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Genetıc Algorıthm Optımızatıon Method in the Tımetable Schedules of Publıc Transportatıon

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Abstract

Deciding is the process which is the most useful and convenient to the purposes. To decide something, there is to be more than one choice, so person or people who are going to decide will express their ideas and will be able to choose the most suitable alternatives.

The goal of human beings and companies is not only improving just one choice, but also deal with alot of choices in order to shorten the period of time or increase their incomes or profits.

The transportation system has been trying to do its best to serve the customer very well. In transportation both public and private company just cares aboout its profit. However, for passengers, the most important thing is the service quality and certainly low price, but for the companies, the most important thing is cost.

In this article, optimization of the public transportation timetables has been tested with genetic algorithm method.

Keywords: Genetic Algorithm, Public Transport Planning, Optimization, Timetable Optimization.

Introduction

Urban transportation, covers the movements of passenger and goods in order to maintain daily activities of rapidly growing urban population of our country. In addition to the increase in the population of the country, the rapid growth of the ratio of urban population and together with the booming economic activities the increasing ratio of daily trip per capita arises large increases in the total number of urban trips After all while the dimensions of urban transportation sector is rapidly expanding, its coverage is increased, and so the length of journeys also increases in the urban areas that are spreading and increasing in number a little more day after day. Urban transportation is directly related to many issues concerned with the city, whereas it has to be considered as a whole along with it. In this context the preparation of urban transportation plans as integrated with urban land use plans has not ever been possible in any of our citiesuntil now. The implementation of transportation plans prepared in a few cities after the land use plan had no chance, land use and transportation plan integrity could not been maintained. A target / goal / set of principles could not yet be established which will guide transportation planning and management and will determine the lines of plans and practices and several studies have been put forth; whereas practices conflicting with recommendations have become widespread.

Considering all of these facts, the concept of urban public transportation plays a very active role in solving the problem of urban traffic congestion and it is gaining importance day by day. The more successful the establishment of public transportation system is, the easier becomes the operation of urban transportation problems in general. In order to create a successful system it is required to approach the subject as a scientific problem with system understanding and to produce solution methods.

Based on the above-mentioned facts in the public transportation systems that use the superstructure of the highway optimization method with genetic algorithm shows its face as a usable method in order create to the best timetable of buses. In this study that is prepared using genetic algorithm methods in order to optimize the time table of bus lines in the public transportation system data, such as the current number of passengers, line route, bus number, bus capacity and travel demand make up the most important input of the method set forth.

There are different optimization techniques for different sectors and areas of expertise [1]. This topic includes optimization concepts based on certain differences according to the problem field.

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Transportation area is also a vast field where analysis and modeling can be done with so many different techniques. When an optimization problem is gone about first of all, the characteristics of the objective function, constraint functions and the situation of the, decision variables should be examined [2]. The situation to show up will indicate how to solve the optimization problems.

In line with the aforementioned purposes one of the intelligent optimization techniques is the method of Genetic Algorithm used in the solution of complex problems.

Public transport and method

Public transport system

The principles presented below are expected to be covered by the system for a quality public transportation system.

***Comfort*;** vehicles within the public transportation system and the road network must be at a level to make the passengers feel comfortable. Vehicles should not be overloaded, be shabby and should have comfort-enhancing features such as air conditioning, ventilation. Apart from these, the quality of the physical characteristics of the road network is an important factor in increasing the comfort.

Trust; includes many issues from the system's working hours upto the safety levels of vehicles. Together with the principle of reliability, it is meant to describe both the confidence in the system itself and making safe journey on the vehicles within the system.

***Accessibility*;** All of the elements such as the busstop, bus, main busstop which take place in the system should be available so as to be easily accessible by the passengers. It is important for an accessible system to select the stops and the intervals of stops, according to the intensity of passengers to determine the vehicles that conform with all of the members of society.

***Punctuality*,** Punctuality is a feature that affects the confidence in the system. Departure times of vehicles will be determined and announced in advance in the public transportation system. The adherence to the announced hours is a feature brought by the principle of punctuality.

***Frequency*;** Vehicles that are running in the system should be serving at different times during the day in accordance with the frequency of travel demand. Generally, the starting and ending times of business hours are defined as peak hours and a journey regulation is required in the frequency to meet the demand in these times and to reduce the waiting times at stops.

***Economical*;** The regular users of public transportation system are mostly middle and low-income workers and salaried employees and students. The price paid for public transportation is very important by the inherent nature of the passenger profile. It must be determined so as not to give harm to the operation of transportation services provided but in contrast it shall not involve significant profit rates.

