DEVELOPMENT OF PASSENGER TRAIN SERVICE QUALITY MODEL FOR SPECIAL OCCASION THROUGH NEURAL NETWORKS AND FUZZY INFERENCE SYSTEM

by

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DEDICATED

TO MY

PARENTS AND TEACHERS

The thesis titled "**DEVELOPMENT OF PASSENGER TRAIN SERVICE QUALITY MODEL FOR SPECIAL OCCASION THROUGH NEURAL NETWORKS AND FUZZY INFERENCE SYSTEM**" submitted by D. M. Ghius Malik, Student number – 1014042401 P and session October, 2014 has been accepted as satisfactory in partial fulfillment of the requirement for the degree of **Masters of Science in Civil Engineering (Civil and Transportation)** on 6/11/..., 2017

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DECLARATION

It is hereby declared that, except where specific references are made, the work embodied in this thesis is the result of investigation carried out by the author under the supervision of Dr. Md. Mizanur Rahman, Professor, Department of Civil Engineering, BUET.

It is hereby declared that the work presented in this thesis has been done by the author and that full or part of this thesis has not been submitted elsewhere for the award of any degree or diploma.

6-11-2017

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ABSTRACT

The Adaptive Neuro-Fuzzy Inference System (ANFIS) and an Artificial Neural Network (ANN) namely Probabilistic Neural Network (PNN) techniques were used in this thesis to model intercity train passengers' perception on its service quality (SQ). A stated preference survey was carried out with 6 skilled enumerators of intercity train users at Kamlapur Railway Station, Dhaka on the month of July, 2016. There are three sections in the survey questionnaire. The first section aims to get demographic and socio-economic information (age, gender, occupation etc.) of commuters and the reason for using intercity trains. The second section focuses on 18 attributes that are accountable for the evaluation of intercity train SQ. The third section organized to get priority ranking of the attributes from the respondents. These attributes were in a close ended arrangement with relevant multiple choices. The respondents were asked to assess the present situation of the service by marking the checkboxes from their point of view against each attribute. The multiple-choice check boxes are numbered by 1 to 5 where "5" corresponds to excellent quality and "1" corresponds to very poor quality.

After survey, incomplete data sets were screened out from collected data. Finally, 1037 and 553 user's data were used to calibrate the ANFIS and PNN structures for intercity train SQ estimation during regular days and special days, separately. The training and forecasting sets contained 80% of whole sample (830 samples for regular days, and 443 samples for special days) and 20% of whole sample (207 samples for regular days, and 110 samples for special days) observations, respectively. MATLAB 2014b is used for the development of these models. The proposed ANFIS structures with eighteen attributes showed 54.1% and 60.2% accuracy and PNN structure showed 50.7% and 57.3% accuracy in predicting train SQ for regular days and special days, respectively. Finally, a stepwise approach was followed for ranking the intercity train SQ attributes influencing its overall SQ and the results were compared with that of the empirical observations (public opinions). Study found that besides waiting place condition, attributes related to *physical conditions* and *service features* of intercity train are important determinants of its perceived SQ for regular days and special days, respectively. Beside waiting place

condition, ‘Toilet cleanliness’, ‘Fitness of car’, ‘Air ventilation system’, ‘Convenience of online ticketing system’, ‘Seat comfort’, ‘Ease at entry and exit’, were the most significant *physical attribute* those influence the users’ decision-making process on regular days. In contrast, on special days, ‘Travel cost’, ‘Air ventilation system’, ‘Convenience of online ticketing system’, ‘Car arrangement’, and ‘Travel delay’ were the most significant service attribute which influence the users’ decision making process.

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LIST OF ABBREVIATIONS

ACRONYM	DEFINITION
ADA	Americans with Disabilities Act
AI	Artificial Intelligence
ANFIS	Adaptive Neuro-fuzzy Inference System
ANN	Artificial Neural Network
ANOVA	Analysis of Variance
BR	Bangladesh Railway
CEN	European Committee for Standardization
CI	Central Intelligence
CIA	Central Intelligence Agency
DOT	Department of Transport
FFNN	Radial basis Function Network
FIS	Fuzzy Inference System
FL	Fuzzy Logic
GRNN	Generalized Regression Neural Network
MF	Membership Functions
ML	Multinomial Logit
MLFN	Multi-layer Feed Forward Neural Network
MPN	Multilayer Perception Network
MRT	Mass Rapid Transport
MV	Motorized Vehicle
NCHRP	National Cooperative highway Research Program
NN	Neural Network

LIST OF ABBREVIATIONS

ACRONYM	DEFINITION
PDF	Probability Density Functions
PNN	Probabilistic Neural Network
PRNN	Pattern Recognition Neural Network
PT	Public Transport
R	Coefficient of Correlation
RFN	Radial Basis Function Network
RMSE	Root Mean Square Error
RNN	Recurrent Neural Network
SEM	Structural Equation Model
SOM	Self-organizing Map
SP	Stated Preference
SQ	Service Quality
TRB	Transport Research Board
TRCP	Transit Cooperative Research Program
UK	United Kingdom
US	United States
USA	United States of America

Chapter 1

INTRUDUCTION

1.1 Background of the study

In a Transportation system of a country, passenger train acts like an arterial system of a body. Especially, in the country like Bangladesh with colossal population of about 166 million and high density of about 1237 persons per sq km (Population Report 2016, CIA, USA) train has extra-ordinary role to make in the field of transportation. Due to financial and land constraints, the existing highway facilities will be struggling to meet the expected traffic demand. Therefore, the traffic congestion will be a day-to-day plight in many highways. In this context, the traffic burden on highways can be reduced if a considerable number of travelers switch to an alternative mode of transportation. In this situation, train could be an efficient and economic mode of transportation to meet this long-distance travel demand. It has higher capacity than any other mode of transportation. With promising capacity extension options, it is one of the most reliable solutions for exponentially increasing transportation demand. Furthermore, the capacity of the train can be changed according to the demand. Changing car numbers and types (e.g. single-decker or double-decker), it is possible to meet the travel demand to a great extent. However, like any other mode of public transport (PT), ridership of train also largely depends on the passengers' satisfaction of its services. Hence, train service quality (SQ) is an issue of major concern. To attract people and to retain current users, SQ of train should be under satisfactory level. To improve service quality of train and bring that into satisfactory level, the specific problem and its extent is very important to know. Transportation researchers and practitioners are concerned about adapting appropriate modern technologies and introducing innovations into the train performance.

The notion of service quality (SQ) is well recognized as a performance measurement tool in traffic and transportation engineering operations. To retain attractiveness of public transport (PT) among travelers and boost ridership, operators need to continuously monitor its performance and service quality. Several studies (Hu and Jen 2006; Pham and Simpson 2006; Pérez et al. 2007) have highlighted the importance of the service quality of public transport. Measurements of SQ enable the train operators to decide upon the organizational goals and make crucial decisions regarding future investments. Models of SQ attributes of transport services provide the opportunity to gain an insight into the attributes related to SQ and thus provide a guideline for amelioration. However, modeling service quality has posed considerable challenge to researchers due to the complexity of the concept, uncertainties regarding the attributes to be used, perception heterogeneity of passengers, imprecise and subjective nature of the survey data. Thus, researchers have resorted to a wide variety of tools for modeling service quality.

Modeling of the complex information in this regard from collective data sets have become popular in recent times. Statistical and/or empirical models are most commonly used for modeling transportation data (Transportation Committee 2005, UK). These kinds of model have become more in demand to address complex transportation problems.

Artificial Neural Network (ANN) and Adaptive Neuro-Fuzzy Interface System (ANFIS) are now a day a popular form of Empirical models. Although ANN have been successfully used in various complex transportation problems such as real-time highway traffic state estimation (Karlafis et. al. 2011), travel mode choice modeling (Niu et. al. 2011), road accident prediction (Zhao et. al. 2010), traffic flow prediction model (Hosseinpour et. al. 2013) etc., very few studies have been performed on service quality (SQ) of train of developing countries like Bangladesh (Bao-Ping et. al. 2009, J. Chen et. al. 2007, Wang Zhuo et. al. 2005, Zhang et. al. 2005). Among different ANN models, Probabilistic Neural Network (PNN) is a well classifier and faster and accurate than Multilayer Perception Network (MPN) in prediction of SQ in heterogeneous data. Moreover, passengers' opinions about SQ of any public transportation mode on regular days are significantly different than that for special days. In general, SQ data of special days are more heterogeneous. Thus, this study explores a relationship between train SQ attributes and passenger satisfactions based on perceptions gained from experience. To this end, a stated preference (SP) questionnaire survey was designed to collect data on users' perception about intercity train SQ under different scenarios. A mathematical framework of ANFIS was calibrated using those data to see how models fit the field collected train SQ data. ANFIS is a Fuzzy-Logic Inference System (FIS) based ANN tool, which is robust and convenient to inherent properties of storing empirical knowledge. It is fast and accurate in prediction of SQ of heterogeneous data. ANFIS has been successfully implemented in different complex transportation problems, such as—mode choice modeling, accident prediction, real time traffic state estimation, and travel behavior modeling.

However, few researches have been performed Adaptive Neuro-Fuzzy Interface (ANFIS) on service quality (SQ) of train. Moreover, to the authors' best knowledge no comparison study was found on modeling train SQ using ANN and ANFIS. Furthermore, no studies have been found which investigated the influence of membership functions (MF) and epochs to calibrate ANFIS by utilizing the train SQ dataset. Therefore, in this study, ANN namely Probabilistic Neural Network (PNN) and ANFIS has been used to develop SQ prediction models of train for special occasions and regular time using questionnaire dataset. The calibrated models were used to rank the most significant SQ attributes and the results were compared with the empirical observations.

1.2 Passenger Train Services in Bangladesh

In Bangladesh, there are around 30 intercity train service provided by Bangladesh Railway (BR) from Kamlapur Railway Station, Dhaka. There are several types of services like first class cabin AC, first class chair AC, first class cabin non-AC, first class chair non-AC, second class chair, shovon chair and local standing transportation service. These trains connect the whole country with capital city Dhaka. Train's name and its travelling details are given in the Table 1.1 below.

Table 1.1 Train name, starting location and its destination

Serial No.	Train Name	Starting Location	Destination
01	Shuborna Express	Kamlapur Railway Station, Dhaka	Chittagong Division
02	Sonar Bangla Express	Kamlapur Railway Station, Dhaka	Chittagong Division
03	Mohanagar Provati	Kamlapur Railway Station, Dhaka	Chittagong Division
04	Turna	Kamlapur Railway Station, Dhaka	Chittagong Division
05	Mohanagar Express	Kamlapur Railway Station,	Chittagong Division

(Table 1.1 Continues to next page)

(Table 1.1 Continues from previous page)

Serial No.	Train Name	Starting Location	Destination
		Dhaka	
06	Chotla Express	Kamlapur Railway Station, Dhaka	Chittagong Division
07	Upakul Express	Kamlapur Railway Station, Dhaka	Sylhet Division
08	Parabat Express	Kamlapur Railway Station, Dhaka	Sylhet Division
09	Jayantika Express	Kamlapur Railway Station, Dhaka	Sylhet Division
10	Kalni Express	Kamlapur Railway Station, Dhaka	Sylhet Division
11	Silk City Express	Kamlapur Railway Station, Dhaka	Khulna Division
12	Padma Express	Kamlapur Railway Station, Dhaka	Khulna Division
13	Egaro Shindhu (Provati)	Kamlapur Railway Station, Dhaka	Khulna Division
14	Egaro Shindhu (Godhuli)	Kamlapur Railway Station, Dhaka	Khulna Division
15	Kishorganj Express	Kamlapur Railway Station, Dhaka	Mymanshing Division
16	Jamuna Express	Kamlapur Railway Station, Dhaka	Mymanshing Division
17	Brahmaputra Express	Kamlapur Railway Station, Dhaka	Mymanshing Division
18	Haura Express	Kamlapur Railway Station, Dhaka	Mymanshing Division
19	Tista Express	Kamlapur Railway Station, Dhaka	Mymanshing Division
20	Agnibina	Kamlapur Railway Station, Dhaka	Mymanshing Division
21	Dewanganj Express	Kamlapur Railway Station, Dhaka	Mymanshing Division
22	Rangpur Express	Kamlapur Railway Station, Dhaka	Rajshahi Division
23	Lalmoni Express	Kamlapur Railway Station, Dhaka	Rajshahi Division
24	Parbartipur Eid Express	Kamlapur Railway Station, Dhaka	Rajshahi Division
25	Ekata Express	Kamlapur Railway Station, Dhaka	Rajshahi Division
26	Drutojan Express	Kamlapur Railway Station, Dhaka	Rajshahi Division
27	Neelshagor	Kamlapur Railway Station, Dhaka	Rajshahi Division
28	Chitra Express	Kamlapur Railway Station, Dhaka	Rajshahi Division
29	Shundorban Express	Kamlapur Railway Station, Dhaka	Rajshahi Division
30	Khulna Express	Kamlapur Railway Station, Dhaka	Rajshahi Division

Source: Google Maps

(a)

(b)

(c)

(d)

Figure 1.1 Kamlapur Railway Station, Dhaka, Bangladesh

1.3 Research Objectives

The study is concentrated with the train service quality (SQ) analysis depending on a number of attributes in different routes of Bangladesh. The specific objectives of this study include:

a. To develop ANN and ANFIS-based empirical models for the estimation/prediction of SQ of trains in Bangladesh in special occasion and regular time.
b. To identify and rank the significant attributes influencing SQ of train of special occasion and regular time depending on neuron's connection weights as well as the results obtained from step-wise approach.

1.4 Scope of Work

This study is highlighted the determination of problems in intercity train service and to know the users' satisfaction about intercity train. The determination of problems and users' perception is collected from study sites and a stated preference (SP) questionnaire survey was conducted with intercity train users' including a set of questions related with the service quality, sitting arrangements, availability, security, ticketing system, sound level, air circulation etc.

Artificial Intelligence (AI) paradigms is used in this study as they have gained popularity by modeling the complex information from collective data sets over the years (Niu S. et. al. 2011, Zhao et. al. 2010, Mussa et. al. 2006). Artificial Neural Network (ANN) and Adaptive Neuro-Fuzzy Inference System (ANFIS) are very generic, accurate and convenient Computational Intelligence (CI) based models due to their inherent propensity for storing empirical knowledge. ANN and ANFIS have been successfully used in various complex transportation problems, i.e. real-time highway traffic state estimation (Niu S. et. al. 2011), travel mode choice modeling (Zhao et. al. 2010), road accident prediction (Hosseinpour et. al. 2013), traffic flow prediction model (Bao-ping et. al. 2009), car following model (Khodayari et. al. 2010), travel behavior modeling (Přibyl et. al. 2003) etc.

However, few researches have been performed several empirical framework on service quality (SQ) of train (e.g. Nathanail et.al. 2008). Therefore, this research intended to compare train SQ prediction model using ANN and ANFIS. In the process, the influence of membership functions (MF) and epochs during calibration of ANFIS model using train SQ dataset are investigated. ANN namely Probabilistic Neural Network (PNN) and ANFIS have been used to develop SQ prediction models of train for special occasions and regular time using questionnaire dataset. Afterwards, PNN and calibrated ANFIS model were used to rank the most significant SQ attributes and the results were compared with the empirical observations.

1.5 Organization of the Thesis

There are six chapters in this thesis paper including this introduction.

Chapter 1 states the background and objectives of this research work. The scope of this study is also presented in this chapter.

Chapter 2 represents the past studies about Service Quality (SQ) that helps to understand the contributing attributes that affects the quality of service of intercity train.

Chapter 3 addresses the study methodology that divided into three parts. These three parts contains detail information of survey procedure, description of survey location and development of two models, i.e., PNN and ANFIS.

Chapter 4 investigates and analyses the survey data. The analyses are shown in tabulated and graphical form. This chapter also describes the summery of users' perception of intercity train service quality in Bangladesh.

Chapter 5 compares the performance of the proposed PNN model with that of ANFIS, using the intercity passenger train SQ dataset. It also presents the significant attributes which affect the SQ of intercity trains.

Chapter 6 summarizes the major findings that are obtained from the analyses of chapter5. This chapter also presents the conclusion, recommendations and prospects of this study.

Chapter 2
LITERATURE REVIEW

2.1 General

This chapter presents previous studies and reports about train service quality issues. To complete our objective of this study, this literature review will help to identify the scope of work of this thesis work. Again, this chapter presents a historical overview of a rich variety of modeling approaches developed so far and in use today.

2.2 Definition of Service Quality (SQ) of Transportation Modes

The term service quality (SQ) in the transport literature context has long been investigated and has been defined in many forms. European Committee for Standardization, CEN (2002) defined service quality (SQ) as the accurate measures for which the providers are responsible to provide. Lai et. al. and Dell'Olio et. al. (2010) defined SQ as the measurement process of how the SQ level delivered matches the customer satisfaction. Tyrinopoulos et. al. (2008) defined SQ as the measurements that reflects users` perceptions towards the service. Eboli et. al. (2011) and Hensher et. al. (2002) defined SQ as the pre-defined standard of service attributes relative to the actual service quality. But the most common and internationally accepted SQ definition has been given by Transportation Research Board (TRB) defined SQ on TRCP Report 47 (1999) as the measuring of customer expectation on a constant service standard. These definitions have opened the door for further in-depth analysis of the quality process in the context of intercity train service.

2.3 Past Studies and Limitations

Service quality (SQ) is defined as a measure of users' perceptions grained from public transport's overall service, e.g., performance, comfortability etc. SQ is vital in attracting and retaining new users, therefore, researchers and policy makers are concerned about its influence on different public transportation modes.

Early research work by Parasuraman et al. (1985, 1988) developed SERVQUAL service quality model, where they identified five dimensions—reliability, assurance, tangibles, empathy and responsiveness to measure service quality through questionnaires. Several researches such as—Gronroos (1984), Brady and Cronin (2001), Karatepe et al. (2005) performed extensive SQ assessment in context of user's perception. Later, the techniques of SQ were widely implemented in several fields of market research including performance evaluation of public transportation including bus, train and so on. Several authors introduced different quality measuring methods and parameters to assess railway passenger service quality. The organization named Steer Davies Gleave conducted a study between December 1999 to June 2000 to assess the importance of rail passengers into improvement of the range and quality of facilities and service on stations and in trains in the city of London (Gleave 2000). Wardman (2004) used demand elasticity to estimate influence of travel time, fuel cost, car ownership, population on railway service quality. Fu and Xin (2007) investigated the relationship between rail passenger satisfaction and service attributes in the urban area of Cossenza of Italy. They conducted factor analysis and regression analysis to estimate relationship among attributes. Cavana et al. (2007) presented SERVQUAL method using regression analysis to evaluate passenger rail service quality by incorporating comfort, connection, and convenience. They revealed that reliability, responsiveness and empathy had significant effects on overall service quality. Nathanail (2008) developed framework for assessing the SQ of railway from questionnaire survey of passengers and grouped attributes into six criteria. Those were—itinerary accuracy, system safety, cleanness, passenger comfort, servicing and passenger information among which itinerary accuracy and system safety have been found most important attributes. Cantwell et al. (2009) developed a Multinomial Logit (ML) model and revealed that improvement in service, reliability and a reduction of crowding were related to passengers' satisfaction. Brons et al. (2009) assessed the importance of access to the station with overall satisfaction of railway journey through a regression analysis. Geetika (2010) evaluated the factors that determine user satisfaction with the SQ provided on railway platforms. Determinants found from factor analysis were availability, safety and security, quality of refreshments, effectiveness of information systems, behavior of railway staff, basic amenities provided on platforms. Refreshments and behavioral factors were considered the most significant by passengers.

