3	1.7	3.1	0.9	1.3	2.4	4.3	1.6	3.4	5.1	6.7
4	1.1	1.8	1.3	0.9	1.2	3.1	2.9	3.3	5.0	5.4
5	2.3	3.0	2.4	1.2	0.9	1.9	2.0	2.2	3.9	4.2
6	3.6	2.1	4.3	3.1	1.9	0.9	3.9	4.1	4.8	2.3
7	3.3	4.7	1.6	2.9	2.0	3.9	0.9	1.8	3.5	5.9
8	4.4	5.1	3.4	3.3	2.2	4.1	1.8	0.9	1.7	4.1
9	6.1	6.8	5.1	5.0	3.9	4.8	3.5	1.7	0.9	2.4
10	5.9	4.4	6.7	5.4	4.2	2.3	5.9	4.1	2.4	0.9

8.1.2

$W_i F(C_{ji})$ and total, $\sum_i W_i F(C_{ji})$ (first iteration)

	1	2	3	4	5	6	7	8	9	10	total
1	3.37	3.63	2.19	1.46	1.00	0.38	0.52	0.10	0.00	0.00	12.66
2	2.86	4.27	0.52	1.01	0.44	2.39	0.08	0.03	0.00	0.06	11.67
3	2.52	0.77	2.92	1.40	0.83	0.14	3.28	0.40	0.02	0.00	12.29
4	3.41	2.98	2.84	1.44	2.18	0.78	0.92	0.45	0.03	0.01	15.05
5	1.55	0.86	1.01	1.44	2.18	2.82	2.45	1.80	0.16	0.08	14.44
6	0.30	2.35	0.09	0.26	1.41	4.35	0.25	0.17	0.04	0.93	10.15
7	0.43	0.08	2.34	0.32	1.30	0.26	4.10	2.50	0.26	0.01	11.60
8	0.09	0.04	0.33	0.18	1.10	0.21	2.87	3.58	1.94	0.09	10.43
9	0.00	0.00	0.03	0.02	0.13	0.07	0.41	2.69	2.58	0.85	6.78
10	0.00	0.12	0.00	0.00	0.08	1.82	0.01	0.15	0.98	2.23	5.41

8.1.3

Simultaneous Residential Location and Trip
Matrix from Origin to Destination(first iteration)

origin	dest 1	dest 2	dest 3	dest 4	dest 5
1	79	85	51	34	23
2	49	73	9	17	8
3	33	10	38	18	11
4	109	95	90	46	69
5	60	33	43	56	84
6	1	9	0	1	6
7	9	2	48	7	27
8	3	1	10	6	34
9	0	0	0	0	2
10	0	1	0	0	0
total	342	309	290	185	264

origin	dest 6	dest 7	dest 8	dest 9	dest 10
1	10	12	2	0	0
2	41	1	1	0	1
3	2	43	5	0	0
4	25	30	15	1	1
5	109	95	70	6	3
6	17	1	0	0	4
7	5	85	52	5	0
8	6	88	109	60	3
9	1	5	32	30	10
10	8	0	1	4	10
total	224	359	287	107	31

origin	total
1	296
2	200
3	160
4	480
5	560
6	40
7	240
8	320
9	80
10	24
total	2480

8.1.4

Loaded Volumes on Each Link(first iteration)

	1	2	3	4	5	6	7	8	9	10
1	79	94	63	60						
2	50	73		35		51				
3	42		38	49			91			
4	172	141	173	46	157					
5				203	84	151	96	95		
6		11			9	17				9
7			76		32		85	63		
8					52		103	110	75	
9								39	30	14
10						10			5	10

8.2.1

Travel Times or Costs in the Network(second iteration)

