GENETIC ALGORITHM APPROACH TO EVALUATE BUS AND PARATRANSIT PUBLIC TRANSPORT IN URBAN AREAS

Halim Ceylan[*] **, Y. Sazi Murat, Soner Haldenbilen, Ozgur Cengiz**
Department of Civil Engineering, Engineering Faculty, Pamukkale University, Denizli, 20017, Turkey.

Abstract

This study estimates the total demand in urban areas using the Vehicle Ownership Figures (VOF), Gross Domestic Product (GDP) based on Genetic Algorithm (GA) approach. Three forms of the **G**enetic **A**lgorithm **D**emand **E**stimation for **P**ublic **T**ransport (GADEPT) mathematical models are developed, of which one is linear, the second is exponential and the third is the quadratic. The best fit GADEPT model in testing period is selected for future total demand estimation. Based on the survey of Transport Master Plan (TMP), the modal-split figures are obtained to evaluate and plan the bus and *paratransit* mode of public transport for future using the share of each mode from total demand. Definition of paratransit is correspondingly given. Policy proposal in terms of reorganizing the bus and paratransit mode are introduced. The efficiency of bus mode in terms of fuel use, travel time reliability and vehicle headways are dealt with. Data are collected from a city Denizli, which is located west part of Turkey, are used. Results show that the GADEPT model can be used to estimate the total demand, and using the share of the *two* mode of public transport may correspondingly be planned for future demand. Results also show that assuming the observed demand, as a multiplication of mobility figure, may not make a significant effect to an overall planning objective of the bus and paratransit mode of public transport.

Keywords: Public transport; Bus; Paratransit; Genetic algorithm; Mobility; Turkey
Topic Area: C1 Integrated Planning of Transport Systems

1. Introduction

Public transport has the potential to provide the community with social, economic and environmental savings. The ability of public transport to reduce costs to the community through reducing congestion, safety, pollution and environmental degradation is something that has reached the attention of traffic engineers. An externalization of the municipal public service provision tends to separate the responsibility of attending to the basic needs of the citizens and the management of public services as a way of improving efficiency. Reasons that encourage the externalization of public services brings out the hypothesis that the private sector is more efficient in managing public sector economic activities, the pressure to reduce budget deficits and public dept, and the search for formulas that bypass the rigidities of public administration procedures.

The transfer of public service management to the private sector involves the regulation of the transfer conditions and the monitoring of agreements with respect to the quality of services, prices, employment, investment, etc. Moreover, since the political responsibility of public entities

[*] Author for correspondence address is: Pamukkale University, Muh. Fak. Denizli, Turkey. E-mail. halimc@pamukkale.edu.tr **Tel**: +90 258 2134030; **Fax:** +90 258 2125548

is not transferred to the private sector with the management of services, the audit offices will have to control and to follow-up the efficiency and the quality of the public transport provision.

Public transport in many developing countries shows different characteristics like Turkey. It has somewhat special modes of urban public transportation system. There are mainly two types: Bus and *paratransit* mode, which is a kind of transport mode that can be said "public controlled private initiative transport". Management department of the buses and paratransit are respectively City Council and private partnership. Paratransit public transport in Turkish cities is composed of the minibus (so called *Dolmus*) that each has a capacity of 14 passengers. This is the allowable maximum limit, but they uses far more than this number to violate the traffic and safety rules. This is because the lack of coordination between the managing agencies and lack of control by police due to the high number of vehicles, especially in peak periods. This mode of the public transport operates the same route with the bus mode of public transport. This may cause to bus mode of transport, which is owned by city council to loose profit and to leave them into a debt. Hence they both need to better coordination, control and improve efficiency. In addition, the composed transportation mode of bus and paratransit causes some problems in urban areas such as a meaningless rivalry, leading to a violation in the urban traffic system. This violation not only forms dangerous situations for the public safety but also brings out road capacity problems.

The measures for improvement of on-road public transport within the traffic system can be facilitated via many means. However difficulty in planning arises due to the diverse nature of travel patterns: Origins and destinations are dispersed and travel occurs throughout the day. Therefore components relating to the level of service provided by on-road public transport produce a framework form which to work. Improvements target the demand enticing commuters to use public transport and hence, indirectly reducing other road users, which leads to a reduction in congestion and thus increasing efficiency. The latter improvements relate more to the marketing approach applied to public transport.

Pedersen (2003) studied the optimal fare policies in urban transportation in the supplier and travelers point of view, where the positive and negative externalities within groups of consumers exist under the capacity constraints. It provided a theoretical framework for a particular public transport mode how to estimate the marginal operational costs and the costs an additional passenger. It also dealt with the long run marginal operational costs. The study showed that demand is directly affected by average generalized cost. In developing countries, the demand for particular public transport may not be a function of fare costs due to the inelastic demand. Costa and Markellos (1997) dealt with efficiency of public transport based on the concepts of productive efficiency using Artificial Neural Networks (ANN). The productivity is defined as the ratio of its outputs to its inputs. That study used as a case study of London Underground Metro. The results were compared with the ordinary least squares (OLS) and promising results were obtained in terms of productive efficiency of public transport under consideration.