All of these features are the necessary properties for an ideal public transportation system [3]. A system that has the characteristics listed above or approaching these goals can be called as optimal

Genetic algorithm

The main idea of Genetic Algorithms is the transformation of the society characterized by the individuals having a chromosome [4]. Genetic algorithm is a search method, modeled on the evolutionary mechanism in nature. It is used to find specific data among a set of data. In other words it is an iterative search method trying to seize the best solution by scanning the set of possible solutions that is developed by establishing the similarity of Evolutionary Genetics and Darwin's natural selection [5].

Goldberg, has made quite simple and understandable definition for GA in his book published in 1989. According to Goldberg; GAs are a form of random research techniques which selected characters are combined with the process of probabilities. GAs are search techniques that try to find a solution by random search techniques, on the basis of parameter coding [6]. The structure of GA operate in a iterated circular loop. According to this algorithm, first of all the initial population is generated, then these created characters are subjected to conversion (transformation) and start to create new individuals. It is checked whether the algorithm meets the stopping criteria for the newly created population and if it meets the algorithm is stopped if not, it will return to the beginning [7].

Province of Çanakkale public transportation lines were selected in order to test the genetic algorithm method to determine the intervals of public transportation journey times. Having made this choice whether it is a medium-sized city and whether the electronic toll collection system is implemented in Çanakkale it has been much easier to achieve the exact number of boarding passengers. In addition to the number of passengers in the data collection section a survey was conducted with 1,393 people on

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bus stops across Çanakkake. The counts of passengers in vehicles were conducted in order to determine the travel demand of the selected centerline for application. Thus both with the number of boarding from the electronic toll collection system the count quantity carried out in the vehicle is controlled and the number of get offs is obtained which is not included in the system as a data. Knowing at which stops that the passengers get off is very important in terms of urban preparing the public transportation trip matrix.

optimization

First level optimization

First of all, the route of the related line should be handled for the optimization of public transportation line [8]. It should be analyzed whether the route is properly selected or not by analyzing the passenger mass which the line route is serving. This step is also called the first level optimization [9]. For this purpose, three important criteria are taken into account which are considered in the choice of lines. These criteria are;

(1) Population density
(2) Road width
(3) Length of the line.

These three criteria will be used to evaluate the route of the aforesaid public transportation line. Due to the fact that the public transport lines in cities have been established on experience and on a supply-demand relationship based on years it is not quite possible for an existing public transportation line to be changed completely. However, is possible to make changes to prevent inefficient operation of the business which will serve more passengers on the route of the line , [10]. In this study, by proposing minor route changes for the center lines is the to comparison will be made with the current situation. A map has been created in which geographical information can be queried by drawing the Çanakkale road network on Aimar traffic simulation software in order to obtain numerical values by determining the criteria.

In order to determine the population, the density of the structures on the main artery and the arteries of the city are taken into account in the readily available map density due to the fact that a special map or data providing the population density of Çanakkale City could not be obtained, (see Figure 1). While calculating the density values the number of structures are based on which are located on the 100 meters right and left of the main artery axle.

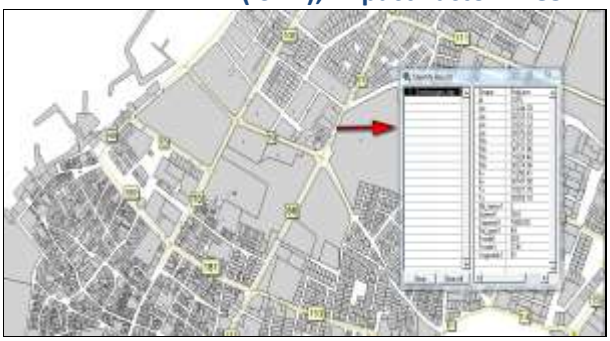

Figure 1. Population Density Map of Canakkale

While the coefficient 1 is used structures such as for the normal household or small offices, coefficients have been used according to the number of students in order to specify the intensity for large structures such as schools, universities, work places.

In order to determine the road width information that is in the query table such as coordinates, speed limit, width was obtained by transferring the drawn map into GIS software. Width value has not been taken as a measure of one to one length, instead, the number of lanes in one direction is considered as the value of width.

As for the path lengths a simple Excel formula has been applied to the coordinates of start and end points of each road section thus lengths were obtained for all of the road sections within the road network. In the data table obtained from the map there are the coordinate values indicating the starting (F_x, F_y) and end points (T_x, T_y) for each route section. According to these values, the length of each link is obtained by the formula;

$$L = \sqrt{(T_x - F_x)^2 + (T_y - F_y)^2} \quad (1)$$

.

Population density, road width and length of the routes across the city have been converted into a table and 327 different links were included in this analysis.

After having determined 3 different criteria values comprising of Density, length and width the weights of these three criteria are required to be determined in the choice function. Weights of each criterion will define the degree of efficacy in the route choice. population density and road width criterion of the criteria while having a positive impact in terms of preference due to the fact that the length criterion would cause loss in terms of fuel and time it will have an adverse effect. The Analytical Hierarchy Process (AHP) method is preferred in order to determine weights. Thus in the first stage the optimization process could be carried out on the route

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that is the component of the public transportation system.

