PARATRANSIT SERVICE QUALITY PREDICTION AND USER ATTRIBUTE RANKING USING NEURAL NETWORK AND FUZZY APPROACH

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DEDICATED

TO MY
PARENTS AND TEACHERS

The thesis titled "***Paratransit Service Quality Prediction and User Attribute Ranking Using Neural Network and Fuzzy Approach***" submitted by Rajib Banik, Student number – 1014042419 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 October 15, 2016.

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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. Hadiuzzaman, Associate 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.

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ABSTRACT

In megacities of developing countries, the need for mobility is increasing in synchronization with the growth of the cities themselves. Conversely, mobility and accessibility are decreasing hastily and it is most severe in case of public transport (PT) users. Currently, in developing countries, the real problem is not the high use of automobiles, but the poor PT service quality (SQ). It is seen that, the services provided by transportation operators of developing countries may not necessarily satisfy passengers' expectations. Like-wise, a developing country like Bangladesh has PT vehicles that are frequently poorly maintained and often overloaded. Particularly, the only requirement is to fulfill the need for mobility with sufficient capacity. Whereas, the quality is constrained by the government's limitation. In that case, the real contribution of paratransit becomes significant. Among the different available PT modes, paratransit plays a vital role, especially where there is insufficient mass transit system. Paratransit is recognized in Dhaka city as a special transportation service with higher flexibility and availability in selected routes operated by private companies as well as individuals. This research aimed to assess users' perception of this PT mode. Moreover, several empirical models were developed to predict its SQ. Through these data driven models, the variables influencing the paratransit SQ were determined, which could lead to improve the overall paratransit SQ of the developing countries.

At first, this study examined fifteen strategic locations for fifteen different paratransit service routes in Dhaka city to collect the required data to assess the overall SQ of this mode and to formulate empirical models. In this context, a stated preference (SP) survey was conducted among the paratransit users in each survey location. For the data collection, the designed SP questionnaire comprised of two sections, where (1) The first section was aimed to get personal and socioeconomic information (age, gender, occupation) of commuters and the reason for using paratransit mode; and (2) the second section was focused on twenty three (23) questions regarding paratransit SQ (twenty-two SQ attributes and a question about overall paratransit SQ) to know the actual conditions of this mode in Dhaka City. All the questions about the paratransit SQ were in a close-ended format with relevant multiple choices those were chosen by the users.

It was found that major portion (42%) of the respondents rated the overall quality of paratransit service 'satisfactory' while 30% users' thought that existing condition is good and 22% opined that it is in poor condition. Based on users' perception and the stated ratings (22 paratransit SQ attributes), it was found that majority of the user opined that the following factors are the advantages of using paratransit service: (i) Cleanliness of the vehicle; (ii) Speed of the vehicle; (iii) Availability of vehicle; (iv) Travel time (Holidays); (v) Integration with supporting modes; (vi) Security of goods; (vii) Travel cost and (viii) Service feature. However, there were some following factors identified by the user, which are the main limitations of paratransit: (i) Meager seat comfort level of paratransit; (ii) Substandard fitness of the vehicle; (iii) Dissatisfactory noise level of the service; (iv) Insufficient lighting facilities; (v) Inconvenient ticketing system (fare collection) to the users; (vi) Unskilled paratransit drivers; (vii) Risky entry-exit system; (viii) Congested sitting arrangements for passengers; (ix) Inadequate movement flexibility in the vehicle; (x) High travel time during office day; (xi) Not enough security of the passenger during off-peak period; (xii) Poor riding safety; (xiii) Ordinary performance of long route movement; (xiv) Low graded movement flexibility of vehicles in any road. With the inadequate resources, developing countries like Bangladesh will find it difficult to invest in improving all of the significant attributes' quality as were found from this study at once. This investigation provides guidance for a stepwise development which will start with the most important attribute.

