Prediction of Modal Shift Using Artificial Neural Networks

Kadir Akgöl [1], Metin Mutlu Aydın [1], Özcan Asilkan [2], Banihan Günay [1]

[1] *Civil Engineering Department, Faculty of Engineering, Akdeniz University, Antalya, Turkey*
[2] *MIS Department, Faculty of Economics and Administrative Sciences, Akdeniz University, Antalya, Turkey*

Abstract **– Various public transport concepts have been developed to provide solutions to the ever growing problem of traffic in modern times. For instance, intelligent subscription bus service is one of them. This concept aims to provide a means of transport at near private car comfort as well as at near public transport cost. By this means, a shift from other modes of transport, especially private car, to public transport is aimed to encourage use of public transport. An artificial neural network model has been developed in this study to be able to calculate modal shift using three sources of data obtained from two questionnaire surveys conducted at Akdeniz University campus and a computer model's output (based on shortest route algorithms). The relationship between the results of the second questionnaire survey and the other data have been entered into Weka and Rapid Miner programs, the accuracy of this machine learning has been calculated and finally the modal shift originated by the intelligent subscription bus services has been estimated. The findings have yielded very reliable results which revealed the potential of applying the technique easily to similar problems.**

Keywords **– Flexible public transport systems, artificial neural networks, modal shift.**

1. Introduction

Improving the quality of journeys in urban transport deserves special attention in terms of efficient and productive use of existing road capacity. The “Vehicle Focused” transport planning requires the increase of transport capacity, namely constructing more roads. As a result, the enlarged living spaces and the lengthened distances force people to drive more and hence increased traffic. The effort to find solutions to the ever growing traffic problem by means of measures encouraging the use of vehicles do not solve traffic problems but rather defer them to a later date. A fundamental solution for this problem is to facilitate intelligent transportation systems and to achieve such works that will shift people to public transport. The benefits of public transport are listed as reduced traffic congestion, achieving more reliable traffic, fuel and energy saving, less environmental pollution caused by exhaust emission and reduced parking problem according to [4]. The service quality of public transport has not been sufficiently upgraded when the contemporary standards are taken into account according to [5]. Also, proper operation of the systems in terms of speed, comfort, reliability and safety, preserving environmental, urban and historical assets and utilizing the capacity of existing infrastructures and facilities has not been in practice yet. In a study conducted for England, it has been reviewed flexible transport systems and grouped in terms of economic framework, technologies, service design, service management, marketing and promotion, and cooperation (partnerships) [2]. The service was mainly applied in rural areas because of its design and operation. Although the system is not yet challenging, with more research in the future, it could be made a very precious service if conducted at the right place, at the right time and with accurate planning according to [6].

Experts working on public transport are needed for the popularization of flexible systems according to [7]. The duties of such experts are the following: preparation of interviews with reference to the data concerning transportation problem, provision of easy access to the system, provision of assistance and control services, following the test results at a given level of service and customer satisfaction, and making decisions and implementation of them if the service is verified in terms of different perspectives. With the help of experts working on public transport, can be promoted flexible transport systems in socially excluded regions, where transport services are insufficient. It has been chosen the main campus of Akdeniz University as a pilot area, developed the concept of intelligent subscription bus services (also called A-service) by [3]. This concept is defined as a flexible and dynamic public transport system, working under a reservation structure and is based on the principle of providing transport with a minimum journey time. They conducted interviews covering address information and times of arrival and return, in order to define the transport characteristics of the people who make regular journeys to the university and to determine at what hours there are transport demands to the campus. By modelling the use of A-service for each journey to the campus of every interviewee, they calculated the new journey time and the mileage to be covered for each person. They

forwarded the defined transport information to the e-mail addresses of all interviewees one by one and thus defined the A-Service and asked them if they would prefer A-Service or not. They enlarged the second interview by employing an interviewer, thus they completed the study with a return rate of 80% in the second interview. Then they calculated the potential modal change, in other words the amount (in percentage) that A-Service shall draw from other modes of transport.

