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STUDY ON ESTABLISHING RELATIONSHIP BETWEEN PER CAPITA TRIP RATE WITH DEMAND VARIABLES USING ARTIFICIAL NEURAL NETWORKS

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ABSTRACT

Trip rate is the ratio of the Total several trips generated per day to the Total population of the considered area. While considering a city as a study area it is difficult to relate the amount of trips that originate in that study area and the amount of trips attracted towards the study area in a conventional way. This study brings out some basic Demand variables that help in estimating the several trips in a study area. Relationship between Dependent (trip rate) and Independent (socio-economic &Land use) variables is established using Artificial Neural Network (ANN) using different learning functions which reflects its performance level. In this study we have used learning functions TRAINLM, TRAINSCG which provided better results in establishing the relation between Trip rate and Demand variables.

KEYWORDS: Artificial Neural Network, Dependent Variables (Trip Rate), Independent Variables (Socio-Economic & Land Use), Trainlm, Trainscg & Feed Forward Back Propagation Network

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Original Article

TERMINOLOGY

Trip Rate: The ratio of the Total number of trips generated per day to the Total population of the considered area.

Trip Rate (All Modes): Number of trips including walk per person of that study area.

Trip Rate (Motorized): Number of trips excluding walk per person of that study area.

Socio-Economic Parameters

***Average Density of the City(p/sq.km*)**:* Ratio of total population of the city to the size of the city.

Male Population (cr): Total male population in the study area.

Female Population (cr): Total female population in the study area.

Literates: Total population in the study area aged above 7 years who can read & write.

Average monthly Household Income (▪): average monthly HH income as per CDP/Master plan.

Average monthly expenditure on transport to total monthly income (▪): Ratio of expenditure on transport to the total income as per CMP.

Registered Vehicles: Two Wheelers, *Cars*, Jeeps and Taxis, Buses, Goods *Vehicles* and Other registered

vehicles in India

Land use Parameters

Administrative Municipal Area (sq.km): Area fallen under municipal and development authority of city.

Residential Area: Distribution of land under residential purpose as per CDP.

Commercial Area: Distribution of land under commercial purpose as per CDP.

Industrial Area: Distribution of land under industrial purpose as per CDP.

Recreational Area: Distribution of land under recreational purpose as per CDP

Agricultural Area: Distribution of land under agricultural purpose as per CDP

Water Bodies Area: Distribution of land under water bodies as per CDP

Transport Area: Distribution of land for transportation purpose as per CDP

Public & Semipublic Area: Distribution of land for use of public & semipublic area as per CDP.

INTRODUCTION

It is difficult to relate the amount of trips that originate in a study area and the amount of trips attracted towards that study area, by conducting surveys regularly. The cost and time for each survey is not affordable. So to bring out a possible solution there is a need of an alternative solution to decide the Trip Rates of all Motorized vehicles that are to be collected. These Trip Rates are correlated with selected socio-economic & Land-use parameters of that area. So with the help of ANN tool future, trip rates are estimated of that area. An ANN is a biologically inspired computational model composed of various

Processing elements called artificial neurons are connected with coefficients or weights, which constructs the neural network's structure. The processing elements have weighted inputs, transfer function and outputs for processing information. There are many types of neural networks with different structures, but all are described by the transfer functions used in processing elements (neurons), the way of training given or learning rule and by the connection formula. ANN is composed of single-layer or multiple layer neurons. A neural network is trained with input and target pair patterns with the ability of learning.

This paper focuses on bringing out the joint behavior of vehicular trip rate and person trip rate using some parameters of the study area, which are listed below in Table 1 and table 2. Combined Impact of vehicular trip rate and person trip rate is labeled as **Trip rate (all-modes)** and the impact due to vehicular trip rate alone is labeled as **Trip rate (motorized).** Selected parameters of the study area are labeled as **Demand variables**

Table 1: Travel Parameters

SOCIO ECONOMIC PARAMETERS	
Average density of the city (persons/sq.km)	Total literates
Male population (crores)	Average monthly household income(・)
Female population (crores)	Average monthly expenditure on transport to total income(・)
Total population (crores)	Total registered vehicles

