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ESTIMATION OF HIGHWAY TRANSPORTATION DEMAND IN TURKEY BY ARTIFICIAL NEURAL NETWORKS AND THE EFFECTS OF OTHER TRANSPORTATION SYSTEMS TO HIGHWAY TRANSPORTATION

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Abstract

In this study, highway transportation demands were estimated until 2020 by artificial neural network (ANN) approach using socio-economic and transportation data. The time series data between 1980 and 2005 were utilized for the model development. The data between the years of 1980 and 1999 were used for training and the remaining data was employed for testing. Population, gross national product and the number of vehicles were used as inputs while the values of passenger-km, ton-km and vehicle-km were taken as outputs in the models. The sum of passenger and fright vehicles was considered for the estimation of vehicle-km, but only the number of passenger vehicles and fright vehicles were taken into account for the estimation of passenger-km and ton-km, respectively. In the ANN models all data were normalized between 0.1 and 0.9 interval. The sigmoid and linear functions were used as activation functions with feed forward-back propagation algorithm. The model estimates and observed values were compared in terms of mean absolute percentage error (MAPE), mean absolute error (MAE), and root mean square error (RMSE). Considering passenger and fright demand shifts among transportations systems some evaluations were presented based on three different scenarios for future highway transportation demand using ANN estimates. The scenario results will help planners and decision makers to develop new transportation policies and strategies.

Keywords: Transportation demand models, artificial neural networks, highway

1. Introduction

Transportation which has been defined as the movement of people or goods in a fast, economical and safe way from one point to another for the purpose of creating more time and place is an important service playing a role in developing both national and international economical, social and cultural activities. Dynamism and social development of a country’s economy are directly associated with the means of transportation. As a result of this, the transportation activities need to be carried out by the applicable plans and policies which are prepared by considering the features and necessities of the country. For this purpose, transportation capacity that will be able to respond the needs should be created and the coordination between different means of transportation should be provided by proportioning this capacity well balanced among the transportation systems [1, 2]. However, the transportation is based on highways in our country today and, passenger and freight transportation are largely conducted through this transportation system. Although it is possible to use the other transportation systems in our country, about %95 of the passenger transportation and %92 of the freight transportation are carried through the highway transportation [3]. Transportation demand which is mainly on highways brings about many problems including traffic safety, and this situation opposes the basic principles of the economical and safe transportation which are the main purposes of transportation.

The main reason for our transportation system being through highways today is the adoption of the main highway transportation policies in historical development. The highway transportation has started with the foundation of the Republic, but the real development of the highway transportation was after the World War II. The financial supports taken from the USA and the foundation of General Directorate of Highways and

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the increase in funds for constructing ways have increased the construction of the highways. While the total length of highways was 47000 km in 1950, it became over 61000 km in 1960. Today, the total highway length in our country is about 64000 km and, 2000 km of that is the motorways and, the state and the country roads, which are nearly at the same length, constitute the rest of the total length.

The increase in the Gross National Product (GNP) depending on the economical developments, which is parallel to the growth of the country's population has caused an increase in the number of vehicles, and therefore, in the vehicles-km on the roads. The number of vehicles which was 36000 in 1950 exceeded 13 millions, increasing up to 360 times of its initial value at the end of 2007. In the same period, the population, which was 21 million, reached to 71 million. GNP inreased in that period of time in Turkey and the per capita income went over $9000 in 2007[4].

This socio-economic acceleration has showed its effects in the highway transportation inside the country. While the ratio of the highways in the transportation of passengers and freight among all of the transportation systems in 1950 was %49.9 and %28.9, respectively, this ratio went up by %95 and %92 in 2007. Depending on that, the vehicle movements reached 69.6 10^9 vehicle-km from 0.56 10^9 vehicle-km and the passenger movements reached 209,1 10^9 passenger-km from 2,6 10^9 passenger km. The fastest increase was observed in the freight transportation, and the value of ton-km has increased by about 190 times and has reached 181,3 10^9 ton-km from 0,96 10^9 ton-km [4].

The energy which was used in transportation sector in our country constıtuted about %16 of total energy consumption. The energy consumption in the highway transportation in 2007 was 14 368 Tep, and this amount corresponds to %83 of the total energy consumed in the transportation sector [4].