Based on the users' stated preferences (on a scale of 1 to 5), two Artificial Intelligence (AI) models namely Probabilistic Neural Network (PNN) and Adaptive Neuro-Fuzzy inference System (ANFIS) were developed using a dataset extracted from 2008 paratransit users. These models can predict the paratransit SQ based on twenty two (22) attributes. A comparison on the prediction capability between PNN and ANFIS was also presented. The comparison results showed that PNN outperformed ANFIS. Particularly, the coefficient of correlation (R) values of PNN and ANFIS prediction were 0.702 and 0.442, respectively. Whereas, the Root Mean Square Error (RMSE) values for those models were 0.745 and 0.929, respectively. The study was further extended to include ranking of the SQ attributes according to their significance. This was necessary to identify the key attributes affecting the paratransit SQ. Out of 22 SQ attributes, 'Ticketing system (Fare Collection)', 'Quality of Driver', and 'Security of passengers' were found to be the top three attributes having the most influences on the users' decision making process. All these findings can aid city transportation officials and service providers in improving the most important paratransit attributes, thereby increasing its ridership.

Keywords: Service Quality, Paratransit, Stated Preference Survey, Probabilistic Neural Network, Adaptive Neuro Fuzzy Inference System.

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List of Abbreviations

Acronym	Definition
PT	Public Transport
MRT	Mass Rapid Transport
SQ	Service Quality
NA	North America
MV	Motorized Vehicle
ADA	Americans with Disabilities Act
DOT	Department of Transport (United States)
US	United States
ANN	Artificial Neural Network
PNN	Probabilistic Neural Network
ANFIS	Adaptive Neuro-fuzzy Inference System
SEM	Structural Equation Model
ANOVA	Analysis of Variance
MLFN	Multi-layer Feed Forward Neural Network
GRNN	Generalized Regression Neural Network
PRNN	Pattern Recognition Neural Network
CNG	Compressed Natural Gas
RMSE	Root Mean Square Error
R	Coefficient of Correlation
GPS	Global Positioning System
GIS	Geographical Information System

Chapter 1

INTRODUCTION

1.1 Background of the Study

Public transport (PT) is the most effective transportation mode to meet the travel demands in densely populated urban areas. Depending on capacity and mobility, PT has numerous categories ranging from mass rapid transit (MRT) to bus service. According to Lyndon and Todd (2006) *(1)* PT plays a vital role in the productivity of cities and it has a direct contribution on the national economy. As PT services are offered directly to customers, the ultimate quality of a service should be seen as an outcome of users' perception *(2)*. In the less developed countries, PT are often insufficient to meet the public demands. Moreover the facilities provided are quite unsatisfactory and as a result people tend to use private vehicles more often than PT. Development in the supplied SQ can attract more users *(3)*, and if public transportation is in general perceived to be good and cheap, it can suppress demand for private cars *(4)*. According to the transportation researchers, quality of PT determined from the users' point of view is considered as one of the important means to assess its performance. The primary objective of quality of service analysis is to improve facilities such that user expectations and needs can be met.

The concept of SQ is widely recognized as a performance measurement tool in traffic and transportation engineering operations *(5, 6)*. Understanding of SQ perception is very beneficial for the operators to provide a suitable service for the users and better managed transit services. According to Hensher and Brewer *(10)*, a decent understanding about quality of service can guarantee the continuity of the business of PT, secure existing users, and help transit agencies to attract new users. Therefore, various studies have been attempted to measure user satisfaction for public transportation. For example, dell'Olio et al. *(7)* evaluated the quality of service desired by bus transit users of the city of Santander, Spain. In that study, multinomial discrete choice models were used where 'waiting time', 'cleanliness' and 'comfort' were shown to be the parameters most valued by the users. However, the degree to which they were valued varies according to the user's category. Some Parameters such as 'driver kindness', 'bus occupancy', and 'journey time' were generally given less weight. Nathanail *(8)* investigated twenty two railway SQ parameters including 'itinerary accuracy', 'system safety', 'cleanliness', 'passenger comfort', 'servicing', and 'passenger information' based on multi-criteria evaluation for SQ evaluation. Simona *(9)* used some important service dimensions such as 'availability', 'service monitoring', 'travel times', 'safety and security', 'cleanliness of vehicles' and 'transport capacity'.

