ESTIMATING OF THE INTERCITY AUTOMOBILE TRAVEL MATRICES AND TRANSFERING THEM INTO GIS ENVIRONMENT

Yasar Vitosoglu, Hakan Guler, Gungor Evren
Istanbul Technical University, Faculty of Civil Eng., Section of Transp'n Eng. Istanbul
yvitosoglu@hotmail.com, hguler@itu.edu.tr, gevren@ins.itu.edu.tr

Abstract

Using conventional methods based on home surveys or roadside interviews disrupting traffic in order to estimate origin-destination (O/D) matrices is generally costly, time consuming, and labour intensive. The validity of data is very short in developing countries like Turkey, where rapid changes occur in land use and demographic structure, and it is necessary to revise frequently the data obtained by using relatively inexpensive methods. Therefore, various methods that are cheaper and do not require intensive labour have been developed in order to form, and especially to revise present and future O/D matrices. Thus, since the early 1980s, the idea of estimating trip matrices and developing demand models from traffic counts has attracted the attention of researchers considerably, and various methods have been suggested on this subject. The model developed by M.G.H. Bell in 1983 was used for estimating the O/D matrix related to intercity automobile travels made in Turkey for the year of 2000. Geographic information systems (GIS) were adopted for capture, storage, manipulation, display, and analysis of geographic information. As a result of using the model developed by Bell, the O/D matrix related to intercity automobile travels made in Turkey for the year of 2000 was estimated. This matrix was transferred into GIS environment to enable the full range of capability need in this research. This paper placed estimating of the intercity automobile travel matrices and the concept of GIS in the broader perspective on research.

Keywords: Origin-Destination (O/D) matrix estimation; Geographic information systems
Topic Area: D4 Applied Geographical Information Systems

1. Introduction

Using conventional methods based on home surveys or roadside interviews disrupting traffic in order to estimate origin-destination (O/D) matrices is generally costly, time consuming, and labour intensive. The life of data is very short in developing countries such as Turkey, where rapid changes occur in land use and demographic structure, and it is necessary to revise frequently the data obtained by using relatively inexpensive methods. Therefore, various methods that are cheaper and do not require intensive labour have been developed in order to form, and especially to revise present and future O/D matrices.

Vehicle counts on highways are in reality a function of a trip matrix and a route-choice pattern of drivers. Therefore, they provide information about all O/D pairs that use the counted links. In addition, traffic counts are very attractive data sources because they could be obtained in a relatively inexpensive and automatic way without disrupting traffic. As a result, since the beginning of 1980s, the idea of estimating trip matrices and developing demand models from traffic counts has attracted serious attention of researchers, and various methods have been suggested on this subject. The model used for estimating the O/D matrix related to intercity automobile travels in Turkey is also one of these methods, and was developed by Bell in 1983.

2. The model developed by Bell

If it is assumed that N zones are interconnected by a road network which consists of a series of nodes and links, it will be clear that the trip matrix is made up of N^2 cells. The number of cells in the trip matrix is N^2 - N if intra-zonal trips can be disregarded. In order to find out these N^2 cells constituting an O/D matrix from traffic counts, it is necessary first to identify paths followed by trips from each origin to each destination. If p_{ij}^a is defined as the probability or proportions of trips from zone i to zone j travelling through link a, the flow in this link (V_a) will be the summation of portions of all trips between zones using link a. This expression can be summarised mathematically as follows:

$$V_a = \sum_{ij} T_{ij} p_{ij}^a \qquad 0 \le p_{ij}^a \le 1. \tag{1}$$

The probability of p_{ij}^a can be obtained by using various trip assignment techniques of which their degree of complexity increases from all-or-nothing assignment to equilibrium assignment. As a result, when all the p_{ij}^a proportions and all the observed traffic counts (V_a) are given, there will be N^2 unknownT_{ij}'s of the problem to be estimated from a set of L simultaneous linear equations, where L is the total number of traffic counts.

In principle, N^2 independent and consistent traffic counts are necessary for determining the trip matrix T uniquely. On the other hand, in practice, the number of traffic counts is much less than the number of unknownT_{ij}'s. Therefore, it is impossible to find out a unique solution for the problem of estimating an O/D matrix. In general, more than one trip matrix that are consistent with the observed traffic counts will be found when they are assigned onto the network. Two basic approaches can be utilised in order to resolve this problem. In the first approach, the set of feasible solutions for the matrix to be estimated can be restricted by imposing a particular structure, which is provided by gravity or a direct demand model. In the second approach, general principles like maximum likelihood or entropy maximisation are utilised in order to provide the minimum additional information required for estimating an O/D matrix.

Assignment methods used for estimating trip matrix from traffic counts are classified under two main groups. In the assignment methods belonging to the first group, it is assumed that the proportion of drivers choosing each route does not depend on flow levels in links. The most common example of assignment methods in this group is all-or-nothing assignment, and the probabilities of p_{ij}^a are defined in this case as follows:

$$p_{ij}^a = \begin{cases} 1 & \text{if trips from origin i to destination j use link a} \\ 0 & \text{otherwise} \end{cases}$$

Pure stochastic methods are also included in the first group. However, in these cases, the probabilities of p_{ij}^a can take values between 0 and 1.

Assignment methods in the second group, on the other hand, take account of congestion effects. Therefore, the probability of trips made between each O/D pair using any link also depends on traffic flow in that link. Equilibrium and stochastic user equilibrium assignment methods are included in this group.