Prasad and Shekhar (2010) identified the quality of a rail service by SERVQUAL model incorporating assurance, empathy, reliability, responsiveness, tangibles, service product, social responsibility and service delivery. Among which service delivery was found as the most important factor. Agunloye and Oduwaye (2011) investigated the relationships among arrival time of train, smoothness of ride, and cleanliness of the coaches. The research proposed that the arrival time of trains at stations and trip frequency have significant relationship with SQ of train. Chou et al. (2011) incorporated the quality satisfaction-loyalty relationship into a Passenger Satisfaction Index (PSI) calculation to evaluate the SQ of high speed rail. The study concluded that level of access to a station and personal spaces on the train were the most important quality indicators to improve customer satisfaction. Irfan et al. (2012) evaluated passengers' perceptions about the SQ of a rail system through a modified SERVQUAL and service qualities are— empathy, assurance, tangibles, timeliness, responsiveness, information system, food, safety and security. The study showed that there is a positive relationship among the SQ attributes. Most significant correlation was found among tangibles and empathy.

Conventional models have underlined assumptions and determined fundamental relationships between users' satisfaction and SQ attributes. Modeling non-linear relationship between users' satisfaction and attributes were widely adopted over last few decades. In these methods, SQ attributes were considered as independent variables and users' satisfaction was taken as dependent variables. Then coefficients were estimated by relating SQ attributes with users' satisfaction. Chou et al. (2014) proposed SEM model to test relationship among service quality, customer satisfaction and customer loyalty on high speed rail service in Taiwan. The study showed that most significant attributes were—cleanness of train, attitude and appearance of employee, comfort of air condition, on time performance of the train. De Oña et al. (2014) focused on the factors affecting the SQ of railway in Northern Italy using the decision tree approach. The research found that courtesy and competence in station, workability of windows and doors, regularity of train frequency were the major factors for SQ of railway. Aydin et al. (2015) proposed a combined fuzzy hierarchy process to assess customer satisfaction levels of rail transit. The study provided operational deficiencies related to rail transit through customer satisfaction surveys.

Non-parametric models of Artificial Intelligence (AI) such as ANFIS can provide advantages over other statistical regression models like linear regression, logistic regression, ridge regression, lasso regression etc, in analyzing large datasets. They can model non-linear relationships with progressive capability and have scope for model validation as well. Recently, these models are applied widely in the field of science, engineering and market researches. Non-linear relationships in many transportation problems can be solved accurately by using Fuzzy logic based approach (Teodorovic and Vukadinovic, 1998). Yen and Langari (1999), Passino and Yurkovich (1998), and Lewis (1997) have performed extensive study on fuzzy logic and Fuzzy Inference System (FIS). Later, Neural Network (NN) based learning was incorporated into FIS to solve many transportation problems. Teodorovic and Vukadinovic (1998) presented potential applications of fuzzy logic and NNs in solving transportation problems. Park (2002) forecasted freeway traffic volume by hybrid network-based fuzzy system. Pribyl and Goulias (2003) developed ANFIS for travel behavior study. Andrade et al. (2006) utilized an adaptive network based fuzzy logic for transport choice modeling.

Mucsi et al. (2011) utilized ANFIS technique to estimate queue length precisely and applied it for queue management at signalized intersections. They adopted trapezoidal MF for computational simplicity and to capture the similarity with the inputs of simulation model. Islam et al. (2016) adopted PNN, Generalized Regression Neural Network (GRNN) and Pattern Recognition Neural Network (PRNN) to assess the significant attributes which influence the SQ for Dhaka city bus transit. In another study, Islam et al. (2016) used PNN and ANFIS to construct and compare the prediction models for bus SQ of Dhaka city. They ranked the SQ attributes according to their effect and identify the significant attributes. The study revealed that ANFIS performed better than PNN for the evaluation of bus transit SQ.

Inspired by the most recent studies, this thesis paper depicts the application of the ANFIS and PNN in the development of a new fuzzy logic-based and neural network based approach for exploring the relationship among attributes of intercity train's SQ with passengers' satisfaction level. Particularly, previous studies showed that the ANFIS based SQ assessment seems to be a feasible approach for any mode of public transport. Dataset were trained and tested using ANN to check the fitness of the calibrated FIS for estimating the parameters of observed attributes or variables of railway SQ under regular days and special day scenarios. Despite uncertainties and nonlinearities, ANFIS represents a mathematical framework that can model the relationship among observed variables, hidden layers and output variables quite remarkably.

On the other hand, ANN models can provide more accurate and realistic study on the SQ and are yet to be introduced in a larger scale for the study and analysis of intercity train SQ with input layer, pattern layer, summation layer and output layer. To the authors' best knowledge, this research is the first of its kind to use PNN and ANFIS to predict user based SQ of intercity train. The next two immediate sections depict the architecture of PNN and ANFIS accompanied by some broad information about these methods.

2.4 Artificial Neural Network (ANN)

The learning aptitude of human in making decision and applying it on changing situations can be simulated by Artificial Neural Networks (ANN). ANN recognizes the characteristics from the defined variables based on existing data, although irregularity is present (Kasabov et. al. 1996). They can buffer the irregularity existed in data and resolve a decision nearly to the actual situation. As a result, no predefined model is mandatory to decide on various situations. ANN consists of processing units analogous to neurons of human brain. They are organized into some interconnected layers. Each neuron has an activation function and some local parameters. Adjustment on local parameter changes the node function.

Neural Network (NN) may be of single or multiple layers. Network composed of input neurons followed by output neurons is called single layer neural network. Multiple layers consist of one or more hidden layers along with an input and an output layer. Artificial Neural Networks (ANN) are of several types such as Radial basis Function Network (RFN), Feed Forward Neural Network (FFNN), Recurrent Neural Network (RNN), and Self-organizing Map (SOM). Among them FFNN and a variant of RNN are used to carry out the research, and in this study Probabilistic Neural Network (PNN) is used for modeling the result.

2.4.1 Probabilistic Neural Network (PNN)

Probabilistic Neural Network (PNN) can map any input pattern to any number of classifications. It is a four-layered neural network which operates by minimizing the 'expected risk' function (Specht et al. 1990). It is based on well-established statistical principles derived from Bayes' decision strategy and non-parametric kernel based estimators of Probability Density Functions (PDFs). Parzen et al. (1962) introduced a smooth and continuous class of estimators that asymptotically approach the real density. Later, Specht et al. (1990) used it in the PNN design. PNN uses the information during testing which were stored at the time of training the network. This implies that for each input data there is a node in the hidden layer. PNN is also an adaptation of radial basis network that is used for classification problems. It has a radial basis portion as activation function and a competitive portion. The four layers of PNN architecture are: input layer, pattern layer, summation layer and output layer. Figure 1 shows a PNN architecture that recognizes classes to determine intercity train SQ by means of a set of user attributes. The first layer shows the input pattern consists of 18 user attributes.

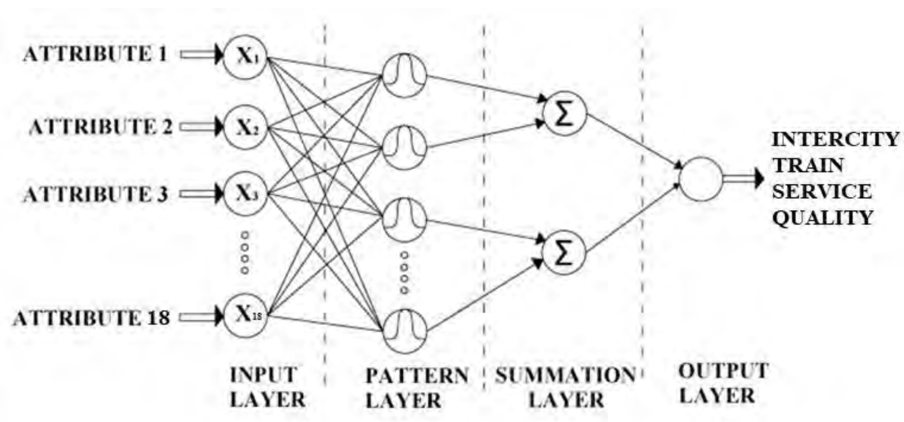


Figure 2.1 Architecture of PNN

The number of nodes in the pattern layer is equal to the number of training instances. The number of nodes in the summation layer is equal to the number of classes in the training instances. The input layer is fully connected to the pattern layer. The input layer does not perform any computation and simply distributes the values of user attributes to the neurons in the pattern layer. The pattern layer is semi-connected to the summation layer. Each group of training instances corresponding to each class is just connected to one node in the summation layer. In other words, the summation units simply sum the inputs from the pattern units that correspond to the category from which the training pattern was selected. Finally, output layer shows the estimated class extracted from summation layer. PNNs are found to be the best neural classifiers among all other ANNs due to their design architecture (Jang et al. 1993). Training in PNN is relatively fast as each input is shown to the network only once. Unlike the traditional neural networks, no learning rule is required to train a PNN and no predefined criterions are needed.

To build the network, at first, the products of the example vector and the input vector are summed. For each class node, these activations are summed. The pattern node activation (*h*) shown in the following equation, is simply the product of the two vectors (E is the example vector, and F is the input feature vector).

$$h_i = E_i F \qquad \text{Eqn (1)}$$

The class output activations (SQ) are then defined as:

$$C_j = \frac{\sum_{i=1}^{N} e^{\frac{(h_i - 1)}{\gamma^2}}}{N} \qquad \text{Eqn (2)}$$

Where,

C_j = output class; N = sample size; h_i = hidden-node activation; γ =smoothing factor.

2.5 Fuzzy Logic

Fuzzy Logic (FL) is based on the idea that humans are capable of highly adaptive control, even though the inputs used are not always precise. In an attempt to mimic the human decision-making process, FL was developed to make decisions on the basis of noisy and imprecise information inputs. Kaehler explains, “FL provides a simple way to arrive at a definite conclusion based upon vague, ambiguous, imprecise, noisy, or missing input information” (Jang et al. 1993). Typically, fuzzy systems rely on a set of if–then rules paired with membership functions used to describe input and output variables. In short, the fuzzy rules work to fuzzify and aggregate the input values, convert them into terms of output variables, and finally defuzzify the values of the output functions (Basser et al. 2014).

2.5.1 Adaptive neuro-fuzzy inference system (ANFIS)

In Service Quality (SQ) evaluation, the complex relationships among all observed attributes create an environment that is difficult to define intuitively. A neuro-fuzzy approach which can learn from the training data was used accordingly. Artificial Neural Network (ANN) creates a computational structure which functionally can perform like human brain. It interconnects neurons or nodes those use input data and Membership Functions (MFs) to process and transmit outputs. Jang et al. (1993) adopted the network learning algorithm to Fuzzy-Logic Inference System (FIS) and named the structure as ANFIS. It combines the FIS and ANN. A like human brain, ANFIS can process train data to grain experience and create a fuzzy-logic based network with complex algorithm. The algorithm works stepwise. The FIS was used to model non-linear relationship and the NN was used to calibrate the parameters of input and output MFs. The ANFIS tool in MATLAB 2014a was used in this research to predict train's overall SQ. This tool offers both Sugeno-type and Mamdani-type inference system. As Sugeno-type is a more compact and computationally efficient representation than a Mamdani system, it gives itself to the use of adaptive techniques for constructing fuzzy models (see, Sugeno 1985). Hence, the current study chooses the Sugeno-type model in FIS to capture the non-linear relationship between intercity train SQ and its attributes. The objective function of ANN training optimizes the weights for a specific set of inputs and outputs. The output calculated by the network was compared with the corresponding training data. Then the randomly set parameters were adjusted in order to reduce the errors of output. The optimization process ends when the error reaches expected value. To calibrate parameters, back propagation or a combination of least-squares and back propagation gradient descent method is used in ANFIS structure.

The calibration of MF was performed by using input data (i.e. observed attributes) and output data (i.e. overall passenger's satisfaction) through the learning process. The process consists of two main steps, the collection of learning data and FIS generation. Data collection consisted of gathering sufficient relevant training data describing the relationship between observed variables or attributes and the corresponding overall passengers' satisfaction level by using numerical ranking. For every individual test, a training database with 1037 respondents for regular days and 553 respondents for special days were collected from Stated Preferences (SP) survey. The structure of the FIS was constrained to allow 181 MFs for input attributes and the shapes of the input MFs were selected for both regular days and special days. The numbers of rules depend on the number of MFs and input variables. However, rule outputs have different strength. The rule outputs were combined to provide a single output. The questionnaire survey data was used to perform the calculations required by the ANFIS. During the learning process, ANFIS modifies the input and output MF parameters with the objective of minimizing the error. The error is the sum of the squared differences between the observed and modeled value.

The structure of ANFIS comprises of five-layers, those are—(i) fuzzification; (ii) fuzzy AND; (iii) normalization; (iv) defuzzification; and (v) output layer as shown in Figure 2 (a). Each of these layers is connected through direct links and nodes. Nodes are process units which consist of adaptive and fixed parameters. By setting learning rules, adaptive parameters can be altered and the membership functions are reformed. In the structure of ANFIS, the first layer consists of attributes or observed variables of train SQ. Second layer comprises of MF of each input. Different rules are organized in the third layer. Each rule represents output MF in the fourth layer. Final output or overall SQ satisfaction is calculated by the weighted average method in the fifth layer.

The first step of ANFIS is identification of the input and output variables. It uses first-order Sugeno fuzzy model and two typical if-then fuzzy rules with a set of two input variables (x, y) and one output (f) is considered. a and b are the coefficient of the input variables and c is the constant term.

Rule 1: If x is P1 and y is Q1, then $f1 = a1x+b1y+c1$ ……………………………..Eqn (3)

Rule 2: If x is P2 and y is Q2, then $f2 = a2x+b2y+c2$ ……………………………. Eqn (4)

All nodes in first layer i.e. fuzzy layer are adaptive. It is also known as input layer. The relationship between the output and input MFs of this layer is as follows:

$O_m^1 = \mu_{P_m}$ (i); m= 1, 2 ………………………………………………..……..… Eqn (5)

$O_n^1 = \mu_{Q_n}$ (j); n= 1, 2 …………………………………………………………..Eqn (6)

Here, x and y are the input of nodes Pm and Qn respectively. Pm and Qn are the linguistic labels used in the fuzzy theory for dividing the MFs. The second layer is labeled as M. The layer is also known as input MF. All nodes are fixed in this layer and perform as simple multiplier. The outputs of this layer are firing strengths represented as:

$O_m^2 = w_i = \mu_{P_m}\mu_{Q_n}$ (j); m, n = 1, 2 …………………………………………………Eqn (7)

The third layer is labeled as N. The layer is known as rule. Nodes are also fixed nodes and perform as a regularizer to the firing strengths from the previous layer. The outputs of this layer are regularized firing strengths and given by:

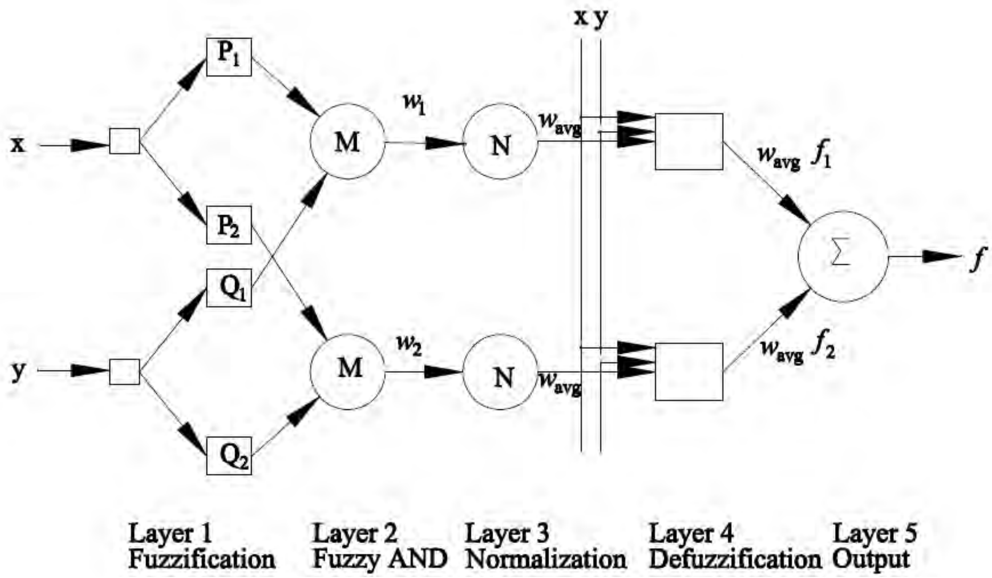
$O_m^3 = w_{avg} = \frac{w_m}{\Sigma w_m}$; m = 1, 2 ……………………………………………………Eqn (8)

All nodes are adaptive in the fourth layer. The layer is also known as output MF. The output of each node in this layer is the product of the regularized firing strength and a first order polynomial. The outputs of the layer are as follows:

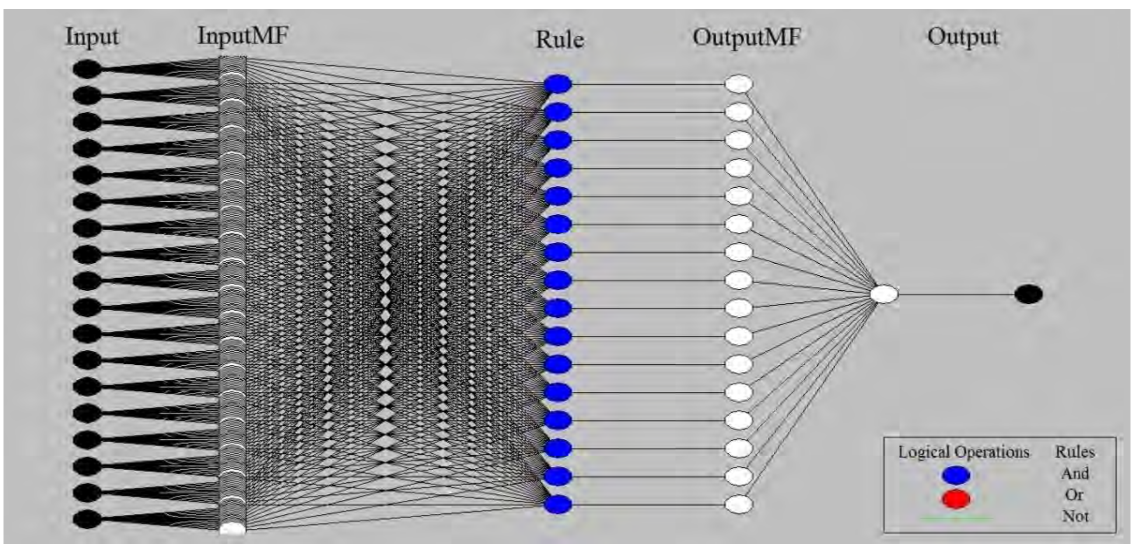
$O_m^4 = w_{avg} f_m = w_{avg}$ $(a_1x+b_1y+c_1)$; m= 1,2 …………………………………………Eqn (9)

Only one single fixed node performs the summation of all incoming signals in the fifth layer and it is labeled as Σ. Therefore, the overall output of the model in the fifth layer represented as:

$O_m^5 = \sum_{i=1}^{2} w_{,avg} f_m = \frac{\sum_{m=1}^{2} w_m f_m}{\Sigma w_m}$; m = 1, 2 ……………………………………….. Eqn (10)



(a)



(b)

Figure 2.2 (a) Structure of ANFIS; and (b) ANFIS framework shown in MATLAB inference.