Attention has recently been given to separate the political responsibility and direct delivery of public transport system in European Union (EU). The reason is that the private sector is more efficient in carrying out economic activities, the pressure to reduce the public deficit and the dept, the search for the management systems that bypass public administration procedures, the increase of control of local governments in auditing and accountability issues. Torres and Pina (2001) compared the efficiency of local government services in urban transport between public and private transport sector in terms of service delivery quality. The efficiency analysis was carried out using Data Envelopment Analysis (DEA) model, multiple linear regression and logit and cluster analysis. It was concluded that exogenous factors are not relevant and the private management of urban transport service is not more efficient than public management.

Planning the urban transport system in terms of their routes of bus and other modes of transport (such as paratransit) in terms of service headway and the accessibility plays the most important part of the service quality. Chien et al (2003) carried out the bus route planning based and the service headway and a bus route serving an area with a commuter travel pattern. Minimizing the total system cost, including operator and user costs, while considering the diagonal links in the studied network, optimized the bus route. It was based on given demand side of the example network, where the demand for particular public transport mode is known, and thus total system cost can be estimated including operator and user costs. The bus route planning starts from multiple zone of the area to a single business district. Overall, there is no consideration to plan all the city's public transport system in terms of demand and management side.

Managing urban transport was carried out by Ferrari (1999) in terms of controlling the road price, transit ticket prices and the service characteristics of transit by means of public and private transport. The study focused on the road user charging to manage public transport system. Two modes of transport in urban areas were taken into account: Bus and Car mode. A mathematical framework of the management scheme was presented. Results showed that the optimum value of the average urban transport generalized cost decreases if a portion of the system revenues is dedicated to the improvement of the car system capacity. Moreover, the optimum of transport cost would be obtained with a number of bus users very close to the number of people who have no availability of a private car.

Hensher and Houghton (2004) proposed a performance-based quality contracts (PBC) for the bus sector. The reform requirement for the bus sector was dealt with. They reviewed the elements of a value for money (VM) regime within the setting of an incentive based performance contract, developed a formal framework for establishing optimum subsidy based on system-wide maximization of social surplus. The effect of the PBCs using the data from private operators in the Sydney Metropolitan Area was demonstrated. Results showed that the method they developed could be applicable under a large number of regulatory and operating regimes. The main focus of study was to improve the urban transport system with price. PBCs might be applied to a more than one services in urban public transport. What if there is a static two mode of public transport in city centers and there is no price elasticity on demand? This question applies the many cities of developing countries. In order to answer the question, we first need to obtain the data for a city under study. The data available in many cities are very short in terms of the public transport use. The only reliable data can be the population, VOF and GDPs of the city. To plan and to manage the public transport provision, from three sources of data, we need to estimate the demand and plan the public transport. This study, therefore, deals with estimating the demand for the public transport services in the city of Denizli, Turkey, and plans the public transport modes for future based on Genetic Algorithms (GA).

GAs are random search techniques in the solution space and they takes the notion of Darwinian evolution of individuals. They are search and optimization procedures motivated by natural principles and selection. They have been applied to a wide variety of problem domains including engineering, sciences, and commerce (Goldberg, 1989). GAs are simple yet powerful in their search for improvement and not fundamentally limited by restrictive assumptions about the search space. It manipulates a population of candidate solutions to a problem. The candidate solutions are typically binary strings, but any representation may be used. At every generation, some of the candidate solutions are paired and parts of each individual are mixed to form two new solutions; this is *crossover*: Crossover exchanges individual bits. Additionally, every individual is subject to random change – *mutation*. The next generation is produced by selecting individuals from the current one on the basis of their fitness, which is a measure of how good each candidate solution is. Eventually, the population should become saturated with individuals of very high fitness.

The deficiency of current literature is that there is no study to estimate the future demand for the public transport to plan and manage the system using genetic algorithms. Therefore, this study deals with the estimation of the demand based on the VOF and population figures of the city based on the GA approach. The main objective of this study is to estimate the demand for the bus and paratransit modes of public transport for the city of Denizli, Turkey. Planning the both modes and making a recommendation for future are the main aims. The reason for applying the GA for demand estimation is that it effectively solves the non-liner mathematical models, where the non-linear models may represents the current data better than the linear models. Studies (Haldenbilen and Ceylan, 2005; Ceylan and Ozturk, 2004) showed that linear models usually underestimate the future demand. Therefore, GA is selected to solve the non-linear mathematical expressions due to its ease to apply. Statistical methods may be applied to solve this problem, but we want to show the GA performance for transport demand estimation. Various forms of the **G**enetic **A**lgorithm **D**emand **E**stimation for **P**ublic **T**ransport (GADEPT) are proposed. The GADEPT outputs are verified with the population estimation with mobility figures.

This paper has been organized in a following way. In the next section, Genetic Algorithms for demand estimation are defined. Section 3 is on data collection and evaluation of public transport. Section 4 is on model verification and future estimation. Conclusions are drawn in Section 5.