Currently in Dhaka city, the real problems are the high use of automobiles and poor service quality of public transport. In the case of Dhaka city, the requirement first to fulfill the need for mobility with sufficient capacity and quality is constrained by the various issues to meet it. Then the real contribution of paratransit becomes significant.

Paratransit is recognized in Bangladesh as special transportation services with more flexibility and availability in selected routes operated by private companies and individuals. Paratransit is used extensively in almost all cities in Dhaka city.

The services paratransit may change significantly on the level of adaptability they give their consumers. At their simplest they may consist of a taxi or small bus that will run along a more or less defined route and then stop to pick up or discharge passengers on request. At the other end of the spectrum—fully demand responsive transport—the most flexible paratransit systems offer on-demand call-up door-to-door service from any origin to any destination in a service area. In addition to public transit agencies, paratransit services are operated by community groups and private companies or operators. Typically minibuses are used to provide paratransit service, but taxis and jitneys are also important providers in the developing countries. Most paratransit vehicles are equipped with wheelchair lifts or ramps to facilitate access in some modern countries in North America (NA).

In the United States, private transportation companies often provide paratransit in cities and metropolitan areas under contract to local public transportation agencies. Veolia Transport, First Transit and MV Transportation are among the largest private contractors of paratransit in the United States (US) and Canada.

The higher utilization of private transportation has prompted sudden weight on the transportation framework. For example, city centers are usually comprised of high building density but their roads are designed for low traffic density. This existing situation reduces the scope for the expansion of the road widths. Further, encroachment on carriageway by informal traders and unorganized vehicle parking especially in the business areas reduces the effective road width. In recent years, the growing necessity for public transport and incapacity of administration to invest has to lead to the emergence of paratransit system.

This study investigates user satisfaction of using paratransit operation, regarding quality of service, availability of vehicles, travel expenses, negative experiences (expresses the respondent's loyalty. The respondent was asked whether he or she will make use of paratransit in the future and whether the respondent will recommend paratransit to others.) etc. In this study, two of the most advanced modeling techniques namely: Probabilistic Neural Network (PNN) and Adaptive Neuro-fuzzy Inference System (ANFIS) are used to predict the user based SQ of paratransit transit in Dhaka. Based on a questionnaire data set, this study presents a comparison of prediction capability of PNN and ANFIS. Also PNN and ANFIS models are used to rank the most significant attributes among 22 selected attributes those affect paratransit SQ the most.

This article begins by providing some brief information about private paratransit in Dhaka city, and service quality of the transport, followed by a concise explanation of PNN and ANFIS architecture; study methodology; data analysis; the key findings of this study and finally conclusion with future research directions.

1.2 Definition of Paratransit

Paratransit services are special transportation services that are distinct from the conventional transportation choices in a given area. The prefix "para-" literally translates to mean "alongside of" in Greek. In the context of public transportation, paratransit services are typically flexible services that don't conform to a fixed schedule or route. They are utilized for the purposes of transporting people with disabilities directly from their origin to their destination. This is a supplemental service to the fixed-route, fixed-schedule services of transit agencies.

In the context of developed countries, paratransit is a specialized, door-to-door transport service for people with disabilities who are not able to ride fixed-route public transportation. This may be due to an inability to:

- Board, ride or disembark independently from any readily accessible vehicle on the regular fixed-route system.
- Access existing accessible fixed-route transportation because that transportation is not available at the needed time on that route.
- Get to boarding/alighting locations of regular public transportation.

Paratransit first emerged in response to the the Federal Rehabilitation Act of 1973, which required transportation agencies that receive federal funding to either make their systems accessible to disabled persons or provide complementary mobility services. Most agencies opted for the complementary services, as it was the less expensive of the two options. In 1990, the Americans with Disabilities Act (ADA) expanded this mandate to all public transportation systems, regardless of their funding sources. It also required any new public transit projects to be accessible to disabled individuals, while also mandating complementary mobility services for destinations that fell within ¾ miles of all existing routes.