The model developed by Bell is fundamentally based on the principle of maximum likelihood. In this method, the equation to be solved for estimating O/D matrices from traffic counts is given in the following equality:

$$V_a = \sum_{ij} t_{ij}^{o} \tau \left(\prod_{a} X_a^{p_{ij}^{a}} \right) p_{ij}^{a} \qquad (2)$$

where V_a = the observed flow at count site a,
t_{ij}^{o} = the initial estimate of trips made between zones i and j,
τ = an overall scaling factor,
X_a = vector of parameters to be estimated,
p_{ij}^{a} = the probability that trips made between zones i and j pass through count site a.

The vector of parameters X_a is initially set to unity, and unless other values for τ have been defined by the user, the value of τ is calculated by using the following formula:

$$\tau = \frac{\sum_{a} V_a}{\sum_{a} \sum_{ij} p_{ij}^{a}} \qquad (3)$$

The value of τ remains set at the level defined or calculated by the formula above during later phases. As for the solution procedure, it involves improving upon the initial estimated values of X_a by carrying out more iteration.

For every count site, an adjustment factor h_a is calculated in the each iteration. This adjustment factor is then added to the prior estimate of X_a in order to obtain the value of $X_a^{'}$ as shown in the following formula:

$$X_a^{'} = X_a + h_a. \qquad (4)$$

The formula used to calculate the value of h_a is also as follows:

$$h_a = \frac{V_a - \sum_{ij} t_{ij}^{o} \tau \left(\prod_{a} X_a^{p_{ij}^{a}} \right) p_{ij}^{a}}{\sum_{ij} t_{ij}^{o} \tau p_{ij}^{a\,2} \left(\prod_{b \neq a} X_b^{p_{ij}^{b}} \right) X_a^{(p_{ij}^{a} - 1)}} \qquad (5)$$

The process of iteratively calculating the values of h_a for each count site continues until the difference between observed and estimated traffic flows will remain the limits specified by the user. After the final values of X_a are determined for every link, the cells of trip matrix are calculated by the following formula:

$$T_{ij} = \tau t_{ij}^{o} \prod_{a} \left(X_a \right)^{p_{ij}^{a}} \qquad (6)$$

Finally, the trip matrix has been formed by determining all its T_{ij} elements (Bell, M. G. H., April, 1983, Bell, M. G. H., May, 1983, Ortuzar, J. de D. and Willumsen, L. G., 1990).

3. A GIS application for Turkey

In determining the intercity automobile travel matrix for the year of 2000 in Turkey, all the provinces were not considered, and the analyses were carried out for highly populated and economically developed provinces. Furthermore, the provinces which are close to each other geographically were considered as only one region, and the centre of the province which was economically more developed was assumed as being centroid. As a result, the study was carried out for 27 regions. These regions were listed with respect to their region numbers as follows: Edirne and Kirklareli (1), Istanbul (2), Kocaeli and Sakarya (3), Bursa (4), Balikesir (5), Izmir and Manisa (6), Afyon (7), Aydin (8), Denizli (9), Eskisehir and Kutahya (10), Ankara (11), Yozgat (12), Sivas (13), Konya (14), Kayseri (15), Antalya (16), Adana and Icel (17), Hatay (18), K.Maras and G.Antep (19), Diyarbakir (20), Siirt (21), Malatya and Elazig (22), Erzurum (23), Erzincan (24), Trabzon and Rize (25), Samsun (26), Zonguldak (27). Besides, the settlement centres which became province after 1980 were not considered as separate regions, and were included in the boundary of the province where they were a part of it at the beginning.

The network has been formed as simply as possible. Therefore, there are relatively unimportant differences between the existing highway network and the constituted one. However, it is possible to determine the intercity automobile travel matrix for 81 provinces more realistically by forming a more detailed network. Furthermore, all or noting assignment algorithm was employed for estimating trip matrix from traffic counts. Hence, all or noting trees and shortest paths were built, taking into account the distances among the centroids of the regions as transportation cost. As a result, the probabilities of p_{ij}^{a} were obtained from these all or noting trees.

In order to estimate the intercity automobile travel matrix for the year of 2000 in Turkey, VMAT Subprogram, which is a part of TRANSPORT Software and can determine O/D matrices from traffic counts, was utilized. The working principle of this subprogram is based on the model developed by Bell.

TRANSPORT Program was developed by Halcrow Fox, and written in FORTRAN language. This program enables users to implement powerful analytical techniques without the need to resort to mainframe computers. Some of these techniques are summarized as follows: automatic calibration of trip distribution models, logit modal split analysis, matrix estimation from traffic counts, and equilibrium assignment. The program enables the modeller to formulate a model suitable for his application by designing the package as a series of independent modules linked by means of common files. Because the file format of the program is simple, it is easy to reach these files from other programs. As mentioned previously, in estimating the matrices from traffic counts, VMAT Subprogram is used. This program consists of three subprograms. VMAT1 is the first of two programs used to produce the data files required for input to VMAT3. The main purpose of Program VMAT1 is to define the probability of a trip between each origin-destination pair passing through each count site. Program VMAT2 is the second of the two programs used to produce the data files required for input to VMAT3. The purpose of this second program is to create a data file of traffic counts. Program VMAT3 creates trip matrix consistent with input traffic counts and route probabilities and also with input trip length distribution if required. The main purpose of this program is to identify the most likely trip matrix from input files of traffic counts at individual sites or groups of sites and from route probabilities, using Newton-Raphson Technique (Transport User Guide, 1986).