2. Genetic algorithm for demand estimation

GA applies the principles of the survival of the fittest. It tends in probability to select stronger dynasties in proportion to their fitness, leaving the weaker ones to wither away in probability. This means that while the GA tends to select superior dynasties the best is not always selected and the worst is not always excluded. However, in contrast to more conventional gradient-type algorithms, which search from one single point to the next, GA applies the principles of selection, crossover and mutation (see Goldberg, 1989, for definitions of these parameters) to check whether new and better strains and varieties of model specification happen to exist. Selection and crossover enable the fitter strains to float to the surface, while mutation process prevents GA from getting stuck on inferior solutions. Moreover, it carries out this task efficiently because GA does not proceed model by model as an exhaustive search, but by model class. This reduces the need to sift through numerous individual models, which happen to belong to an inferior class. Goldberg (1989) and Gen and Cheng (1997) have succinctly summarized GA's efficiency in numerical optimization. It has attracted growing attention for demand estimation (see Haldenbilen and Ceylan, 2005; Ceylan and Ozturk, 2004; Ceylan and Ozturk, 2003, Ozturk et al, 2004; Canyurt et al., 2003).

The key feature of a GA is the manipulation of a population whose individuals are characterized by possession of a chromosome. The chromosome consists of a string of characters, in this case bits, which describe the individual. The link between the GA and the problem at hand is provided by the fitness function (F). F establishes a mapping from the chromosome to a set of real numbers. The greater the value of F, the better is the adaptation of the individual.

The procedure is generative. It makes use of three main operators; reproduction, crossover and mutation. Each generation of a GA consists of a new population produced from the previous generation. The pz individuals are assigned allelic values to their chromosomes, where the assignment can be either deterministic or random. Reproduction is a process that selects the fittest chromosomes according to some selection operator, such as tournament selection (Goldberg and

Deb, 1991). This operator chooses the members that will be allowed to reproduce during the current generation. Further manipulation is carried out by the crossover and mutation operators before replacement of members in the next generation.

The following GA formulation procedure is applied during the demand estimation for public transport problem.

The representation of the weighting variables into binary strings requires determining the bit string length. The lower bound value corresponds to all zero digits (0000...), while the upper bound value corresponds to all one digits (1111...). The values between the lower and upper bound are linearly scaled and associated to corresponding binary strings. While dealing with binary string representation, one may need to use large number of bits to represent the variables to high accuracy. The number of binary digits needed for an appropriate representation can be calculated from the following equation

$$2^m \geq \frac{w_i^U - w_i^L}{\Delta w} + 1, \; i=1,2,3,\ldots,k \qquad (1)$$

where Δw_i is the precision of weighting variable and can be calculated as: $\Delta w_i = \dfrac{w_{i,}^U - w_i^L}{2^{l_i} - 1}$, l_i is the required number of binary digits, and k is the total number of weighting variables. Although a higher degree of precision can be obtained by increasing the string length, it is not always desirable because computational cost of GAs also increase as the binary string gets longer. Suppose that the possible values of a weighting variables were 0.6, 0.7, 0.8, 1.9, 10, 1.1, 12 and 13, then the binary coding would be as shown below:

0.6	0.7	0.8	1.9	10	1.1	12	13
000	001	010	011	100	101	110	111

Then $\Delta w = 1.85$, and l=3, $w_i^L = 0$ and $w_i^U = 13$. So, if that section of the chromosome reads "011" then β_i=3, and ψ=6+3x1=5.55.

Mapping from a binary string of weighting variables to real numbers is carried out in the following way:

$$w_i = w_i^L + \beta_i \Delta w_i \quad i=1,2,3,\ldots\ldots,k \qquad (2)$$

where β_i is the integer resulting from binary representation of the weighting variables.

With previous operations, a population is changed in form and characteristics, and represents a new generation. Iterative search after many generations of evolution leads the population to an optimal design. Although the operations previously mentioned can improve the designs as a collective population and, consequently, also best design, optimization searches are generally more interested in finding the best design. The elitist strategy that retains the current best individual to next generation without altering any information is a relatively easy operation that facilitates the search process.

The GA works with the expression operation that is performed based on fitness evaluation. The fitness indicates the *goodness* of design, and therefore, the objective function is a logical choice for the fitness measure. The fitness function selected in the GADEPT model estimation is:

$$Max\ F(x) = 1 / \sum_j^m s_j (E_{actual} - E_{predicted})^2 \qquad (3)$$

where *Eactual* and *Epredicted* are the actual and predicted energy demand, *m* is the number of observations *sj* is the weighting factor that is taken as 1 for this study.

The three forms of the GADEPT models for this study takes the following forms:

The linear form of GADEPTcan be written as

$$GADEPT_{lin} = w_1 X_1 + w_2 X_2 \quad (4)$$

The exponential form of GADEPT can be written as

$$\mathrm{GADEPT}_{exp} = w_1 X_1^{w_2} + w_3 X_2^{w_4} \quad (5)$$

The quadratic form of GADEPT can be written as

$$\mathrm{GADEPT}_{quad} = w_1 X_1^{w_2} + w_3 X_2^{w_4} + w_5 X_1 X_2 \quad (6)$$

where *X1* and *X2* are the Gross Domestic Product (GDP) and vehicle ownership figures (VOF), and *wi* are the corresponding weighting factors.

3. Data collection and evaluation of current public transport

Data are collected from different sources. The population the City of Denizli is collected from the National Statistics (NS, 2003), The VOF numbers are collected from General Directorate of Turkish Highways (GDTH, 2000) and Transport Master Plan (TMP) of Denizli (2003). The GDP of the City is collected from the Central Bank of Turkey (CBT, 2003). The number of bus and the number of paratransit vehicles are taken from TMP (2003). The data are normalized relative to the 1990 (i.e. fixed at 1990 units). The normalized data can be seen in Table 1.

