Bus Network Modeling Using Ant Algorithms

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ABSTRACT

Bus transit network modeling is a complex and combinatorial problem. The main purpose of this paper is to apply a contemporary method for designing a bus transit network with the objective of achieving optimum results. The method is called Ant Algorithms, a Meta Heuristic method, which has been applied to optimization problems in transportation with noticeable success. The description of the algorithm, as well as the main methodology and computations, is presented in this paper. Furthermore, a case study using Ant Algorithms applied to the city of Ghazvin, one of the most important suburbs of Tehran, Iran, is presented.

Keywords: Ant Algorithms, Bus, Network, Meta-Heuristic Methods, Optimization.

1. INTRODUCTION

Inspired by ants' normal behavior, the algorithm uses factors in each stage, found by previous searches to be the most optimum. This is accomplished by two key concepts: first, the way each path is selected by the ants, and second, by using the concept of accumulation of pheromone trailing on the paths in order to use the best results for further searches.

Numerical results demonstrate that using this method produces optimum results for determining the best paths for minimizing bus transit travel time. The results, advantages and disadvantages of Ant Algorithms to this class of problems, as well as opportunities for further research, are presented.

2. ANT ALGORITHMS

Ants have a remarkable capability of finding sources of food through a cooperative process using a substance called pheromone. When an ant discovers a source of food, it comes back to inform others about it while depositing a chemical substance, called pheromone, sensible by ants, to mark the path leading to the food source from the nest. Pheromone evaporates over time. Hence, only trails with higher pheromone concentration persist in leading ants to the food sources [1].

This can happen when other searching ants find the food and emphasize this information by laying their pheromone on the ground on the same trails. Thus, less frequently visited (e.g., distant) food sources lose address by evaporation of pheromone markers of the paths leading to them from the nest. As put correctly by Theraulaz, et al., [2], the ants' environment plays the role of a spatio-temporal memory for the ant colony. An ant colony converges toward an optimal solution, while this may not be the case for a single ant in a reasonable time span by this mechanism. It may be shown that this pheromone trail following behavior of a colony of ants leads to the shortest paths between the nest and the food sources. This phenomenon may be exploited to devise Meta Heuristic algorithms for finding appropriate solutions to difficult combinatorial optimization problems [3, 4, 5].

3. METHODOLOGY

To apply this algorithm to a certain network and to perform the required tests, EMME/2 software was selected because of its capabilities. EMME/2 is among the most popular transportation planning software able to model a complete city network and generate detailed reports [6]. Due to this, the EMME/2 software evaluates different alternatives produced by the ant algorithms. This software solves the problem of bus system assignment using the optimum strategy method. Figure 1 shows the general process for solving the problem of designing a bus network using ant algorithms.

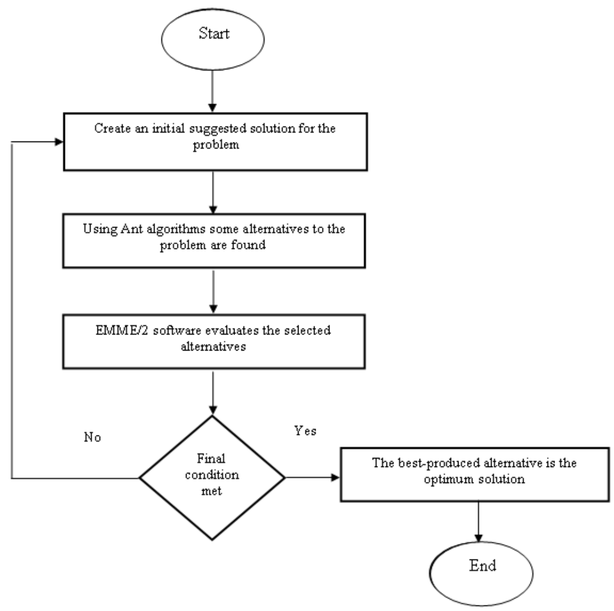

FIGURE 1 Process of Solving the Problem of Bus Network Design Using the Ant Algorithms.

The objective function of the problem is defined as follows:

$$F=T_1+T_2+\alpha K \qquad (1)$$

In this relation T_1 is access time to the system (total time for reaching the station and waiting time), T_2 is the time in a vehicle in the system, and K is the total traveled distance by a fleet and α is the conversion coefficient of costs.

The value of α can be determined by using the information of bus companies' costs and distance traveled by their fleet. Because α is one of the model parameters, by changing it the proportion of important parameters of the objective function can be changed.