Table 2: Land use Parameters

LAND USE PARAMETERS	
Administrative municipal area (sq.km)	Recreational (sq.km)
Residential (sq.km)	Public and Semipublic (sq.km)
Commercial (sq.km)	Transport (sq.km)
Industrial (sq.km)	Water bodies & coastal (sq.km)
Agricultural (sq.km)	

ARTIFICIAL NEURAL NETWORK

Back Propagation Algorithm (Trainlm)

Levenberg–Marquardt backpropagation (Trainlm) algorithm, locates the least of a multivariate function that is expressed as the sum of squares of non-linear real-valued functions. It is an iterative technique that works in such a way that, performance function will always be reduced in each iteration of the algorithm. This feature makes Trainlm the fastest training algorithm for networks of moderate size.

Scaled Conjugate Gradient (Trainscg):

This does not need line search at each iteration step like other conjugate training functions. Step size scaling mechanism is used, which avoids a time consuming line search per learning iteration. This mechanism makes the algorithm program quicker than the other second order algorithms. The Trainscg function needs more iteration to converge than the opposite conjugate gradient algorithms, however the amount of computations, in the iteration is considerably reduced as a result of no line search is performed.

METHODOLOGY

Cities which are densely populated and have a good share of trips per day has selected in this study. Data related to these 46 cities about various travel parameters and Land –use parameters have obtained using various sources & surveys. Average density of the city (persons/sq.km), Male population, Female population (Cr), Total population (Cr), Total literates, Average monthly household income (₹), Average monthly expenditure on transport to the total income, Total registered vehicles are the travel parameters considered. Administrative municipal area (sq.km), Agricultural (Sq.km), Water bodies and Coastal (Sq.km), Residential (Sq.km), Industrial (Sq.km), Public and Semi-public (Sq.km), Recreational (Sq.km), Transport (Sq.km), Commercial (Sq.km) are the Land-use parameters considered. These **Travel parameters** and **Land use parameters** are now used to bring out relation with **Trip Rate (all modes)** using **Artificial Neural Networks.**

The selected **Travel parameters** and **Land-use parameters** were considered as inputs for the artificial neural network.

- Eight **travel parameters** and Nine **land use parameters** were considered as inputs for the artificial neural network.
- The target data here are trip rates of the selected cities. Trip rates include both motorized and all modes trips.
- The selected travel and land use parameters were sent through a selected two-layer perceptron network then trained with the chosen type of learning functions.
- A Feed Forward Back Propagation Network is selected with Trainlm and Trainscg Training functions. The architecture of the Network is as shown in the Network Modeling.

- Weights and biases are automatically updated based on the network structure adopted.
- This process is repeated for required number of iterations until the results are favorable and the final network is saved.
- Data division is random and weights Initialization is also random controlled by random number generator.
- Neural network provides the results in the form of MSE and Regression Value (R)