Table 1. Observed data for the analysis (fixed at 1990 values) Vehicle

Years	Population	GDP of Denizli	Vehicle Ownership
1990	1.00	1.00	1.00
1991	1.02	1.00	1.07
1992	1.04	1.06	1.23
1993	1.06	1.11	1.46
1994	1.08	1.11	1.56
1995	1.11	1.21	1.92
1996	1.13	1.32	2.14
1997	1.15	1.44	2.13
1998	1.18	1.49	2.41
1999	1.20	1.47	2.51
2000	1.23	1.57	2.72

Table 1 shows that the VOFs increased about 2.7 times in 2000 when it is compared with 1990. The population growth rate is above the national average of 0.015%. The VOF per capita is more than double (22%) from the national average of 10%. The VOF numbers of the city of Denizli are taken into account as the total of car, truck bus and minibus. The motorcycle numbers are removed from the original data, which can be obtained in the TMP of Denizli (2003). The GDP of Denizli has an significant contribution to a national economy which corresponds about 2% of national GDP. The City is highly industrialized and its main industry is textile sector. The City takes quite significant number of immigrants.

3.1. Transport master plan (TMP) of Denizli, Turkey

Transport Master Plan (TMP) of Denizli, Turkey, has been carried out under control of the Municipality of Denizli, since 2001. In the TMP, the current situation is analyzed and the travel survey is carried out. Socio-demographic characteristics of the City are classified into two main groups: Working group and non-working group. Among the working group, 53% is the employee, 19% is the government employee and the rest is the retailer. Among the non-working group, about 59% is housewife and 26% is the retired. 14% of the population in the city is jobless.

The modal split in the City according to TMP (2003) is given in Table 2. The highest mode in the City is the walking. An average of 44% people walks in between 0-3 km (TMP, 2003). Over the 3 km long of travel distance, the private car and the public transport is dominant. An average travel distance by public transport vehicles is between 5 and 12.5 km that takes about the 67% of the total travels (TMP, 2003). Note that the travel behavior of the people in Denizli, Turkey, usually uses the walking mode as much as 6 km long (TMP, 2003). It was also noted that the private car owners use their vehicles in the distance of 0-2 km, 7%, long of travel (TMP, 2003).

Table 2. Modal split of the City of Denizli, Turkey (TMP, 2003) Modal split %

Modal split	**%**
Walking	44
Service vehicles	16
Paratransit	15
Private car	14
Bus	9
Motorcycles	1

Table 2 shows that, total of 24% (16+9) people uses the public transport modes (i.e. Bus and Paratransit modes). Usage of *service vehicles* also takes the significant portion of the model split. Service vehicles can be defined as the part of the public transport which carry the employees and the students from home to work and vice versa. But this mode of transport is not scheduled and not usually works in the city center. Their routes are flexible and usually takes the fixed set of passengers like students and employees. Therefore, analyzing the service vehicles is beyond the scope of this study. Only consideration in this study is to analyze the bus and paratransit mode of public transport. Both modes show the similar characteristics in terms of commuter routes and operational efficiency. The paratransit mode of public transport needs to planned, because they usually cause the congestion in the city centers, especially in peak-periods. Although those vehicles are controlled by the traffic agency of the City, they do not usually obey the traffic rules, like stopping in the middle of the street in order to take a passenger instead of their reserved stops or they make over-speeding.

The problem in the City is to control the paratransit mode of public transport in terms of obeying the rules and removing from the city center, but how? Thus, the demand for the public transport needs to be estimated in order to make concrete public transport planning for future to answer the question. At the current literature, there is no analysis to plan the both types of public transport. Some scenarios need to be done, like; if we remove the paratransit mode of public transport how we can deal with the bus mode of public transport in order to meet the demand without decreasing the current state of public transport usage.

3.2. The GADEPT models

The three forms of the GADEPT models are developed using the GA notion by minimizing the sum of squared error (SSE) between the observed and estimated values based on in Eqn. (3) in order to estimate the weighting variables. Total transport demand is estimated using the population and mobility numbers between 1990-2000. The demand is given in Table 3. It can be calculated based on the *mobility number*. The mobility number of Denizli, Turkey, is 1.34

meaning that an average 1 trip per day per person, which is obtained from the TMP (2003). In this study, the mobility figure is 1.34 based on the TMP (2003). Studies showed that in the medium scale cities (i.e. population is less than 1 million) in Turkey, the mobility might not change (TMP for Denizli, 2003) over the short term in the future. Thus, the mobility is kept fixed for the projection period.