In developing countries, the most rational and precise definition of paratransit is the functional one, which states 'Paratransit is an urban passenger transportation service usually in highway vehicles operated on public streets and highways in mixed traffic; it is provided by private or public operators and it is available to certain groups of users or to the general public, but adoptable in its routing and scheduling to individual user's desires in varying degrees' *(11)*. Paratransit modes are usually demand responsive and provide shared rides. It has become a vital mobility option in many developing countries, filling in gaps left unserved by public transit systems and providing efficient feeder connections *(12)*. Paratransit offers several advantages compared to other public transport modes, such as high accessibility and mobility, more beneficial operating cost for short trips, easy and unimpeded lane movement, and relatively low maintenance cost. Paratransit supply is the best in meeting the transport requirements of the low income people in terms of fares and flexibility *(13)*. Proficient and economical operation of paratransit system requires proper maintenance and increasing reliability of that system. So improving SQ of paratransit is now a significant task of transport researchers, practitioners and transport agencies.

The most popular individual type of motorized paratransit has various local names in different countries such as ‘tempo’ in Bangladesh, ‘becak’ in Indonesia, ‘jeepney’ in the Philippines, ‘tuk-tuk’ in Thailand, ‘mammy wagons’ and ‘matatu’ in Africa and ‘xiclos’ in Vietnam. To have a clear understanding of the types of vehicles used as a paratransit in Bangladesh, the photographs of usual vehicle of each group of paratransit are shown in Figure 1.

(a) Leguna

(b) Battery Auto-rickshaw

(c) Tempo

(d) CNG Auto-rickshaw

Figure 1.1 Usual Types of Paratransit in Bangladesh

In Bangladesh, paratransit pattern is varying rapidly. In Dhaka, it is found that almost 72 percent households in the area use rickshaws for their daily travel *(14)*. However, since 2001 people are willing to use small vehicles (locally known leguna and CNG (compressed natural gas) vehicles) as a paratransit mode for reduced travel time.

1.3 Definition of Service Quality of Transport

The term service quality (SQ) in the transport literature context has long been investigated and has been defined in many forms. It has been defined as; the quality criteria and the accurate measures for which the providers are responsible to provide *(16),* the measurement process of how the SQ level delivered matches the customer satisfaction *(17, 18*) the measurements that reflects users` perceptions towards the service *(15),* the pre-defined standard of service attributes relative to the actual SQ (19, 20), the measuring of customer expectation on a constant service standard base *(21)*. These definitions have opened the door for further in-depth analysis of the quality process in the context of paratransit service.

1.4 Research Objectives

The study is concerned with the paratransit service quality (SQ) analysis depending on a number of attributes in different routes of Dhaka city. Specifically, the major objectives behind this study are:

i. To assess users' perception about the SQ of paratransit in Dhaka city.

ii. To develop ANN and ANFIS-based empirical models for the estimation/prediction of SQ of paratransit in Dhaka city.

iii. To identify and rank the significant attributes influencing SQ of paratransit depending on the results obtained from step-wise approach.

1.5 Scope of Work

This study highlighted the determination of problems in paratransit service and to know the users' satisfaction about paratransit. The determination of problems and users' perception is collected from study sites and a questionnaire survey was conducted with paratransit users' including a set of questions related with the service quality, sitting arrangements, availability, security, driver's quality 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 *(22*, 23*,24)*. 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*(22)*, travel mode choice modeling*(23)*, road accident prediction*(25)*, traffic flow prediction model*(26)*, car following model *(27)*, travel behavior modeling *(28)* etc. However, very few studies have been performed on SQ of paratransit of developing countries like Bangladesh *(29, 30).*

Moreover, to the authors' best knowledge no comparative study can be found on paratransit SQ using ANN and ANFIS. Therefore, in this study, ANN namely Probabilistic Neural Network (PNN) and ANFIS have been used to predict the service quality of paratransit in Dhaka city. Among different ANN models, PNN is well classifier, faster and accurate than Multilayer Perceptron Networks in prediction of SQ in heterogeneous data. In this study, PNN and ANFIS are utilized to forecast the user based SQ of paratransit in Dhaka city. In view of a questionnaire data set, a comparison is drawn between the forecasting ability of PNN and ANFIS. Moreover, PNN and ANFIS models are utilized to rank the most noteworthy qualities among 22 chosen attributes those significantly influence the paratransit SQ.