Because of the transportation system which is mostly based on highways, the traffic accidents and the deaths and injuries as a result of these accidents have reached significant levels. According to the data of 2008, over 929 thousands of traffic accidents happened, and nearly 4 thousands of people died and over 183 thousands of people were injured [5]. All of the indicators mentioned above show that the current transportation system is creating a problem and forming a sustainable transportation is obligatory. The prospective transportation demands obtained from the available data need to be estimated for a sustainable transportation plan. The reliability of demand estimation depends on the determination of the factors affecting the accuracy of the demand, the reliability of the data belonging to these factors and the methods used in the demand estimation. The regression analysis which is one of the traditional estimation methods has been used widely in the prospective demand estimations. However, although there is a great relationship between the dependent variable and the independent variable in the models established with this method, there may be some deficiencies in the models. Consequently, in this article the highway transportation demand is estimated by making use of the Artifical Neural Networks (ANN) which has recently been used more widely in the solutions of the engineering problems and the demand shifts among the transportation systems have been evaluated by considering the possible scenarios which would happen in the future.

In the literature, the developed transportation demand models utilizing artificial intelligence techniques, which are mainly ANN, are available. Nijkamp et al. analyzed the model split problem with the traditional logit model and ANN model in their study. They studied the model split between the modes of railway and highway related to the high-speed railway technology in Italy and stated that the model of ANN performed better [6]. Demir investigated the use of ANN in the transportation planning in his study. He used three model practices by using both regression analysis and ANN in modelling the transportation demand which is one of the most important parts of the transportation planning and has compared his results. He has stated that ANN gives better results compared to the regression analysis [7]. Tortum modelled the mode choices with ANN and the integrated neuro-fuzzy systems in the intercity freight transportation and compared his results to the classical models. He claimed that ANN and the integrated neuro-fuzzy system models are more successful than the classical models in representing the non-linear attitude of freight transportation [8].

Haldenbilen et al. evaluated the demand of intercity transportation in the entrance procedure to the European Union in terms of sustainable development and have stated that the demand-based macro planning is beneficial in terms of directing the investments to the other systems and calculating the external effects of transportation [9]. Haldenbilen and Ceylan developed a genetic algorithm model which is another subbranch of artificial intelligence and the genetic algorithm demand estimation models which use socio-economic data to be able to determine the intercity transportation demands. With the help of the selected models, they have tried to estimate the expected passenger, freight and vehicle-kms on the intercity roads in our country by 2025, and made recommendations by comparing their values to those of the European Union countries and evaluating in them through long-term planning [10,11]. In another study, Haldenbilen and Ceylan developed four different types of demand estimation models with genetic algorithm approach using the population, numbers of vehicle and GNP data. They estimated the transportation demands in the future using the best model and made suggestions for transportation demand management by developing three different scenarios [12].

Çelikoğu and Cığızoğlu made a comparison between the generalized regression neural network which is a branch of ANN and a stochastic method for the estimation of daily passenger flows. They stated that the estimation of ANN is quite close to the observation results and the performance of stochastic model is insufficient based on the findings of this study [13].

Gurbuz estimated the intercity transportation demands for the transportation systems (highway, railway and airway transportations) using ANN approach and the socio-economic and transportation data. He made suggestions towards planning the transportation systems effectively in the future by producing different transportation scenarios [14].

2. Artificial Neural Networks

ANN is a structure which is composed of simple processors trying to simulate the features of the human brain such as learning, generalizing and memorizing. There are biological neurons carrying out the processes of the brain. These neurons transmit the signals which they transmit to other neurons after some processes, and therefore, some reactions occur. There are artificial neurons in ANN which are quite similar to the neurons in brain. The artificial neutral networks are composed of linking these artificial neurons to each other in various architectural structures[15]. An artificial neuron mainly consists of five components. These five components can be listed as inputs, weights, summing function, transfer function and output. The inputs are the data which enter from the external environment or the other cells. The data given to the artificial neuron enter the cell over the weights on the links and these weights are effective in determining the effect of the entrance on the cell. The summing function is a function that calculates the net inputs which come to a cell and the net input is usually expressed as the sum of the product of the entrances of the related weights. Activation functions are also known as transfer functions. It is a function which determines the output of the neuron by processing the net input coming from the summing function. It is important that activation function must be differentiable and continuous due to the algorithms used in the training of the network. Although many different activation functions are used in the literature, linear, sigmoid and tangent hyperbolic functions are usually preferred because they have given better results.The structures of artificial neutral networks are composed of neurons which are the basic processors. As seen in Figure 1, there is an input layer where the inputs enter to the cell in ANN architecture and, a hidden layer where the inputs coming from the input layer and being processed are transmitted to output layer. In the figure, X and Y values show the input and the output values, respectively. One of the basic superiorities to the regression techniques of ANN is that the architecture is determinable and there can be one or more than one exit layers against the number of inputs which has the aimed number.