Analytical Hierarchy Process (AHP) model is one of the multi-criteria decision-making methods. AHP provides to the decision-makers, the ability to define the model showing the relationship between complex problems, the main objective of the problem with criteria and sub criteria and the alternatives in a hierarchical structure [11]. Solution of decision problems by AHP may be given as, respectively, forming the hierarchical structure (decomposition), making paired comparisons, calculation of the relative priority (synthesis), calculation of proportion of consistency calculating priority values [12]. AHP method can be described as expressing the synthesis method by putting forward the priority level of the variables according to the obtained results of judgment the hierarchical order of the components and variables of a complex, not well structured situation,according to the comparative level of importance of each alternative to assign quantitative values to related personal jurisdictions and [13].

5 experts in the field of public transport (decision makers) were interviewed as required by AHP method in order to determine the weight of criteria of the population density road width and link length that is the first stage of the optimization of the problem. In AHP the evaluation of decision-makers is very important [14]. In this study, those who complete the questionnaire are the academics who serve as experts in the subject of traffic accidents during a long time in many cases and the decision-makers in the field of public transportation of the local governments.

for the practice of AHP to the experts of each criterion that is compared by himself/herself with the first questionthat the population density, the route length and road width criteria is graded against each other to be the second question to be two questions are asked Muster (Annex 1). In the Questions asked the first three criteria are evaluated individually, then all criteria are investigated with each other mutually. in order for the AHP model to be established according to the answers from experts , analysis of the first question in Table 1.

Table 1. Analysis of the first question

Criteria	Answer1	Answer2	Answer3	Answer4	Answer5	Geom. Avg.	Fact or Ratings
Population Density	**9**	**9**	**9**	**9**	**9**	**9**	**0,490649**
Line Length	**3**	**5**	**5**	**5**	**7**	**4,82865**	**0,263241**
Road Width	**3**	**5**	**5**	**5**	**5**	**4,51440**	**0,24611**
Total						**18,3431**	**1**

In order to determine the relative importance of criteria weight coefficients for each of the three criteria were calculated by implementing the AHP model to the results of the first and second questions by establishing a matrix of paired comparisons. The values presented in Table 2 show the values obtained as a result of AHP.

Table 2. Paired Comparison Matrix

	N	U	G.	Total	Factor Ratings	Weights	Network. Coefficient
N	**0,6020**	**0,5728**	**0,6357**	**1,8105**	**0,4906**	**0,8883**	**0,7453**
U	**0,2289**	**0,2178**	**0,1857**	**0,6324**	**0,2632**	**0,1665**	**0,1397**
G.	**0,1691**	**0,2094**	**0,1786**	**0,5571**	**0,2461**	**0,1371**	**0,1150**
Total	**1**	**1**	**1**	**3**	**1**	**1.1919**	**1**

The weight coefficients of the criteria of population density, the route length and road width criteria among each other has been calculated as respectively, 0.7453, 0.1397 and 0.1150 according to the results obtained in the selection of routes in public transportation systems. According to these results, the population density is the most effective criterion, while the road width has been determined as a relatively less effective criterion. A preference function is prepared in order to analyze the resulting weights, the road network and the bus lines of Canakkale.

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$$T = 0.7453\ x\ N_i - 0.1397\ x\ U_i + 0.1150\ x\ G_i$$ 2

In the above functions;

N_i ,shows Population density value,

U_i, shows the value of route length in the route section,

G_i, shows the width of the section of road along the line.

With this function, the new values obtained are given in Table 3.

Table 3. Çanakkale Public Transport Line Analysis

Lines	Line Length (km)							
	Ç-1	Ç-2	Ç-3	Ç-4	Ç-5	Ç-6	Ç-7	Ç-8
Existing line	23,2	23,3	3,9 2	36,4	9,5	9,5	26	33
Suggested line	22,4	22,5	4,9 2	35	11	13	27	28

Second level optimization

The recommended line values contained in the table, will be used in the optimization in the second phase. In the second stage analyzes will be done with alternatives according to the both of the line length values including both existing and recommendation situations. Objective of the study is to overcome the problems resulting from the route and timing problems. For this purpose in order for the time optimization of the existing public transportation line some data are needed. This data have been determined as:

- Daily average number of passenger
- The hourly distribution of journeys
- Type and capacity of the vehicle to be used
- Routes belonging to line

. Although all of said data are available some assumptions were also used in order to quickly achieve the solution. These assumptions can be summarized as;

- The number of buses to be used are fixed
- Single type of buses
- Hourly journeys are distributed evenly within the relevant hour

. These assumptions are such, so as not affect the content of the work that is intended to be put forth and that will accelerate the achievement of results. Objective function prepared considering all of these criteria and assumptions for the genetic algorithm function is defined by:

$$Min\ Z = \sum_{i=1}^{n} T_k x f_k$$ 3

T_k : the time elapsed between the beginning i and the ending j.

f_k: in order to meet the passenger demand the number of trips to be organized in the relevant time frame.