The results of this study would help to introduce a facile way to improve the overall quality of paratransit in Dhaka city. Hence, the policy makers and paratransit operators may emphasize on improving the most important attributes with a view to improving the SQ.

1.6 Organization of the Thesis

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

Chapter 1 gives an introduction of the relevant research background, statement of problems as well as the objectives and scope of this research.

Chapter 2 provides an overview on previous studies and literature published on the thesis topic. The detail description of some widely used paratransit study around the world help to understand the contributing attributes that affects the SQ of paratransit. It also reviews previous works on various statistical and empirical models for predicting SQ with a special focus on two empirical models ANN and ANFIS.

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 PNN and ANFIS.

Chapter 4 explores the survey and analyses the socio economic condition of paratransit users. The analyses are shown as tabulated form and graphical presentation are also presented in this chapter. This chapter also describes the summery of users' perception of paratransit in Dhaka City.

Chapter 5 compares the performance of the proposed PNN model with an ANFIS, using the paratransit base data. And it also mentions the significant attributes which affect the SQ of paratransit.

Chapter 6 summarizes the main conclusions of this research and discusses recommendations for future research works related to the opportunity and applicability of PNN and ANFIS models for other transport service.

Chapter 2
LITERATURE REVIEW

2.1 General

This chapter presents previous studies and reports about paratransit issue. In recent years, studies regarding paratransit in developing countries have become popular. 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 variety of modelling approaches developed so far and in use this study.

2.2 Past Studies and Limitations

Service quality (SQ) reflects users' perceptions towards the service which is a key factor in attracting and retaining new users in the arena of public transport. Therefore, researchers and practitioners are concerned about the influence of SQ. Several methodologies have been used by researchers to investigate SQ of the PT system and create attractive public transportation.

There are mainly two methods for measuring SQ and customer satisfaction, namely, statistical analysis and coefficient modeling. Statistical analysis techniques comprise quadrant and gap analysis, factor analysis, scatter graphs, bivariate correlation, cluster analysis, conjoint analysis and other analytical approaches. On the other hand, regression models, structural equation models (SEM), ANN models, and ANFIS are some of the modeling techniques to estimate coefficient values relating to the SQ and SQ attributes.

Among the statistical methods, some provided an assessment of the service attributes using Logit model; others provided the connection of the service attributes with overall satisfaction using SERVQUAL method*(3)*. dell'Olio et al.*(7)* assessed the quality of service desired by public transportation users of Santander city, Spain using multinomial discrete choice models. Kim et al. *(30)* assessed quality of bus service by using regression analysis focusing on various attributes such as responsiveness, assurance, tangibility, conformity, reliability, efficiency, and accessibility.

Understanding the behavioral intentions of public transportation users are also important. Parasuraman, et al. *(31)* conducted research on several specific types of service industry. Prior to the group in five dimensions, this research identified ten factors that were considered to the main factor that determines the quality of services, namely: access, communication, competence, courtesy, credibility, reliability, responsiveness, security, understanding, and tangible. According to Chen and Lai *(17)*, user loyalty was seen as a major determinant of long-term financial performance of PT. Shiftan and Sharaby *(32)* evaluated the effect of fare integration of public buses on travel behavior and transit ridership for Haifa city, Israel. Using travel-behavior model, the study found that the reduction of fair was a significant parameter in drawing attention to transit users, and also encouraged travelers to shift from private cars to PT.