In this paper, the results obtained (in the above study) from the persons who have replied to the second interview are used as the data set and it is estimated by Weka and Rapid Miner programs using artificial neural networks, one of the artificial intelligence methods, if those who do not reply the interview will prefer this service. Also the levels of accuracy of these estimates will be calculated using the same programs. Thus the amount of change that intelligent subscription bus service concept shall create on the distribution of the use of modes of transport shall have been calculated to cover all interviewees and it will be compared with the results of the study conducted by [3].

2. Material and Methods

In order to be able to calculate the modal shift that the intelligent subscription bus service will cause, firstly it is necessary to determine the distribution of the use of the existing modes of transport. For this purpose, the following information concerning the existing transport characteristics of the interviewee were obtained from the Questionnaire-I data of the study conducted by [3], at the main campus of Akdeniz University:

- Modes of transport for their journeys to the campus
- The level of satisfaction of their existing mode of transport
- The order of preference they would have made if they had the chance to elect the desired mode of transport for travelling to the campus
- What reservation technique will be chosen for a bus service operating on such a reservation basis,
- Profession,
- Age,
- Gender,
- Current journey time to the campus,
- Current journey cost to the campus.

Also in the same study, the following was determined to use in the modelling of the intelligent subscription bus service concept:

- Address information (district, area, street).
- The hours of commuting to the campus according to the days in a typical week.

Finally, their e-mail addresses were requested in order to access these people for a second time. At the end of the study a data set of 606 people was obtained. The use of this service by the interviewees was modelled, the new journey times were calculated, and the results were forwarded to the same people via their e-mail addresses, and finally, if they would prefer the intelligent subscription bus service were asked. Also the interviewees were informed of the detailed definition of A-service. The returns of 194 interviewees, who replied the e-mails, were included in the data set of 606 people. The data set was arranged in such a way that those who replied the second interview and those who did not (Table 1) were grouped into two separate sets.

While creating the data sets shown in Table 1, the first 16 columns, which are thought to be effective on preferring A-Service by the interviewees and their final preferences, were given. A relationship is established between the input and output data by means of artificial neural networks. The input data in the artificial neural network models are weighed and correlated with output data. But no mathematical equation is formed in the model. A learning process takes place by using the first data set (Table 1.a) where the input and output are. After the learning process takes place, the resulting data in the data set having the input data shown in Table 1.b, can then be estimated. Also the learning process can be tested and the level of accuracy can be defined at this stage. Artificial neural network models are divided into two groups like feed forward and back propagation. It was used Elman artificial neural network model with feed backward and Multilayer perceptron artificial neural network model with feed forward and back propagation by [1]. They concluded that Elman artificial neural network model gave better results for modelling dynamic systems whereas Multilayer Perceptron networks were more widely used for cost estimation. It was found appropriate in the present study to establish artificial neural network models with feed forward and back propagation (Multilayer Perceptron).

Table 1. (a) A sample data set for those who replied the second questionnaire, (b) those who did not.