2.6 Summary

This chapter provided an overview on the previous studies on Service Quality (SQ) assessment. Again this chapter described two Artificial Intelligence (AI) models namely Probabilistic Neural Network (PNN) and Adaptive Neuro-Fuzzy Inference System (ANFIS). The models were reviewed with respect to their categories in terms of level of detail, scale of independent variables, nature of independent variables and model representations. There were a very limited work on predicting of SQ using PNN and ANFIS. Hence, this research work aims at introducing two models based on intercity train users' data which is expected to show the SQ of intercity train including most important attributes which is needed to improve for users' satisfaction.

Chapter 3

STUDY METHODOLOGY AND DATA COLLECTION

3.1 General

This chapter gives a detailed overview of the study methodology as well as the data collection in the study location. The methodology section of this chapter is composed of three subsections: Selection of SQ attributes, Data collection, and Model development.

A Stated Preference (SP) questionnaire survey is conducted to collect the intercity train users' opinion. Collected data are then studied with the help of analyzing tools. This section also contains the location map of selected survey routes and information about survey location.

The research procedure is chronologically outlined below.

3.2 Selection of SQ Attributes

The first component addresses Service Quality (SQ) attributes selection process to perform a purpose-built questionnaire survey. This process mainly consists of two steps. Firstly, the analysis of the intercity trains users' view. Secondly, the analysis of public transport specialists' view towards SQ indicators. Primarily, all the SQ attributes are noted from the focus group discussions for both present and potential users. Another list is prepared from the consultations of public transport experts and recommendations of previous researches (Pandit et. al. 2013, Eboli et. al. 2009, Dell'Olio et. al. 2010 and NCHRP Report, 2008). Finally, a concise set of 18 SQ attributes is selected to carry out the research work. The list of selected 18 attributes is given in Table 3.1.

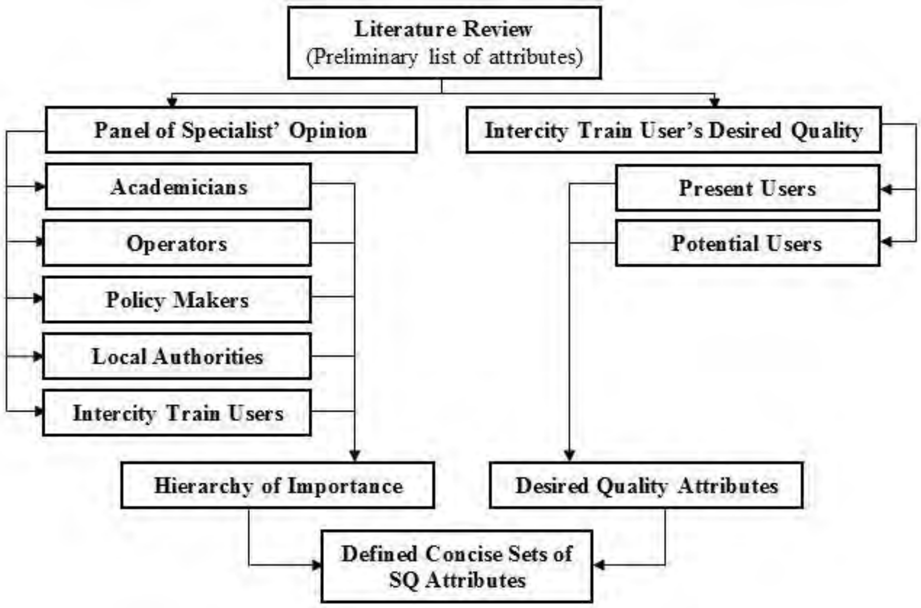


Figure 3.1 Framework for SQ Attributes Selection

Table 3.1 Selected Attributes of Intercity Trains

Serial No.	Attribute Names	Attribute References	Recommended By
01	On-time performance	Previous Research	Academicians
02	Travel delay	Intercity Train Users	Academicians
03	Convenience of online ticketing system	Intercity Train Users	Academicians, Policy Makers, Local Authorities and Intercity Train Users
04	Convenience of ticket purchasing at counter	Intercity Train Users	Academicians, Operators, Policy Makers, Local Authorities, Intercity Train Users
05	Travel cost	Intercity Train Users	Academicians, Operators, Policy Makers, Local Authorities and Intercity Train Users
06	Car arrangement	Intercity Train Users	Academicians, Policy Makers and Intercity Train Users
07	Seat comfort	Previous Research	Academicians, Policy Makers, Intercity Train Users
08	Ease at entry and exit	Intercity Train Users	Academicians, Operators, Policy Makers, Local Authorities, Intercity Train Users
09	Overall security	Previous Research	Academicians and Intercity Train Users
10	Air ventilation system	Previous Research	Academicians
11	Waiting place condition	Intercity Train Users	Academicians and Intercity Train Users
12	Meal service	Previous Research	Academicians
13	Toilet cleanliness	Intercity Train Users	Local Authorities and Intercity

(Table 3.1 Continues to next page)

(Table 3.1 Continues from previous page)

Serial No.	Attribute Names	Attribute References	Recommended By
			Train Users
14	Female harassment	Previous Research	Academicians
15	Courtesy of employees	Previous Research	Academicians
16	Fitness of car	Previous Research	Academicians
17	Car cleanness	Previous Research	Academicians
18	Noise insulation in car	Previous Research	Academicians

3.3 Procedure of Stated Preference (SP) Questionnaire Survey

Stated Preference (SP) surveys, also called self-stated preferences for market products or services, have been widely applied in the areas of marketing and travel demand modeling, separately or jointly with Revealed Preference (RP) surveys with observed choices of product purchase or service use. It is an efficient method to analyze consumers' evaluation of multi-attributed products and services, especially when there are hypothetical choice alternatives and new attributes.

In the case of intercity train's service quality of Bangladesh, there are no Revealed Preference (RP) data for the proposed intercity train services. Therefore, a Stated Preference (SP) survey is well designed and implemented for the thesis objectives.

A copy of questionnaire data sheet is attached in Appendix-A.

Survey location has been selected based on concentration of intercity train routes in Bangladesh. Maximum intercity train routes converge in Kamlapur Railway Station. Detail of train routes are given in the Table 3.2 below.

Table 3.2 Available Intercity Train routes in Bangladesh

Serial No.	Train Name	Starting Location	Destination
01	Shuborna Express	Kamlapur Railway Station, Dhaka	Chittagong Division
02	Sonar Bangla Express	Kamlapur Railway Station, Dhaka	Chittagong Division
03	Mohanagar Provati	Kamlapur Railway Station, Dhaka	Chittagong Division
04	Turna	Kamlapur Railway Station, Dhaka	Chittagong Division
05	Mohanagar Express	Kamlapur Railway Station, Dhaka	Chittagong Division
06	Chotla Express	Kamlapur Railway Station, Dhaka	Chittagong Division
07	Upakul Express	Kamlapur Railway Station, Dhaka	Sylhet Division
08	Parabat Express	Kamlapur Railway Station, Dhaka	Sylhet Division

(Table 3.2 Continues to next page)

(Table 3.2 Continues from previous page)

Serial No.	Train Name	Starting Location	Destination
09	Jayantika Express	Kamlapur Railway Station, Dhaka	Sylhet Division
10	Kalni Express	Kamlapur Railway Station, Dhaka	Sylhet Division
11	Silk City Express	Kamlapur Railway Station, Dhaka	Khulna Division
12	Padma Express	Kamlapur Railway Station, Dhaka	Khulna Division
13	Egaro Shindhu (Provati)	Kamlapur Railway Station, Dhaka	Khulna Division
14	Egaro Shindhu (Godhuli)	Kamlapur Railway Station, Dhaka	Khulna Division
15	Kishorganj Express	Kamlapur Railway Station, Dhaka	Mymanshing Division
16	Jamuna Express	Kamlapur Railway Station, Dhaka	Mymanshing Division
17	Brahmaputra Express	Kamlapur Railway Station, Dhaka	Mymanshing Division
18	Haura Express	Kamlapur Railway Station, Dhaka	Mymanshing Division
19	Tista Express	Kamlapur Railway Station, Dhaka	Mymanshing Division
20	Agnibina	Kamlapur Railway Station, Dhaka	Mymanshing Division
21	Dewanganj Express	Kamlapur Railway Station, Dhaka	Mymanshing Division
22	Rangpur Express	Kamlapur Railway Station, Dhaka	Rajshahi Division
23	Lalmoni Express	Kamlapur Railway Station, Dhaka	Rajshahi Division
24	Parbartipur Eid Express	Kamlapur Railway Station, Dhaka	Rajshahi Division
25	Ekata Express	Kamlapur Railway Station, Dhaka	Rajshahi Division
26	Drutojan Express	Kamlapur Railway Station, Dhaka	Rajshahi Division
27	Neelshagor	Kamlapur Railway Station, Dhaka	Rajshahi Division
28	Chitra Express	Kamlapur Railway Station, Dhaka	Rajshahi Division
29	Shundorban Express	Kamlapur Railway Station, Dhaka	Rajshahi Division
30	Khulna Express	Kamlapur Railway Station, Dhaka	Rajshahi Division

Kamlapur Railway Station is one of the hub of intercity trains of Bangladesh. Therefore, it is selected as a survey location to cover the maximum number of Intercity Train service in Bangladesh.

After selection of survey locations, a survey schedule has been prepared to complete the survey properly. The schedule of questionnaire survey is given in the Table 3.3 below.

Table 3.3 Questionnaire Survey Schedule

From	Date	Day	Time		To	Remarks
			From	To		
Dhaka Kamlapur Rail Station	04/07/2016	Sunday	7.00 am	6.00 pm	Chittagong Division, Sylhet Division, Khulna Division, Mymanshing Division and Rajshahi Division	Eid Days (Before)
	05/07/2016	Monday	7.00 am	6.00 pm		Eid Days (Before)
	07/07/2016	*Thursday*	*Eid ul-Azha*			*Eid ul-Azha*
	09/07/2016	Saturday	7.00 am	6.00 pm		Eid Days (After)
	19/07/2016	Wednesday	7.00 am	6.00 pm		Regular Days (Weekdays)
	21/07/2016	Thursday	7.00 am	6.00 pm		Regular Days (Weekend Starting)
	23/07/2016	Saturday	7.00 am	6.00 pm		Regular Days (Weekend Ending)

3.4 Details of study locations

Kamlapur Railway Station is one of the biggest intercity train hubs of Bangladesh. Figure 3.2 shows the location map of the Rail Station. The map had been taken through from Google maps.

Figure 3.2 Survey location (Source: Google maps)

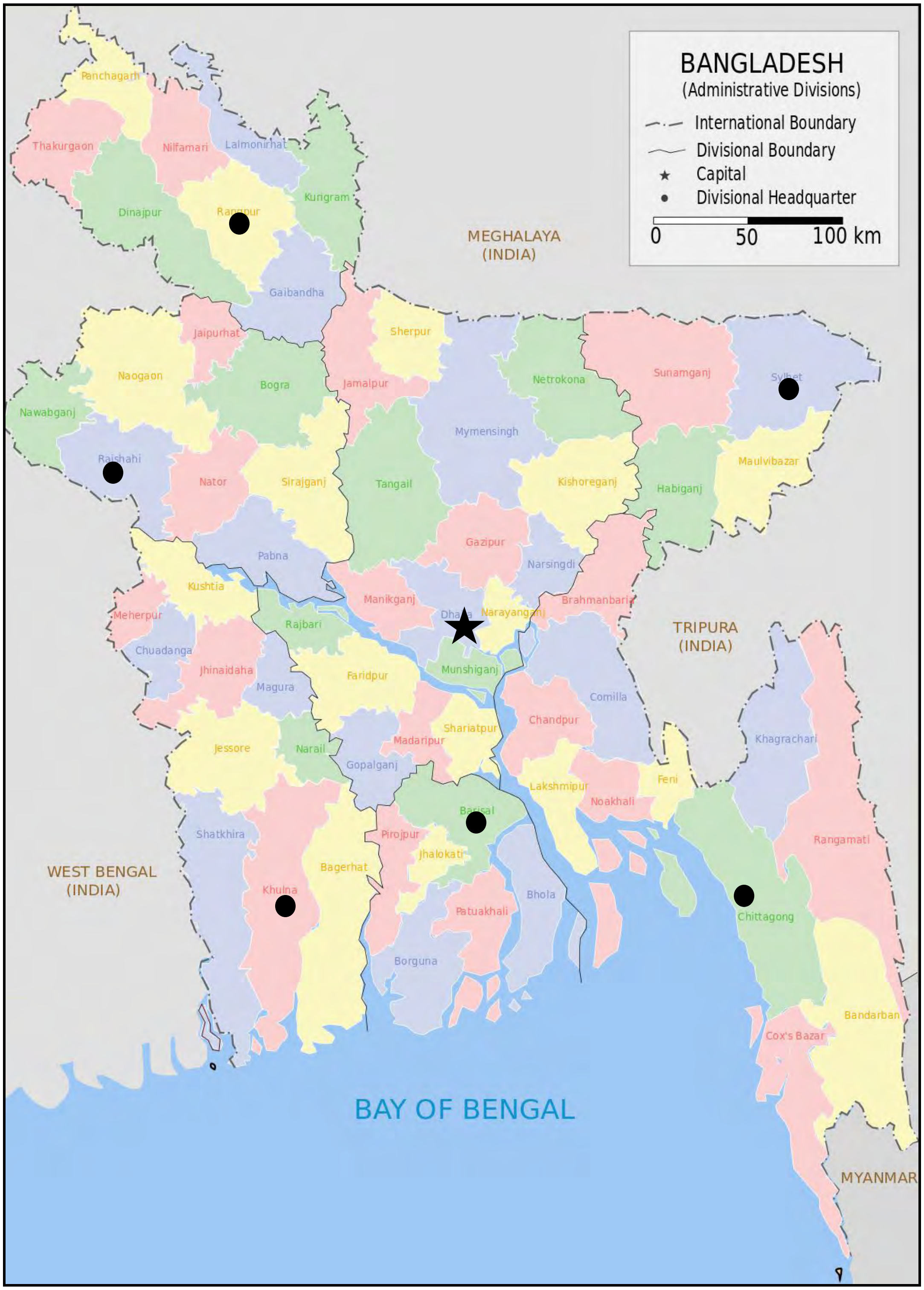


Figure 3.3 Divisions of Bangladesh (Source: Banglapidia)

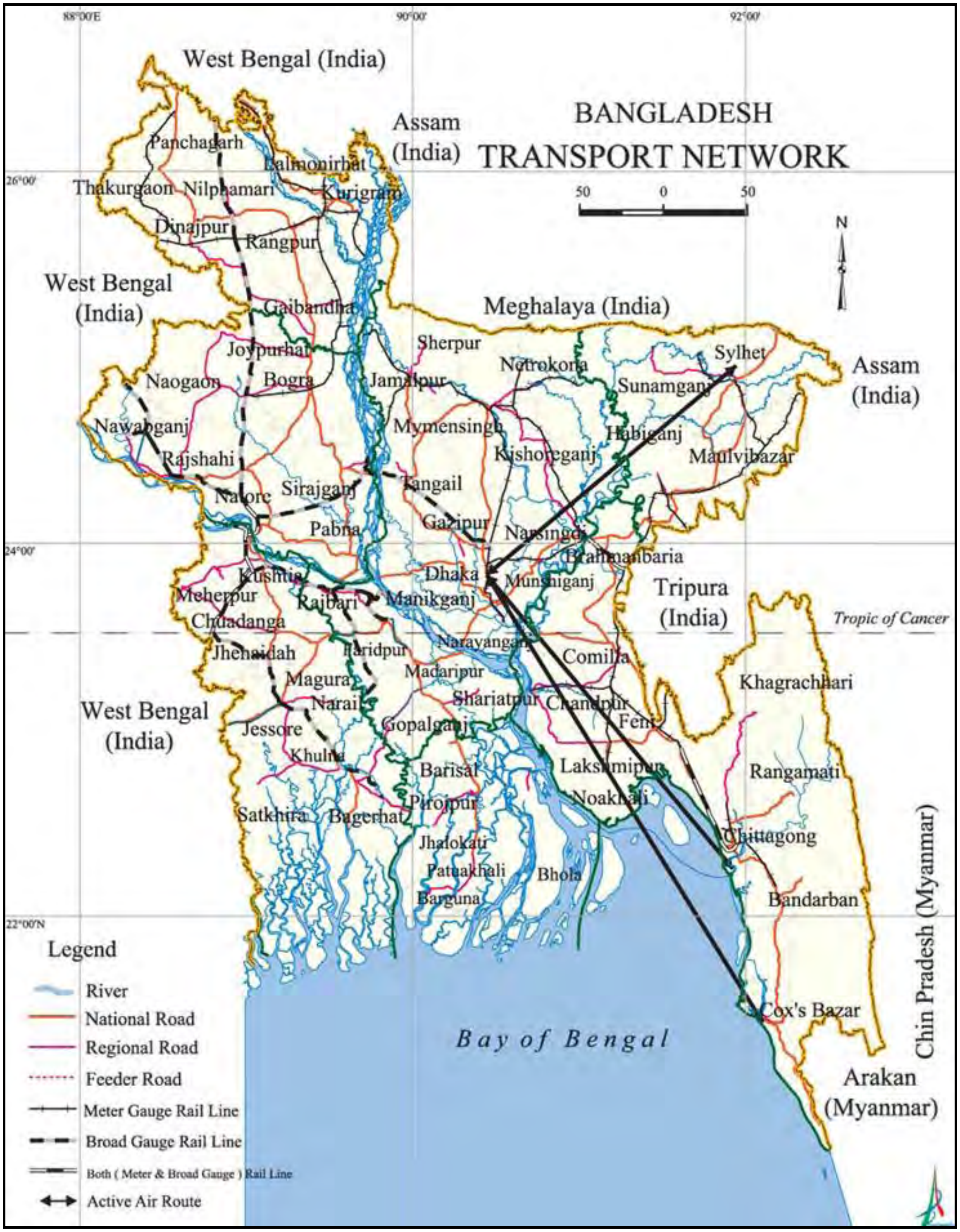


Figure 3.4 Transport Network of Bangladesh (Source: Banglapidia)