Table 3. Total current demand for the City of Denizli, Turkey

Years	Population	Mobility	Total Demand
1990	1.00	1.34	1.34
1991	1.02	1.34	1.37
1992	1.04	1.34	1.40
1993	1.06	1.34	1.42
1994	1.08	1.34	1.45
1995	1.11	1.34	1.48
1996	1.13	1.34	1.51
1997	1.15	1.34	1.54
1998	1.18	1.34	1.58
1999	1.20	1.34	1.61
2000	1.23	1.34	1.64

The three forms of the GADEPT model takes as input GDP, population and the VOF. The steps of GADEPT models are follows:

Step 0. Initialisation. For given lower (wi^L))and upper (wi^U) bounds of weighting variables of the GADEPT, represent the weighting parameters as binary strings to form a chromosome **x.**

Step 1. Generate the initial random population of model parameters and set *t*=1

There are no clear theoretical formulae exist for the appropriate population sizing, but Carroll (1996) suggestion for this kind of problems is between 40-50.

Step 2. Decode all model parameters using (2) to map the chromosomes to the corresponding real numbers.

Step 3. Calculate the fitness functions for each chromosome x*j* using (3)

Step 4. Reproduce the population according to the distribution of the fitness function values.

Step 5. Carry out the crossover operator by a random choice with probability *pc*.

Based on previous studies Goldberg (1989) and Carroll (1996) set the probability of crossover (*pc*) between 0.5 and 0.6 for uniform crossover. Hence, *pc* is selected as 0.5 in this study,

Step 6. Carry out the mutation operator by a random choice with probability *pm*, then we have a new population.

Probability of mutation (*pm*) can be set to 1/*pz* (Carroll, 1996).

Step 7. If the difference between the population average fitness and population best fitness index is less than 5%, re-start population and go to the Step 1 and *t=t+1*. Else go to 8.

Step 8. if *t*=maximal number of generation, the chromosome with the highest fitness is adopted as the optimal solution of the problem. Else set *t*=*t*+1 and return to Step 2.

The three form of the GADEPT model is performed with the following GA parameters:

Population size (*pz*) : 20
Generation number (*t*) : 250
Number of weighting variables(*wi*) : 2 for Eqn. (4), 4 for Eqn. (5) and 5 for Eqn. (6)
Probability of crossover (*pc*) : 0.5
Probability of mutation (*pm*) : 1/20=0.05

The GADEPT results are given in the following way.

The linear form of the $GADEPT_{lin}$ is:

$$GADEPT_{lin} = 1.817X_1 - 0.433X_2 \qquad R^2=0.972 \qquad (7)$$

The exponential form of $GADEPT_{exp}$ can be written as

$$GADEPT_{exp} = 0.493X_1^{0.455} + 0.850X_2^{0.182} \quad R^2=0.999 \qquad (8)$$

The quadratic form of $GADEPT_{quad}$ can be written as

$$GADEPT_{quad} = 0.010X_1^{0.01} + 1.283X_2^{0.067} + 0.059X_1X_2 \quad R^2=0.999 \qquad (9)$$

where *X1* is the GDP and *X2* is the VOF (fixed at 1990)

The convergence of the GADEPT models can be obtained in Ceylan and Bell (2004) and Ceylan (2002).

As can be seen from Eqns. (7-9), the R^2 are statistically significant between dependent and independent variables. But, linear model provides negative coefficient for the VOF. It is known that the increase on VOF leads to increase the demand. Therefore, the linear form of the GADEPT model is discarded from future estimation.

The GADEPT*exp* and GADEPT*quad* forms of the models are used for future estimation. Both models are tested in backwards to obtain the population (see Section 4 for model verification).

4. Model verification and future estimation

4.1. Model verification

The GADEPT*exp* and GADEPT*quad* forms of the models are verified according to the backward estimation of the model. The details of the verification can be explained in the following way.

Future estimation for the population is estimated based on the population growth rate (i.e. cumulative growth rate of 0.20%,). This procedure is carried out due to the linear increase on population. The validation is carried out as: 1) The total demand using GADEPT models based on the GDP and VOF is estimated; and then 2) the estimated demand is divided to the mobility (i.e. 1.34) number, named as backward estimation. Whenever the backward estimated population is close to cumulative growth rate of population, the future projection of demand is reported. The total demand and the estimated population from GADEPT*exp* and GADEPT*quad* are given in Table 4. As can be seen from the last column of Table 4, the estimated population is very close to column 2 of Table 4. Therefore, the GADEPT*quad* model is selected for future estimation of the demand and for further analysis.

The demand estimation may be more reliable if we have a yearly-observed demand, but it is difficult to find data on this kind. Therefore, above-mentioned transformation is used to obtain reliable results. This approach (i.e. to take into account the mobility figures as fixed based on the population) may not affect the overall output of this study. These results may be drawn from the rest of this research.

Table 4. GADEPT models verification

Years	Pop.	$GADEPT_{exp}$	Est. Pop	$GADEPT_{quad}$	Est. Pop.
2000	1.23	1.63	1.21	1.64	1.22
2005	1.36	1.73	1.29	1.81	1.35
2010	1.50	1.81	1.35	2.00	1.49
2011	1.53	1.83	1.37	2.04	1.52
2012	1.56	1.85	1.38	2.08	1.55
2013	1.60	1.86	1.39	2.13	1.59
2014	1.63	1.88	1.40	2.17	1.62
2015	1.66	1.89	1.41	2.21	1.65
2016	1.70	1.90	1.42	2.26	1.69
2017	1.73	1.92	1.43	2.31	1.72
2018	1.77	1.93	1.44	2.35	1.76
2019	1.80	1.95	1.45	2.40	1.79
2020	1.84	1.96	1.46	2.45	1.83

4.2. Future estimation for total transport demand

Travel demand estimation for future is carried out based on the GADEPT*quad* using the following indicators.