(a) TRAINING DATASET																
Transportation Mode	Public Transport	Service	Passenger Car	Motorcycle	Bicycle	Pedestrian	Satisfaction Degree	Reservation Type	Profession	Age	Gender	Travel Time	Cost(₹)	A-Service (km)	A-Service (min.)	Choice
Passenger Car	1	2	3	5	4	6	1	Ringing Centre	AcademicStaff	52	Male	10	1.4	2	4	No
Passenger Car	2	1	3	6	4	7	1	Calling Centre	Academic Staff	62	Male	30	4.2	16	26	Yes
Pedestrian	3	2	1	1	1	4	4	Ringing Centre	Administrative staff	27	Female	25	0.0	4	10	Sometimes
Bicycle	2	6	3	5	1	4	8	Smart Phone App.	AcademicStaff	42	Male	20	0.0	4	9	Sometimes
Bicycle	2	5	1	6	3	4	5	Sending Message	Student	22	Female	50	0.0	5	10	No
Pedestrian	2	1	6	5	3	4	2	Internet	Student	27	Male	50	0.0	4	9	Sometimes
Public Transport	4	3	1	2	6	5	5	Calling Centre	Student	18	Male	70	1.0	17	32	No
Motorcycle	3	2	4	1	5	6	2	Calling Centre	Administrative staff	32	Male	10	1.8	2	3	Yes
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(b) TEST DATASET																
Passenger Car	5	3	1	2	4	6	1	Sending Message	Student	22	Male	45	1.6	5	13	?
Passenger Car	1	7	1	7	5	6	1	Calling Centre	Student	22	Male	15	2.5	12	24	?
Motorcycle	2	1	4	3	6	7	3	Internet	AcademicStaff	32	Male	15	2.9	5	10	?
Pedestrian	5	4	1	2	3	7	10	Sending Message	Student	22	Male	60	0.0	5	8	?
Pedestrian	4	3	1	2	5	6	5	Calling Centre	Student	22	Female	15	0.0	3	7	?
Bicycle	1	2	3	5	4	7	10	Calling Centre	Administrative staff	37	Female	25	0.0	4	7	?
Public Transport	5	4	3	7	1	2	6	Ringing Centre	AcademicStaff	27	Female	50	1.8	7.5	16	?
Public Transport	4	3	1	2	5	6	8	Calling Centre	Student	22	Male	45	1.0	5.5	11	?
Motorcycle	5	6	2	1	3	4	1	Calling Centre	Student	32	Male	15	1.2	4	7	?
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While developing the model, learning rate decrease in time was prevented. The number of hidden layers was automatically defined. The parameters defining learning rate were left as "learningRate=0.3", "momentum=0.2", which are the assumed values. All data were converted into "1 and "0" values in binary base. The data were normalized on the basis of property and class. Finally it was deemed sufficient to have 500 training time for the learning process and the model was then completed (Figure 1). In Weka program, the experience and the recommendations of [8], were used in defining the learning parameters.