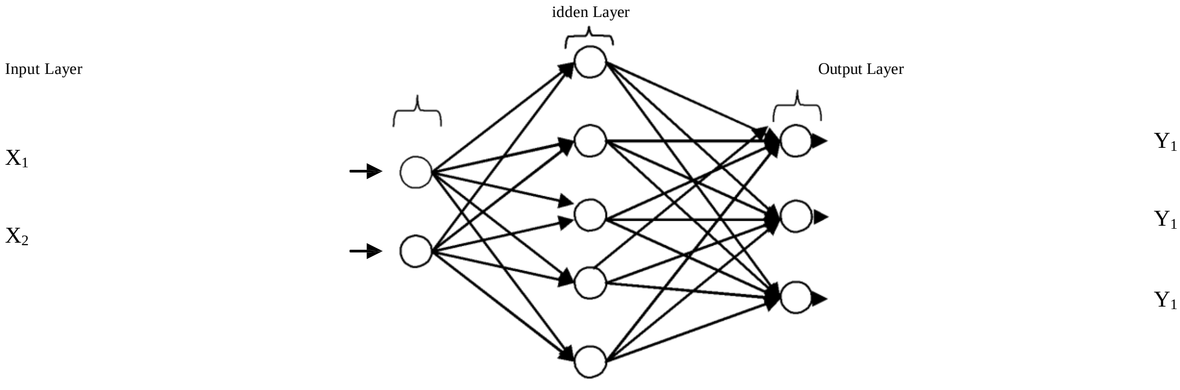

Figure 1. Multilayer ANN architecture

3. Demand Estimation Models and Different Scenario Analyses for the Highway Passenger, Freight and Vehicle Transport

In this study, while developing ANN models, 26-year time serial data was used; population, gross national product, number of vehicles were used as input data and, passenger-km, ton-km and vehicle-km values have been used as output data.The data which belongs to population and gross national product were taken from Turkish Institute of Statististics [16] and those belonging to transportation were taken from the General Directorate of Highways [17]. While the data belonging to the years of 1980-1989 was used to develop the model, the remaining data was used for testing the developed models.The needed input data between the years of 2005-2020 was predicted. The total numbers of passengers and freight vehicles were considered in the vehicle-km estimations. Passenger cars (automobile, bus, minibus) were taken into account in the passenger-km estimation, while freight vehicles (lorry and light truck) were considered in the ton-km estimation. All of the data was normalized in the range of 0,1-0,9. A variety of network architectures were examined and 3-3-1 network architecture which has given the best solution among the three models was used. The models were trained with the feed-forward and back propogation algorithm. Also learning rate was started from 0,9 and it was aimed that the network does both fast and sensitive learning by reducing 0,2 in each of 5000 steps. The memorization of the network was prevented during the training by keeping the number of neurons low in the hidden layer. The used network architecture is given in Figure 2. Seperate networks were constructed for each value of the passenger-km, ton-km and vehicle-km and, all of them were showed together in Figure 2. ANN estimations and real values belonging to highway-km, ton-km and vehicle-km are given in Figure 3 ,4 and 5.

ANN models in this study were improved utilizing Matlab7.4 program. This program is largely used in numerical calculation, data analysis and graphic processes in the field of engineering. Besides being a multi-purpose program, it has a lot of special purpose tool boxes. The artificial neural network tool box is one of them. This program supports many network structures, provides the selection of neuron and weight in parallel with the demand and, has many ready application codes [15].