COLLECTED DATA: SOCIO-ECONOMIC PARAMETERS

Table 3

City	Average Density of City (Persons/Sq.Km)	Total Population (Male)	Total Population (Female)	Total Population	Total Literates	Average Monthly Household Income (▪ .)	Ave. Monthly Exp. Transport to Total Monthly Income (▪)	Total registered vehicles
Agartala	4348	200132	199872	400004	344711	8506	851	71807
Agra	8765	845902	739802	1585704	1014872	13200	554	475700
Ahmedabad	13050	2938985	2638955	5577940	4376393	4985	285	929757
Ajmer	5750	278545	263776	542321	416511	2925	333	266490
Amritsar	7137	601008	531375	1132383	855415	17392	2435	692791
Bathinda	3838	151524	134264	285788	207197	9058	997	687028
Bellary	4996	206149	204296	410445	280610	16523	1405	208214
Bhubaneswar	6205	444806	396028	840834	697615	3250	293	422994
Bidar	5023	110628	103745	214373	161094	15000	1650	5560
Chitradurga	5365	70132	70074	140206	110215	15000	1440	59425
Davanagere	6337	219776	215195	434971	329003	7500	1350	161795
Dehradun	8700	298638	270940	569578	449950	20298	2781	435208
Delhi	11320	5685041	4976135	10661176	8291288	25413	8387	8293167
Gangtok	4797	52459	47827	100286	81309	20584	824	3977
Gulbarga	8313	271660	261927	533587	382775	15053	1927	157396
Haridwar	5716	122007	106825	228832	168576	12000	1080	23107
Hospet	4048	102668	103499	206167	141475	6725	471	84145
Hubli-Dharwad	4700	474518	469270	943788	727103	19400	1397	312552
Indore	15316	1020057	944029	1964086	1486321	13500	2063	1187009
Jaipur	8054	1603125	1443038	3046163	2215535	11600	2552	709638
Jalandhar	6921	457636	405250	862886	666926	15470	1702	37505
Jammu	5697	263141	239056	502197	411558	9530	382	407400
Kalyan-Dombivali	155	649626	597701	1247327	1029041	7696	308	257250
Kanpur	9756	1489062	1276286	2765348	2059105	6516	326	557896
Kochi	6811	296949	305097	602046	532492	29093	2852	303436
Kohima	3900	51626	47413	99039	78961	11654	758	80330
Lucknow	1456	1460970	1356135	2817105	2081727	2500	250	1010226
Ludhiana	10120	874908	743971	1618879	1230545	13414	1288	63725
Mangalore	3660	242512	246456	488968	417649	17000	1360	189729
Mathura	1464	185983	163926	349909	229061	5000	250	125613
Meerut	7400	688118	617311	1305429	858441	15200	760	271207
Mysore	6130	446676	446386	893062	708130	18659	607	523353
Nagpur	9500	1225405	1180260	2405665	1984123	19600	2352	1236174
Nainital	3797	21648	19729	41377	34786	17643	1677	15518
Nanded	18305	290354	269504	559858	419433	18356	1946	110033
Pathankot	5757	78117	70820	148937	118533	13647	2921	79532
Patiala	10950	215617	190575	406192	313583	13029	1303	510245
Patna	13740	893399	790823	1684222	1234931	8522	1620	484366
Shillong	12825	70135	73094	143229	119642	10000	780	52350
Shimla	4777	93152	76426	169578	146062	19017	951	139304
Shimoga	5482	162018	160632	322650	254531	7500	1020	199638
Surat	13680	2543623	1924174	4467797	3443411	8000	800	1800641
Tirupati	6896	146225	141257	287482	227140	14536	2137	24649
Tumkur	5899	152925	149218	302143	60873	15000	2300	97751
Udaipur	7700	233959	217141	451100	361498	7000	560	339594
Vijaywada	15322	518590	515768	1034358	757667	5347	682	564914