	1	2	3	4	5	6	7	8	9	10
1	0.9	1.5	1.7	1.2	4.4	3.6	3.3	5.1	6.8	5.9
2	1.5	0.9	3.2	1.8	4.0	2.1	4.9	6.6	6.8	4.4
3	1.7	3.2	0.9	1.3	3.6	5.3	1.6	3.4	5.1	7.6
4	9.0	10.5	7.3	0.9	3.2	12.3	5.7	5.9	7.6	10.0
5	5.8	7.3	4.1	5.3	0.9	9.1	2.5	2.7	4.4	6.8
6	3.6	2.1	5.3	3.9	1.9	0.9	4.4	4.6	4.8	2.3
7	3.3	4.9	1.6	2.9	2.0	6.9	0.9	1.8	3.5	5.9
8	5.4	7.0	3.7	5.0	2.2	6.5	2.1	0.9	1.7	4.1
9	7.1	6.8	5.4	6.7	3.9	4.7	3.8	1.7	0.9	2.4
10	5.9	4.4	7.7	6.2	4.2	2.3	6.2	4.1	2.4	0.9

8.2.2

$W_i F(C_{ji})$ and total, $\Sigma W_i F(C_{ji})$ (second iteration)

	1	2	3	4	5	6	7	8	9	10	total
1	3.37	3.63	2.19	1.41	0.06	0.38	0.52	0.03	0.00	0.00	11.60
2	2.86	4.27	0.42	1.01	0.12	2.39	0.06	0.00	0.00	0.06	11.19
3	2.52	0.61	2.92	1.40	0.19	0.03	3.28	0.40	0.02	0.00	11.39
4	0.00	0.00	0.00	1.44	0.33	0.00	0.02	0.01	0.00	0.00	1.80
5	0.01	0.00	0.13	0.01	2.18	0.00	1.50	1.04	0.08	0.00	4.94
6	0.30	2.35	0.02	0.09	1.41	4.35	0.13	0.08	0.04	0.93	9.70
7	0.43	0.06	2.34	0.32	1.30	0.00	4.10	2.50	0.26	0.01	11.32
8	0.02	0.00	0.22	0.02	1.10	0.00	2.17	3.58	1.94	0.09	9.14
9	0.00	0.00	0.02	0.00	0.13	0.07	0.27	2.69	2.58	0.85	6.61
10	0.00	0.12	0.00	0.00	0.08	1.81	0.00	0.15	0.98	2.23	5.40

8.2.3
Simultaneous Residential Location and Trip
Matrix from Origin to Destination(second iteration)

origin	dest 1	dest 2	dest 3	dest 4	dest 5
1	166	178	107	70	25
2	100	150	16	35	10
3	68	19	79	38	13
4	109	95	91	431	157
5	61	33	58	57	331
6	2	19	0	1	11
7	18	3	98	14	55
8	4	1	18	6	72
9	0	0	1	0	3
10	0	1	0	0	1
total	527	499	467	652	678

origin	dest 6	dest 7	dest 8	dest 9	dest 10
1	19	25	3	0	0
2	84	2	1	0	2
3	2	89	11	1	0
4	25	34	17	1	0
5	109	265	187	15	3
6	35	2	1	0	8
7	6	172	105	11	0
8	7	164	235	127	6
9	2	8	64	62	20
10	16	0	1	9	20
total	304	761	626	225	60

origin	total
1	592
2	400
3	320
4	960
5	1120
6	80
7	480
8	640
9	160
10	48
total	4800

8.2.4

Loaded Volumes on Each Link(second iteration)

	1	2	3	4	5	6	7	8	9	10
1	165	356	155	95						
2	122	150		38		123				
3	419		79	115			145			
4	0	0	0	431	554					
5				0	331	0	804	360		
6		24			25	35				10
7			672		68		172	131		
8					75		202	235	305	
9								78	62	173
10						161			10	20

8.3.1

Travel Times or Costs in the Network(third iteration)