As mentioned before, in order to determine the intercity automobile travel matrix for the year of 2000, the model developed by Bell was used. As known, using a well-defined initial matrix ensures that the estimated matrix is more realistic. The initial matrix is generally constituted based on the matrices obtained from the previous studies. However, since any study on this subject was not carried out in Turkey during previous years, the principles of Gravity Model were used to form the initial matrix related to intercity automobile travels. Thus, it has been assumed that the automobile travels made from province i to province j are proportional to the multiplication of the exponential functions of populations of provinces i and j, and inversely proportional to the exponential function of the distance between these two provinces. This statement can be summarised by the following equation:

$$t^{o}_{ij} = k\frac{P_i^{\alpha} P_j^{\beta}}{d^{\gamma}} \qquad (7)$$

where

t^{o}_{ij} : the daily automobile travels made from province i to province j,
P_i : the population of province i,
P_j : the population of province j,
k : a coefficient,
d : the distance between province i and province j,
α : a calibration constant,
β : a calibration constant,
γ : a calibration constant.

Assuming that the calibration constants of α, β, and γ are equal to 1, 1, and 2, respectively, the oldest and simplest form of the Gravity Model was used.

The populations of the provinces considered in this study are given in Table 1. Thus, using the initial matrix constructed by the gravity model mentioned before and traffic counts for the year of 2000 given as average annual daily traffic, the intercity automobile travel matrix for the year of 2000 was obtained. Automobile counts recorded on highways and freeways for the year of 2000 that were used to determine the O/D matrix are summarized in Table 2 (Traffic and Transportation Survey (2000), 2001). As for the intercity automobile travel matrix for the year of 2000, it is given in Table 3.

Table 1. The population of provinces for the year of 2000

No	Provinces	Populations	No	Provinces	Populations
1.	Edirne+Kiklareli	731,067	15.	Kayseri	1,060,432
2.	Istanbul	10,187,328	16.	Antalya	1,719,751
3.	Kocaeli+Sakarya	1,961,878	17.	Adana+Icel	3,959,660
4.	Bursa	2,125,140	18.	Hatay	1,253,726
5.	Balikesir	1,076,347	19.	K.Maras+G.Antep	2,402,357
6.	Izmir+Manisa	4,630,402	20.	Diyarbakir	1,362,708
7.	Afyon	812,416	21.	Siirt	1,073,607
8.	Aydin	951,390	22.	Elazig+Malatya	1,423,274
9.	Denizli	850,029	23.	Erzurum	937,389
10.	Eskisehir+Kutahya	1,362,912	24.	Erzincan	316,841
11.	Ankara	4,391,368	25.	Rize+Trabzon	1,341,075
12.	Yozgat	682,919	26.	Samsun	1,209,137
13	Sivas	755,091	27.	Zonguldak	1,025,134
14.	Konya	2,435,376			

Table 2. Average annual daily automobile traffic counts on highways for the year of 2000

Origin Node	Destination Node	Auto. Counts	Origin Node	Destination Node	Auto. Counts
201 (Edirne)	202 (Istanbul)	8672	215 (Kurtalan)	224 (Erzurum)	-
201 (Edirne)	240 (Canakkale)	1690	216 (Ankara)	217 (Delice)	-
202 (Istanbul)	203 (Kocaeli)	74012	216 (Ankara)	242 (Gerede)	-
203 (Kocaeli)	204 (Eskisehir)	4210	216 (Ankara)	243 (Kulu)	-
203 (Kocaeli)	234 (Zonguldak)	3346	217 (Delice)	218 (Yerkoy)	4861
203 (Kocaeli)	241 (Bursa)	16347	217 (Delice)	232 (Havsa)	2522
203 (Kocaeli)	242 (Gerede)	12055	218 (Yerkoy)	219 (Kayseri)	4168
204 (Eskisehir)	205 (Kutahya)	-	218 (Yerkoy)	220 (Sivas)	2800
204 (Eskisehir)	216 (Ankara)	4464	218 (Yerkoy)	243 (Kulu)	471
204 (Eskisehir)	241 (Bursa)	3144	219 (Kayseri)	220 (Sivas)	1317
205 (Kutahya)	206 (Afyon)	2912	220 (Sivas)	222 (Erzincan)	638
206 (Afyon)	207 (Konya)	2140	220 (Sivas)	232 (Havsa)	1239
206 (Afyon)	216 (Ankara)	2460	222 (Erzincan)	223 (Askale)	1152
206 (Afyon)	225 (Dinar)	2836	222 (Erzincan)	232 (Havsa)	-
206 (Afyon)	229 (Usak)	2454	223 (Askale)	224 (Erzurum)	-
207 (Konya)	208 (Pozantı)	1430	223 (Askale)	244 (Trabzon)	1301
207 (Konya)	219 (Kayseri)	1892	225 (Dinar)	226 (Denizli)	2740
207 (Konya)	225 (Dinar)	911	225 (Dinar)	229 (Usak)	-
207 (Konya)	243 (Kulu)	2348	225 (Dinar)	245 (Antalya)	-
207 (Konya)	245 (Antalya)	1330	226 (Denizli)	227 (Aydın)	4174
208 (Pozantı)	209 (Adana)	-	226 (Denizli)	229 (Usak)	-
208 (Pozantı)	219 (Kayseri)	1641	226 (Denizli)	245 (Antalya)	1422
208 (Pozantı)	243 (Kulu)	3780	227 (Aydın)	228 (Izmir)	11724
209 (Adana)	210 (Toprakkale)	13882	228 (Izmir)	229 (Usak)	-
209 (Adana)	245 (Antalya)	1446	228 (Izmir)	230 (Balikesir)	5547
210 (Toprakkale)	211 (Narli)	8673	228 (Izmir)	240 (Canakkale)	-
210 (Toprakkale)	231 (Iskenderun)	-	229 (Usak)	230 (Balikesir)	701
211 (Narli)	212 (Malatya)	1279	230 (Balikesir)	240 (Canakkale)	-
211 (Narli)	214 (Diyarbakir)	1635	230 (Balikesir)	241 (Bursa)	8157
212 (Malatya)	213 (Elazig)	-	232 (Havsa)	233 (Samsun)	-
212 (Malatya)	219 (Kayseri)	1635	232 (Havsa)	242 (Gerede)	-
212 (Malatya)	220 (Sivas)	1076	233 (Samsun)	244 (Trabzon)	3689
213 (Elazig)	214 (Diyarbakir)	812	234 (Zonguldak)	242 (Gerede)	-
213 (Elazig)	222 (Erzincan)	745	240 (Canakkale)	241 (Bursa)	-
214 (Diyarbakir)	215 (Kurtalan)	-			