Table 4

LAND USE PARAMETERS									
City	Administrative Municipal Area (sq.km)	Residential Area (sq.km)	Commercial Area (sq.km)	Industrial Area (sq.km)	Recreational Area (sq.km)	Agricultural Area (sq.km)	public and Semipublic Area (sq.km)	Transport Area (sq.km)	water Bodies and Coastal (sq.km)
Agartala	62.60	20.00	2.88	3.08	4.20	10.04	4.50	8.50	12.50
Agra	141.00	95.00	3.23	10.30	9.30	4.56	5.50	11.01	6.70
Ahmedabad	190.84	93.00	7.50	12.67	8.88	14.50	10.78	25.60	18.78
Ajmer	55.00	26.00	2.82	5.94	1.76	5.80	3.98	6.87	3.75
Amritsar	142.37	49.00	4.78	6.69	5.32	52.65	7.78	14.62	3.62
Bathinda	73.00	24.00	2.09	4.09	2.01	21.70	6.09	8.26	3.23
Bellary	67.80	39.00	1.15	3.57	2.45	5.36	5.51	6.87	2.76
Bhubaneswar	270.00	128.00	5.76	7.87	4.51	63.97	11.34	14.37	32.16
Bidar	43.00	20.00	2.07	1.45	1.76	7.95	3.87	2.87	5.98
Chitradurga	29.50	14.00	1.14	2.18	1.37	3.30	2.07	3.73	4.51
Davanagere	68.63	48.00	1.18	2.09	1.63	6.87	2.09	6.91	1.39
Dehradun	67.00	35.00	2.90	3.50	2.26	4.20	3.13	3.76	12.95
Delhi	118.00	37.00	5.19	3.67	5.88	8.70	5.38	30.79	11.51
Gangtok	112.00	71.00	5.08	3.54	4.08	6.45	6.16	8.47	6.87
Gulbarga	64.00	32.00	2.40	3.10	1.50	5.28	4.09	5.70	11.60
Haridwar	11.90	22.00	6.60	1.47	3.87	4.30	3.50	5.54	5.00
Hospet	50.92	26.00	8.67	1.01	2.79	2.70	3.87	4.81	1.26
Hubli-Dharwad	202.00	62.00	6.00	10.00	12.00	28.00	32.00	41.00	14.40
Indore	131.71	57.00	4.63	9.56	8.73	12.70	11.30	14.43	10.60
Jaipur	467.00	247.00	21.98	33.61	24.95	57.80	25.44	16.70	36.87
Jalandhar	110.43	48.00	4.21	9.65	3.55	8.73	10.29	13.97	12.73
Jammu	112.00	57.00	3.92	6.65	4.86	11.95	9.96	9.67	10.98
Kalyan-Dombivali	111.39	62.00	4.04	7.08	1.42	8.20	9.16	8.70	10.30
Kanpur	260.00	123.00	12.58	22.37	17.83	26.30	11.98	17.90	24.58
Kochi	94.88	31.00	7.22	9.96	7.78	9.50	7.36	9.34	12.40
Kohima	10.98	8.00	1.30	1.10	1.00	2.20	1.50	2.10	2.50
Lucknow	143.00	90.00	3.60	9.90	4.35	8.80	14.40	9.80	5.10
Ludhiana	159.37	84.00	4.60	9.98	6.78	13.70	16.09	7.70	14.80
Mangalore	73.71	23.00	3.52	7.90	4.70	8.62	6.69	10.20	11.82
Mathura	28.50	13.00	2.87	1.76	2.98	4.00	1.30	2.50	3.10
Meerut	146.39	98.00	5.65	4.56	5.22	11.87	6.45	7.98	9.60
Mysore	128.00	61.00	3.44	15.55	8.55	8.98	7.80	18.80	6.78
Nagpur	217.56	84.00	5.40	11.40	10.96	34.90	29.70	32.90	5.40
Nainital	11.73	7.00	1.17	2.58	1.03	1.10	1.90	1.14	2.90
Nanded	51.76	24.00	5.76	4.87	2.50	3.50	2.92	4.08	5.50
Pathankot	15.56	5.00	1.15	1.41	1.05	2.80	2.50	1.71	3.10
Patiala	37.00	19.00	2.10	4.30	2.25	3.87	3.59	2.18	2.92
Patna	109.22	43.00	5.17	4.13	3.66	18.36	11.32	18.25	8.67
Shillong	10.60	4.00	1.05	2.60	1.10	3.92	1.26	2.32	2.49
Shimla	35.54	21.00	1.71	1.62	1.00	2.30	3.40	2.20	2.70
Shimoga	50.00	18.00	3.43	2.47	2.94	3.70	4.11	4.28	6.30
Surat	112.00	56.00	7.45	9.27	5.31	10.26	6.50	8.21	13.20
Tirupati	16.07	7.00	4.01	1.20	3.50	3.10	1.12	2.32	3.30
Tumkur	48.60	30.00	1.22	3.40	1.42	4.10	3.83	4.85	3.05
Udaipur	64.00	33.00	2.67	6.29	2.17	5.21	2.86	5.10	9.53
Vijaywada	61.88	37.00	3.73	6.51	2.76	5.50	2.05	4.99	5.17

TRIP RATES

Table 5

City	Per Capita Trip Rate Excluding Walk Trips (MOTORIZED)	Per Capita Trip Rate Including Walk Trips(ALL MODES)
Agartala	0.8	1.01
Agra	0.96	1.06
Ahmedabad	0.72	1.16
Ajmer	0.76	1.57
Amritsar	0.34	0.84
Bathinda	0.52	0.77
Bellary	0.42	1.23
Bhubaneswar	0.72	1.34
Bidar	0.58	0.83
Chitradurga	0.73	0.98
Davanagere	0.7	1.03
Dehradun	1.11	1.56