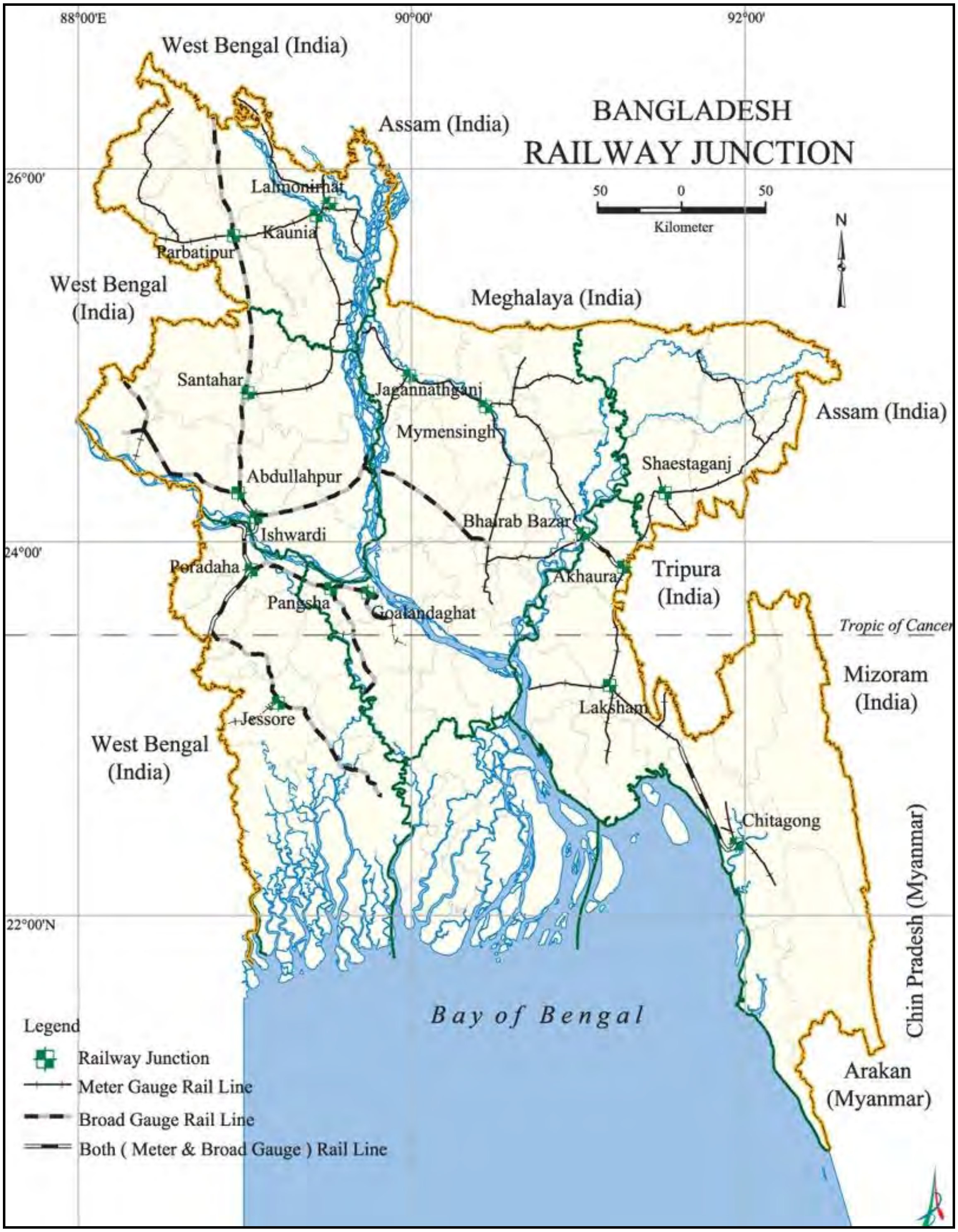


Figure 3.5 Intercity Railway Network in Bangladesh (Source: Banglapidia)

3.5 Data Collection

Face-to-face interviews were carried out with 6 skilled enumerators of intercity train at Kamlapur Railway Station on the month of July, 2016. There are three sections in the survey questionnaire. The *first section* aims to get personal and socioeconomic information (age, gender, occupation etc.) of commuters and the reason for using intercity trains. The *second section* focuses on 18 attributes that are accountable for the evaluation of intercity train SQ. The *third section* organized to get priority ranking of the attributes from the respondents. These attributes are in a close ended arrangement with relevant multiple choices. The respondents are asked to assess the present situation of the service by marking the checkboxes from their point of view against each attribute. The multiple-choice check boxes are numbered by 1 to 5 where “5” corresponds to excellent quality and “1” corresponds to very poor quality.

Data collection was set forth with an initial target of 2000 samples. However, reluctance to participate from the users, rush hour movements, and other unexpected situations restricted the random data samples to 1800. After filtering the anomalies, outputs from 1590 data (Regular day’s 1037 data and special day’s 553 data) samples are used in this research work.

3.6 Model Development (Training)

In this research, Probabilistic Neural Network (PNN) and Adaptive Neuro-Fuzzy Interface System (ANFIS) are introduced and the out-of-sample forecasting technique is applied to examine the predictive power of those models. The accuracy of a prediction model is tested by comparing its predicted outputs with corresponding observed targets. The training and forecasting sets contained 80% of whole sample (830 samples for regular days, and 443 samples for special days) and 20% of whole sample (207 samples for regular days, and 110 samples for special days) observations, respectively. MATLAB 2014b is used for the development of these models. To get the best performance, the parameters (e.g. neuron number, learning rate, momentum factor, smoothing factor, transfer functions) of the models are randomly altered by trial-and-error technique. The parameters of PNN and ANFIS models are shown in Table 3.4.

Table 3.4 Parameters Related to Probabilistic Neural Network (PNN) and Adaptive Neuro-Fuzzy Interface System (ANFIS) for Intercity Train SQ Prediction Models

PNN		ANFIS	
Number of input variables	18	Number of input variables	18
Number of layers	4	Number of layers	5
Initial function	initlay	Number of membership function	181
Performance function	mse	MF type	Gaussian
Performance parameter	normalization	Transfer function of hidden layer	tansigmoid
Scaling method	normalization	Scaling method	normalization
Training algorithm	Radial basis	Transfer function of output layer	linear
		Training algorithm	Back-propagation
		Training cycles, epochs	10
		Training goal	0.01

Four layered neural networks are created by using the Probabilistic Neural Network (PNN) whereas in Adaptive Neuro-Fuzzy Interface System (ANFIS) there are five layered neural networks. Every network has an input layer and an output layer. The SQ attributes are applied as input variable and the intercity train SQs as output. Some properties have to be defined to build the models to get best performances which are shown in above Table 3.4. Adaptive Neuro-Fuzzy Interface System (ANFIS) is defined with two hidden layers, membership functions and *tansigmoid* transfer function of hidden layer, *linear* transfer function of output layer, *normalization* as scaling method, 0.01 as training goal and training cycle is 10. The training algorithm of PNN performs their training by following *radial basis* algorithm.

On the other hand, PNN is defined with four layers in which there is one pattern layer and one summation layer, initlay as initial function and mse as performance function.

Both PNN and ANFIS use normalization technique as scaling method. The training algorithm of ANFIS is *back-propagation*, whereas PNN perform their training by following *radial basis* algorithm.

3.7 Summary

This chapter aims at developing the PNN and ANFIS model for the prediction of intercity train service quality of Bangladesh. This analysis prerequisites high-quality and high-volume data sets. In this context, an attribute selection process has been developed as a flow chart giving priorities to academicians, transportation researchers, previous research works, concern authorities and intercity train users. After finalizing attributes, the study location with time scheduling is planned to conduct the stated preference (SP) survey. Then, survey sheet and collected data arrangement and sorting are briefly presented. Finally, at the end to the chapter, a section briefly discussed the development of PNN and ANFIS model.

Chapter 4

SURVEY DETAIL DATA ANALYSIS AND RESULTS

4.1 General

This Chapter contains the characteristics of intercity train users, details description of users' perception for each question of survey and the details of model development.

4.2 Characteristics of Intercity Train User

1037 respondents in regular days and 553 respondents in special days were selected randomly from kamlapur rail station, intercity train hub of Bangladesh. Trains depart and arrive in kamlapur rail station from different locations of Bangladesh. Table 4.1 illustrates the general characteristics of the respondents collected from the questionnaire survey.

Table 4.1 General characteristics of the Intercity Train Users

Characteristics	Statistics	Occasional Days		Regular Days	
		No. of Respondents	Percentage	No. of Respondents	Percentage
Gender	Male	407	73.68 %	804	77.54 %
	Female	156	26.32 %	233	22.45 %
Age	11 ~ 20 Years old	121	21.88 %	169	16.28 %
	21 ~ 30 Years old	292	52.80 %	557	53.74 %
	31 ~ 40 Years old	92	16.64 %	211	20.31 %
	41 ~ 50 Years old	42	7.59 %	79	07.66 %
	51 ~ 60 Years old	5	0.90 %	16	01.53%
	> 60 Years old	1	0.18 %	5	0.48%
Occupation	Service Holder	158	28.62 %	315	30.39%
	Business	281	20.65 %	211	20.33%
	Student	143	25.91 %	282	27.23%

(Table 4.1 Continues to next page)

(Table 4.1 Continues from previous page)

Characteristics	Statistics	Occasional Days		Regular Days	
		No. of Respondents	Percentage	No. of Respondents	Percentage
	Worker	97	17.57 %	180	17.35%
	Housewife	40	7.25 %	49	4.70%
Motivation of Choosing Intercity Train	Captive Rider	23	4.24%	23	2.23 %
	Economical	60	10.89%	137	13.20 %
	Comfortable	138	24.91%	308	29.71 %
	Safer	315	56.83%	550	53.01 %
	Other	17	3.14%	19	1.82 %
Will choose Alternative Mode if Delay	1hr+	34	6.12%	115	11.08 %
	2hr+	123	22.32%	351	33.85 %
	3hr+	252	45.57%	388	37.38 %
	4hr+	100	18.04%	123	11.85 %
	5hr+	44	7.95%	61	5.85 %

4.3 Users' Satisfaction Ratings about Intercity Train

4.3.1 Overall service quality of intercity train

Question: What is your view on overall service quality of intercity train?

The overall service quality of intercity train from user's perspective has reflected by this question.

In special days and regular days, overall service quality has given in detail in the following Table 4.2.

Table 4.2 Overall Service quality of Intercity Train

Characteristics	Statistics	Special Days		Regular Days	
		No. of Respondents	Percentage	No. of Respondents	Percentage
Overall Service Quality from User's Perspective	Very Poor	0	0.00 %	0	0.00 %
	Poor	14	2.47 %	50	4.79 %
	Satisfactory	432	78.20 %	697	67.24 %
	Good	102	18.43 %	266	25.67 %
	Very Good	5	0.90 %	24	2.30 %

In this question, the respondents were asked about the existing condition of intercity train service quality. Major portion (67.24 % on regular days and 78.20 % on special days) of the respondents said that overall quality of intercity train service is satisfactory while 25.67% users on regular days and 18.43% on special days think that existing condition is good. The user perception about prevailing intercity train quality is shown in Figure 4.1 below.

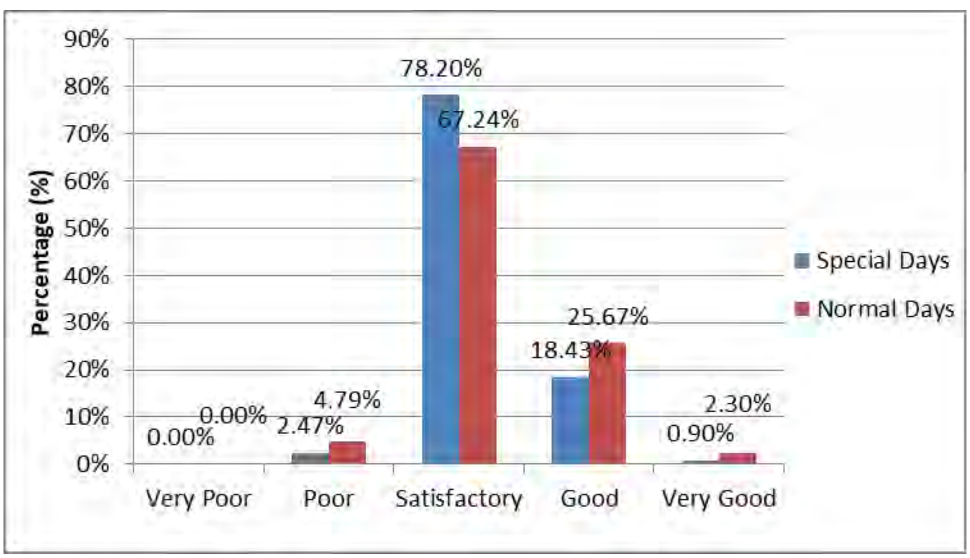
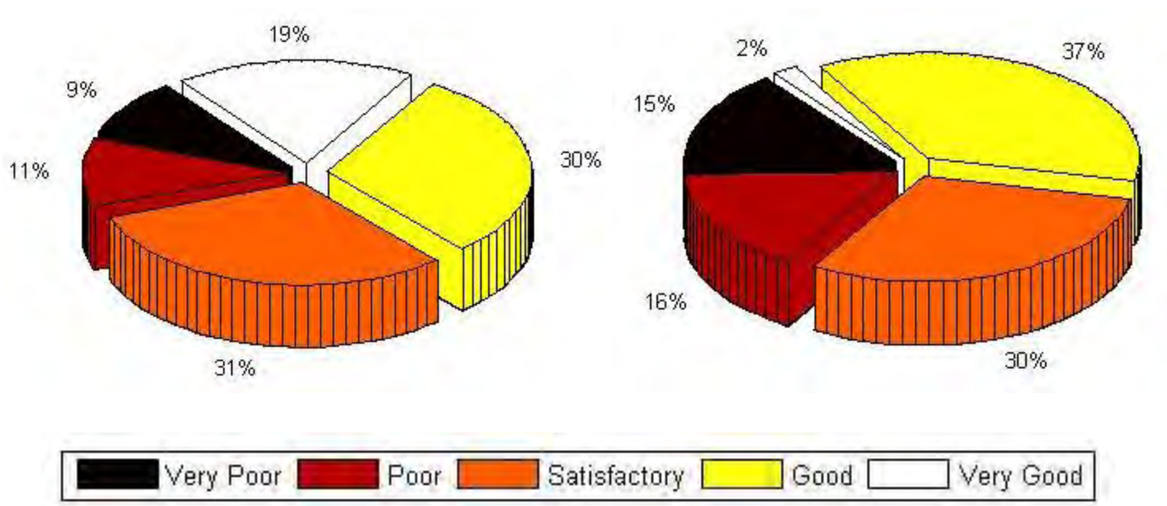


Figure 4.1 User Perception about prevailing intercity train's overall service quality

4.3.2 Question wise users' satisfaction ratings of Intercity train

Question 1: How is the on-time performance of the intercity train of Bangladesh? (On-time performance)

In intercity train service of Bangladesh, on-time performance is good on regular time but slightly degrades on occasional periods like on Eid festival. These also reflect on user's responses. About 19% and 2% respondents replied that on-time performance is very good on regular days and special days, respectively. On the contrary, about 9% and 15% of the respondents replied that the on-time performance of intercity train is very poor on regular days and special days, respectively. Therefore, it is clear from the respondents that on-time performance of the intercity train degrades on special occasions in Bangladesh. But surprisingly about same percentage of the respondents (31% and 30% on regular days and special days, respectively) feels that on-time performance is satisfactory.

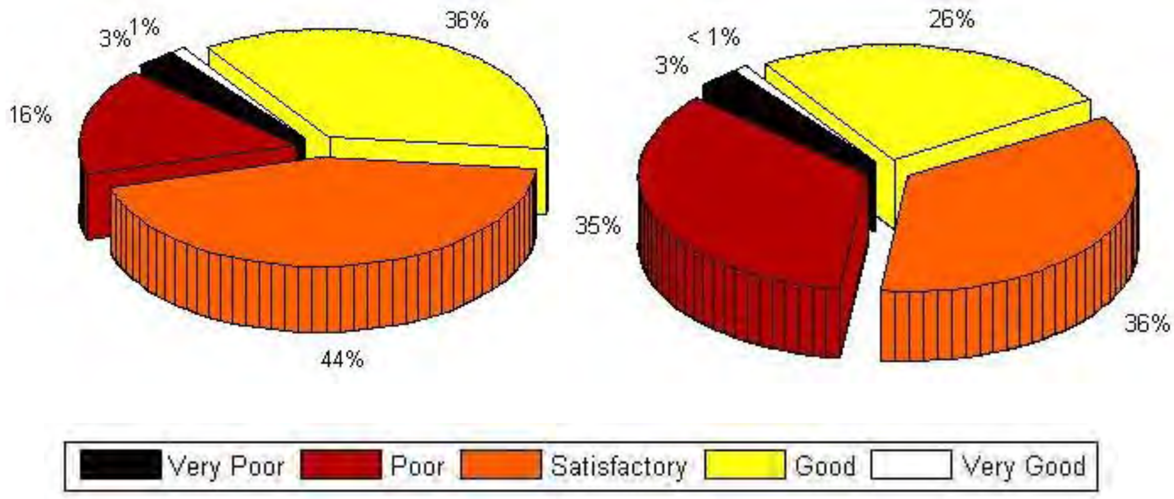


(a) Regular Days (b) Special Days

Figure 4.2 User Perception about on-time performance level of intercity train service

Question 2: What is your opinion about travel delay reaching destination? (Travel Delay)

In Bangladesh, travel delay of intercity train increases in occasional periods like Eid festival. This reflects in the respondents replies. About 80% (44% and 36% respondents replied good and very good, respectively) of the respondents satisfied about travel time and marked above Satisfactory as their satisfactory level on regular days. On the other hand, on the special days this decreases to 62%. But surprisingly on the both occasions respondents replied in same percentages on very poor and poor of about 1% and 3%.



(a) Regular Days (b) Special Days

Figure 4.3 User Perception about travel delay of intercity train service

Question 3 How <u>convenient</u> is the <u>online ticketing system?</u> (<u>Convenience of online ticketing system</u>)

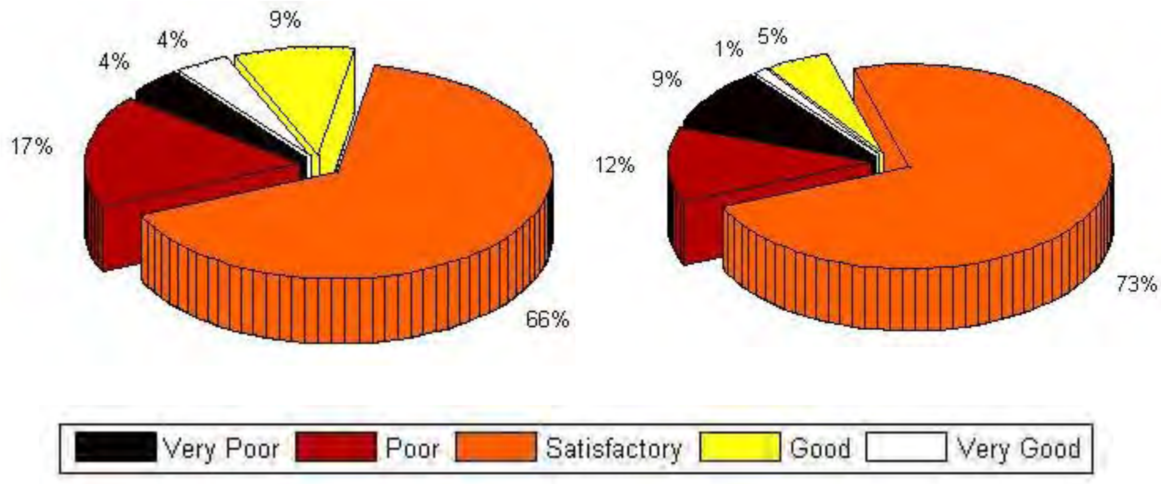
Although Online ticketing system is a revolutionary step in the intercity train service, most of the people in developing countries couldn't avail the full benefit of the system. This is due to cause of the availability of the internet connectivity. This fact also reflected in the user's responses of this study. Respondents of about 91% of regular days and 89% of special days, responded positively and given opinion 'Satisfactory' and above satisfactory, i.e., 'Good' and 'Very Good' to the online ticketing system. On the contrary, about 9% and 11% of regular days and special days replied poor and very poor because of the unavailability of ticket and internet connectivity.