Table 3. Intercity automobile travel matrix in 2000

ID	Regions	Population	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1	Edirne+Kırklareli	731,067	0	3153	442	177	159	469	19	110	55	63	180	5	14	19	25	52	42	13	17	3	1	10	7	5	47	25	70
2	İstanbul	10,187,328	3153	0	22670	3927	762	854	244	191	175	1044	2524	67	158	204	275	154	385	106	141	20	12	75	45	33	393	238	1144
3	Kocaeli+Sakarya	1,961,878	442	22642	0	1673	179	151	45	32	29	278	517	12	23	34	43	24	57	16	20	3	2	10	6	5	58	39	287
4	Bursa	2,125,140	177	3926	1674	0	972	458	74	83	54	621	363	9	21	59	37	32	48	13	17	3	2	9	4	3	34	20	88
5	Balıkesir	1,076,347	159	761	179	971	0	795	52	97	55	82	94	3	7	41	7	55	12	3	4	1	1	13	2	1	14	7	22
6	İzmir+Manisa	4,630,402	469	855	152	458	797	0	269	4170	814	78	266	8	22	209	35	304	60	17	22	7	4	69	7	5	60	32	28
7	Afyon	812,416	19	241	44	73	52	265	0	71	190	266	293	5	10	273	20	111	32	8	9	3	2	26	3	1	22	16	19
8	Aydın	951,390	110	191	32	83	97	4168	72	0	377	45	72	2	5	116	21	67	36	10	13	4	3	42	2	1	15	9	6
9	Denizli	850,029	55	175	29	54	55	814	192	377	0	86	129	4	9	211	29	176	55	15	18	5	4	52	2	2	25	12	12
10	Eskişehir+Kütahya	1,362,912	63	1046	279	622	82	78	269	45	87	0	1192	19	33	130	62	65	83	22	26	3	2	15	8	7	77	54	28
11	Ankara	4,391,368	181	2529	519	364	94	268	299	73	130	1192	0	315	242	571	488	103	534	117	147	16	9	75	41	34	394	377	703
12	Yozgat	682,919	5	67	12	9	3	8	6	2	4	19	315	0	307	236	751	3	237	54	69	10	6	58	30	26	25	28	13
13	Sivas	755,091	14	158	23	21	7	22	10	5	9	33	242	307	0	59	181	25	55	3	12	6	3	56	19	30	24	259	23
14	Konya	2,435,376	19	205	34	59	41	208	275	115	210	130	570	236	58	0	241	563	355	68	78	18	10	208	12	9	47	30	35
15	Kayseri	1,060,432	25	275	43	37	7	35	20	21	29	62	488	751	181	243	0	64	205	39	44	45	20	341	12	13	19	144	41
16	Antalya	1,719,751	52	156	24	33	55	304	114	67	176	66	104	3	25	564	64	0	334	76	95	27	15	13	8	5	23	12	12
17	Adana+İçel	3,959,660	42	386	57	48	12	60	33	36	55	83	534	238	55	355	205	334	0	2832	2244	175	75	117	14	11	26	119	55
18	Hatay	1,253,726	13	106	16	13	3	16	8	10	15	22	117	55	3	68	39	76	2832	0	691	51	21	34	4	3	7	7	14
19	K.Maraş+G.Antep	2,402,357	17	141	20	17	4	22	9	13	18	26	147	69	12	79	44	95	2244	691	0	297	96	310	15	14	25	26	18
20	Diyarbakır	1,362,708	3	20	3	3	1	7	3	4	5	3	16	10	6	18	45	27	175	51	297	0	396	124	15	17	22	13	3
21	Siirt	1,073,607	1	12	2	2	1	4	2	3	4	2	9	6	3	10	20	15	75	21	96	396	0	31	47	6	45	7	2
22	Elazığ+Malatya	1,423,274	10	75	10	9	13	69	27	42	52	15	75	58	56	210	342	13	117	34	309	124	31	0	47	61	65	66	10
23	Erzurum	937,389	7	45	6	4	2	7	3	2	2	8	41	30	19	12	12	8	14	4	15	15	47	47	0	48	230	154	5
24	Erzincan	316,841	5	33	5	3	1	5	1	1	2	7	34	26	30	9	13	5	11	3	15	17	6	62	48	0	33	16	4
25	Rize+Trabzon	1,341,075	47	393	58	34	14	61	23	15	25	77	394	25	24	47	19	23	26	7	25	22	45	65	230	33	0	406	49
26	Samsun	1,209,137	25	239	39	20	7	32	16	10	12	54	378	28	259	30	144	12	118	7	26	13	7	67	155	16	407	0	39
27	Zonguldak	1,025,134	70	1144	288	88	22	28	19	6	12	28	703	13	23	35	42	12	55	14	18	3	2	10	5	4	49	39	0

4. Transfering O/D matrix into GIS environment

GISs are computer-based systems employed for the capture, storage, manipulation, display, and analysis of geographic information. The multiple functionality afforded by GIS distinguishes it from older technologies. The integration of multiple functionality within one rather seamless environment dispenses users from mastering a collection of disparate and specialized technologies. As it turns out, this aspect is often held by organizations as one of the decisive criteria in their decision to adopt GIS technology because of its efficiency benefits (Yomralioglu, T., 2000).