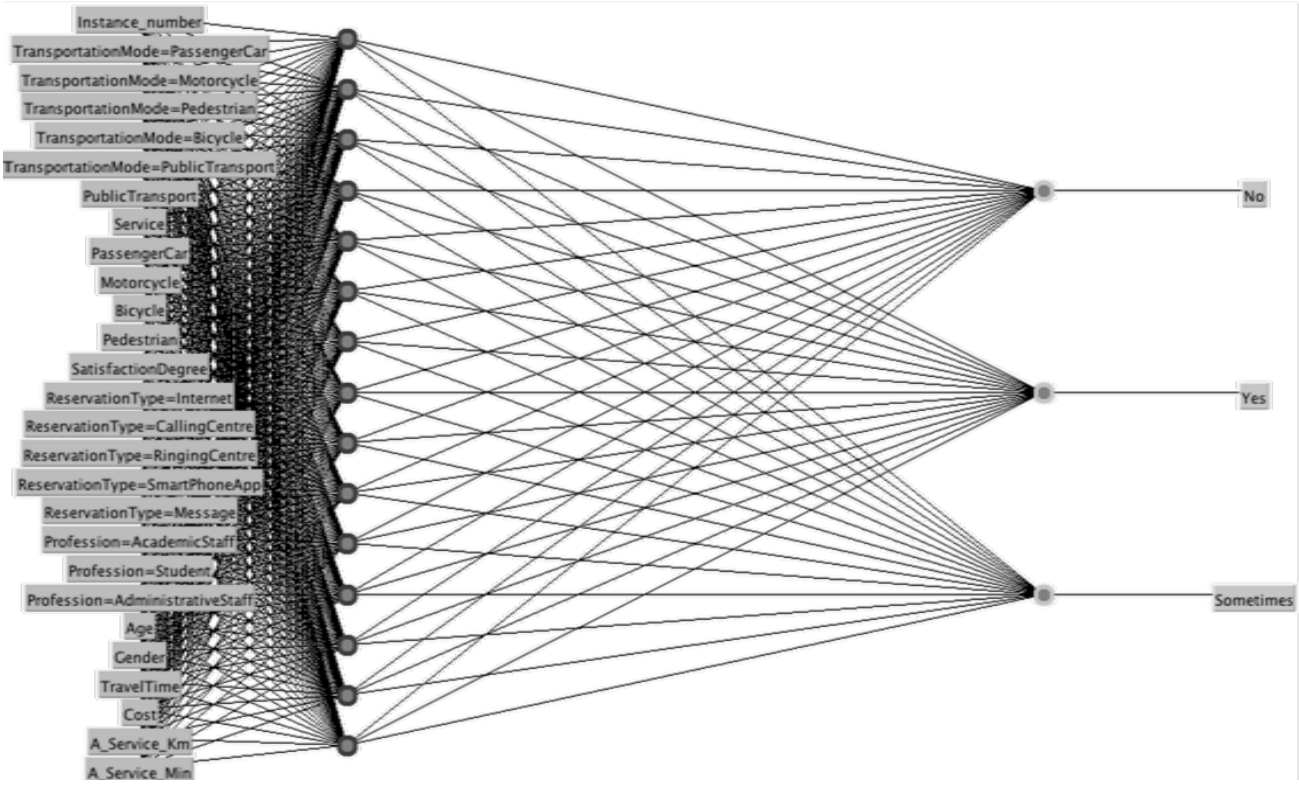

Figure 1. Multilayer Perceptron (MLP) artificial neural network.

The artificial neural network model was evaluated at Weka and Rapid Miner models one by one and estimated data were obtained. When the accuracy of the learning process for the first data set was tested with Weka, the result was 99.48% accurate and when tested with Rapid Miner, the result was 89.69% accurate.

After the missing data in the second data set are completed through estimation, in order to test the consistency of the results, the data were subjected to another learning process and an accurate classification of 97.82% was obtained with Weka and of 85.54% with Rapid Miner. Also the results obtained in both programs were compared with actual data (Figure 2).

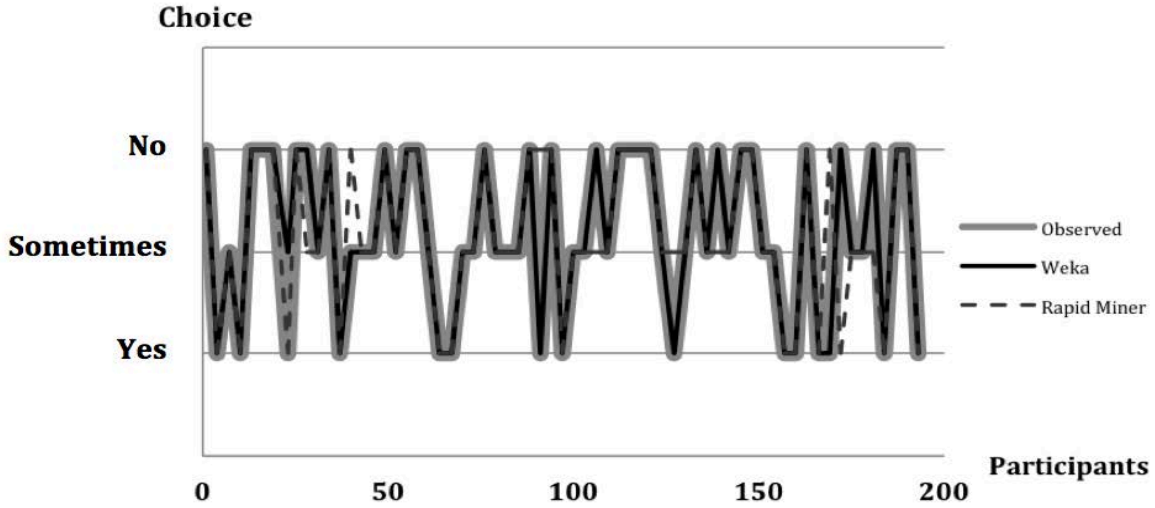

Figure 2. Comparison of Weka and Rapid Miner data.