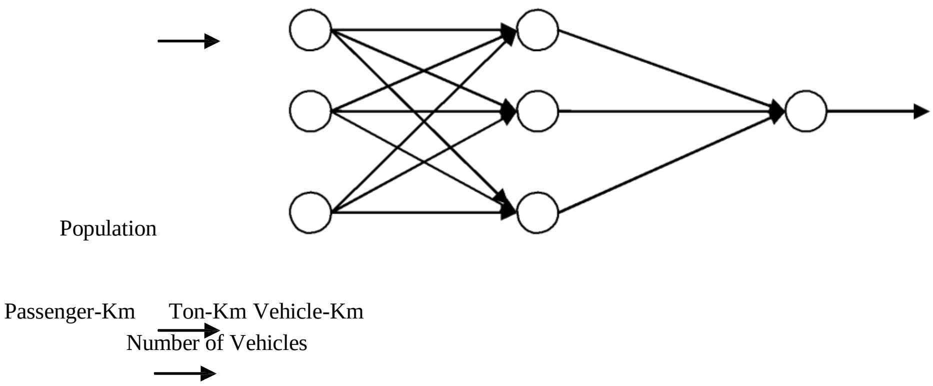

Figure 2. ANN network architecture for highway passenger-km, ton-km and vehicle-km.

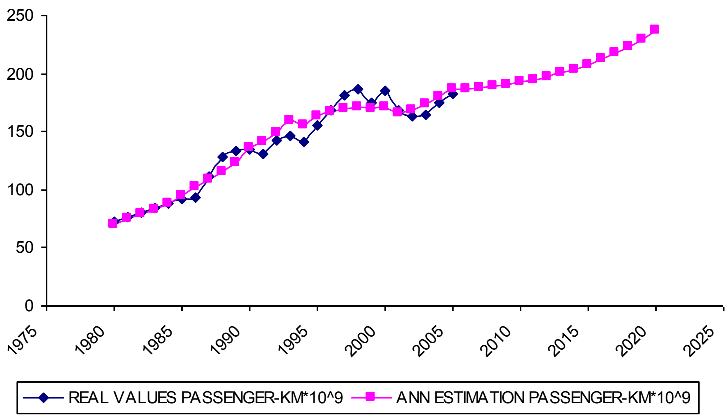

Figure 3. Highway paasenger-km real values and ANN estimations.

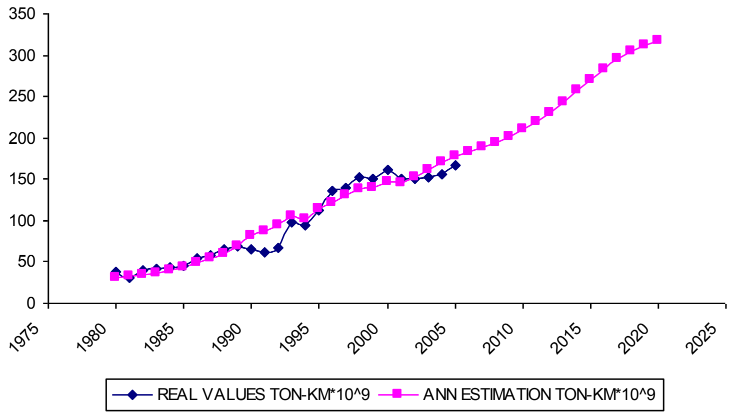

Figure 4. Highway ton-km real values and ANN estimations

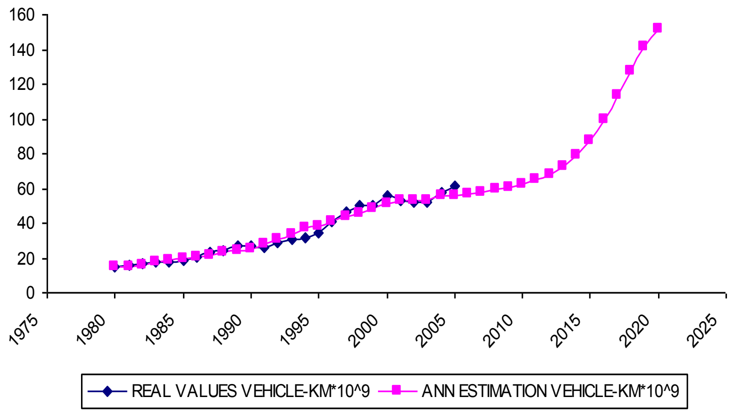

Figure 5. Highway vehicle-km real values and ANN estimations

In order to reveal the performances of ANN models, the values of mean absolute percentage error (MAPE) , mean absolute error (MAE) and root mean square error (RMSE) were calculated for both training and test data by utilizing the differences between the estimation and actual values and, it was given in Table 1. Considerin the values belonging to the performance criteria, it can be seen that ANN models are successful and they can be used for the estimation of transportation movements in the future.