Components of GIS: GIS consists of some important components to carry out its fundamental functions properly. These components are as follows:

a) Hardware: The computer and the secondary devices attached to it, which enable GIS to operate, are called as hardware.
b) Software: Software is sum of algorithms written in high level programming languages in order to storage, analyze, and display geographical data.
c) Data: Data is the most important component of GIS. The complexity of data sources and huge amount of data having different structures require much more time and high costs.
d) People: GIS technology has a wide application with human creativity. People manage the required systems to solve real world problems, and prepare long and short term plans.
e) Methods: GIS works properly only when plans and work principles are prepared precisely. These plans and principles are generally in the form of models and applications specific to each organization.

In order to exploit the advantages of GIS technology mentioned previously, the intercity automobile travel matrix was transferred into GIS environment so that the obtained data could be evaluated in a healthy and appropriate manner. For this purpose, at first, a digitalised Turkish State map having 1/1,000,000 scale, ED50 (European Datum), UTM (Universal Transverse Mercatory) 36 was used. The 27 provinces were created on this map in GIS environment, and all these provinces were identified by using ID numbers (Figure 1). Then, the intercity automobile travel matrix and the population data of 27 provinces in 2000 were transformed into a suitable format for MapInfo in order to carry out GIS analyses. Thus, it is possible to see O/D matrix in a visual environment and to perform comparisons and query analyses among these provinces (Figure 2,3,4,5,6).

MapInfo used in this study is a GIS software written in high level programming languages by MapInfo Corporation in order to perform geographical analyses. As can be seen, it is easy to evaluate the obtained intercity automobile travel matrix in GIS environment created by this software. Thus, one can easily perform various analyses related to the automobile travels made from one province to other provinces only by clicking on the desired region on the map (Mintsis, G., et al., 10th June, 2003; Wittwer, E., et al., 2002; Thill, J.C., 2000).