(a) Regular Days (b) Special Days

Figure 4.4 User Perception about the Convenience of online ticketing system of intercity train service

Question 4: How <u>convenient</u> it is to <u>purchase ticket at counter</u>? (<u>Convenience of ticket purchasing at counter</u>)

Counter ticketing system is convenient for everybody who does not know how to use internet or do not have internet connectivity. But in the rush hours or occasional periods, counters are very crowded. For any person, purchasing ticket in the counter is being very problematic. Respondents of about 78% of regular days and 76% of special days, responded positively and given opinion 'Satisfactory' and above satisfactory, i.e., 'Good' and 'Very Good' to the counter ticketing system. On the contrary, about 22% and 21% of regular days and special days replied poor and very poor because of the crowded scenarios of the counter ticketing system.

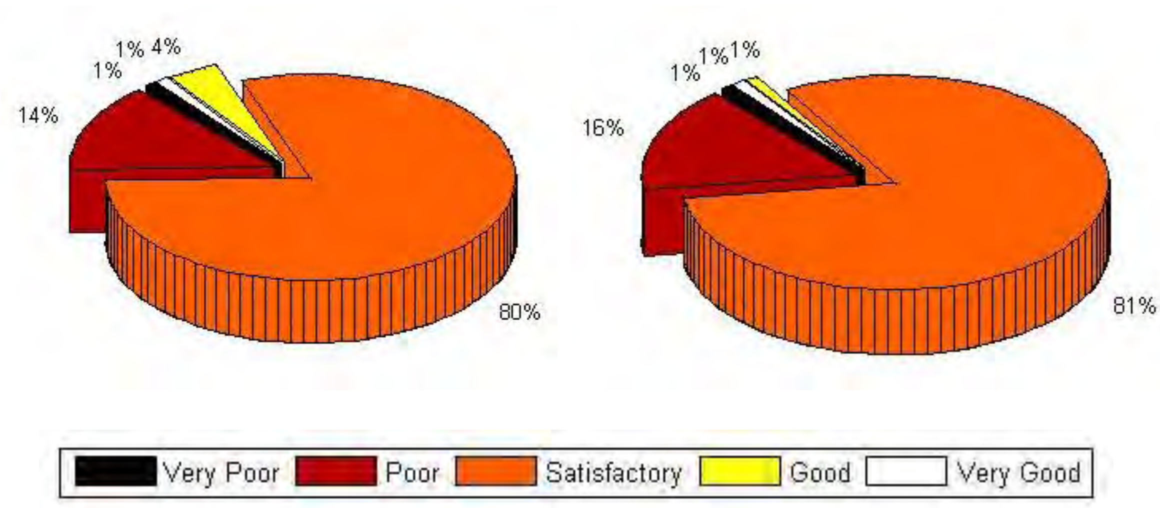


(a) Regular Days (b) Special Days

Figure 4.5 User Perception about the Convenience of ticket purchasing at counter of intercity train service

Question 5: What is your idea about <u>travelling cost</u> of intercity train? (<u>Travel cost</u>)

On regular days, travel cost of intercity train is low comparing with other mode of transport in developing countries. But as the demand does not meet with the capacity, on occasional time intercity train ticket price increases unofficially as people intended to profit unethically by syndicating ticket price. Respondents of about 85% of regular days and 83% of special days, responded positively and given opinion 'Satisfactory' and above satisfactory, i.e., 'Good' and 'Very Good' to the counter ticketing system. On the contrary, about 15% and 17% of regular days and special days replied poor and very poor because of the crowded scenarios of the counter ticketing system.



(a) Regular Days (b) Special Days

Figure 4.6 User Perception about travel cost of intercity train service

Question 6: What is your opinion about intercity train's <u>car arrangement</u>? (<u>Car arrangement</u>)

Normally, cars of the intercity trains are arranged alphabetically. But during rush hour periods of festival time, sometime that happens to be overlooked and cars are attached in disorderly manner. Respondents of about 94% of regular days and 95% of special days, responded positively and given opinion 'Satisfactory' and above satisfactory, i.e., 'Good' and 'Very Good' to car arrangement. On the contrary, about 6% and 5% of regular days and special days replied poor and very poor because of the random car arrangement.

(a) Regular Days (b) Special Days

Figure 4.7 User Perception about car arrangement of intercity train service

Question 7: How comfortable is the seat of the intercity train? (Seat comfort)

In long journey, seat comfort is a big issue for intercity train. Respondents of about 77% of regular days and 83% of special days, responded positively and given opinion ‘Satisfactory’ and above satisfactory, i.e., ‘Good’ and ‘Very Good’ to seat comfort. On the contrary, about 23% and 17% of regular days and special days replied poor and very poor because of some poor quality seat about seat comfort.

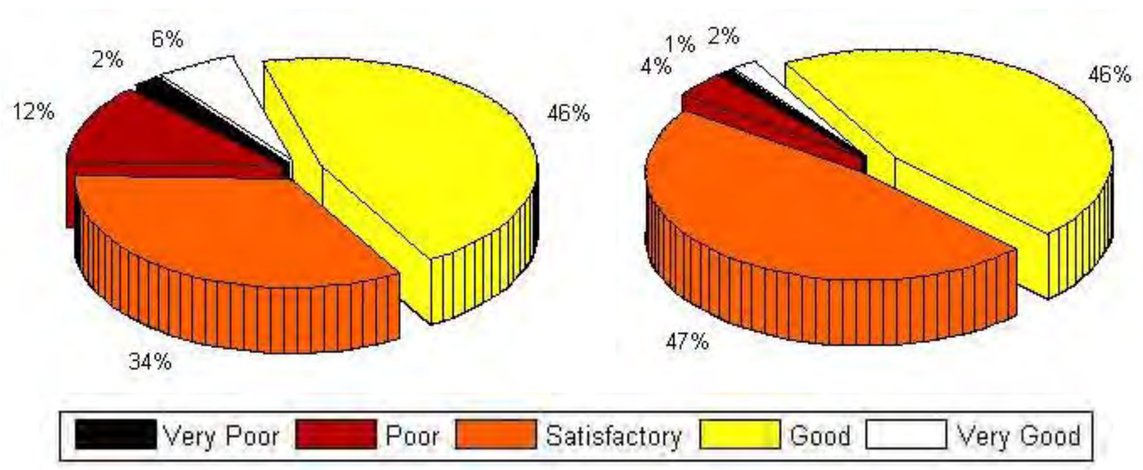
(a) Regular Days (b) Special Days

Figure 4.8 User Perception about seat comfort of intercity train service

Figure 4.9 Seat condition of intercity train

Question 8: What is your opinion about ease of entry-exit in intercity train? (Ease at entry and exit)

Bangladesh railway cars are way above the platform. That's why it is very troublesome to step in the cars. Respondents of about 86% of regular days and 95% of special days, responded positively and given opinion 'Satisfactory' and above satisfactory, i.e., 'Good' and 'Very Good' to ease of entry and exit. On the contrary, about 14% and 5% of regular days and special days replied poor and very poor because of vertical stair and its height about ease of entry and exit.



(a) Regular Days (b) Special Days

Figure 4.10 User Perception about ease at entry and exists of intercity train service

Figure 4.11 Entry Exit pathway of Intercity Train (Tista)

Question 9: What is your opinion about overall security in intercity train? (Overall security)

In most of the developing countries, security is a very important issue. This reflects in the respondents replies. Respondents of about 90% of regular days and 88% of special days, responded positively and given opinion 'Satisfactory' and above satisfactory, i.e., 'Good' and 'Very Good' to overall security. On the contrary, about 10% and 12% of regular days and special days replied poor and very poor about overall security.

(a) Regular Days (b) Special Days

Figure 4.12 User Perception about overall security of intercity train service

Question 10: What is your opinion about air ventilation system of intercity train of Bangladesh? (Air ventilation system)

Air ventilation system of Bangladesh railway cars are mainly doors, windows and car top fans. In air-conditioned cabin, AC is the main air ventilation system. From user's responses, it was obtained that air ventilation system of intercity train is better in regular days than special days. Respondents of about 94% of regular days and 90% of special days, responded positively and given opinion 'Satisfactory' and above satisfactory, i.e., 'Good' and 'Very Good' to air ventilation system. On the contrary, about 6% and 10% of regular days and special days replied poor and very poor about overall security.

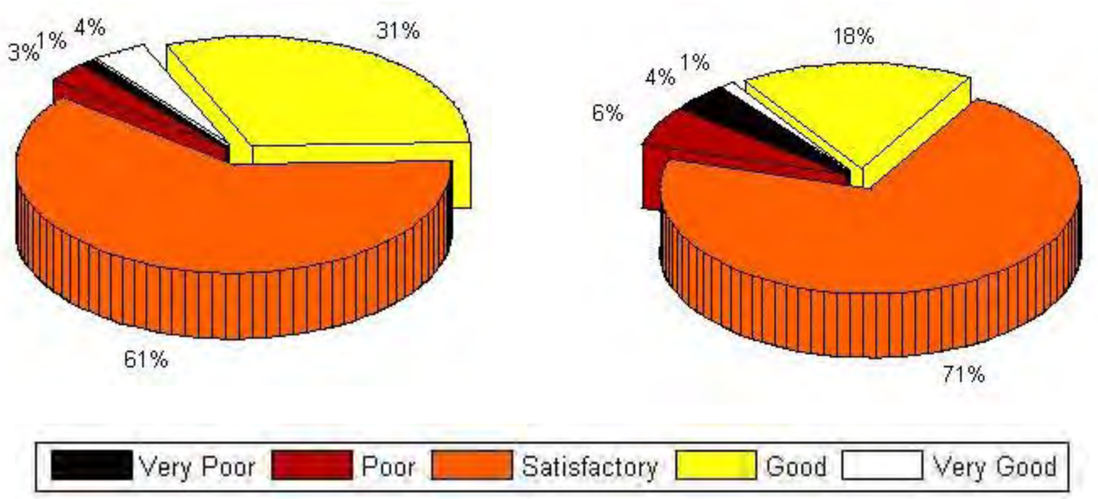
(a) Regular Days (b) Special Days

Figure 4.13 User Perception about air ventilation system of intercity train service

Figure 4.14 Air ventilation system of Intercity Train

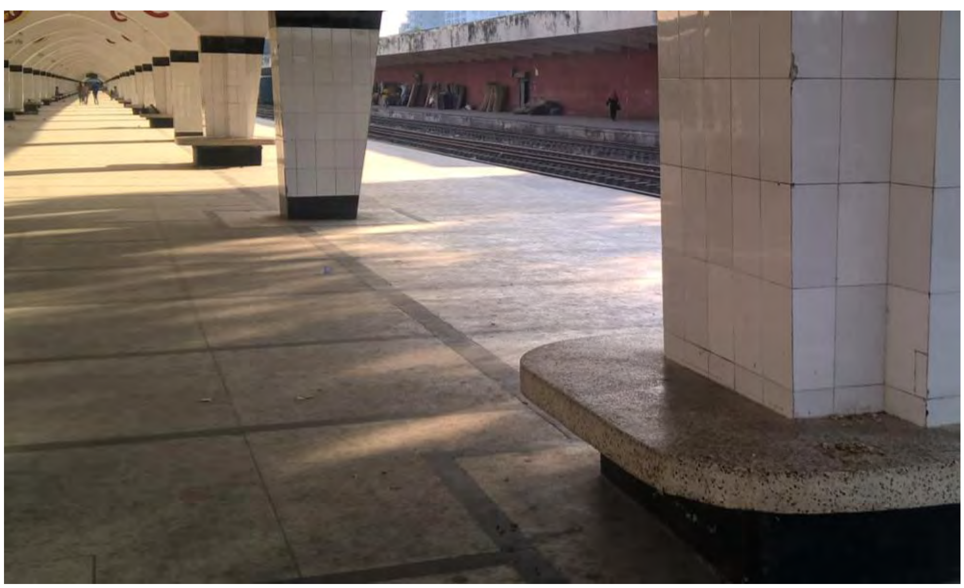
Question 11: What do you think about <u>waiting place condition</u> of intercity train service of Bangladesh? (<u>Waiting place condition</u>)

Waiting place condition of intercity train station is a vital factor. As in some cases, many people had to wait for long time for train in railway station. As crowed increases, quality of waiting place becomes very important for the positive perception of intercity train users. Respondents of about 96% of regular days and 90% of special days, responded positively and given opinion 'Satisfactory' and above satisfactory, i.e., 'Good' and 'Very Good' to waiting place condition. On the contrary, about 4% and 10% of regular days and special days replied poor and very poor because of long waiting period on railway station about waiting place condition.



(a) Regular Days (b) Special Days

Figure 4.15 User Perception about waiting place condition of intercity train service



(a)

(b)

Figure 4.16 Waiting place condition, (a) Regular days, and (b) Special days

Question 12: What is your idea about meal service of intercity train of Bangladesh? (Meal service)

In long journey, users takes meals in different periods. Respondents of about 90% of regular days and 94% of special days, responded positively and given opinion 'Satisfactory' and above satisfactory, i.e., 'Good' and 'Very Good' to meal service. On the contrary, about 10% and 6% of regular days and special days replied poor and very poor about meal service

(a) Regular Days (b) Special Days

Figure 4.17 User Perception about meal service of intercity train service

Question 13: What is your comment about toilet cleanliness of intercity train of Bangladesh? (Toilet cleanliness)

Like all long distance traveling transportation modes, toilet is an essential part of an intercity train car. Respondents of about 95% of regular days and 98% of special days, responded positively and given opinion 'Satisfactory' and above satisfactory, i.e., 'Good' and 'Very Good' to toilet cleanliness. On the contrary, about 5% and 2% of regular days and special days replied poor and very poor about toilet cleanliness.

(a) Regular Days (b) Special Days

Figure 4.18 User Perception about toilet cleanliness of intercity train service

Question 14: In your point of view, what is the condition of Security for female (harassment) in intercity train service of Bangladesh? (Female harassment)

Female harassment is very sensitive issue. In some cases, even victim do not want to complain or disclose the issue. That is why it is very difficult to collect data. In this research study, Respondents of about 91% of both regular days and special days, responded positively and given opinion 'Satisfactory' and above satisfactory, i.e., 'Good' and 'Very Good' to female harassment. On the contrary, about 10% and 6% of regular days and special days replied poor and very poor about female harassment.

(a) Regular Days (b) Special Days

Figure 4.19 User Perception about female harassment of intercity train service

Question 15: What is your opinion about courtesy of employees of intercity train? (Courtesy of employees)

Courtesy of the employees are very important to retain existing users and attract new users. Respondents of about 97% of regular days and 98% of special days, responded positively and given opinion 'Satisfactory' and above satisfactory, i.e., 'Good' and 'Very Good' to courtesy of employees. On the contrary, about 3% and 2% of regular days and special days replied poor and very poor about courtesy of employees.

(a) Regular Days (b) Special Days

Figure 4.20 User Perception about courtesy of employees of intercity train service

Question 16: What is your idea about fitness of the car of intercity train? (Fitness of car)

Car fitness is a prerequisite of comfort and safety of intercity train. Respondents of about 93% of regular days and 96% of special days, responded positively and given opinion 'Satisfactory' and above satisfactory, i.e., 'Good' and 'Very Good' to car fitness. On the contrary, about 7% and 4% of regular days and special days replied poor and very poor about car fitness.

(a) Regular Days (b) Special Days

Figure 4.21 User Perception about fitness of car of intercity train service

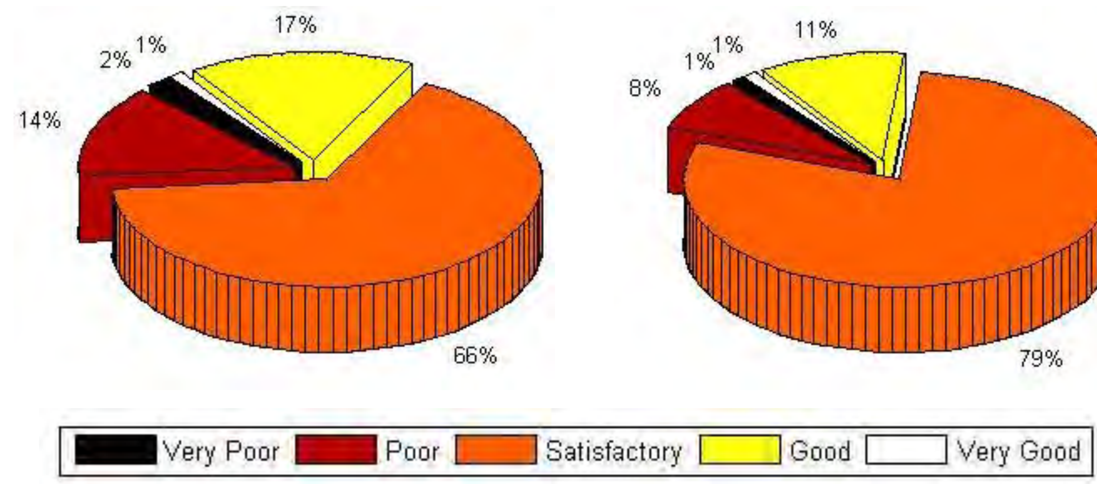
(a)

(b)

Figure 4.22 Car fitness of Intercity Train

Question 17: What do you think about car cleanness of intercity train? (Car cleanness)

Car cleanness is a prerequisite of retaining existing users and attract new users. Respondents of about 84% of regular days and 91% of special days, responded positively and given opinion ‘Satisfactory’ and above satisfactory, i.e., ‘Good’ and ‘Very Good’ to car cleanness. On the contrary, about 16% and 9% of regular days and special days replied poor and very poor about car cleanness.



(a) Regular Days (b) Special Days

Figure 4.23 User Perception about car cleanness of intercity train service

Question 18: What is your opinion about noise insulation in the car of intercity trains? (Noise insulation in car)

Noise insulation in cars is a vital requirement for comfort intercity train ride. Respondents of about 36% of both regular days and special days responded positively and given opinion ‘Satisfactory’ and above satisfactory, i.e., ‘Good’ and ‘Very Good’ to noise insulation in the cars. On the contrary, about 64% of both regular days and special days replied poor and very poor about noise insulation in cars.

(a) Regular Days (b) Special Days

Figure 4.24 User Perception about noise insulation in cars of intercity train service

These are the rating percentages given by respondents during questionnaire survey. According to these survey results it is found that people are using intercity train services mainly because of comfort and safety of intercity train. There are some problems in the service also such as, waiting place condition of intercity train service, travel cost, noise level during the service, lighting facilities, ease of entry-exit system, travel time during special days and security of the passenger.

4.4 Summery of Users' Perception about Intercity Train Service

Nineteen (19) questions (among them 18 used as intercity train attributes and one used for gathering information about the overall quality of intercity train) were used in this study to know the users' perception about intercity train service. Respondents were asked to provide a rating which reflects their opinion about different features of intercity train. They rated the questions as "Very Good", "Good", "Satisfactory", "Poor" or "Very Poor". Table 4.3 represents the summery of overall users' perception ratting for different factors of intercity train service in Bangladesh.