The GDP of Denizli, Turkey, is estimated based on 1990 fixed prices. Figure 1 shows the estimated GDP based on *time-series* approach. The fitted trend line is in linear form and the resulted R^2 is 0.957.

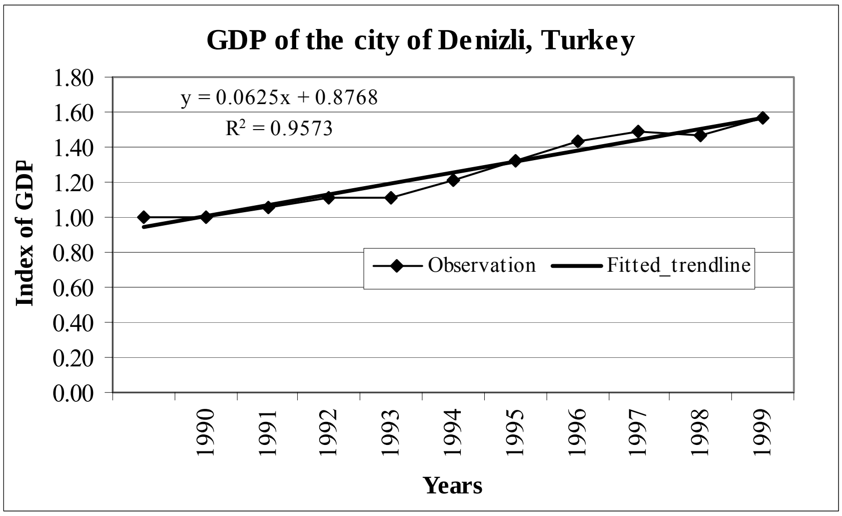

Figure 1. The estimation of GDP in the City of Denizli, Turkey

Figure 2 shows the estimated VOF for the he city of Denizli, Turkey. The fitted trend line for the VOF is in polynomial and R^2 is 0.986.

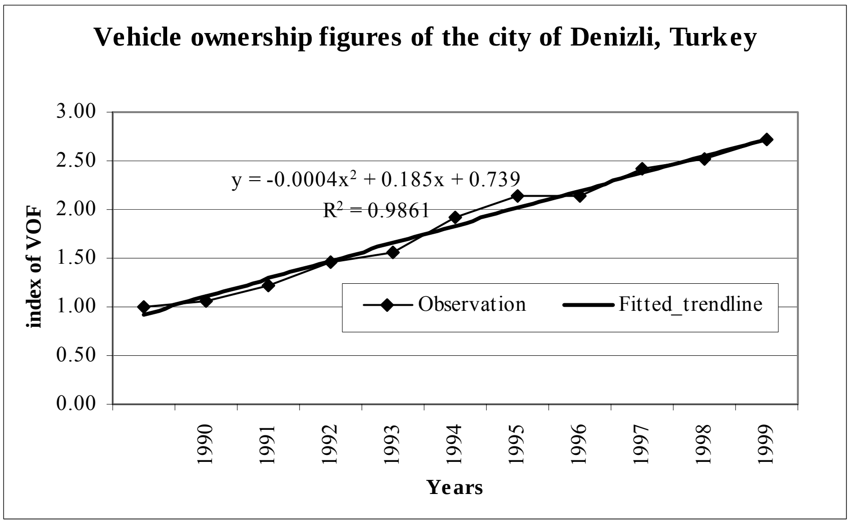

Figure 2. Future estimation of the VOF

In Figures 1 and 2, *x* indicates the time series like 1990=1, 1991=2,….., and 2020=31

The estimated demand at 1990 fixed values and its corresponding transformed real numbers can be seen in Table 5 based on GADEPT*quad*. The total demand in 2020 is 2.2 times higher than in 2000 demand. Those figures comprise of the City including suburb municipalities. After demand is known, the evaluation of the current public transport system and future projections can easily be made.

4.3. Evaluation of current bus and paratransit mode

Table 6 shows the estimated demand and the modal-split for the bus and paratransit modes of public transport based on the share of public transport usage TMP (2003). The bus carries 61018 pass./day and of paratransit carries 101697 pass./day 2000.

Table 5. Total demand of the city of Denizli, Turkey.

Years	Demand
2000	677979
2005	828234
2010	1013372
2015	1241411
2016	1292897
2017	1346509
2018	1402323
2019	1460416
2020	1520867

According to TMP (2003), the number of paratransit vehicles is 679 and the number of buses is 60, 27 of them are more than 15 years of age, 5 of them are between 13 and 15 years old and the rest are less than 10 years old. Those vehicles work on 31 different routes and making an average of 17 rings per day. There is also a bus services for the suburbs of the municipality of the City. The suburb municipalities own total of 8 buses (TMP, 2003). Total number of bus-passengers in 2001 is about 17.5 million per year. The daily average passengers for buses are $17.5*10^6/365=47945$ passenger/bus/day. In Table 6, the numbers of passengers are obtained

64089 from the estimations. The difference comes from the calculation procedure, for which the whole population of the city (i.e. population of suburbs of the municipality is included as well) is taken into account. Basically, three is no separate population figures for the City, like city center or suburbs. Therefore, 64089-47945=16144 pass./day move around the suburban municipalities.