	1	2	3	4	5	6	7	8	9	10
1	0.9	21.5	3.2	2.4	7.9	24.3	5.9	8.5	29.0	26.6
2	2.0	0.9	5.2	1.8	4.7	2.8	7.9	9.3	7.6	5.1
3	14.6	21.7	0.9	2.6	4.7	22.9	2.7	5.3	27.6	25.2
4	12.0	19.1	8.4	0.9	13.1	21.9	11.1	13.7	26.6	24.2
5	18.9	20.3	15.3	6.9	0.9	18.2	18.0	20.6	23.0	20.5
6	4.1	2.1	7.3	3.9	1.9	0.9	10.0	6.5	4.8	2.3
7	20.9	22.2	17.3	8.9	2.0	20.2	0.9	2.6	24.9	22.5
8	21.0	22.4	17.5	9.1	2.2	20.3	7.4	0.9	24.0	22.7
9	14.5	12.4	17.7	10.8	3.9	10.4	9.1	1.7	0.9	5.7
10	8.8	6.7	12.0	8.5	6.3	4.7	11.5	4.1	2.4	0.9

8.3.2

$W_iF(C_{ji})$ and total, $\Sigma W_iF(C_{ji})$ (third iteration)

	1	2	3	4	5	6	7	8	9	10	total
1	3.37	0.00	0.44	0.55	0.00	0.00	0.01	0.00	0.00	0.00	4.37
2	1.91	4.27	0.02	1.01	0.04	1.10	0.00	0.00	0.00	0.02	8.37
3	0.00	0.00	2.92	0.43	0.04	0.00	1.14	0.03	0.00	0.00	4.56
4	0.00	0.00	0.00	1.44	0.00	0.00	0.00	0.00	0.00	0.00	1.44
5	0.00	0.00	0.00	0.00	2.18	0.00	0.00	0.00	0.08	0.00	2.18
6	0.15	2.35	0.00	0.08	1.41	4.35	0.00	0.00	0.04	0.93	9.32
7	0.00	0.00	0.00	0.00	1.30	0.00	4.10	1.13	0.00	0.00	6.53
8	0.00	0.00	0.00	0.00	1.10	0.00	0.00	3.58	0.00	0.00	4.68
9	0.00	0.00	0.00	0.00	0.13	0.00	0.00	2.69	2.58	0.01	5.41
10	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.15	0.98	2.23	3.45

8.3.3
Simultaneous Residential Location and Trip
Matrix from Origin to Destination(third iteration)

origin	dest 1	dest 2	dest 3	dest 4	dest 5
1	279	178	122	89	25
2	123	201	16	47	10
3	68	19	130	46	14
4	109	95	91	671	157
5	61	33	58	57	611
6	3	24	0	1	14
7	18	3	98	14	79
8	4	1	18	6	109
9	0	0	1	0	4
10	0	1	0	0	1
total	664	555	533	931	1024

origin	dest 6	dest 7	dest 8	dest 9	dest 10
1	19	25	3	0	0
2	97	2	1	0	2
3	2	109	11	1	0
4	25	34	17	1	0
5	109	265	187	15	3
6	44	2	1	0	10
7	6	247	126	11	0
8	7	164	357	127	7
9	2	8	84	81	20
10	16	0	2	12	28
total	326	856	790	247	70

origin	total
1	740
2	500
3	400
4	1200
5	1400
6	100
7	600
8	800
9	200
10	60
total	6000

8.3.4

Loaded Volumes on Each Link(third iteration)

	1	2	3	4	5	6	7	8	9	10
1	279	0	197	286						
2	147	201		49		155				
3	0		130	132			855			
4	260	337	924	671	0					
5				785	611	197	0	0		
6		69			24	44				52
7			0		427		247	345		
8					155		172	357	127	
9								101	81	23
10						20			44	28

Table 9.1.1

Times or Costs in the Network(first iteration)

	1	2	3	4	5	6	7	8	9	10
1	1	1.7	1.9	1.2	2.5	4	3.7	3.9	5.8	6.6
2	1.7	1	3.4	2	3.3	2.3	5.2	4.7	6.6	4.9
3	1.9	3.4	1	1.4	2.7	4.8	1.8	3.8	5.7	7.4
4	1.2	2	1.4	1	1.3	3.4	3.2	2.7	4.6	6
5	2.5	3.3	2.7	1.3	1	2.1	2.2	1.4	3.3	4.7
6	4	2.3	4.8	3.4	2.1	1	4.3	3.5	5.3	2.6
7	3.7	5.2	1.8	3.2	2.2	4.3	1	2	3.9	6.6
8	3.9	4.7	3.8	2.7	1.4	3.5	2	1	1.9	4.6
9	5.8	6.6	5.7	4.6	3.3	5.3	3.9	1.9	1	2.7
10	6.6	4.9	7.4	6	4.7	2.6	6.6	4.6	2.7	1