Table 4.3 Summary of Users' Perception about Intercity Train Service

Sl. No	Attributes	Ratings									
		Special Days					Regular Days				
		Very Good	Good	Satisfactory	Poor	Very Poor	Very Good	Good	Satisfactory	Poor	Very Poor
01	On-time performance	2 %	37 %	30 %	16 %	15 %	19 %	30 %	31 %	11 %	9 %
02	Travel Delay	26 %	36 %	35 %	3 %	1 %	36 %	44 %	16 %	3 %	1 %
03	Convenience of online ticketing system	1 %	14 %	74 %	7 %	4 %	3 %	32 %	56 %	7 %	2 %
04	Convenience of ticket purchasing at counter	1 %	5 %	73 %	12 %	9 %	4 %	9 %	65 %	17 %	5 %
05	Travel cost	1 %	1 %	81 %	16 %	1 %	1 %	4 %	80 %	14 %	1 %
06	Car arrangement	1 %	15 %	79 %	4 %	1 %	2 %	21 %	71 %	5 %	1 %
07	Seat comfort	5 %	15 %	63%	14 %	3 %	1 %	16 %	60 %	10 %	13 %
08	Ease at entry and exit	2 %	46 %	47 %	4 %	1 %	6 %	46 %	34 %	12 %	2 %
09	Overall security	1 %	12 %	75 %	11 %	1 %	2 %	21 %	67 %	9 %	1 %
10	Air ventilation system	1 %	16 %	73 %	9 %	1 %	1 %	31 %	62 %	5 %	1 %
11	Waiting place condition	1 %	18 %	71 %	6 %	4 %	4 %	31 %	61 %	3 %	1 %
12	Meal service	1 %	16 %	77 %	5 %	1 %	1 %	22 %	67 %	8 %	2 %
13	Toilet cleanliness	1 %	34 %	63 %	1 %	1 %	2 %	38 %	55 %	4 %	1 %
14	Female harassment	2 %	15 %	76 %	5 %	2 %	9 %	22 %	60 %	4 %	5 %
15	Courtesy of employees	1 %	30 %	67 %	1 %	1 %	1 %	38 %	58 %	2 %	1 %
16	Fitness of car	1 %	16 %	79 %	3 %	1 %	2 %	18 %	73 %	6 %	1 %
17	Car cleanness	1 %	11 %	79 %	8 %	1 %	1 %	17 %	66 %	14 %	2 %
18	Noise insulation in car	1 %	7 %	28 %	48 %	16 %	1 %	9 %	26 %	50 %	14 %

From questionnaire survey, opinions from intercity train user were found about quality of transport, service quality, service reliability, safety and security of the service etc. From Table 4.3, the idea of actual condition of the perception of intercity train user on individual attribute which affects the quality of service of intercity train was obtained. Existing condition of intercity train service found satisfactory for – i) Convenience of online ticketing system, ii) Convenience of ticket purchasing at counter, iii) Travel cost, iv) Car arrangement, v) Seat comfort, vi) Overall security, vii) Air ventilation system, viii) Waiting place condition, ix) Meal service, x) Toilet cleanliness, xi) Female harassment, xii) Courtesy of employees, xiii) Fitness of car, and xiv) Car cleanness. Two parameters were found in good condition during survey which are- i) On-time performance, ii) Travel Delay and iii) Ease at entry and exit. There are some parameters that found poor in condition like - Noise insulation in car.

4.5 Summary

This chapter analyses the demographic data and respondent's responses data collected through stated preference survey for intercity train service. Demographic data analysis presented in the table 4.1. Overall service quality data analysis presented in table 4.2 and all the respondent's responses analyzed accordingly under section 4. Finally, a summary of the intercity train users' perception is presented in the table 4.3. Moreover, a concluding summary of the analysis of the SP survey data is also given after the table 4.3. Furthermore, this chapter provides a clear idea about existing condition of Intercity Train by the perception of Intercity Train user.

Chapter 5
ANALYSIS RESULTS AND DISCUSSION

5.1 General

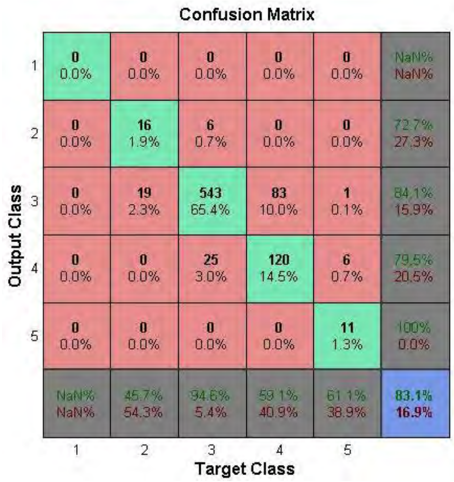
This Chapter shows the model performance of PNN and ANFIS for Intercity Train Service Quality (SQ). It also reveals the attribute ranking and finds the significant attributes for improving SQ of intercity train.

The details are chronologically outlined below.

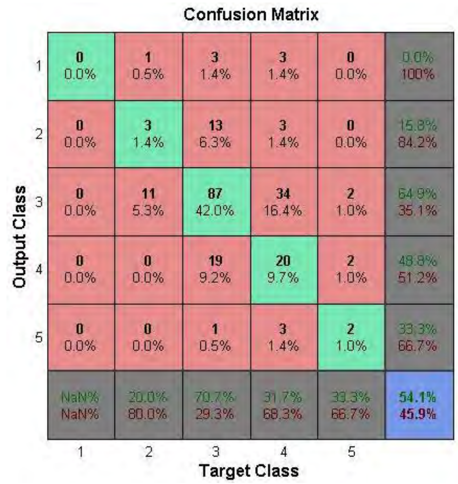
5.2 Model Evaluation

There are several ways to evaluate the model performance. However, the performance evaluation techniques will be used in this study are: confusion matrix, root-mean-square error (RMSE) and correlation co-efficient (R). Confusion matrix will be used to check the one-to-one matching between output classes of predicted Service Quality (SQ) and target classes of actual SQ. Whereas, R and RMSE values will show the correlation and error between actual SQ and predicted SQ of intercity train.

Confusion matrix is used to check the one-to-one matching between output classes (1 to 5) and target classes (1 to 5). The diagonal green boxes in Figure 4 illustrate the amounts and percentages that are identical in both output and corresponding target classes. The red boxes illustrate the amounts of misclassifications. The right-bottom blue box represents the total correct classifications (green) and misclassifications (red) in percent (%).



(a)



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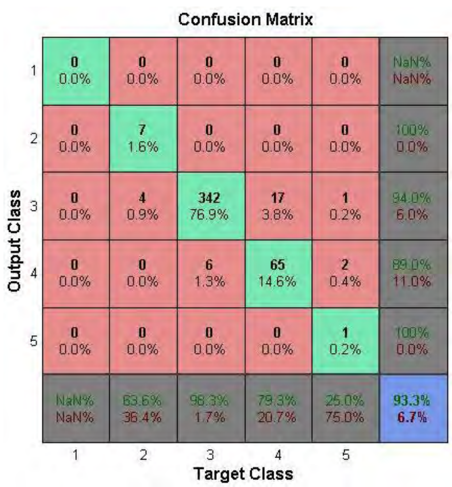

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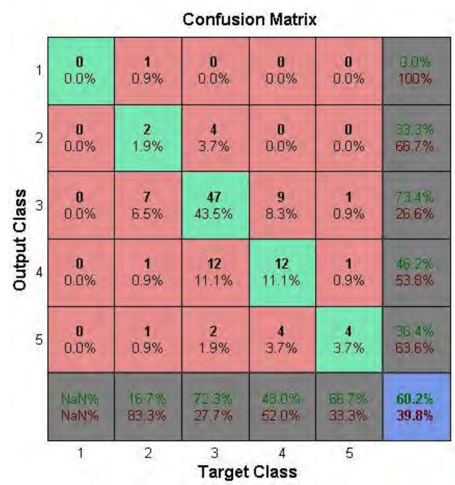
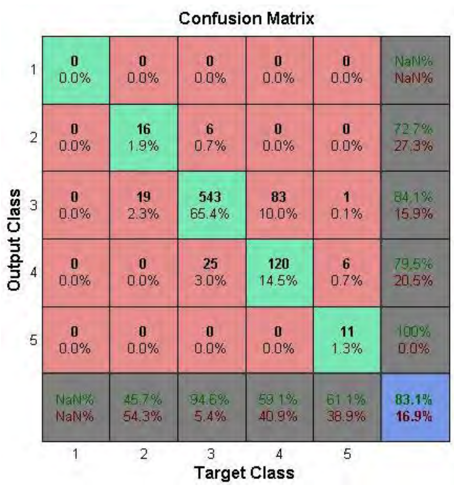


(d)

Figure 5.1 Confusion matrices for ANFIS of, (a) trained model for regular days; (b) tested model for regular days; (c) trained model for special days; and (d) tested model for special days.



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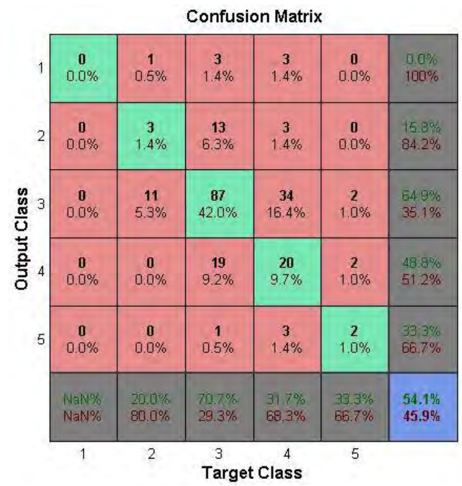

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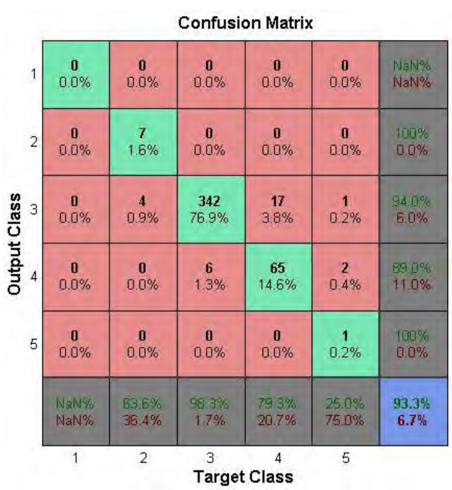

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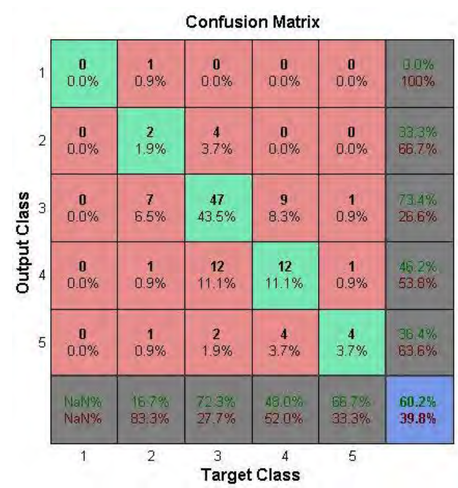

(h)

Figure 5.2 Confusion matrices for PNN of, (e) trained model for regular days; (f) tested model for regular days; (g) trained model for special days; and (h) tested model for special days.

The predicted classifications of developed ANFIS and PNN models are shown in Figure 5.1 and Figure 5.2 by means of confusion matrix.

It is observed that, ANFIS and PNN have different accuracy in prediction given in Table 5.1 below.

Table 5.1 ANFIS and PNN model accuracy in predicting Service Quality (SQ)

	Regular Days		Special Days	
	Training Period	Testing Period	Training Period	Testing Period
ANFIS	83.10% (690 out of 830)	54.10% (112 out of 207)	93.30% (413 out of 443)	60.20% (66 out of 110)
PNN	99.40% (825 out of 830)	50.70% (105 out of 207)	99.50% (441 out of 443)	57.30% (63 out of 110)

In quantitative term, ANFIS has shown accuracy in predictions 112 out of 207 and 66 out of 110 on regular days and special days, which implies that 112 and 66 predictions match with the actual SQ value, respectively. However, PNN has shown accuracy in predictions 105 out of 207 and 63 out of 110 on regular days and special days, which implies that 105 and 63 predictions match with the actual SQ value, respectively. Therefore, it is clear that the ANFIS is more efficient than PNN in predicting SQ in both regular and special days.

5.2.1 Correlation Coefficient

Correlation often measured as a correlation coefficient which indicates the strength and direction of a linear relationship between two variables (for example model output and observed values). A number of different coefficients are used for different situations. The best known is the Pearson product-moment correlation coefficient (also called Pearson correlation coefficient or the sample correlation coefficient), which is obtained by dividing the covariance of the two variables by the product of their standard deviations. If we have a series n observations and n model values, then the Pearson product-moment correlation coefficient can be used to estimate the correlation between model and observations.

Correlation co-efficient(R) is defined as:

$$R = \frac{\sum_{i=1}^{n}(x_i - \bar{x}) \cdot (y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2 \cdot \sum_{i=1}^{n}(y_i - \bar{y})}} \qquad \text{(Eqn 11)}$$

Where,

$\bar{x}$= mean of target classes; . = mean of predicted classes;

x_i = i^{th} target class; and y_i = i^{th} predicted class.

The correlation is +1 in the case of a perfect increasing linear relationship, and -1 in case of a decreasing linear relationship, and the values in between indicates the degree of linear relationship between for example model and observations. A correlation coefficient of 0 means the there is no linear relationship between the variables. The square of the Pearson correlation coefficient (r^2), known as the coefficient of determination, describes how much of the variance between the two variables is described by the linear fit.

5.2.2 Root Mean Square Error (RMSE)

Root Mean Square Error (RMSE) (also called the Root Mean Square Deviation, RMSD) is a frequently used measure of the difference between values predicted by a model and the values actually observed from the environment that is being modeled. These individual differences are also called residuals, and the RMSE serves to aggregate them into a single measure of predictive power. However, the RMSE values can be used to distinguish model performance in a calibration period with that of a validation period as well as to compare the individual model performance to that of other predictive models.

The RMSE of a model prediction with respect to the estimated variable X_{model} is defined as the square root of the mean squared error:

Root-mean-square error is defined as:

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(X_{obs,i} - X_{model,i})^2}{n}} \qquad \text{Eqn (12)}$$

Where, X_{obs} is observed values and X_{model} is modeled values at time/place *i*.

The RMSE is the square root of the variance of the residuals. It indicates the absolute fit of the model to the data–how close the observed data points are to the model's predicted values. Whereas R-squared is a relative measure of fit, RMSE is an absolute measure of fit. As the square root of a variance, RMSE can be interpreted as the standard deviation of the unexplained variance, and has the useful property of being in the same units as the response variable. Lower values of RMSE indicate better fit. RMSE is a good measure of how accurately the model predicts the response, and is the most important criterion for fit if the main purpose of the model is prediction.

Comments can be made on the model performances based on the RMSE values between the predicted and actual SQ of the forecasting sample (207 and 110 data of regular days and special days, respectively). The RMSE values for those models for regular days and special days were 0.085759 and 0.067187 with ANFIS, respectively. And the RMSE values for those models for regular days and special days were 1.3744 and 0.8766 with PNN, respectively. RMSE value of ANFIS model was smaller than PNN model. It showed that based on user stated preferences, ANFIS performs better than PNN in SQ prediction of intercity train. This study used 18 attributes in ANFIS and PNN models to estimate the intercity train SQ. As the relationship between input variables (SQ attributes) and the output variable is indistinct, ranking of these SQ attributes can be performed by analytical techniques. Cross-correlation, principal component analysis (PCA), stepwise approach and connection weights are some of the techniques for attribute ranking. However, in this study, stepwise approach is followed for ranking the significant intercity train attributes which is shown in following section.

5.2.3 Stepwise Approach

The Stepwise approach is a simple, standardized and popular method for evaluating and validating the model. In stepwise approach, various cases are developed by subsequently introducing every attributes from input variable matrix. Isolated networks are trained with the 'training sample' for every new case. After that there is an estimation of the predictions of these networks for the 'forecasting sample'. Then, performances for each model are evaluated. Model performance can also be measured by inspecting the dissimilarity between actual and predicted results through average percentage error, coefficient of determination (R_2) and root-mean-square error (RMSE). However, in this study the last method is used to assess the effects of attributes. These measures are compared for both PNN and ANFIS models in Table 5.2. Here, value of 'RMSE', the corresponding attribute is more significant and vice versa. As an example, in case of the model developed with 'waiting place condition', the prediction is most inaccurate. Because, among all the other models, this model has the lowest RMSE value. It means, this variable has significant control on the intercity train SQ determination. Conversely, 'on-time performance' is less important due to the corresponding RMSE values.

The sequences of relative significance within first ten of the SQ attributes revealed by the models are important for SQ of intercity train. However, slight variations in the relative importance of the attributes are found in different models. These may occur due to the model behavior on intercity train attributes. Table 5.2 shows the ranking of the attributes based on their effect on the SQ prediction.

Beside waiting place condition attribute *physical conditions* on regular days and *service features* on special days are found to be the most concerning factor to the users while deciding whether a service is satisfactory or not. As physical conditions-toilet cleanliness, fitness of the car, air ventilation system, convenience of online ticketing system and seat comfort are the most influential factor for users in determining SQ on regular days. As service features-travel cost, air ventilation system, convenience of online ticketing system, car arrangement and travel delay are the most influential factor for users in determining SQ on special days.

Among other influencing attributes, overall security, ease of entry and exit, courtesy of employees, female harassment, convenience of ticket purchasing at counter, noise insulation in car, meal service, car cleanness and on-time performance. One of the surprising findings from this research work is the on-time performance of intercity train least influences the user's perception of SQ. That might be the fact that, very few people uses intercity train in their day to day life and business purposes. And they take train service with considerable safe time on hand.

5.3 Attribute Ranking

In this study, eighteen attributes were used to calibrate ANFIS models and PNN model and estimate the train SQ. Since the relationship between input attributes and the overall SQ assessment is indistinct, analytical methods were adopted to rank these SQ attributes. Some of the statistical tools for attributes rankings are—cross-correlation, principal component analysis (PCA) stepwise approach and connection weightage. However, stepwise approach was followed in this study to rank the train service quality attributes. In this approach, a single attribute from all the attributes was considered separately to develop ANFIS and PNN network. For each case, the isolated network was trained with the training sample whereas; forecasting sample was used to estimate the SQ. After that, performance of each model was evaluated by checking the differences between actual and predicted SQ using RMSE.

The orders of relative significance of the SQ attributes found in the models are essential for assessing SQ of train. Moreover, the variations in the relative significance of those attributes under different scenarios need to be identified. This indicates the perceptions, needs and demands on intercity train under different scenarios. Table 5.2 shows the ranking of the attributes based on their effect on the SQ prediction. From the Table 5.2, it can be seen that waiting place condition is the most significant factor for both regular days and special days. It is logical since the train schedules for the specific survey location are not maintained properly. Passengers need to wait for a prolonged time to board a train. Consequently, waiting place condition influences the most in their perceived SQ. However, the RMSE value in case of special days is less compared to that of regular days as can be found in Table 5.2. Specifically, the weightage of this attribute is 42% more in case of special days. Besides, toilet cleanliness, fitness of car, and air ventilation systems are also important attributes for regular days. In contrast, travel cost, air ventilation system and convenience of online ticketing system are found to be the important factors for special days. It indicates that attributes related to *physical conditions* and *service features* of train are important determinants of perceived SQ for regular days and special days, respectively.

The second most significant attribute is travel cost for special days. This is because a large number of people leave city to enjoy long vacation during special occasions. It increases travel demand by many folds. Due to the limited number of train tickets, oftentimes, its price is hiked unofficially. People are compelled to buy tickets at a higher price. However, the travel cost is ranked as less significant during regular days. As the ticket price remains same, people do not mark this attribute as an important one for regular days. Air ventilation system is noticed as third and fourth most significant attribute for special days and regular days, respectively. Train cars become crammed, overcrowded and large number of standing tickets are sold officially during special days. Hence, people feel that air ventilation system is one of the important factors for train SQ and the rank of this attribute is changed by one unit upward in special days compared to regular days. Convenience of online ticketing system is one of the important attribute for both regular days and special days. However, the RMSE of this attribute is much lower; thus, ranked higher for special days compare to regular days. People wait in a long queue to purchase tickets from train stations during special occasions. Many of them want to avoid this hassle and emphasize on the convenience of online ticketing system. In addition, ANFIS models for both regular days and special days show that car cleanness, on time performance and meal services are less important due to corresponding high RMSE values.