In designing the bus network system, the terms in the algorithm of ants system will be defined as follows:

The number of ants in the system of bus network will be converted into the number of alternatives, the ants' pheromone of path will be converted into the effect of the path alternative, and the evaporation coefficient will be converted into the deletion coefficient of path. Logit model has been used as a possible function of selection in this paper, considering the nature of performed investigations and research subject. This gives the ability to assign negative points to those answers that have negative function in the selection method. Because of given explanations, the possible relation of selection has been considered in this paper as follows:

$$P_{R,ANT} = \frac{e^{f_R}}{\sum_{R=1}^{n} e^{f'_R}} \qquad (2)$$

In the above relation, P_R is the probable selection function, f_R is the effect of path alternative R, and n is total number of suggested bus paths, which have that ability to be chosen by an alternative.

Regarding the ant algorithms, the likelihood of selection has a direct relation to the number of alternative paths. That means the more the amount of the effect of alternative paths, the more possible selections. On the other hand, if a number of suggested paths produce a better answer, (objective function of the selected number is a smaller amount), and the more effective the alternatives should be placed on the paths. Then, the improvement amount in the objective function ΔF is one of the efficient factors in effectiveness of alternatives. Therefore, whenever the amount of transferred passengers by a bus line in a path is increased, it shows the high efficiency of that line. Thus, the number of transferred passengers influences the amount of alternative effect placed on each path.

Therefore, the effect of alternatives placed on the paths will be computed from the following relation:

$$F_{R,ANT} = \beta \left(\frac{L_R}{L}\right) \times \Delta F \qquad (3)$$
$$L = \sum_{R=1}^{n} L_R \qquad R \in feasible(ant)$$

In the above relation, L_R is the number of transferred passengers through path R, and L is the total number of transferred passengers in the selected complex of alternatives. β is an equal-marker coefficient for alternative amount. On the other hand, from a selection in which the domain of changes in the amount of ΔF is in high levels, the sensitivity of the e^x function to it is negligible; the coefficient β will cause meaningful changes to the alternative effect through internal changes of the objective function. This coefficient has been considered by trial and error to be equal to β =0.001 in the section of model process.

After all alternatives place their effect on the paths, the effect of the alternative for each path will be computed and some amounts will be deleted. This process will be stated as the following relation:

$$F_R(n) = \sum_{ant=1}^{n} F_{R,ant} + (1-\gamma) F_R(n-1) \qquad (4)$$

In the above relation, $F_R(n)$ is the amount of alternative effect of path R in the nth repetition of the program and γ is the coefficient of path deletion.

4. CASE STUDY

In order to apply this model, the Ghazvin bus system was selected. To apply this model to Ghazvin, it is required to introduce into the model the information of demand and supply for Ghazvin city obtained by the survey.

In Ghazvin network, in addition to 17 existing bus lines, 16 new lines were introduced as ring and shuttle, which raised the total to 33. Possible modes for selection of an optimum path have been 2^{33} modes, and in this program, the suitable modes are selected using the ant algorithms.

In this project, optimum strategy will be used for assigning public transportation vehicles. The data for travel demand was collected from a survey of Ghazvin, and in accordance with this demand, the matrix of travel demand

(OD) was obtained separately for different transportation vehicles. Supplying data of physical features of the passengers' network and the information of the public transportation system including the information for travel path, origin-destination, travel time and stop time in origin and destination stations have been used. Using this information and EMME/2 software, the volume of passengers in each line, coming and going time in each line and the number of boarded and alighted passengers can be found. Figure 2 shows the transferred volume of passengers in the Ghazvin bus system. As was indicated, objective function is equal to the sum of costs for system authorities and users.

The outputs of EMME/2 software are the parameters of access time to the system, inner time of transportation vehicle and conversion coefficient of cost.

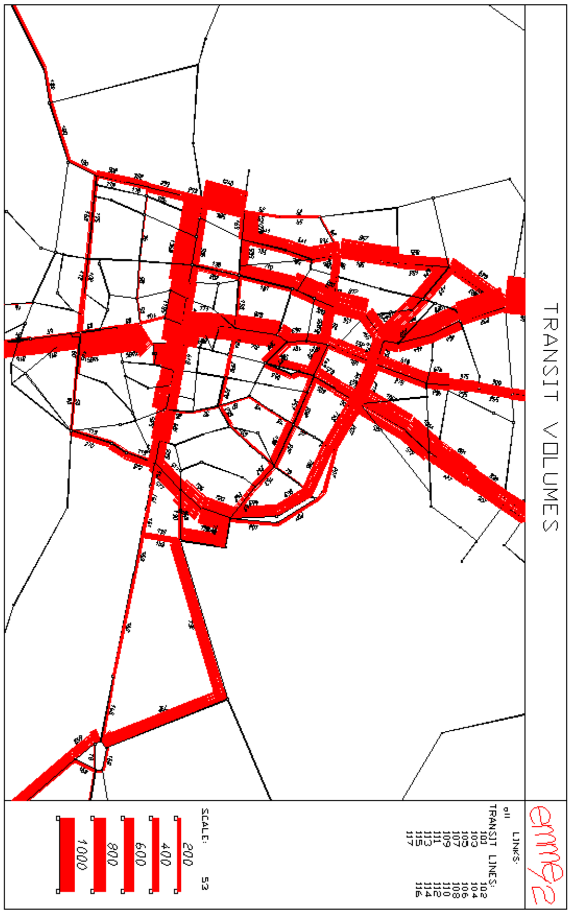

FIGURE 2 The amount of transferred passengers in Ghazvin bus system at morning peak hour.