9.1.2

$W_i F(C_{ji})$ and total, $\sum_i W_i F(C_{ji})$ (first iteration)

	1	2	3	4	5	6	7	8	9	10	total
1	3.42	3.23	1.87	1.43	0.76	0.22	0.32	0.21	0.00	0.00	11.47
2	2.54	4.34	0.34	0.85	0.29	1.90	0.04	0.07	0.00	0.03	10.38
3	2.16	0.49	2.96	1.32	0.61	0.07	2.87	0.24	0.01	0.00	10.73
4	3.34	2.51	2.67	1.47	2.09	0.50	0.62	1.00	0.05	0.01	14.24
5	1.18	0.56	0.81	1.38	2.21	2.32	1.98	3.28	0.34	0.04	14.11
6	0.17	1.86	0.05	0.16	1.16	4.41	0.14	0.36	0.02	0.70	9.04
7	0.26	0.04	2.04	0.22	1.05	0.14	4.16	2.10	0.15	0.00	10.17
8	0.20	0.08	0.20	0.40	2.00	0.44	2.41	3.64	1.66	0.04	11.06
9	0.01	0.00	0.01	0.03	0.29	0.03	0.24	2.30	2.62	0.62	6.16
10	0.00	0.06	0.00	0.00	0.04	1.36	0.00	0.08	0.72	2.27	4.54

9.1.3

Simultaneous Residential Location and Trip
Matrix from Origin to Destination(first iteration)

origin	dest 1	dest 2	dest 3	dest 4	dest 5
1	88	83	48	37	20
2	49	84	7	16	6
3	32	7	44	20	9
4	112	84	90	49	70
5	47	22	32	55	88
6	1	8	0	1	5
7	6	1	48	5	25
8	6	2	6	12	58
9	0	0	0	0	4
10	0	0	0	0	0
total	341	293	275	195	284

origin	dest 6	dest 7	dest 8	dest 9	dest 10
1	6	8	5	0	0
2	37	1	1	0	1
3	1	43	4	0	0
4	17	21	34	2	0
5	92	79	130	14	2
6	20	1	2	0	3
7	3	98	50	4	0
8	13	70	105	48	1
9	0	3	30	34	8
10	7	0	0	4	12
total	196	323	361	105	27

origin	total
1	296
2	200
3	160
4	480
5	560
6	40
7	240
8	320
9	80
10	24
total	2400

9.1.4

Loaded Volumes on Each Link(first iteration)

	1	2	3	4	5	6	7	8	9	10
1	88	89	56	62						
2	50	84		30		43				
3	38		44	43			76			
4	165	117	150	49	165					
5				177	88	128	79	188		
6		9			9	20				6
7			66		28		98	57		
8					94		78	105	69	
9								38	34	10
10						8			4	12

9.2.1

Travel Times or Costs in the Network(second iteration)

	1	2	3	4	5	6	7	8	9	10
1	1	1.7	1.9	1.4	5.5	4	3.7	5.7	7.6	6.6
2	1.7	1	3.6	2	4.4	2.3	5.4	7.4	7.6	4.9
3	1.9	3.6	1	1.4	4	5.9	1.8	3.8	5.7	8.4
4	7.8	9.5	5.9	1	4.1	11.8	6.3	8.3	10.2	12.9
5	5.9	7.6	4	5.0	1	9.9	2.2	4.2	6.1	8.8
6	4	2.3	5.9	4.3	2.1	1	4.3	6.3	5.3	2.6
7	3.7	5.4	1.8	3.2	2.2	7.7	1	2	3.9	6.6
8	5.7	7.4	3.8	5.2	1.7	7.2	2	1	1.9	4.6
9	7.6	7.6	5.7	7.1	3.6	5.3	3.9	1.9	1	2.7
10	6.6	4.9	8.4	6.9	4.7	2.6	6.6	4.6	2.7	1