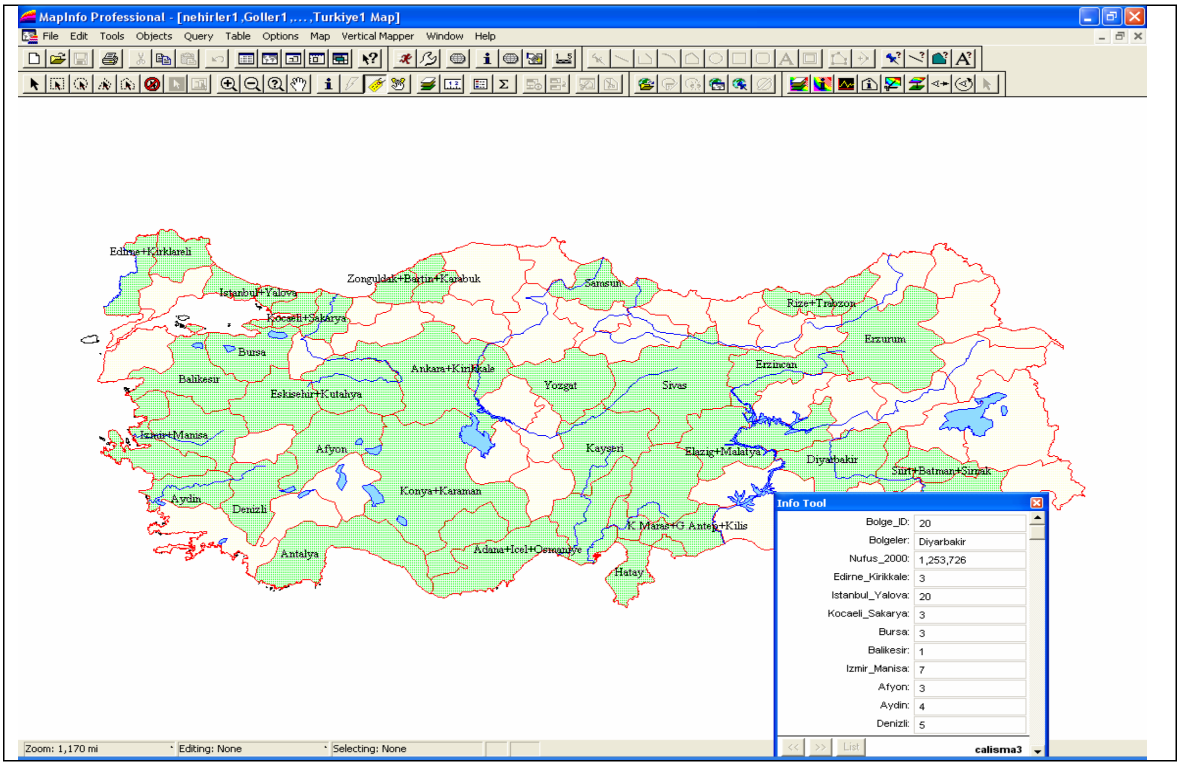


Figure 1. Study regions on GIS in Turkey

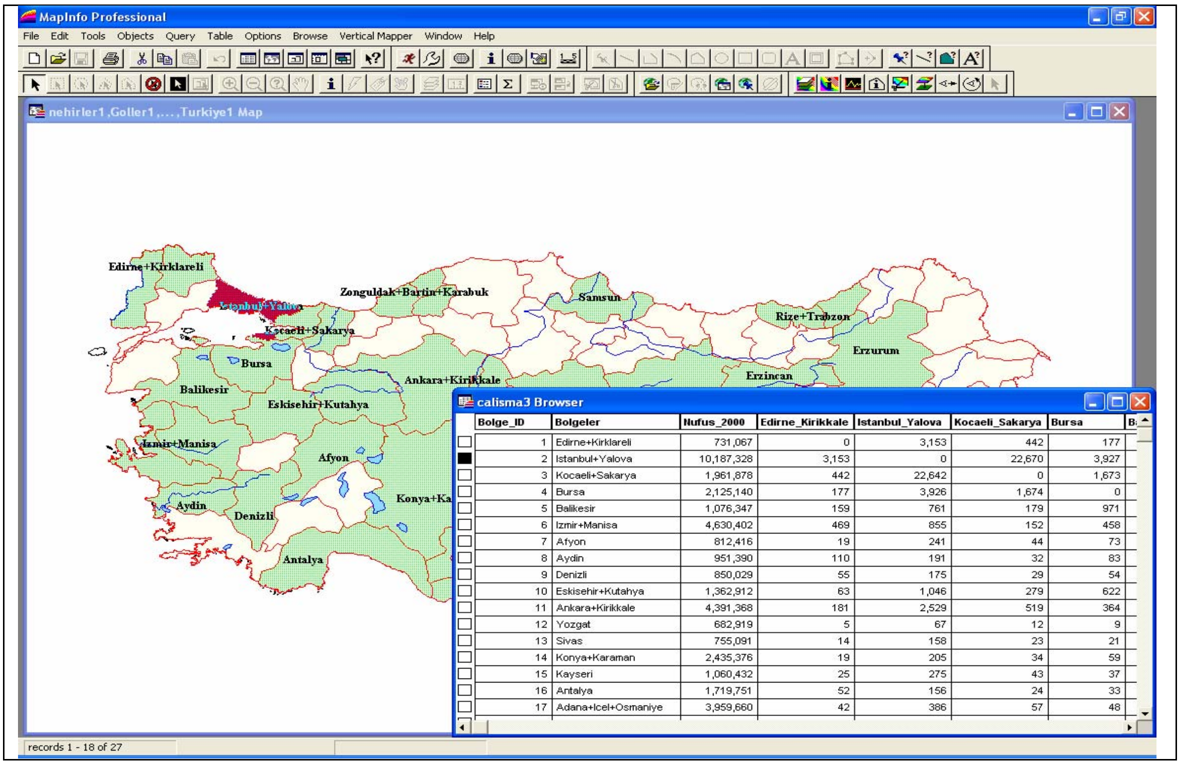
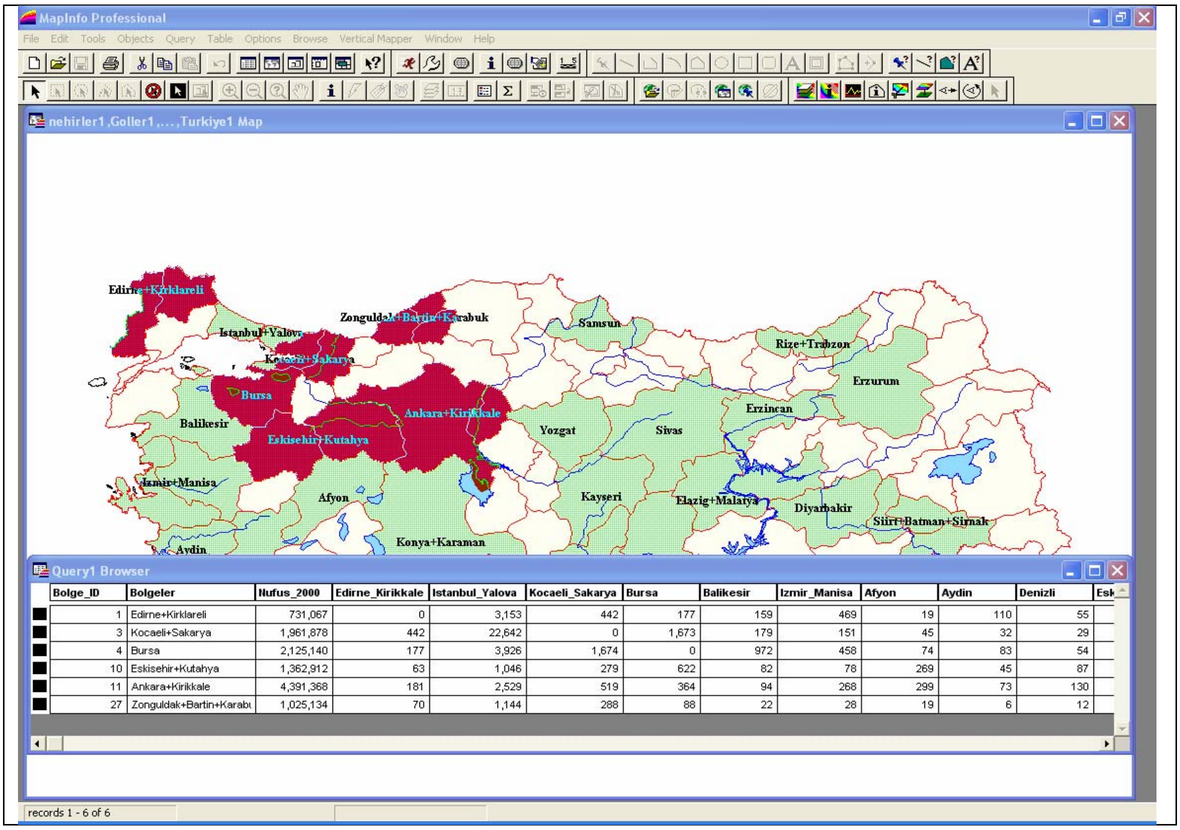