$$MAPE = \frac{1}{n}\sum\left(\left|\frac{ANN_E - R_V}{R_V}\right| * 100\right) \tag{1}$$

$$MAE = \frac{1}{n}\sum\left|ANN_E - R_V\right| \tag{2}$$

$$RMSE = \sqrt{\left(\frac{1}{n}\sum_{j}\left|ANN_E - R_V\right|^2\right)} \tag{3}$$

Here n is the number of data, R_V is real values, and ANN_E is ANN estimations.

Table1. Error values belonging to highway passenger, freight and vehicle transport

	Training (1980–1999)			Testing (2000–2005)		
	MAPE	**MAE**	**RMSE**	**MAPE**	**MAE**	**RMSE**
Passenger-km	0.049	6.632	8.338	0.041	7.181	8.237
Ton-km	0.125	8.789	11.393	0.060	9.535	10.372
Vehicle-km	0.057	1.716	2.284	0.048	2.710	3.299

The expected transportation actitivities are given for the years of 2006-2020 in Table 2. According to this table, the fastest increase is expected in vehicle-km in 15 years and, the ton-km and passenger-km follow that.

Table 2. Expected intercity transportation demand.

Years	**Passenger-km 10^9**	**Ton-km 10^9**	**Vehicle-km 10^9**
2006	186.84	182.51	56.90
2007	188.11	188.26	58.09
2008	189.51	194.66	59.36
2009	191.05	201.94	60.80
2010	192.82	210.34	62.58
2011	194.90	219.99	64.88
2012	197.32	231.07	68.06
2013	200.15	243.49	72.57
2014	203.46	256.88	78.99
2015	207.33	270.55	87.90
2016	211.85	283.58	99.53
2017	217.08	295.14	113.36
2018	223.05	304.63	127.89
2019	229.77	311.82	141.08
2020	237.18	316.82	151.44

When the demand estimations given in the table are taken into account, the demand does not seem possible to be meet only by using the highways in their present conditions, and the capacity should be increased with additional investments. And this means that the transportation is done by using more energy and higher budget, so it doesn’t seem a rational solution. For this reason, as the most reasonable solution, the passenger and freight traffic which are intensified in highway transportation system should be shifted to the other transportation systems, mainly the railway system.

According to ANN estimations, it was predicted that the freight traffic will increase about 75% and passenger traffic will increase about 30% in the coming 15 years. By considering that the freight traffic increases 190 times in 57 years, it seems more reasonable that the demand management should be done initially for freight and then for passenger transportation. It has also been emphasized by some researchers that it is beneficial for both investments and indirect expenses to give the priority to the freight transportation in demand management [11]. For this purpose, three different scenarios were prepared.

Scenario I: The demand was aimed to shift from highway to the other transportation systems, which is an annual of 0.5% for passenger transportation, 1% freight transportation between the years 2013-2015 and an annual of 1% for passenger transportation, 2% for freight transportation between the years of 2015-2020. At the end of the year 2020, a total of 6.5% in the demand for passenger transportation and a total of 13% in the demand for freight transportation will have been shifted to the other transportation systems.