As mentioned earlier, in the fourth section of the questionnaire, the respondents were asked to tick 10 most important attributes out of 18 attributes. The percentages of the attributes ticked by most of the respondents were ranked in an ascending order for both regular days and special days. It has been found from the analysis shown in Table 5.2 that the ANFIS and PNN model outputs and public opinions of top most 6 attributes of regular days and top most 4 attributes of special days were a direct match. From 7th attributes of regular days and 5th attributes of special days, there were randomly matched. Finally, in the last few attributes there were also random matching in the both regular days and special days.

The above research findings match with the real world scenario quite remarkably which indicates the novelty of the proposed ANFIS and PNN models. Note that the public opinion data (obtained from fourth section of the questionnaire) are independent of the data used for ANFIS and PNN models development (obtained from second section of the questionnaire) and finding attributes ranking. Thus, it can be interpreted that the respondents were very much precise in answering questions of different sections of the designed questionnaire showing the data accuracy and validity.

Table 5.2 Attributes ranking comparison among ANFIS, PNN and Public Opinion under different scenarios.

Attributes	**ANFIS model with regular day dataset**		**PNN model with regular day dataset**		**Public opinions for regular days**	**ANFIS model with special day dataset**		**PNN model with Special day dataset**		**Public opinions for Special days**
	RMSE	RANK	RMSE	RANK		RMSE	RANK	RMSE	RANK	
Waiting place condition	1.1428	**1**	0.6099	**1**	**1**	0.6577	**1**	0.7515	**1**	**1**
Toilet cleanliness	1.1615	**2**	0.6880	**2**	**2**	0.6622	7	0.7757	**6**	7
Fitness of car	1.1633	**3**	0.7453	**4**	**3**	0.6699	14	0.8277	13	15
Air ventilation system	1.1752	**4**	0.7518	**5**	**4**	0.6594	**3**	0.7637	**3**	**3**
Convenience of online ticketing system	1.1793	**5**	0.7053	**3**	**5**	0.6603	**4**	0.7698	**5**	**4**
Seat comfort	1.1821	**6**	0.7677	**6**	**6**	0.6797	18	0.8443	16	18
Overall security	1.1831	7	0.8311	9	8	0.6729	15	0.8221	12	14
Travel delay	1.1924	8	0.8653	11	7	0.662	**6**	0.7817	7	**5**
Ease at entry and exit	1.1996	9	0.8982	7	9	0.6697	13	0.8108	11	13
Courtesy of employees	1.2003	10	0.9299	12	11	0.6623	8	0.7876	9	8
Travel cost	1.2022	11	0.9555	8	10	0.6577	**2**	0.7515	**2**	**2**
Female harassment	1.2041	12	1.000	10	14	0.6644	10	0.7817	8	9
Convenience of ticket purchasing at counter	1.2143	13	1.0517	14	16	0.6695	12	0.8333	14	12
Noise insulation in car	1.2299	14	1.0586	13	12	0.6625	9	0.8050	10	10
Car arrangement	1.2348	15	1.1207	15	18	0.6618	**5**	0.7698	**4**	**6**
Meal service	1.2385	16	1.2491	17	13	0.6669	11	0.8766	18	11
Car cleanness	1.2672	17	1.2834	18	15	0.6755	17	0.8498	17	16
On-time performance	1.4004	18	1.3743	16	17	0.6742	16	0.8333	15	17

5.4 Summary

This chapter compared the performance of the proposed PNN model with an ANFIS, using the intercity train data. Based on the performance of the two models and the comparison analysis presented above, it can be concluded that the prediction of service quality from the PNN model is better than that from ANFIS model. Also, by analyzing the two models (PNN and ANFIS), this chapter found some most suitable attributes that have significant impact on SQ of intercity train. The major finding from the analysis of this chapter is the important influencing determinants of the user's perception about intercity train SQ besides waiting place condition, relates with *physical conditions* and *service features* on regular days and special days, accordingly.

Chapter 6
CONCLUSION & RECOMMENDATIONS

6.1 General

This research study was conducted to understand the users' perception of intercity train in Bangladesh. Moreover, in this research work two models were developed which can predict the SQ of intercity train in any context using the base data. The major findings of this study are summarized in the following sections. Recommendations and future research scopes are stated in this chapter for further research work.

6.2 Major Findings

In this study the research findings were divided into two categories, first were from questionnaire data sets and second were based on modeling technique.

In this research work, eighteen (18) questions regarding intercity train service quality were asked to the intercity train user in this study to know the actual condition of its service in Bangladesh. Kamlapur Railway Station, Dhaka is one of the biggest hubs of intercity train of Bangladesh was selected as the survey location. Passengers from around 30 intercity trains were surveyed to conduct this research. The subjective assessment was made using a rating scale of very good, good, satisfactory, poor, and very poor.

Nowadays, a lot of people travel by intercity train. But service is not advanced according to the expectations of the user. Therefore, the respondents were asked to give their rating according to their travelling experience on intercity trains recently made.

There are some limitations present in the existing system and authority should improve these limitations to keep the ridership and attract new user. From the first section which was based on users rating, it was found that majority of the intercity train users complained that the following factors are the main limitations of intercity train service:

1. Waiting place condition
2. Toilet cleanliness

3. Fitness of car
4. Air ventilation system
5. Convenience of online ticketing system
6. Seat comfort
7. Overall security
8. Travel delay
9. Ease at entry and exit
10. Travel cost
11. Female harassment
12. Convenience of ticket purchasing at counter
13. Noise insulation in car
14. Car arrangement
15. Car cleanness
16. On-time performance

Predicting service quality based on users' perception is a non-linear process. At this point, Artificial Intelligence (AI) can be a dependable tool in case of non-linear relationship. So, in the second stage, this study was conducted with two main objectives:

(1) Comparison of prediction capability of ANFIS and PNN, and

(2) Evaluation of intercity train SQ attributes according to their importance. Two of the most advanced and popular techniques of AI: ANFIS and PNN had been implemented in this research work to predict intercity train service quality based on selected SQ attributes.

To reach the goals, two models were developed using ANFIS and PNN structures involving all the 18 attributes. From the results, it was found that ANFIS outperforms PNN in SQ prediction capability with 54.10% (on regular days) and 60.20% (on special days) accurate prediction, whereas PNN shows 50.70% (on regular days) and 57.30% (on special days). ANFIS predicted superior to PNN in prediction cases because, ANFIS executes neuro-fuzzy neural network algorithm, which is well classifier and accurate in predicting heterogeneous data than PNN models.

Using RMSE values, most prominent attributes are ranked from 1 to 18 using the architectures. According to both ANFIS and PNN, ‘Waiting place condition’, ‘Toilet cleanliness’, ‘Fitness of car’, ‘Air ventilation system’, ‘Convenience of online ticketing system’, ‘Seat comfort’, ‘overall security’, ‘Travel Delay’, ‘Ease at entry and exit’, ‘Travel cost’ are ten of the most significant attribute those influence the users’ decision making process on regular days. And on special days, ‘Waiting place condition’, ‘Travel cost’, ‘Air ventilation system’, ‘Convenience of online ticketing system’, ‘Car arrangement’, and ‘Travel delay’ are the most significant attribute which influence the users’ decision making process. To improve the service quality the authority can take a note from this research study and start from improving the most significant attribute first, and then concentrating on the others in the series.

6.3 Recommendations

In a Transportation system of a country, passenger train acts like an arterial system of a body. Especially, in the country like Bangladesh with colossal population of about 166 million and high density of about 1237 persons per sq km train has extra-ordinary role to make in the field of transportation. It is contributing a striking percent of traffic flow during occasional festival periods. However, due to the meteoric increase in travelling population, the existing intercity train service is incapacitating to meet the increasing travel demand. Therefore, day by day traffic are shifting towards roadway alternative low capacity transportation system like bus, car etc. These gradually increase traffic congestion in highways and causing huge national. At this point, transport authorities and policy makers need to make serious game changing decisions toward sustainable transportation system putting commuter preferences in front.

But frustratingly, commuter preferences are hardly taken into account by decision makers in most of the developing nation during introduction of new policies or adding infrastructures in the existing transportation systems. There are ways, however, for policy-makers getting closer to popular views. The stated preference approach used in this study has shown its potential in modeling peoples’ attitudes, thus planning and policy-making can be done from peoples’ preferences for more sustainability and meeting the desires of the society. Service Quality (SQ) experiments also help us to investigate the propensity of the commuters to change their perceptions in relation to the SQ of the mode for regular days and special days.

The study analyzed the users' perceptions towards the existing service of intercity train and compared the service and preferences on their responses. This study reached two of its goals in (1) identifying travelers' perceptions towards the existing service of intercity train; and (2) assessing the influence of different attributes on service quality of the existing intercity train. This research work can be used to identify the influencing attributes of service quality of intercity train in order to prioritization and improving them. Moreover, in allocating development fund policy makers and practitioners will have specific directions for both regular days and special days. Furthermore, the Study found that besides waiting place condition, attributes related to *physical conditions* and *service features* are important determinants of perceived SQ for regular days and special days, respectively. Therefore, from this study, policy makers and practitioners will have proper direction in prioritizing and improving service quality of intercity train more effectively.

One of the significant contributions of this research work was to propose the two models that outperformed regression analysis, multinomial logit model. Also, this study helped to substantiate weaknesses of the existing models.

6.4 Further Research

Railway is an important long distance public transportation mode. It can carry huge number of passengers due to its ridership potentiality and reduce pressure on road transportation. Due to increase in traffic congestion in highways, the railway service can be sustainable solution to meet the increasing travel demand. This study provides a clear perception about understanding and improving the overall train SQ. Specifically, it relates user's demand and overall train SQ. Furthermore, *Physical conditions* and *Service features* are found the most important attributes for regular days and special days, respectively. This result carries key information to the planners and transport practitioners in improving railway SQ.

Considering the complexity in human decision making process, ANN can be a suitable tool to model service quality of train. ANFIS and PNN are an advanced and popular technique of this genre which was implemented to predict train SQ based on eighteen attributes. This research focuses on evaluation of train SQ attributes according to their importance during regular days and special days, separately. Results showed that ANFIS models have 83.1% and 93.3% accuracy and PNN models have 99.4% and 99.5% accuracy in training SQ dataset for regular days and special days, respectively. In contrast, the ANFIS models showed 54.1% and 60.2% accuracy and PNN models have 50.7% and 57.3% accuracy in forecasting SQ for those days, respectively. It demonstrates that the calibrated models execute NN algorithm into FIS, which is faster and accurate in predicting heterogeneous data.

Although User have been studied for more than half a century in the developed world, research on this topic in Bangladesh as well as in other south-east Asian countries is extremely scarce and challenging. This is mainly due to the complexity of data collection and processing and the wide variations of user population and train's travelling facilities. In this section some recommendations are provided for future research following the studies carried out in this dissertation. These are listed below.

1. The data set used in this research work represents the intercity train user group of intercity train hub Kamlapur rail station of Dhaka city, capital of Bangladesh. Although the sample size in this research work is sufficient, a further research can be done with a larger data set which will more confidently represent the intercity train users. Researches targeting particular user groups (i.e. female, student, senior citizens, people with lower monthly income etc.) may lead to other significant findings which will provide valuable insight into the Intercity train SQ.

2. Particular attention could be given in future to overcome the limitations of this research work. These limitations include,
    a) Lack of information about the income variables for the respondents,

b) Lack of information about infrastructure parameters such as track quality, signaling system, safety features and correlation among these variables.

3. Two models have been checked for finding SQ of Intercity train, so for better results others modeling technique such as Structured Equation Modeling (SEM) and SERVQUAL method may be compared in predicting SQ of this service.

4. The prediction capabilities of ANFIS and PNN found in this research work are expected to encourage practitioners around the world to apply these tools for SQ studies of other PT systems (intercity bus, train, ferries etc.)

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Appendix A

QUESTIONARY SURVEY ON USERS' SATISFACTION OF INTERCITY TRAIN SERVICE OF BANGLADESH

USERS INFORMATION

Name:
Age:
Occupation:
Train Name:
Destination:
Date:
Aim of Travel:
Reason of Travelling:
Time of Choosing Alternative Mode:

RELIABILITY

A. How is the on-time performance of the intercity train of Bangladesh? (On-time performance)

(1) Very Good
(2) Good
(3) Satisfactory
(4) Poor
(5) Very Poor

RELIABILITY

B. What is your opinion about travel delay reaching destination? (Travel Delay)

(1) Very Good
(2) Good
(3) Satisfactory
(4) Poor
(5) Very Poor

SERVICE QUALITY

C. How convenient is the online ticketing system? (Convenience of online ticketing system)

(1) Very Good
(2) Good
(3) Satisfactory
(4) Poor
(5) Very Poor

SERVICE QUALITY

D. How convenient it is to purchase ticket at counter? (Convenience of ticket purchasing at counter)
(1) Very Good
(2) Good
(3) Satisfactory
(4) Poor
(5) Very Poor

ECONOMY

E. What is your idea about travelling cost of intercity train? (Travel cost)
(1) Very Good
(2) Good
(3) Satisfactory
(4) Poor
(5) Very Poor

SERVICE QUALITY

F. What is your opinion about intercity train's car arrangement? (Car arrangement)
(1) Very Good
(2) Good
(3) Satisfactory
(4) Poor
(5) Very Poor

QUALITY OF TRANSPORT

G. How comfortable is the seat of the intercity train? (Seat comfort)
(1) Very Good
(2) Good
(3) Satisfactory
(4) Poor
(5) Very Poor

QUALITY OF TRANSPORT

H. What is your opinion about ease of entry-exit in intercity train? (Ease at entry and exit)
(1) Very Good

(2) Good
(3) Satisfactory
(4) Poor
(5) Very Poor

SERVICE QUALITY

I. What is your opinion about overall security in intercity train? (Overall security)
(1) Very Good
(2) Good
(3) Satisfactory
(4) Poor
(5) Very Poor

QUALITY OF TRANSPORT

J. What is your opinion about air ventilation system of intercity train of Bangladesh? (Air ventilation system)
(1) Very Good
(2) Good
(3) Satisfactory
(4) Poor
(5) Very Poor

SERVICE QUALITY

K. What do you think about waiting place condition of intercity train service of Bangladesh? (Waiting place condition)
(1) Very Good
(2) Good
(3) Satisfactory
(4) Poor
(5) Very Poor

SERVICE QUALITY

L. What is your idea about meal service of intercity train of Bangladesh? (Meal service)
(1) Very Good
(2) Good
(3) Satisfactory
(4) Poor
(5) Very Poor

QUALITY OF TRANSPORT

M. What is your comment about toilet cleanliness of intercity train of Bangladesh? (Toilet cleanliness)

(1) Very Good
(2) Good
(3) Satisfactory
(4) Poor
(5) Very Poor

SAFETY & SECURITY

N. In your point of view, what is the condition of Security for female (harassment) in intercity train service of Bangladesh? (Female harassment)

(1) Very Good
(2) Good
(3) Satisfactory
(4) Poor
(5) Very Poor

SERVICE QUALITY

O. What is your opinion about courtesy of employees of intercity train? (Courtesy of employees)

(1) Very Good
(2) Good
(3) Satisfactory
(4) Poor
(5) Very Poor

QUALITY OF TRANSPORT

P. What is your idea about fitness of the car of intercity train? (Fitness of car)

(1) Very Good
(2) Good
(3) Satisfactory
(4) Poor
(5) Very Poor

QUALITY OF TRANSPORT

Q. What do you think about car cleanness of intercity train? (Car cleanness)

(1) Very Good

(2) Good
(3) Satisfactory
(4) Poor
(5) Very Poor

QUALITY OF TRANSPORT

R. What is your opinion about noise insulation in the car of intercity trains? (Noise insulation in car)
(1) Very Good
(2) Good
(3) Satisfactory
(4) Poor
(5) Very Poor

S. What rating point will you give as Overall Service Quality of the Train you have traveled recently? (Overall Service Quality)
(1) Very Good
(2) Good
(3) Satisfactory
(4) Poor
(5) Very Poor

Rank 15 most important features of Service Quality you will mention from the train journey you have experienced recently from table below.

Serial No		Rank														
01	On-time performance	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
02	Travel Delay	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
03	Convenience of online ticketing system	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
04	Convenience of ticket purchasing at counter	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
05	Travel cost	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
06	Car arrangement	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
07	Seat comfort	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
08	Ease at entry and exit	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
09	Overall security	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
10	Air ventilation system	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
11	Waiting place condition	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
12	Meal service	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
13	Toilet cleanliness	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
14	Female harassment	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
15	Courtesy of employees	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
16	Fitness of car	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
17	Car cleanness	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
18	Noise insulation in car	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

Appendix B

Probabilistic Neural Network (PNN) Matlab Coding

```
load NSQTr.prn; load NSQTs.prn;

SQ1 = NSQTr';SQ2 = NSQTs';
Y1 = ind2vec (SQ1);Y2 = ind2vec (SQ2);

load N18NAttDTr.prn;load N18NAttDTs.prn;
load N17NAttDTr.prn;load N17NAttDTs.prn;
load N16NAttDTr.prn;load N16NAttDTs.prn;
load N15NAttDTr.prn;load N15NAttDTs.prn;
load N14NAttDTr.prn;load N14NAttDTs.prn;
load N13NAttDTr.prn;load N13NAttDTs.prn;
load N12NAttDTr.prn;load N12NAttDTs.prn;
load N11NAttDTr.prn;load N11NAttDTs.prn;
load N10NAttDTr.prn;load N10NAttDTs.prn;
load N09NAttDTr.prn;load N09NAttDTs.prn;
load N08NAttDTr.prn;load N08NAttDTs.prn;
load N07NAttDTr.prn;load N07NAttDTs.prn;
load N06NAttDTr.prn;load N06NAttDTs.prn;
load N05NAttDTr.prn;load N05NAttDTs.prn;
load N04NAttDTr.prn;load N04NAttDTs.prn;
load N03NAttDTr.prn;load N03NAttDTs.prn;
load N02NAttDTr.prn;load N02NAttDTs.prn;
load N01NAttDTr.prn;load N01NAttDTs.prn;

P18 = N18NAttDTr';T18 = N18NAttDTs';
P17 = N17NAttDTr';T17 = N17NAttDTs';
P16 = N16NAttDTr';T16 = N16NAttDTs';
P15 = N15NAttDTr';T15 = N15NAttDTs';
P14 = N14NAttDTr';T14 = N14NAttDTs';
P13 = N13NAttDTr';T13 = N13NAttDTs';
P12 = N12NAttDTr';T12 = N12NAttDTs';
P11 = N11NAttDTr';T11 = N11NAttDTs';
P10 = N10NAttDTr';T10 = N10NAttDTs';
P09 = N09NAttDTr';T09 = N09NAttDTs';
P08 = N08NAttDTr';T08 = N08NAttDTs';
P07 = N07NAttDTr';T07 = N07NAttDTs';
P06 = N06NAttDTr';T06 = N06NAttDTs';
P05 = N05NAttDTr';T05 = N05NAttDTs';
P04 = N04NAttDTr';T04 = N04NAttDTs';
P03 = N03NAttDTr';T03 = N03NAttDTs';
P02 = N02NAttDTr';T02 = N02NAttDTs';
P01 = N01NAttDTr';T01 = N01NAttDTs';

NN18 = newpnn(P18,Y1);O18 = sim(NN18,T18);
NN17 = newpnn(P17,Y1);O17 = sim(NN17,T17);
NN16 = newpnn(P16,Y1);O16 = sim(NN16,T16);
NN15 = newpnn(P15,Y1);O15 = sim(NN15,T15);
NN14 = newpnn(P14,Y1);O14 = sim(NN14,T14);
NN13 = newpnn(P13,Y1);O13 = sim(NN13,T13);
```

```
NN12 = newpnn(P12,Y1);O12 = sim(NN12,T12);
NN11 = newpnn(P11,Y1);O11 = sim(NN11,T11);
NN10 = newpnn(P10,Y1);O10 = sim(NN10,T10);
NN09 = newpnn(P09,Y1);O09 = sim(NN09,T09);
NN08 = newpnn(P08,Y1);O08 = sim(NN08,T08);
NN07 = newpnn(P07,Y1);O07 = sim(NN07,T07);
NN06 = newpnn(P06,Y1);O06 = sim(NN06,T06);
NN05 = newpnn(P05,Y1);O05 = sim(NN05,T05);
NN04 = newpnn(P04,Y1);O04 = sim(NN04,T04);
NN03 = newpnn(P03,Y1);O03 = sim(NN03,T03);
NN02 = newpnn(P02,Y1);O02 = sim(NN02,T02);
NN01 = newpnn(P01,Y1);O01 = sim(NN01,T01);

OI18 = (vec2ind (O18))';
OI17 = (vec2ind (O17))';
OI16 = (vec2ind (O16))';
OI15 = (vec2ind (O15))';
OI14 = (vec2ind (O14))';
OI13 = (vec2ind (O13))';
OI12 = (vec2ind (O12))';
OI11 = (vec2ind (O11))';
OI10 = (vec2ind (O10))';
OI09 = (vec2ind (O09))';
OI08 = (vec2ind (O08))';
OI07 = (vec2ind (O07))';
OI06 = (vec2ind (O06))';
OI05 = (vec2ind (O05))';
OI04 = (vec2ind (O04))';
OI03 = (vec2ind (O03))';
OI02 = (vec2ind (O02))';
OI01 = (vec2ind (O01))';
```