9.2.2

$W_i F(C_{ji})$ and total, $\Sigma W_i F(C_{ji})$ (second iteration)

	1	2	3	4	5	6	7	8	9	10	total
1	3.42	3.23	1.87	1.31	0.12	0.22	0.32	0.01	0.00	0.00	10.40
2	2.54	4.34	0.26	0.85	0.06	1.90	0.02	0.00	0.00	0.03	10.00
3	2.16	0.38	2.96	1.32	0.11	0.01	2.87	0.24	0.01	0.00	10.06
4	0.00	0.00	0.01	1.47	0.10	0.00	0.01	0.00	0.00	0.00	1.58
5	0.01	0.00	0.15	0.02	2.21	0.00	1.98	0.14	0.01	0.00	4.51
6	0.17	1.86	0.01	0.05	1.16	4.41	0.14	0.01	0.02	0.70	8.53
7	0.26	0.02	2.04	0.22	1.05	0.00	4.16	2.10	0.15	0.00	10.01
8	0.01	0.00	0.20	0.01	1.62	0.00	2.41	3.64	1.66	0.05	9.60
9	0.00	0.00	0.01	0.00	0.19	0.03	0.24	2.30	2.62	0.62	6.02
10	0.00	0.06	0.00	0.00	0.04	1.36	0.00	0.08	0.72	2.27	4.53

9.2.3
Simultaneous Residential Location and Trip
Matrix from Origin to Destination(second iteration)

origin	dest 1	dest 2	dest 3	dest 4	dest 5
1	185	175	101	74	20
2	100	170	12	33	7
3	67	13	91	41	11
4	112	84	93	495	100
5	48	22	51	57	362
6	2	17	0	1	11
7	12	2	97	10	50
8	6	2	12	12	112
9	0	0	0	0	6
10	0	1	0	0	0
total	533	487	458	724	679

origin	dest 6	dest 7	dest 8	dest 9	dest 10
1	12	17	6	0	0
2	74	1	1	0	1
3	1	88	7	0	0
4	17	23	33	2	0
5	92	325	147	14	2
6	40	1	2	0	6
7	3	198	100	7	0
8	13	150	227	103	3
9	9	6	61	69	16
10	14	0	1	8	24
total	268	810	585	204	53

origin	total
1	592
2	400
3	320
4	960
5	1120
6	80
7	480
8	640
9	160
10	48
total	4800

9.2.4

Loaded Volumes on Each Link(second iteration)

	1	2	3	4	5	6	7	8	9	10
1	185	425	139	94						
2	116	170		34		208				
3	484		91	63			133			
4	0	0	307	495	179					
5				57	362	0	762	0		
6		20			21	40				8
7			371		60		198	323		
8					118		190	227	145	
9								75	69	35
10						29			8	24

9.3.1

Travel Times or Costs in the Network(third iteration)

	1	2	3	4	5	6	7	8	9	10
1	1	13.9	3.0	2.7	7.8	19.1	5.6	14.2	17.3	20.0
2	2.2	1	5.1	2	10.0	8.8	7.8	16.0	14.1	11.4
3	12.9	12.5	1	1.4	4.8	16.2	2.6	11.2	14.4	17.1
4	11.5	11.1	14.5	1	16.0	19.9	17.1	22.4	25.2	22.5
5	15.8	13.6	18.8	5.0	1	11.3	12.3	6.4	9.5	12.2
6	4.5	2.3	7.5	4.3	2.1	1	10.1	7.2	5.3	2.6
7	18.0	15.8	20.1	7.2	2.2	13.5	1	8.6	11.7	14.4
8	12.9	10.7	15.9	7.7	2.7	8.4	5.9	1	3.1	5.8
9	9.8	7.6	12.7	9.6	4.6	5.3	7.8	1.9	1	2.7
10	7.1	4.9	10.0	6.9	4.7	2.6	10.5	4.6	2.7	1