As seen, while the actual and estimated data given by Weka give different results at one point only, the estimated data obtained by Rapid Miner give different values at more points. The reason why the analyses carried out with Weka and Rapid Miner produced different results is due to the use of different algorithms. But the accuracy of the estimate at Rapid Miner program was 89.69%. Because accuracy of the analyses with Weka was higher, it can be claimed that more reliable results could be obtained in similar studies by using Weka program. The remaining part of the study was carried out using the estimated data obtained by Weka program.

Thus, data loss originating from those not replying to the second interview was eliminated.

3. Results

Through the estimated data by the program and the replies of the participants to the second interview, the results regarding whether 660 persons would use the intelligent subscription bus service (A-Service) or not were obtained. Firstly, the preference of A-service by the persons using various other transport modes was investigated (Figure 3).

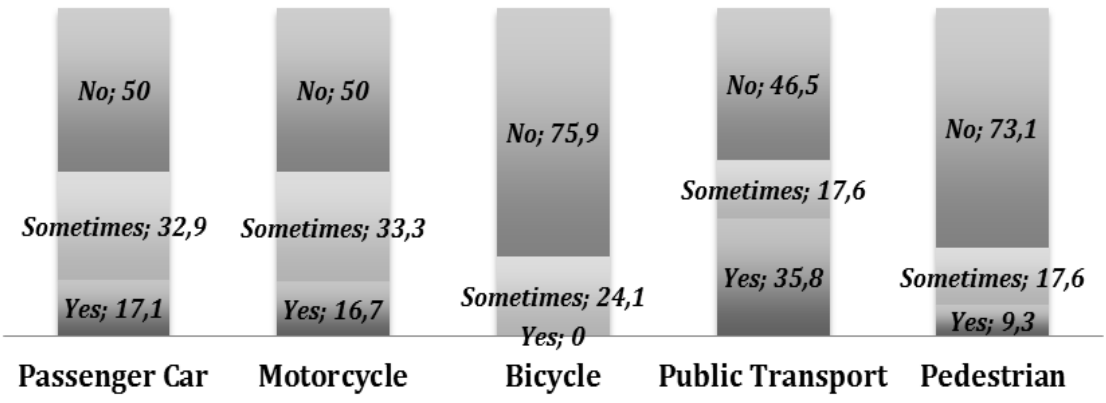

Figure 3. Preference of A-service by the persons using other transport modes (%).

Such reasons as cycling having no major running costs and Antalya being an ideal city for cycling (weather, existing bicycle routes, topography, etc.) had an effect on the lack of interest towards A-Service. Such reasons and living in the neighbourhood of the campus are also valid for pedestrians for not preferring A-Service. But, longer walking times for the pedestrians when compared with bicycle slightly increased the interest towards A-Service.

Automobile drivers and motorcycle riders are the group, which is expected to contribute much to the modal change. For this group a 50% modal shift to A-Service is achieved. This contributed the most to the overall modal change. Public transport users have been the group showing the highest interest to A-Service. Because A-Service is more expensive than traditional public transport, 46.5% of participants did not prefer this service. Preferences according to profession and gender are given in Figure 4.