The "f_k" values to keep the objective function to a minimum to achieve this purpose, there are also the problems constraints to be found with genetic algorithm method, will allow the optimization of departure timetable of public transport system. To achieve this purpose, there are also the problem constraints. Logic constraints and passenger demand constraints, including constraints can be grouped under two headings.

a. Logic Constraints: These constraints are the constraints that are found with genetic algorithm method, ensuring that the number of journeys remain within a one-hour time limit. Therefore, the h value must be greater than or equal to $60/f_k$. Due to the fact that the number of buses would not be enough in the case of a smaller number this constraint may also be called the non-small constraint.

$$h \geq \frac{60}{f_k}$$ 4

In conjunction with this constraint the minimum and maximum number of buses that can be used within the system should also be determined. For this purpose a constraint equation is further prepared in order to determine the upper and lower limits of the number of buses. Here, the lowest value is due to the fact that there are eight different lines. The number 50 indicates the number of buses that we can use in the fleet.

$$8 \leq R_f \leq 50$$ 5

b. Travel Demand Constraints: The number of journeys to be offered in the public transport system in an hour has to meet the travel demand in that hour. In case of failure to meet travel demand Thus such a system will not be able to speak of optimizations it will cause long waiting periods, complaints and overcrowding situation in the buses. It is

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defined as the distance until each full-journey returns to the starting point for Çanakkale bus lines. With this point of view, constraint equation is formed as follows during a full journey of a bus basing on the prediction that it could carry passengers in double the capacity [9].

$$2\ x\ f_k\ x\ q_{cap} \geq O_{ij(hourly)} \qquad 6$$

Existing data and the two different scenarios will be analyzed. According to the morning peak hour trips the situation including the route change and situation including no-change has been fictionalized with the GA for the optimization of lines. All of constraint equations are entered separately for each line. In this way, each line is constrained with its own travel demand and the number of journeys. In the prepared model the number of GA searches (trials) has been selected as 6000. The model parameters of the GA method are as follows [15]:

Initial Population Size: 100
Cross Rate: 0,5
Mutation rate: 0,1

These values are the common model parameters used are prepared for all scenarios.

Results obtained in the consequence of analysis carried out using the genetic algorithm are presented in Table 4. Table 4. Results of the scenario 1 and 2

LINES	Scenario 1			Scenario 2		
	f	h_{min}	T_k x f_k	f	h_{min}	T_k x f_k
Ç-1		11	418		11	403
Ç-2		11	419		11	405
Ç-3		8	574	0	8	598
Ç-4	1	8	699	1	8	672
Ç-5		30	57		34	66
Ç-6		30	29		40	39
Ç-7		12	390		13	405
Ç-8		15	330		15	280
Total	**9**	Min Z	**2915**	**9**	Min Z	**2868**

When the objective function of GA is taken as a reference, it is seen that it gives better results for the morning peak hour in Scenario 2 where there is a route change. Due to the fact that an equal level of service provided by a lower cost with the same number of buses, te plan presented in Scenario 2 is an option that should be the preferred.

Conclusion

In the study the urban public transport systems that are selected as the application subject are an issue that directly affect the daily lives which thousands of people use every day in the city. In transition to fast and environmentally friendly public transport systems has been slow as in many countries, the backbone of the public transport system in Turkey is made of public transportation that is made up by buses on tires The biggest advantage of public transportation made by bus is that it has a flexible structure and the ability to access is higher than the other systems. It will be important that the optimization results realized by the GA method of model are checked by an expert in that area. This control stage will provide an effective security in order not to overlook local features and region-specific demands and to operate the system efficiently.

The obtained results consist of the number of buses and the journey intervals which should be run each week.. The results presented the travel demand so as to create the least cost for the business together with an average occupancy rate.

Previous studies have clearly demonstrated that GAs can be effectively used determining the bus

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timetable and the number in the public transport problems, Together with GA a much more detailed optimization project will be able to be solved by adding constraints to social factors in the model within walking distance, such as the psychological effects by ensuring the participation of experts from different fields public transportation system optimization projects.

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APPENDIX-1: Survey Questions

1. You are asked to make a significance level rating in the first survey population density, line length, and for the width of the route sections in the rest of the way that are considered as important factors in the choice of public transport routes.

Criteria	1	3	5	7	9
Population Density					
Line length					
Road width					

	Absolutely Important	**More important**	**Less Important**	**qual**	**Less Important**	**More important**	**Absolutely Important**	
Population Density								**Line Length**
Population Density								**Road Width**
Line length								**Road Width**