Table 5: Contd.,		
Delhi	0.91	1.38
Gangtok	0.39	0.87
Gulbarga	0.55	0.96
Haridwar	0.5	0.83
Hospet	0.72	1.45
Hubli-Dharwad	0.95	1.48
Indore	0.92	1.12
Jaipur	0.87	1.1
Jalandhar	0.36	0.76
Jammu	0.83	1.31
Kalyan-Dombivali	0.57	1.68

Table 6

City	Per Capita Trip Rate Excluding Walk Trips (MOTORIZED)	Per Capita Trip Rate Including Walk Trips(ALL MODES)
Kanpur	0.52	0.7
Kochi	0.6	0.8
Kohima	0.48	1.1
Lucknow	0.65	1.1
Ludhiana	0.9	1.33
Mangalore	0.94	1.11
Mathura	0.46	0.91
Meerut	0.7	1.02
Mysore	0.98	1.08
Nagpur	0.95	1.26
Nainital	0.72	1.45
Nanded	0.54	1.23
Pathankot	0.89	1.29
Patiala	1.05	1.32
Patna	0.5	0.8
Shillong	0.84	1.5
Shimla	0.45	0.67
Shimoga	0.67	0.92
Surat	0.73	1.13
Tirupati	1.07	1.57
Tumkur	0.78	0.98
Udaipur	0.73	1.12
Vijaywada	1.02	1.36

NETWORK MODELLING

Two-Layer Perceptron Network

As the name suggests, it consists of two layers. The architecture of this class of network, besides having the input and the Output layers, also has one Intermediate layer called hidden layers. The computational units of the hidden layer are known as hidden neurons.

The hidden layer does intermediate computation before directing the input to the output layer. The structure of proposed network is shown in the figure 1. Our Network is consisting of eight inputs which pass through 14 neurons of the hidden layer and output is obtained after required iterations and minimum error is obtained.

The network is trained using feed forward back propagation algorithm and two transfer functions which are 1. Back propagation Algorithm (Trainlm). 2. Scaled Conjugate Gradient (Trainscg).

Two Layer Perceptron Network

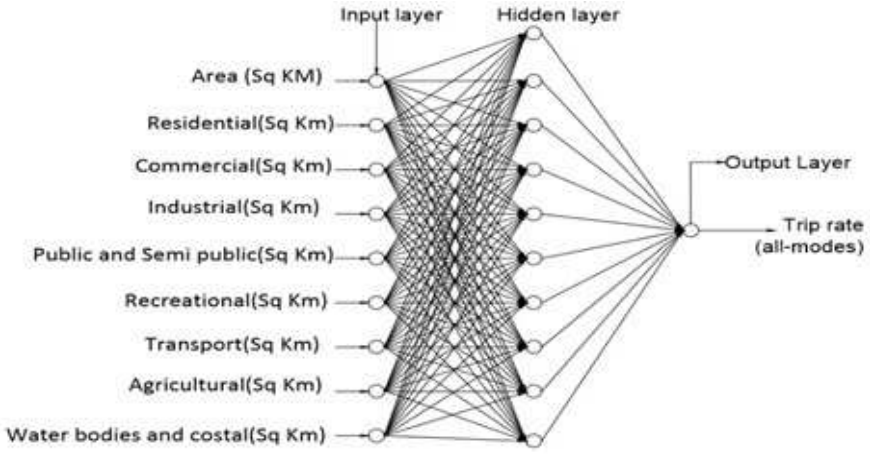

Figure 1: Model of the Proposed Neural Network

SOCIO-ECONOMIC PARAMETER RESULTS: {ALL MODES}

Table 7: Training & Testing Data Size

Input Data Size	Training set	Validation set	Testing set
46*8	32*8	7*8	7*8

Model Architecture Selection

For selecting the number of neurons to use in this problem, we have processed the data by starting with 10 neurons and increasing two neurons in ascending there up to 14 and calculated the value (R) for different training functions and selected 14 neurons as the best solution for solving this network. By using the assigned network structure along with training Functions Levenberg Marquardt Optimization TRAINLM and scalar conjugate gradient TRAINSCG, with 14 neurons in the Hidden Layer two combinations are tested which are:

- Feed Forward back propagation Algorithm with Trainlm as training function.
- Feed Forward back propagation Algorithm with Trainscg as training function.