5. NUMERICAL RESULT AND DETERMINATION OF OPTIMUM BUS LINES NETWORK

In this research, the model works with parameters γ =0.5, Ant=6, Cycle=8 as optimum, and the best obtained answer includes 14 lines from 23 suggested lines. The objective function is equal to 5858 for these paths that have improved the position about 30% in proportion to the objective function of the current situation, which was 7600. The results of running EMME/2's suggested alternative and its comparison to the current situation of Ghazvin city's network are shown in table 1. As seen in this table, the average speed of 37.7km/h (23.4mi/h) rose to 37.8km/h (23.5mi/h) which has increased about 0.26%, and due to this some number of passengers of personal transportation vehicles have used public transportation vehicles and the streets have become less congested. Furthermore, increasing (0.1 km/h) (0.06 mi/h) in speed reduces costs. Studies have shown that increasing one unit to the average speed in one city will provide more money for constructing new roads because the bus line network's efficiency has improved. Figure 3 shows the number of transferred passengers in the bus system of the city of Ghazvin.

TABLE 1 Comparing the Results of Suggested Alternative to the Results of the Current Condition

Type of vehicle		Current condition	Suggested alternative	Percent of change	Note
Average speed in the network	(km/h)	37.7	37.8	0.26	Some number of passengers Of personal transportation, vehicles have used public transportation vehicles and the streets have become emptier.
	(mi/h)	23.42	23.48		
Number of boarding passengers		17721	19356	9.23	---
Total travel time of passengers inside the vehicle (hour)		3423	2819	17.64	---
Average speed of passenger inside the vehicle	(km/h)	15.5	14.8	-4.52	Increasing use of public transportation has caused a decrease of speed in the lines.
	(mi/h)	9.6	9.2		
Total traveled distance of passengers	(km)	52932	41827	-20.98	---
	(mi)	32890	25990		

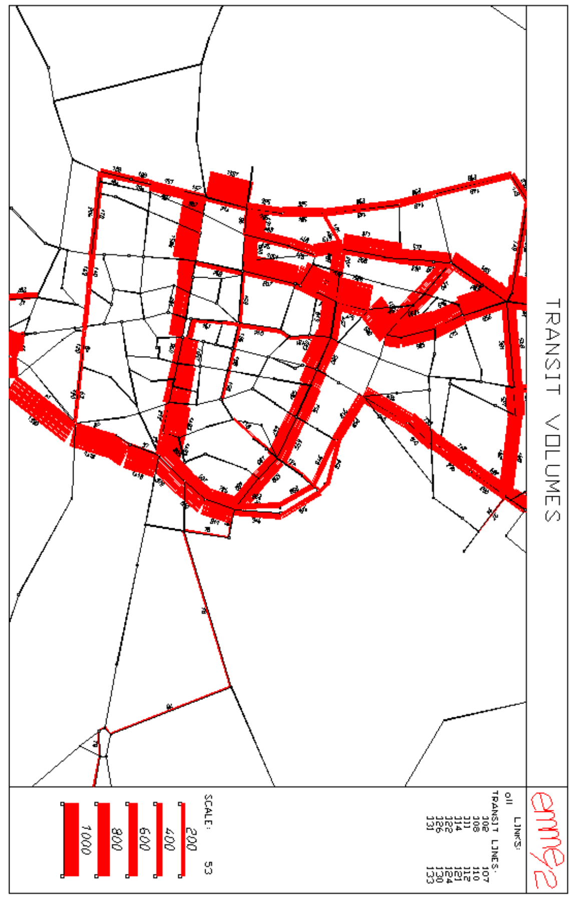

FIGURE 3 The amount of transferred passengers in Ghazvin optimized bus system at morning peak hour.

6. CONCLUSIONS

The new method for designing bus paths based on ant algorithms is able to make considerable improvement for a bus network system by determining suitable paths to reach target function.

The results show that, with a limited fleet (fleet is fixed), objective function can be improved up to 30%. In this mode, total travel time spent by passengers in public transportation has decreased by 17.64%, and total traveled vehicle-kilometers (vehicle-miles), which is an indicator of system authorities' costs, has been decreased by 20.98%.

The model applied to the Ghazvin bus network system can be applied to other bus networks, but the effects of parameters such as coefficient for path deletion, the number of alternatives, etc., should be investigated to determine the efficiency of this method. Such an investigation is necessary because sensitivity analysis of the parameters affecting the bus network shows the effects of the parameters in the optimization of the objective function.

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