9.3.2

$W_l F(C_{jl})$ and total, $\Sigma W_l F(C_{jl})$ (third iteration)

	1	2	3	4	5	6	7	8	9	10	total
1	3.42	0.00	0.59	0.40	0.00	0.00	0.02	0.00	0.00	0.00	4.42
2	1.69	4.34	0.03	0.85	0.00	0.00	0.00	0.00	0.00	0.00	6.91
3	0.00	0.00	2.96	1.32	0.03	0.00	1.24	0.00	0.00	0.00	5.55
4	0.00	0.00	0.00	1.47	0.00	0.00	0.00	0.00	0.00	0.00	1.47
5	0.00	0.00	0.00	0.02	2.21	0.00	0.00	0.00	0.08	0.00	2.23
6	0.09	1.86	0.00	0.05	1.16	4.41	0.00	0.00	0.02	0.70	8.30
7	0.00	0.00	0.00	0.00	1.05	0.00	4.16	0.00	0.00	0.00	5.22
8	0.00	0.00	0.00	0.00	0.62	0.00	0.01	3.64	0.41	0.01	4.69
9	0.00	0.00	0.00	0.00	0.05	0.03	0.00	2.30	2.62	0.62	5.63
10	0.00	0.06	0.00	0.00	0.04	1.36	0.00	0.08	0.72	2.27	4.53

9.3.3
Simultaneous Residential Location and Trip
Matrix from Origin to Destination(third iteration)

origin	dest 1	dest 2	dest 3	dest 4	dest 5
1	299	175	122	87	20
2	125	233	12	45	7
3	67	13	134	60	11
4	112	84	93	735	100
5	48	22	51	59	639
6	2	21	0	1	14
7	12	2	97	10	74
8	6	2	12	12	133
9	0	0	0	0	6
10	0	1	0	0	0
total	672	554	521	1010	1004

origin	dest 6	dest 7	dest 8	dest 9	dest 10
1	12	18	6	0	0
2	74	1	1	0	1
3	1	106	7	0	0
4	17	23	34	2	0
5	92	325	148	14	2
6	51	1	2	0	8
7	3	294	100	7	0
8	13	150	351	117	3
9	1	6	76	88	20
10	18	0	1	10	30
total	283	925	726	239	65

origin	total
1	740
2	500
3	400
4	1200
5	1400
6	100
7	600
8	800
9	200
10	60
total	6000

9.3.4

Loaded Volumes on Each Link(third iteration)

	1	2	3	4	5	6	7	8	9	10
1	299	0	475	263						
2	374	233		46		96				
3	0		134	140			214			
4	295	293	0	735	138					
5				82	639	341	0	643		
6		279			14	51				15
7			0		371		294	0		
8					152		481	351	177	
9								93	88	60
10						54			15	30

VITA

Sang Yool Lee was born at Taegu in Korea on November 17, 1959. He graduated from the Attached High School of Kyungpook National University, Taegu, Korea. He entered the Kyungpook National University, Taegu, Korea, in 1977, and received a Bachelor of Arts degree in Geography in 1981. He then attended the graduate school of the Seoul National University with a major in geography from 1981 to 1983. Then, he served the Korean Army from 1983 to 1985. He came to the United States in 1986 to study at the University of Tennessee with aids from the International Rotary Foundation. In May 1990, he received a Master of Science degree in Geography.

He received honors of Alumni scholarship in 1980 and international Rotary scholarship in 1986. He worked as planning assistant at the Seoul National University, Seoul, Korea, from 1981 to 1982, and as graduate assistant at the University of Tennessee from 1987 to 1988. Currently, he plans to work towards a Ph.D degree in the Department of Geography and Regional Development at the University of Arizona, Tucson, from January in 1990.

He is married to Kyung Hee and has one son, Kevin(Jung Hoon)