Figure 2. Intercity automobile travel matrix transferred into GIS environment



Bolge_ID	Bolgeler	Nufus_2000	Edirne_Kirikkale	Istanbul_Yalova	Kocaeli_Sakarya	Bursa	Balikesir	Izmir_Manisa	Afyon	Aydin	Denizli	Esk
1	Edirne+Kirklareli	731,067	0	3,153	442	177	159	469	19	110	55	
3	Kocaeli+Sakarya	1,961,878	442	22,642	0	1,673	179	151	45	32	29	
4	Bursa	2,125,140	177	3,926	1,674	0	972	458	74	83	54	
10	Eskisehir+Kutahya	1,362,912	63	1,046	279	622	82	78	269	45	87	
11	Ankara+Kirikkale	4,391,368	181	2,529	519	364	94	268	299	73	130	
27	Zonguldak+Bartin+Karabı	1,025,134	70	1,144	288	88	22	28	19	6	12	

Figure 3. The daily automobile travels made into Istanbul and Yalova region which are higher than 1000 trips on GIS

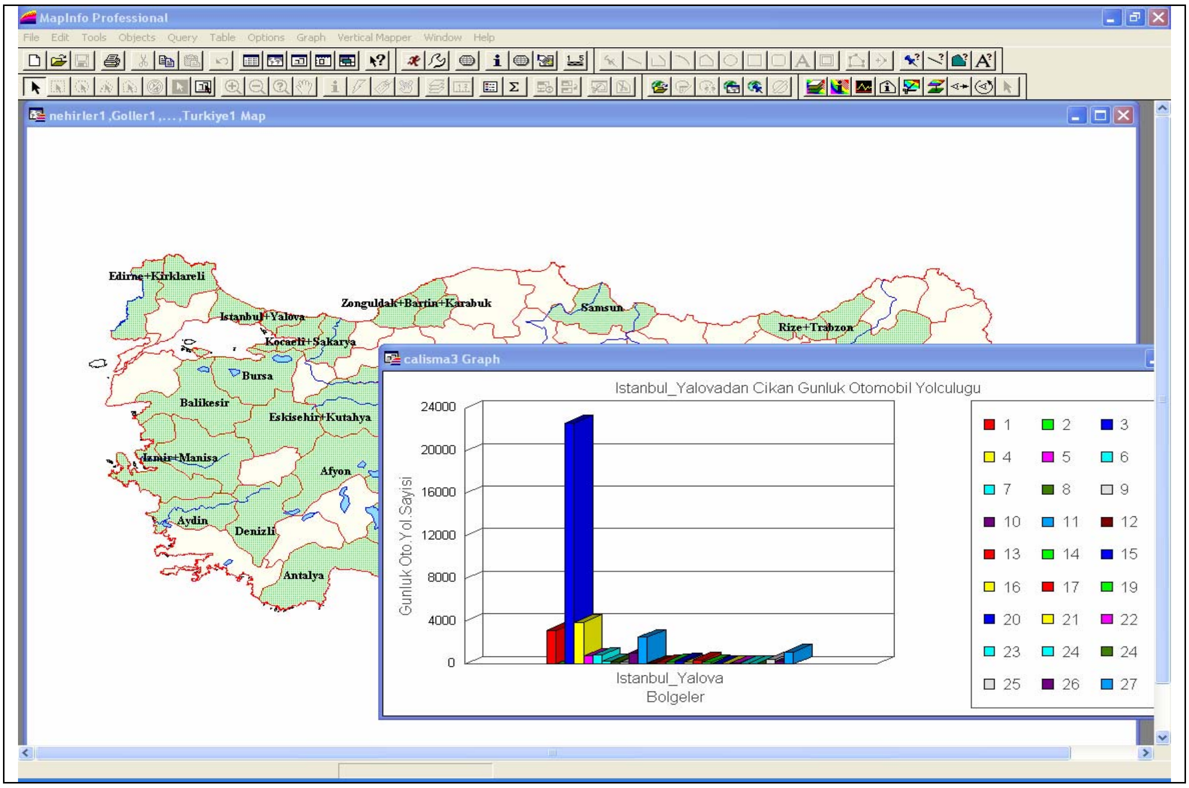


Figure 4. The daily automobile travels made from Istanbul and Yalova to other regions on GIS