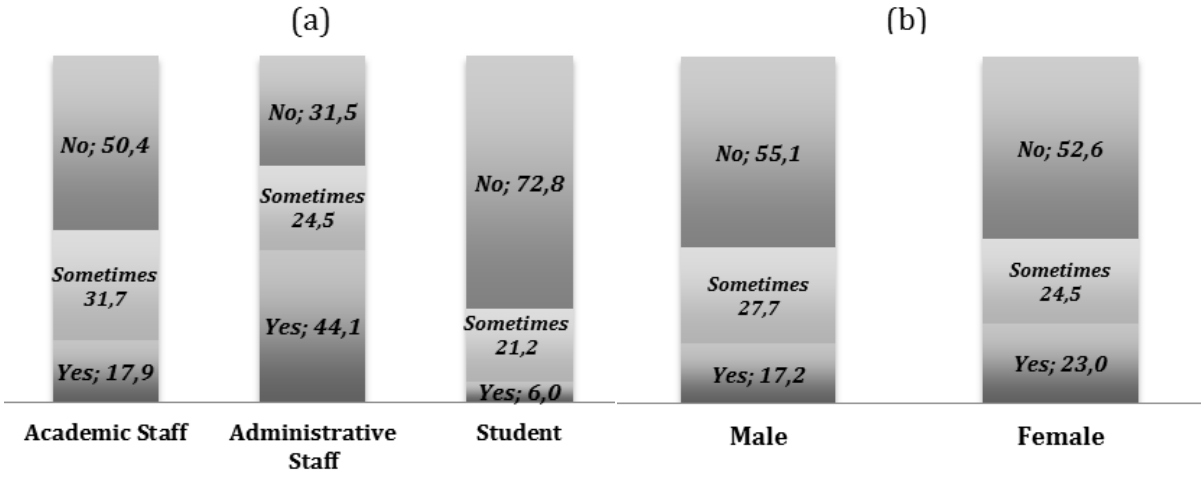

Figure 4. Preference of A-Service according to (a) Profession and (b) Gender (%).

In Figure 4.a, academic members of staff prefer private cars because of time and comfort, and students prefer traditional public transport, which is more economic, the shift to A-Service is low. On the other hand, other staff did find A-Service attractive. In Figure 4.b, preference of A-Service by women is slightly higher possible because they are more sensitive to environment and intolerant to traffic problems. To study the satisfaction levels and preference of A-Service (Figure 5), those who are most satisfied are represented by '1' and the least satisfied are denoted by '10' compared with their existing modes of transport.

Although the modal shift by those who are most dissatisfied is more, it is seen in Figure 5 that it has the potential to attract people from every satisfaction level of the service. In Figure 6, participants were grouped according to the transport mode that they would have chosen if they had been given the chance to select. As seen clearly, A-Service would cause the participants who tend to shift to different transport mode would have an effect on changing their preferences.

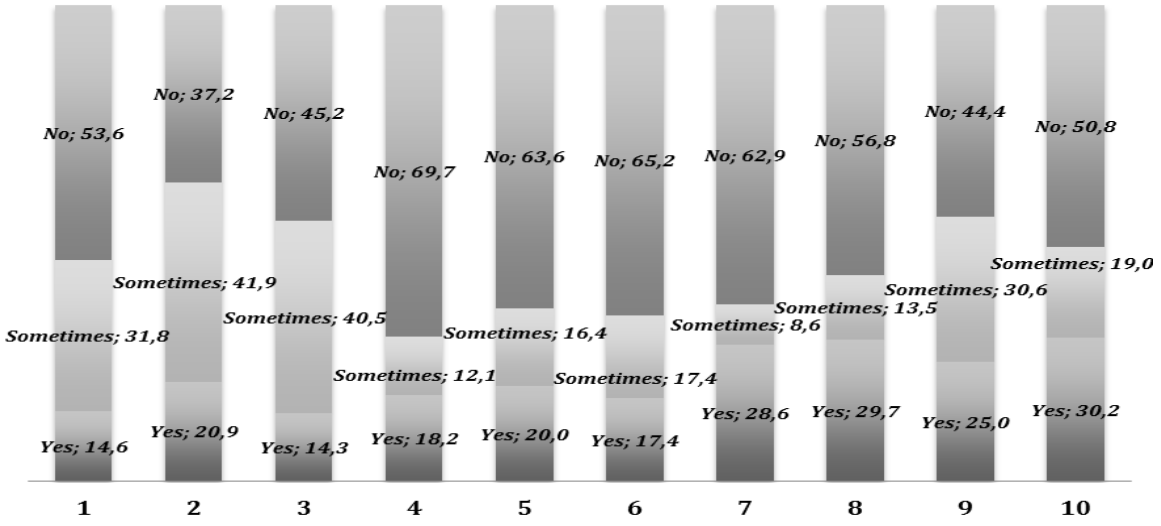

Figure 5. Level of satisfaction (between 1-10) from existing transport mode.