Table 6. Estimated demand and its corresponding modal split

Years	Demand	Share of bus (%)	Demand for bus (pass./day)	Share of paratransit (%)	Demand for paratransit (pass./day))
2000	677979	9	61018	15	101697
2001	712098	9	64089	15	106815
2005	828234	9	74541	15	124235
2010	1013372	9	91203	15	152006
2015	1241411	9	111727	15	186212
2016	1292897	9	116361	15	193935
2017	1346509	9	121186	15	201976
2018	1402323	9	126209	15	210348
2019	1460416	9	131437	15	219062
2020	1520867	9	136878	15	228130

Currently, total expenditure of the bus fleet are about 240.000$ and total revenues are about 80.000$ and the deficit is 160.000$. The amount of subsidy to buses at least in 2001 is 160.000$ (TMP, 2003). Surveys also show that (TMP, 2003) 31-bus fleet of the city makes total of 7556 km and of 3430 *lt* fuel use per day. The consumption of the petrol (i.e. diesel) is 45 *lt*/100 km. Paratransit mode of the public transport is not subsidized and they are profit making operating vehicles. In addition, paratransit vehicle operators are also prevent the joblessness. But, they cause to congestion in city centers and meaningless rivalry to the other vehicles. Traffic authority (Tuncturk, 2003) considers removing the paratransit mode of public transport to the suburbs of the city where the bus mode of public transport is not providing a service. In order to do this, re-organization of the bus and paratransit can be carried out using the data in Table 7.

Table 7 shows the estimated passengers per day for each type of vehicle takes. As can be seen from Table 7, there are still reserve capacities for the paratransit vehicles, which can carry an average 200 passengers per day. Therefore, there is no need to introduce new paratransit vehicles until 2008. After that 1 bus vehicle needs to be introduced to the each prescribed route. Paratransit vehicles need to be doubled in 2020 for each route from the current level.

The last column of Table 7 shows the number of bus-passengers per day. The relative frequency of the *standing passengers* to *sitting passengers* can be calculated as: 1525/17*2=45 passengers per trip, where the 17 are the one-way trip per bus that are obtained from TMP (2003). Second, the relative frequency is 45/40= 1.28. Total capacity of the buses is 60, for which the 40 passengers sitting and 20 are standing. Relative frequency of 1.5 is in an allowable limit (Kutlu, 1964). Thus in the current situation there are still reserve capacity for buses. After that year there is a need to introduce one-more buses to each route in order to meet the demand.

Table 7. Planning the bus and paratransit mode of public transport

Years	Paratransit (passenger/day)	Bus (passenger/day)
2000	150	1525
2001	157	1602
2005	183	1864
2008	206	2103
2009	215	2190
2010	224	2280
2015	274	2793
2016	286	2909
2017	297	3030
2018	310	3155
2019	323	3286
2020	336	3422

All this calculations have carried out so far if there is no change on the share of the bus and paratransit mode of public transport use as well as the mobility number of 1.34.

4.4. Proposed planning policy

This policy is based on the assumption of not being changes on the share of public transport (i.e. total of 24 percent of population), it is based on removing paratransit vehicles from city centers to the suburbs of the city. This is because to improve bus mode of public transport in terms of efficiency (i.e. improving the congestion conditions), traffic congestion, and decrease in excess expenditure.

We may not have a planning prerequisites for public transport in the city until 2008 other than improving the operating efficiency of buses in terms of fuel use and travel time reliability as well as renewing the old-age buses as can be seen in Table 7. Basically, we may not need to introduce extra buses or paratransit vehicles to the routes. This is all because of the available reserve capacity on both modes.

This planning policy says that we should keep the current number of paratransit vehicles and no allowance is given to them when they cannot meet the demand after 2008. The demand they take needs to be diverted to the bus. For instance, when paratransit vehicle-capacities are reached to 200 passengers per day, the extra demand of 6 passengers per paratransit vehicle should transfer to bus. We have 679 paratransit vehicles and this 6*679=4074 passenger are transferred to bus (i.e.124 pass/bus/day) as well as 2103 passengers, and total bus passengers=2227 pas/bus/day. In 2020, the diverted passengers are about 2800 and total of 2800+3422=6222 pas/bus/day. The current capacity of the busses, therefore, needs to be increased three times (i.e. 33 bus to about 100 buses).

5. Conclusions

This study deals with the evaluation of paratransit and bus mode of public transport. Total demand is first estimated based on GA approach using the GDP and the VOF. The population growth is used for testing the GAPEPT models. Three forms of the GADEPT models are developed and verified with the population-based demand estimation for which the measured population is increased with the mobility number of 1.34. GADEPT*quad* model is provided good estimation of total demand in terms of re-obtaining the population. Thus, The GADEPT*quad* is proposed for future estimation of the total demand. The planning issues are based on the current situations and the fix values of mobility number. The share of the bus and paratransit mode of public transport is used to evaluate the current situation and this share is kept fixed during the study period. The reason for is that the total share of public transport use of the population is good, total of 24%. The following conclusions can be drawn from this study.