Table 3. According to the scenario I estimated and planned passenger-km and ton-km values for 2013-2020 years

Years	Estimated Passenger-km 10^9	Planned Passenger-km 10^9	Demand Shift Rate	Estimated Ton-km 10^9	Planned Ton-km 10^9	Demand Shift Rate
2013	200.15	199.15	0.005	243.49	241.06	0.01
2014	203.46	201.43	0.010	256.88	251.74	0.02
2015	207.33	204.22	0.015	270.55	262.43	0.03
2016	211.85	206.55	0.025	283.58	269.40	0.05
2017	217.08	209.48	0.035	295.14	274.48	0.07
2018	223.05	213.01	0.045	304.63	277.21	0.09
2019	229.77	217.13	0.055	311.82	277.52	0.11
2020	237.18	221.76	0.065	316.82	275.63	0.13

Scenario II: It was aimed that shifting of demand from highway to the other transportation systems, an annual of 1% for passenger transportation, 1.5% for freight transportation between the years 2013-2015 and an annual of 2% for passenger transportation, %3 for freight transportation between the years of 2015-2020. At the end of the year 2020, a total of 13% in the demand for passenger transportation and 19.5% in the demand for freight transportation will have been shifted to the other transportation systems.

Table 4. According to the scenario II estimated and planned passenger-km and ton-km values for 2013-2020 years

Years	Estimated Passenger-km 10^9	Planned Passenger-km 10^9	Demand Shift Rate	Estimated Ton-km 10^9	Planned Ton-km 10^9	Demand Shift Rate
2013	200.15	198.15	0.01	243.49	239.84	0.015
2014	203.46	199.39	0.02	256.88	249.17	0.030
2015	207.33	201.11	0.03	270.55	258.38	0.045
2016	211.85	201.26	0.05	283.58	262.31	0.075
2017	217.08	201.88	0.07	295.14	264.15	0.105
2018	223.05	202.98	0.09	304.63	263.50	0.135
2019	229.77	204.50	0.11	311.82	260.37	0.165
2020	237.18	206.35	0.13	316.82	255.04	0.195

Scenario III: It was estimated that every year beginning from 2013-2015 the travels by automobile will decrease 1.5%; and 2.5% between the years 2015-2020 due to the demand shifts in passenger and freight transportation in the highways, constant increase in the petrol prices, the increase in the service and comfort in railway transportation with the high-speed railway technology in Turkey and, “Auto couchette train” (transportation of passengers and automobiles in the same train) project which TCDD has planned to put into effect [18]. Therefore, there will be 17% decrease in vehicle-km done on highway by the end of 2020.

Table 5. According to Scenario III estimated and planned vehicle-km values for the years of 2013–2020

Years	Estimated Vehicle-km 10^9	Planned Vehicle-km 10^9	Demand Shift Rate
2013	72.57	71.48	0.015
2014	78.99	76.62	0.030
2015	87.90	83.94	0.045
2016	99.53	92.56	0.070
2017	113.36	102.59	0.095
2018	127.89	112.54	0.120
2019	141.08	120.62	0.145
2020	151.44	125.70	0.170

4. Result and Discussion

In this study, the general condition of highway transportation in our country was examined by taking socio-economic factors into account and this examination indicated that ANN can be used as a method in transportation demand estimation. The transportation demand models were improved by using ANN approach, and with the help of these improved models the movements of passenger, freight and vehicle expected in our country in the future were tried to be estimated. Determining passenger-km, ton-km and vehicle-km values, which need to be shifted to the other transportation systems with the demand management by producing different scenarios, was tried. It was seen that unless the passenger and freight transport on the highways shift to the other transportation systems, the problems in the highway transportation will be inextricable. This is since the increase in the transportation activities related to highway takes places over the increase belonging to the socio-economic indicators. Therefore, a part of this demand on the highway should be met by the other transportation systems in terms of applying the demand management as soon as possible. This situation has been evaluated by improving three scenarios. In the first scenario, a total of 6.5% in the passenger transportation and 13% in freight transportation demand shift were aimed till the year 2020. And these correspond to 15,42 10^9 passenger-km and 41,19 10^9 ton-km, respectively. In the second scenario, a total of 13% in the passenger transportation and 19.5% in freight transportation demand shift were aimed untill the end of year 2020. And this means that a value of 30,83 10^9 passenger-km in the passenger transportation, 61,78 10^9 ton-km in the freight transportation is shifted from the highway transportation. In the last scenario, the demand shift which results from a decrease in the use of vehicles, especially automobiles was taken into account. As a result of the decrease in using the vehicles on the highway, a shift of 17% in vehicle-km corresponds to a value of 25,74 10^9 vehicle-km. It is considered that a well-balanced transportation will be reached in the passenger and freight transportation in the next years with the increase in the rate of the other transportation systems after 2020.

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