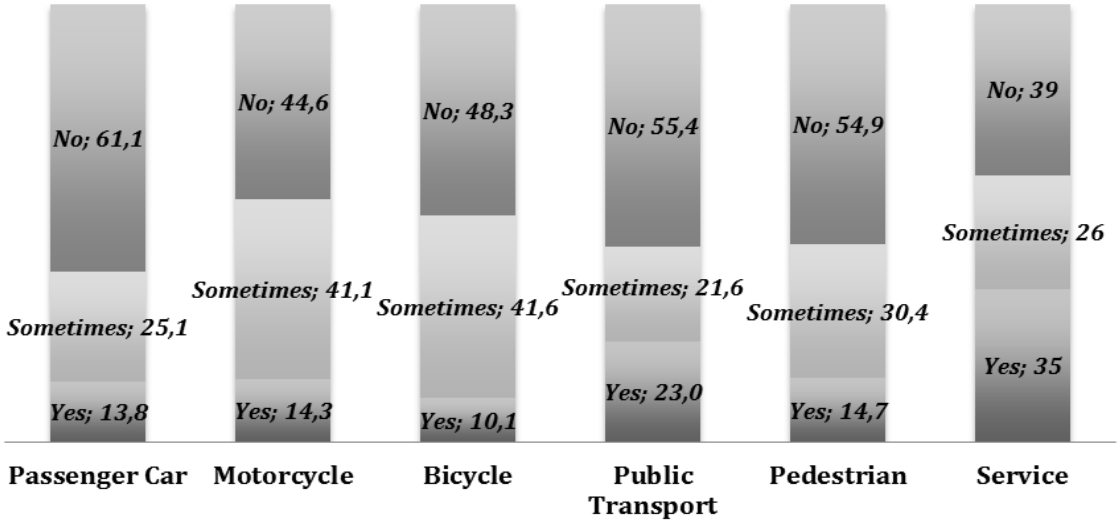

Figure 6. Preference of A-Service according to the transport mode that the participants would like to choose (%).

As seen in Figure 7, whilst the rate of use of passenger car is 48% in the existing situation, it is drawn back to the second ranking with 24% after A-Service was launched. A-Service ranks first with 46%. This may show that an alternative service to be launched in public transport would be an important step taken in the solution for traffic problems in general.

Finally, the mode distribution obtained by [3], and the mode distribution obtained in this study are compared (Figure 8). It is generally observed that the results are quite close implying once more that the estimates made by artificial neural network are reasonably rational.

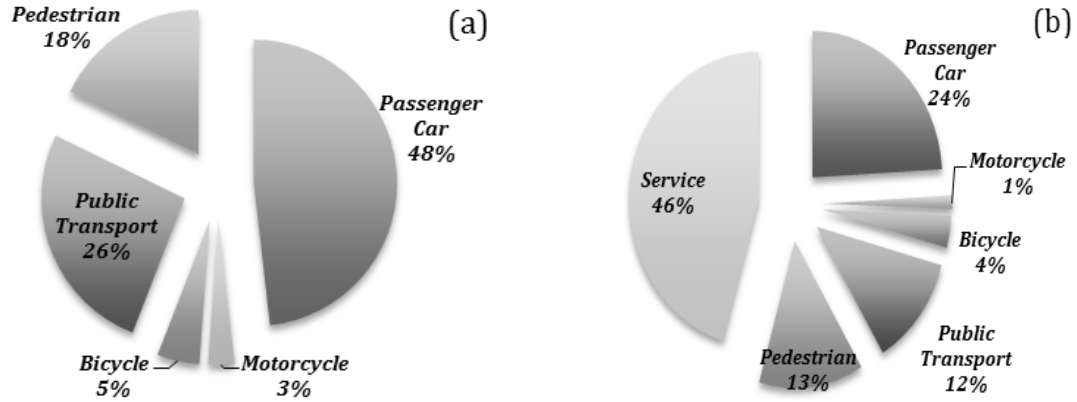

Figure 7. Distributions of transport modes (a) in the existing mode and (b) when A-Service were to be launched (%).