1. GA approach can be use to estimate the total demand in a city like Denizli, Turkey, if population, GDP, VOF and mobility are known. The GADEPT models can be calibrated by re-calculating the population. The modal-split is played an important role, which can be obtained from the city Transport Master Plans.

2. The concept of paratransit mode of the public transport are evaluated and planned for future. There is also planning policy proposed to improve the revenues from the buses.

3. All the evaluation and planning issues are considered in this study based on the total demand and the fix share of public transport use between bus and paratransit. This assumption may be a weak point of this study in terms of data, but this analysis provides an alternative way of planning the public transport for future even if there is no enough data.

4. In this study current situation and planning issues are dealt with, but in future, alternative evaluation of the public transport system based on the variable share of public transport use as well as the results of the introduction of the complete removal of paratransit mode needs to be evaluated in terms of meeting demand, the revenues and efficiency.

5. The mobility and travel behavior of the people may change over future. The increase on vehicle ownerships may result in the decrease in the share of public transport. In this study, even if the vehicle ownerships increases, the mobility number is kept fixed. The introduction of the new public transport system such as Light Rail System (LRT) may not make a significant effect to the share of public transport until 2020. This is because if there is no planning until 2020, the total demand for public transport is about 350.000 pass/day. This demand can be managed by an efficient bus system.

References

Canyurt, O. E., Ceylan, H., Ozturk, H.K. and Hepbasli, A. 2004. Energy Demand Estimation Based on Two-Different Genetic Algorithm Approaches. Energy Sorces, **, 26**, pp.1313–1320.

Carroll, D.L., 1996. Genetic Algorithms and Optimizing Chemical Oxygen-Iodine Lasers Developments in Theoretical and Applied Mechanics, 18, eds. H.B. Wilson, R.C. Batra,

C.W. Bert, A.M.J. Davis, R.A. Schapery, D.S. Stewart, and F.F. Swinson. School of Engineering, The University of Alabama, 1996, pp. 411-424.

CBT, 2003, Central Bank of Turkey, http//.www.tcmb.gov.tr (in Turkish).

Ceylan, H. And Bell, M.G.H. 2004. Traffic Signal Timing Optimization based on Genetic Algorithm Approach, Including Drivers' Routing. Transportation Research 38B(4), 329,342 (2004).

Ceylan, H., 2002. A Genetic Algorithm Approach to the Equilibrium Network Design Problem. PhD Thesis, University of Newcastle upon Tyne.

Ceylan, H and Ozturk, H.K. 2004. Estimating Energy Demand of Turkey Based on Economic Indicators Using Genetic Algorithm Approach. Energy Conversion and Management, 45(15-16), pp. 2525-2537.

Ceylan, H. and Ozturk, H.K. 2003. Development of Genetic Algorithm-Time Series (GATS) Model on Electricity Production from Hydraulica and Thermal Sources. The First International Energy, Exergy and Environment Symposium, 17-17 July 2003, Izmir, Turkey, pp. 527-532.

Chien, S, L-JY, Dimitrijevic, B.V. and Spasovic, L. N. 2003. Optimization of bus route planning in urban commuter networks. Journal of public Transportation, 6(1) 53-78

Costa, A. and Marcellos, R. N. 1997. Evaluating public transport efficiency with neural networks models. Transportation Research-C, 5(5), p. 301-312.

Ferrari, P. 1999. A model of urban transport management. Transportation Research-B. 33, 43-61.

GDTH., 2000. General Directorate of Turkish Highways, Annual Statistics of Turkish Highways, http//.www.kgm.gov.tr (in Turkish)

Gen, M., and Cheng, R., 1997. Genetic Algorithms and Engineering Design. John Wiley, New York

Goldberg, D.E., and Deb, K., 1991. A comparative analysis of selection schemes used in genetic algorithms. In: Foundations of Genetic Algorithms (Rawlins, G.J.E., Ed.), Morgan Kaufmann Publishers, San Mateo, 69-93.

Goldberg. D.E., 1989. Genetic Algorithms in Search, Optimization and Machine learning. Addison-Wesley, Harlow, England

Haldenbilen, S. and Ceylan H. 2005. Genetic Algorithm Approach to Estiamte Transport Energy Demand in Turkey. Energy Policy, **33**, pp. 89-98.

Kutlu, K., 1964, Traffic Surveys. Istanbul Technical University Press. No: 563, 138 pp. Istanbul, Turkey. (in Turkish)

NS, 2003, National Statistics http//.www.die.gov.tr (in Turkish)

Ozturk, H. K., Ceylan, H, Hepbasli, A., and Utlu, Z., 2003. Estimating Petroleum Exergy Production and Consumption using Vehicle Ownership and GDP based on Genetic Algorithm Approach. Renewable and Sustainable Energy Reviews, 8(3) 289-302, 2004

Pedersen, P. A. 2003. On the optimal fare policies in urban transportation. Transportation Research-B, 37(5) 423-435.

Pina, V. and Torres, L. 2001. Analysis of the efficiency of local government services delivery: An application to urban public transport. Transportation Research-A, 35, 929-944.

TMP - Transport Master Plan., 2003. Municipality of Denizli, Turkey, 4 Reports (in Turkish).

Tuncturk, Z. 2003. Private communications. Municipality of Denizli, the head of traffic authority, Denizli, Turkey.