Table 8: R Value Obtained While Varying the Neurons for the Two Combinations

	R Value (R)	
Neurons	Back Propagation Trainlm	Back Propagation Trainscg
10	0.3922	0.5693
12	0.4236	0.3365
*14	0.7076	0.7099

*selected neurons for the model network

Table 9: Performance (M.S.E) & Correlation (R) for different Training Functions

Algorithm	Training Function	M.S.E	epochs	R
Feed forward back Propagation	Trainlm	0.034	28	0.707

Table 9: Contd.,				
Feed forward back propagation	Trainscg	0.053	472	0.709

Feed Forward Back Propagation Algorithm using Trainlm

This network consists of Trainlm which is the training function where learning occurs in a training phase i.e.., errors of a target is back propagated from output to the inputs and weights are adjusted accordingly. Once the back propagation learns it is tested on second set of inputs. The performance of the neural network is determined by the mean squared error & data division is index. MSE value is 0.034 at epoch 28. The overall R(R) is=0.707.

Feed Forward Back Propagation Algorithm using Trainscg

This network consists of Trainscg which is the training function where learning occurs in a training phase i.e.., errors of a target are back propagated from output to the inputs and weights are adjusted accordingly. Once the back propagation learns it is tested on second set of inputs. The performance of the neural network is determined by the mean squared error & data division is index. MSE value is 0.053 at epoch 472.The overall R(R) is=0.709.

Variation between surveyed values and network trained values for the two combinations are plotted by taking the 46 cities on X-axis and trip (rate all-modes) on Y-axis as shown in the figure 2.

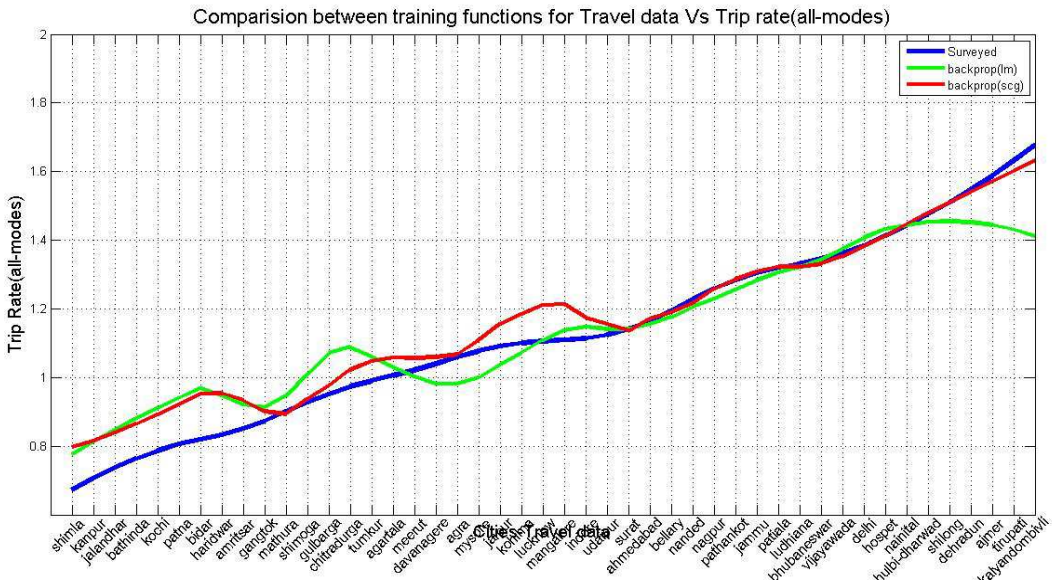

Figure 2: Variation between Predicted Values (Training Functions) vs Surveyed Values

LAND USE PARAMETER RESULTS: {ALL MODES}

Table 10: Training & Testing Data Size

Input Data Size	Training set	Validation set	Testing set
46*9	32*9	7*9	7*9

Model Architecture Selection

For selecting the number of neurons to use in this problem, we have processed the data by starting with 10 neurons and increasing two neurons in ascending there up to 14 and calculated the value (R) for different training functions and selected 14 neurons as the best solution for solving this network.