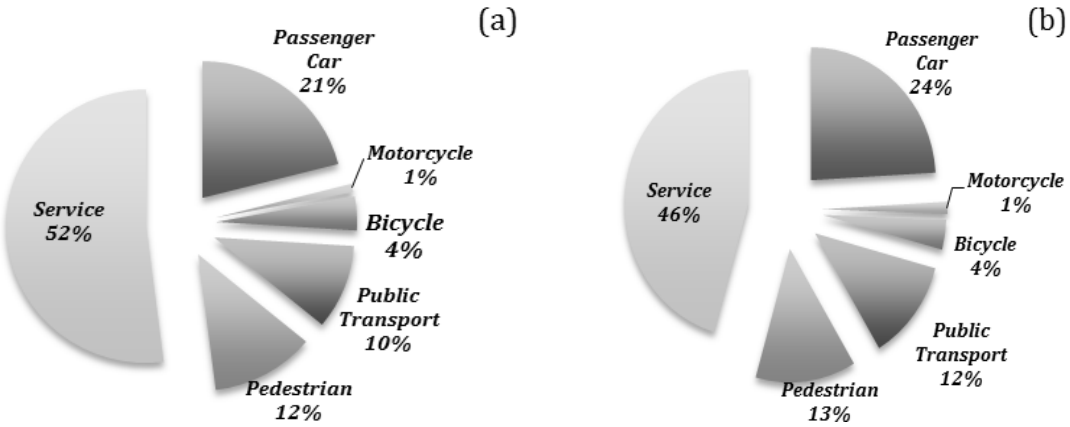

Figure 8. Distributions of transport modes calculated (a) according to those replying the second interview and (b) according to artificial neural network.

4. Results

In this paper, an artificial neural network with feed forward and back propagation was created in order to define the amount of modal change, which the intelligent subscription bus service concept would bring among various modes of transport. Analyses of the results revealed that an estimate was made on accuracy level of at least 95%. Careful selection of input data and the selected artificial neural network has a high effect in the attaining of such a high figure. It was observed that the intelligent subscription bus service concept, which was designed by this study conducted at Akdeniz University campus, had also effects on the modal shift for commuters to the campus. Launching such a service for a campus may not be very sufficient in solving the traffic problem of a city but applying the idea to similar places like airports, bus terminals, shopping centres etc. will have a larger effect.

If the estimation had been based on the second interview instead of completion of the missing data by establishing an artificial neural network, the modal shift, which was 46% in reality, would have been wrongly estimated as 56%.

Such an evaluation, which is made by using less data, would yield a misleading result with an error rate of 10%. Also, because there was a data loss of 68% in Interview-I, a study would be made with a data set of 32%. With the artificial neural network model created, all data obtained in Interview-I was used and the study was completed. With the artificial neural network model, the transport characteristics of those who regularly travel to the campus were defined thus the amount of modal change in transport will be easily calculated by using some information (like address, gender, age, etc.), which could be obtained without an interview. By this study the effect of intelligent subscription bus service concept on modal change is shown and the artificial neural network can be one of the most important and useful tools for such analyses. Also, in this paper, it was found that Weka yielded more successful results when compared with Miner.

Acknowledgements

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Corresponding author: Özcan Asilkan
Institution: Akdeniz University, MIS Department, FEAS, Antalya, Turkey.
E-mail: oasilkan@akdeniz.edu.tr