Appendix C

Adaptive Neuro-fuzzy Inference System (ANFIS) Coding

```
tic;
initime = cputime;
time1 = clock;
pause (1.0);

load EidTrain;
load EidTest;
load EidTarget;
load RegularTrain;
load RegularTest;
load RegularTarget;

EidTestFull=[EidTest,EidTarget];
RegularTestFull=[RegularTest,RegularTarget];

EidTrainAttr=EidTrain(1:end,1:18);
EidTrainSQ=EidTrain(1:end,19);

tD=EidTrainAttr';
tS=EidTrainSQ;

EidTestAttr=EidTest;
EidTestSQ=EidTarget;

cD=EidTestAttr;
cS=EidTestSQ;

trndata=[tS,tS];
chkdata=[cD,cS];


%fismat_1=genfis1(data,numMFs,inmftypes,outmftype);
%fismat_1=genfis3(Xin,Xout,type,cluster_n,fcmoptions);

fismat_1=genfis1(trndata,181,'psigmf','linear')
%fismat_3=genfis3(tD,tS,'mamdani',3)


elapsed = toc;

fintime = cputime;
time2 = clock;

fprintf('TIC TOC: %g\n', elapsed);
fprintf('CPUtime: %g\n', fintime - initime);
fprintf('Clock: %g\n', etime(time2,time1));
```

Fuzzy Logic Toolbox

Version 2.2.19 (R2014a) 27-Dec-2013

GUI editors

anfisedit	-	ANFIS training and testing UI tool.
findcluster	-	Clustering UI tool.
fuzzy	-	Basic FIS editor.
mfedit	-	Membership function editor.
ruleedit	-	Rule editor and parser.
ruleview	-	Rule viewer and fuzzy inference diagram.
surfview	-	Output surface viewer.

Membership functions

dsigmf	-	Difference of two sigmoid membership functions.
gauss2mf	-	Two-sided Gaussian curve membership function.
gaussmf	-	Gaussian curve membership function.
gbellmf	-	Generalized bell curve membership function.
pimf	-	Pi-shaped curve membership function.
psigmf	-	Product of two sigmoid membership functions.
smf	-	S-shaped curve membership function.
sigmf	-	Sigmoid curve membership function.
trapmf	-	Trapezoidal membership function.
trimf	-	Triangular membership function.
zmf	-	Z-shaped curve membership function.

Command line FIS functions

addmf	-	Add membership function to FIS

addrule	-	Add rule to FIS.
addvar	-	Add variable to FIS.
defuzz	-	Defuzzify membership function.
evalfis	-	Perform fuzzy inference calculation.
evalmf	-	Generic membership function evaluation.
gensurf	-	Generate FIS output surface.
getfis	-	Get fuzzy system properties.
mf2mf	-	Translate parameters between functions.
newfis	-	Create new FIS.
parsrule	-	Parse fuzzy rules.
plotfis	-	Display FIS input-output diagram.
plotmf	-	Display all membership functions for one variable.
readfis	-	Load FIS from disk.
rmmf	-	Remove membership function from FIS.
rmvar	-	Remove variable from FIS.
setfis	-	Set fuzzy system properties.
showfis	-	Display annotated FIS.
showrule	-	Display FIS rules.
writefis	-	Save FIS to file.

Advanced techniques

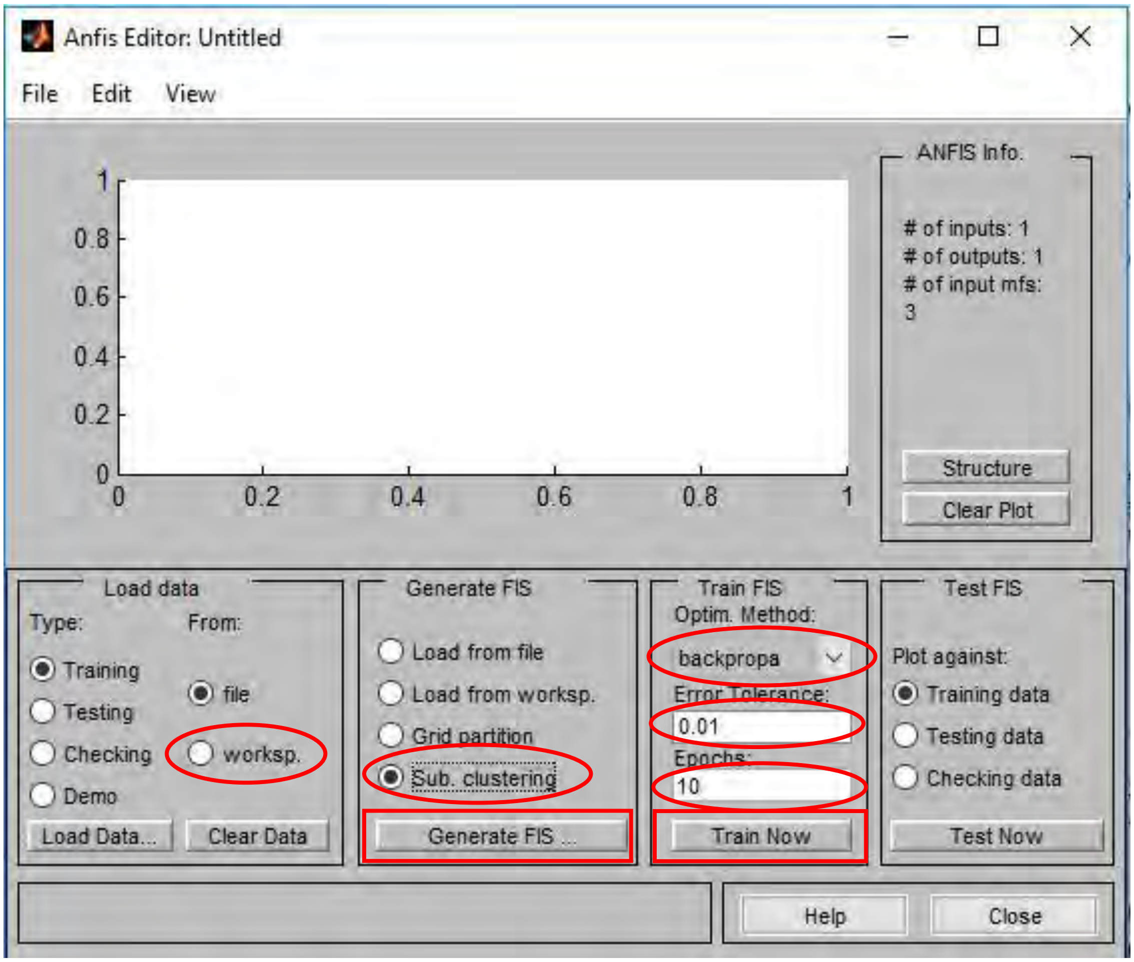
anfis	-	Training routine for Sugeno-type FIS (MEX only).
fcm	-	Find clusters with fuzzy c-means clustering.
genfis1	-	Generate FIS matrix using generic method.
genfis2	-	Generate FIS matrix using subtractive clustering.
subclust	-	Estimate cluster centers with subtractive clustering.

Miscellaneous functions

convertfis	-	Convert v1.0 fuzzy matrix to v2.0 fuzzy structure.
discfis	-	Discretize a fuzzy inference system.
evalmmf	-	For multiple membership functions evaluation.
fstrvcat	-	Concatenate matrices of varying size.
fuzarith	-	Fuzzy arithmatic function.
findrow	-	Find the rows of a matrix that match the input string.
genparam	-	Generates initial premise parameters for ANFIS learning.
probor	-	Probabilistic OR.
sugmax	-	Maximum output range for a Sugeno system.

GUI helper files

cmfdlg	-	Add customized membership function dialog.
cmthdlg	-	Add customized inference method dialog.
fisgui	-	Generic GUI handling for the Fuzzy Logic Toolbox
gfmfdlg	-	Generate fis using grid partition method dialog.
mfdlg	-	Add membership function dialog.
mfdrag	-	Drag membership functions using mouse.
popundo	-	Pull the last change off the undo stack.
pushundo	-	Push the current FIS data onto the undo stack.
savedlg	-	Save before closing dialog.
statmsg	-	Display messages in a status field.
updtfis	-	Update Fuzzy Logic Toolbox GUI tools.
wsdlg	-	Open from/save to workspace dialog.



ANFIS Matlab 2014a Graphics User's Interface (GUI)

Genfis1 Coding

```
function fis = genfis1(data, numMFs, inmftype, outmftype)
%GENFIS1 Generates an initial Sugeno-type FIS for ANFIS training using
a grid
%       partition.
%
%   FIS = GENFIS1(DATA) generates a single-output Sugeno-type fuzzy
inference
%   system (FIS) using a grid partition on the data (no clustering).
FIS is
%   used to provide initial conditions for ANFIS training. DATA is a
matrix with
%   N+1 columns where the first N columns contain data for each FIS
input, and
%   the last column contains the output data. By default, GENFIS1 uses
two
%   'gbellmf' type membership functions for each input. Each rule
generated by
%   GENFIS1 has one output membership function, which is of type
'linear' by
%   default.
%
%   FIS = GENFIS1(DATA, NUMMFS, INPUTMF, OUTPUTMF) explicitly
specifies:
%     * NUMMFS   number of membership functions per input. A scalar
value,
%                specifies the same number for all inputs and a vector
value
%                specifies the number for each input individually.
%     * INPUTMF  type of membership function for each input. A single
string
%                specifies the same type for all inputs, a string array
%                specifies the type for each input individually.
%     * OUTPUTMF output membership function type, either 'linear' or
'constant'
%
%   Example
%       data = [rand(10,1) 10*rand(10,1)-5 rand(10,1)];
%       fis = genfis1(data,[3 7],char('pimf','trimf'));
%       [x,mf] = plotmf(fis,'input',1);
%       subplot(2,1,1), plot(x,mf);
%       xlabel('input 1 (pimf)');
%       [x,mf] = plotmf(fis,'input',2);
%       subplot(2,1,2), plot(x,mf);
%       xlabel('input 2 (trimf)');
%
%   See also GENFIS2, ANFIS.

% Change this to have different default values

default_mf_n = 2;
```

```
default_mf_type = 'gbellmf';
default_output_type = 'linear';

if nargin <= 3,
    outmftype = default_output_type;
end
if nargin <= 2,
    inmftype = default_mf_type;
end
if nargin <= 1,
    numMFs = default_mf_n;
end

% get dimension info
data_n = size(data, 1);
in_n = size(data, 2) - 1;

% error checking
 if length(numMFs)==1,
   numMFs=numMFs*ones(1, in_n);
 end

% Check arguments defining system inputs
if length(numMFs) ~= in_n | (size(inmftype, 1) ~=1 & size(inmftype, 1)
~= in_n),
    error('Wrong size(s) of argument(s) defining system input(s)!');
end
% Check argument defining system output
if size(outmftype,1) ~= 1
    error('Argument data entered may only have one output!');
end
if (strcmp(outmftype,'linear') | strcmp(outmftype,'constant')) ~= 1
    error('Output membership function type must be either linear or
constant!');
end

if size(inmftype, 1) ==1 &  in_n>1
   for i=2:in_n
      inmftype(i,:)=inmftype(1,:);
   end
end

rule_n = prod(numMFs);

fis.name = 'anfis';
fis.type = 'sugeno';

fis.andMethod = 'prod';
fis.orMethod = 'max';
fis.defuzzMethod = 'wtaver';
fis.impMethod = 'prod';
```

```
fis.aggMethod = 'max';

range = [min(data,[],1)' max(data,[],1)'];
in_mf_param = genparam(data, numMFs, inmftype);
k=1;
for i = 1:in_n,
 fis.input(i).name = ['input' num2str(i)];
 fis.input(i).range=range(i,:);
 for j=1:numMFs(i)
  MFType = deblank(inmftype(i, :));
  fis.input(i).mf(j).name = ['in' num2str(i) 'mf' num2str(j)];
  fis.input(i).mf(j).type = MFType;
  if strcmp(MFType,'gaussmf') | strcmp(MFType,'sigmf') ...
                | strcmp(MFType,'smf'),
     fis.input(i).mf(j).params= in_mf_param(k,1:2);
  elseif strcmp(MFType,'trimf') | strcmp(MFType,'gbellmf'),
     fis.input(i).mf(j).params= in_mf_param(k,1:3);
  else
     fis.input(i).mf(j).params= in_mf_param(k,1:4);
  end
  k=k+1;
 end
end

fis.output(1).name='output';

fis.output(1).range=range(end,:);
for i = 1:rule_n,
  fis.output(1).mf(i).name=['out1mf', num2str(i)];
  fis.output(1).mf(i).type=outmftype;
  if strcmp(outmftype, 'linear')
   fis.output(1).mf(i).params=zeros(1, in_n+1);
  else
   fis.output(1).mf(i).params=[0];
  end
end

rule_list = zeros(rule_n, length(numMFs));
for i = 0:rule_n-1,
    tmp = i;
    for j = length(numMFs):-1:1,
        rule_list(i+1, j) = rem(tmp, numMFs(j))+1;
        tmp = fix(tmp/numMFs(j));
    end
end
rule_list = [rule_list (1:rule_n)' ones(rule_n, 1) ones(rule_n, 1)];
fis.rule=[];
fis=setfis(fis, 'rulelist', rule_list);

if length(fis.rule)> 250
```

```
    wmsg = sprintf('genfis1 has created a large rulebase in the FIS.
\nMATLAB may run out of memory if this FIS is tuned using ANFIS.\n');
    warning(wmsg);
end
```

Genfis3

Genfis3

Generate Fuzzy Inference System structure from data using FCM clustering

Syntax

fismat = genfis3(Xin,Xout)

fismat = genfis3(Xin,Xout,type)

fismat = genfis3(Xin,Xout,type,cluster_n)

fismat = genfis3(Xin,Xout,type,cluster_n,fcmoptions)

Description

genfis3 generates a FIS using fuzzy c-means (FCM) clustering by extracting a set of rules that models the data behavior. The function requires separate sets of input and output data as input arguments. When there is only one output, you can use genfis3 to generate an initial FIS for anfis training. The rule extraction method first uses the fcm function to determine the number of rules and membership functions for the antecedents and consequents.

fismat = genfis3(Xin,Xout), generates a Sugeno-type FIS structure (fismat) given input data Xin and output data Xout. The matrices Xin and Xout have one column per FIS input and output, respectively.

fismat = genfis3(Xin,Xout,type), generates a FIS structure of the specified type, where type is either 'mamdani' or 'sugeno'.

fismat = genfis3(Xin,Xout,type,cluster_n), generates a FIS structure of the specified type and allows you to specify the number of clusters (cluster_n) to be generated by FCM.

The number of clusters determines the number of rules and membership functions in the generated FIS. cluster_n must be an integer or 'auto'. When cluster_n is 'auto', the function uses the subclust algorithm with a radii of 0.5 and the minimum and maximum values of Xin and Xout as xBounds to find the number of clusters. See subclust for more information.

fismat = genfis3(Xin,Xout,type,cluster_n,fcmoptions), generates a FIS structure of the specified type and number of clusters and uses the specified fcm options for the FCM algorithm. If you omit fcm options, the function uses the default FCM values. See fcm for information about these parameters.

The input membership function type is 'gaussmf'. By default, the output membership function type is 'linear'. However, if you specify type as 'mamdani', then the output membership function type is 'gaussmf'.

The following table summarizes the default inference methods

Inference Method	Default
AND	prod
OR	probor
Implication	prod
Aggregation	sum
Defuzzification	wtaver

Appendix D

Related Publications

Here a list of publications resulted from this M.Sc. Thesis is written.

Publications in international journals

Md Hadiuzzaman, D M Ghius Malik, Saurav Barua, Dr. Tony Z. Qiu and Dr. Amy Kim, "Modeling Passengers' Perceptions of Intercity Train Service Quality for Regular and Special Days", Submitted and Currently Under Review for publication in the journal "Public Transport" of springer publisher.

Md Hadiuzzaman, Hahid Parvez Farazi, Sanjana Hossain, D M Ghius Malik, "An Exploratory Analysis of Observed and Latent Variables Affecting Intercity Train Service Quality in Developing Countries", Published in the journal "Transportation" of springer publisher on December, 2017. doi: 10.1007/s11116-017-9843-6

Dedicated to,

My Parents:

Father: Engr. Md. Abdul Hye
Civil Engineer, BUET (Graduated 1982)
Additional Chief Engineer (ACE)
Bangladesh Water Development Board (BWDB)

Mother: Mosa. Rowshan Ara Talukder
House Wife
Youngest Child of Late. Abed Ali Talukder

Teachers:

Supervisor: Dr. Md. Mizanur Rahman
Professor, Department of Civil Engineering, BUET

Pervious Supervisor: Dr. Md. Hadiuzzaman
Associate Professor, Department of Civil Engineering, BUET

Deepest Gratitude to,

Thesis Committee Members:

Dr. Ahsanul Kabir
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Professor, Department of Civil Engineering, BUET

Dr. Farzana Rahman
Professor, Department of Civil Engineering, UAP

Whole-hearted Respect to,

Uncle (Maternal): Dr. M. A. Mazid Talukdar
Ex-General Manager, Latif Bawany Jute Mills Ltd.
Chairman, MN Sweaters Ltd.

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