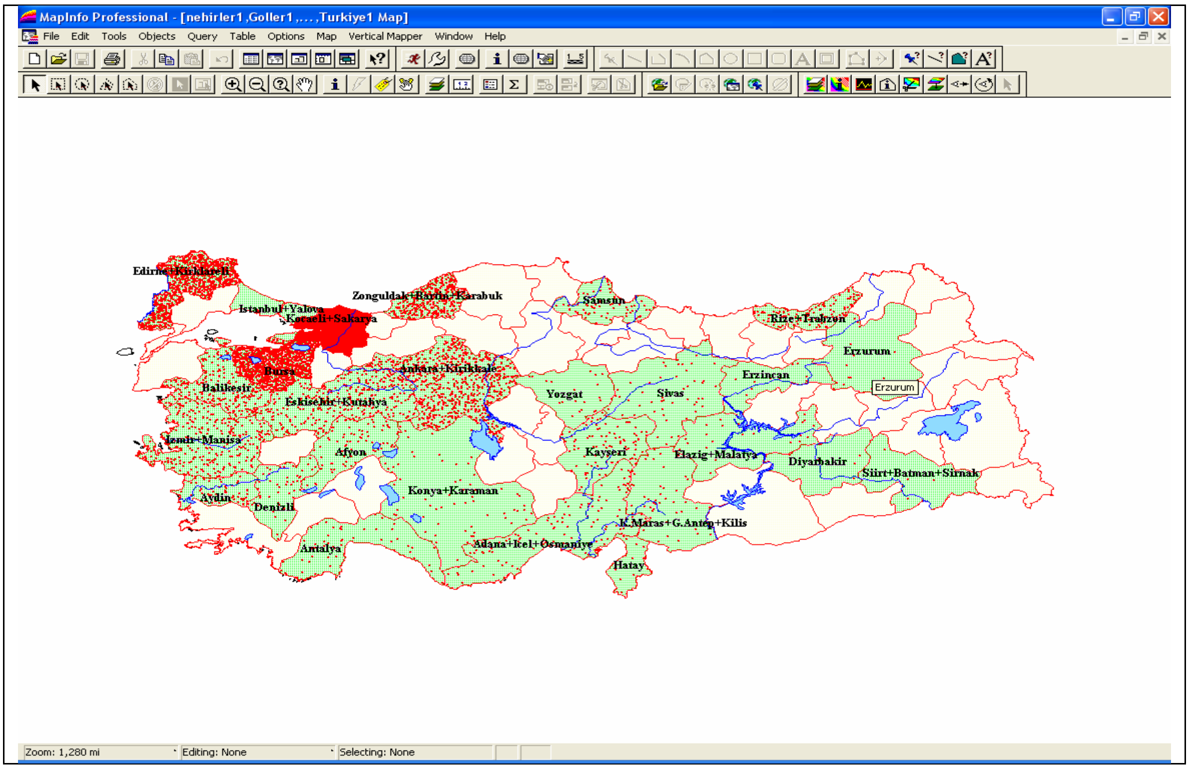


Figure 5. Density demonstration of daily automobile travels made from Istanbul and Yalova to other regions on GIS

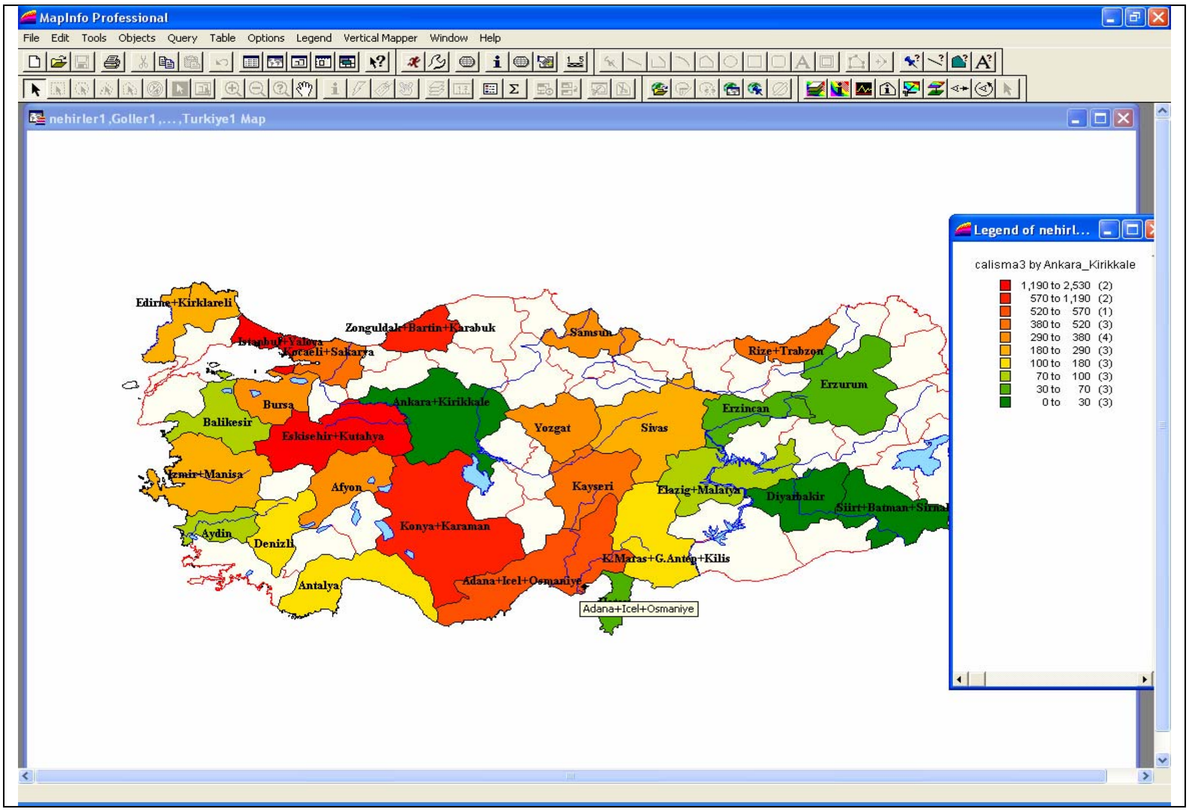


Figure 6. Coloured range demonstration of the daily automobile travels made from Ankara to other regions on GIS

5. Conclusion

Although many methods are used for obtaining O/D matrices, using these methods is costly, time consuming, and labour intensive. It is possible to obtain the O/D matrices easily by using the model developed by Bell in 1983. In this study, the intercity automobile travels made in Turkey in 2000 were estimated by using this model.

Amount and consistency of the data are important factors to take healthy decisions related to transportation. Decision makers need an appropriate information system during the stages of planning and constituting effective policies. Hence, GIS is an effective tool for realizing the spatial analysis. Instead of taking into consideration the data in the form of tables, considering and analyzing the data on computer with their geographical coordinates are definitely more beneficial and efficient.

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