By using the assigned network structure along with training Functions Levenberg

Marquardt Optimization TRAINLM and scalar conjugate gradient TRAINSCG, with 14 neurons in the Hidden Layer two combinations are tested which are:

- Feed Forward back propagation Algorithm with Trainlm as training function.
- Feed Forward back propagation Algorithm with Trainscg as training function.

Table 11: R Value Obtained while Varying the Neurons for the Two Combinations

	R Value (R)	
Neurons	**Back Propagation Trainlm**	**Back Propagation Trainscg**
10	0.4270	0.4512
12	0.4006	0.2074
*14	0.7064	0.6255

*selected neurons for the model network.

Table 12: Performance (M.S.E) & Correlation (R) for different Training Functions

Algorithm	Training Function	M.S.E	epochs	R
Feed forward back Propagation	Trainlm	0.026	8	0.706
Feed forward backpropagation	Trainscg	0.039	68	0.625

Feed Forward Back Propagation Algorithm using Trainlm

This network consists of Trainlm which is the training function where learning occurs in a training phase i.e.., errors of a target is back propagated from output to the inputs and weights are adjusted accordingly. Once the back propagation learns it is tested on second set of inputs. The performance of the neural network is determined by the mean squared error & data division is index. MSE value is 0.026 at epoch 8. The overall R(R) is=0.706.

Feed Forward Back Propagation Algorithm using Trainscg

This network consists of Trainscg which is the training function where learning occurs in a training phase i.e.., errors of a target are back propagated from output to the inputs and weights are adjusted accordingly. Once the back propagation learns it is tested on second set of inputs. The performance of the neural network is determined by the mean squared error & data division is index. MSE value is 0.039 at epoch 68. The overall R(R) is=0.625.

Variation between surveyed values and network trained values for the two combinations are plotted by taking the 46 cities on X-axis and trip (rate all-modes) on Y-axis as shown in the figure 3.

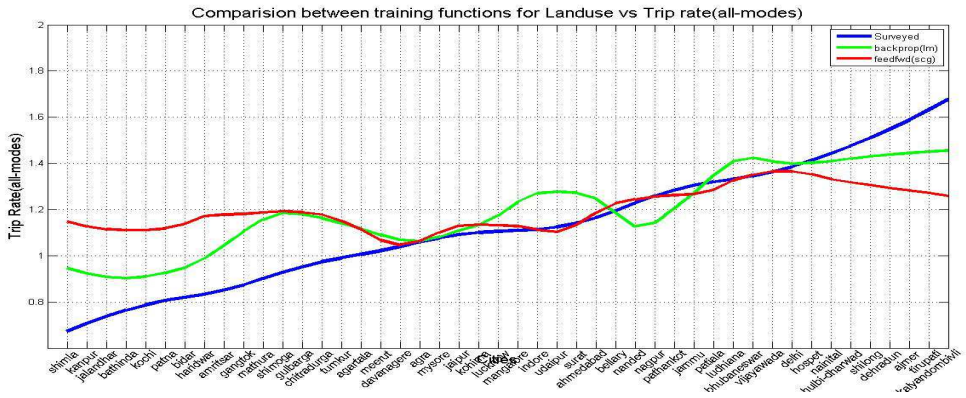

Figure 3: Variation between Predicted Values (Training Functions) vs Surveyed Values

CONCLUSIONS

After Testing the Two Combinations in Both the Parameters it was Found

- In Socio Economic parameters, Trainlm has performed well Using the Feed Forward Back Propagation algorithm producing predicted trip rate value with an R value 0.707, When compared with the performance of Trainscg while processed with Feed Forward Back Propagation algorithm.
- In land use parameters, Trainlm has performed well using the Feed Forward Back propagation algorithm producing predicted trip rate value with a R value 0.706, When compared with the performance of Trainscg while processed with Feed Forward Back Propagation algorithm.
- Results conclude that Trainlm has successfully predicted trip rate values which confirm Artificial Neural Networks have adopted for the problems of similar data size.
- Trainscg has provided optimum prediction of trip rate values for the network structure which stand by Trainlm.
- Relationship between demand variables and per capita Trip rate (all modes) is established by using Artificial Neural Network (ANN) using different Training functions.
- ANN has helped us in establishing boundary conditions for the prediction of trip rates related to a particular city.
- This analysis is helpful for a town planner to know the trip rate and to plan the infrastructure.

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