Very few studies concentrated on evaluating SQ of PT of developing countries (*29, 30, and 33)*. For example, Andaleeb et al. *(33)*demonstrated that there were significant factors which affect PT such as comfort, need to change buses, behavior of the staff, and government supervisions whereas, quality of the ride, co-passengers' behavior, and feelings of insecurity were not significant in predicting user satisfaction about bus service in Dhaka city. He also depicted that fare, frequency of service, waiting time, travel time, etc. also could be the major attributes for evaluating the bus SQ.

Various techniques are found in the literature which evaluates SQ and user satisfaction for PT from users' point of view. Users' perception can be assessed by different approaches: by asking users the satisfaction on provided services, by asking the expectation/importance, or by asking both perception and expectation. Eboli and Mazzulla *(34)* recommended Heterogeneous Customer Satisfaction Index (HCSI) for evaluating bus transit SQ. Fu and Xin *(35)* proposed Transit Service Indicator (TSI) as an alternative measure for the SQ of a transit system which incorporated spatial and temporal variations in travel demand and integrated various attributes such as service headway, service hours, route coverage, and travel time components.

Friman and Gärling *(36)* suggested Analysis of Variance (ANOVA) technique for evaluating overall satisfaction with public transport and inspected effective reactions to passenger waiting times relating to PT and their impact on overall satisfaction with the service in Sweden.

In the last few decades, estimation of coefficients by modeling to analyze the non-linear relations between the attributes and user's satisfaction has gained much popularity. In this practice, to obtain the effects of each attributes, coefficients are estimated by relating the SQ attributes (independent variables) with the user's satisfaction (dependent variable). Lai and Chen *(17)* and de Oña et al. *(37)* proposed multi-attribute approaches using Structured Equation Modeling (SEM) to identify the latent variables influencing the service and the relationships between these variables and the overall SQ. Eboli and Mazzulla *(3)* applied SEM to develop relationships between user satisfaction and several attributes of bus service systems: headway, service routes, service reliability, safety, fare, courtesy of working crews, and management of service for facilities; and found that the management of the bus service facility was one of the most important attributes.

In spite of much progress in modeling, there is still more possibility for improvement over the traditional models of prediction, diagnosis, and optimization to deal with extremely complex social and human systems *(38)*. With such scope, de Oña et al. *(39)* proposed data mining technique to analyze key factors of SQ. They developed a decision tree model that avoids the unique assumptions and predefined fundamental relationships for enormous dataset. Such kind of advantages of tree models can also be found in the non-parametric models of Artificial Intelligence (AI) (such as ANN and ANFIS). These models are successfully applied to a variety of data-intensive applications including wide application in the fields of electronics, computer science, statistics, mathematics, business, and medical science etc. Among these models, probabilistic neural network (PNN) is found to perform more accurately than the other ANNs in these fields. Gan et al. *(40)* compared the predictive power of PNN and a multi-layer feed forward neural network (MLFN) with a logistic model on consumers' choices between electronic banking and non-electronic banking. The comparison results showed that PNN outperformed MLFN to be the best prediction model based on higher percentage correct on consumer choice prediction and very low percentage of errors.

Recent trend in modeling literature points out that ANFIS and PNN structure is gaining popularity due to their progressive capability to model non-linear relationships and scope for model validation. However, there are very few researches those specifically focuses on SQ of PT. Islam et al. *(41)* applied PNN along two other ANN approaches, Generalized Regression Neural Network (GRNN) and Pattern Recognition Neural Network (PRNN) to find out the SQ and significant attributes affecting the SQ of PT for Dhaka city bus transit. The study compared the prediction capabilities of the three models and found out 'punctuality and reliability', 'service frequency', 'seat availability' and 'commuting experience' as the most significant attributes of bus SQ for Dhaka. In another research Islam et al. *(42)* used PNN and ANFIS to develop prediction model for bus SQ of Dhaka city. That study also ranked the SQ attributes according to their effect and found 'Punctuality and Reliability', 'Seat Availability', and 'Service Frequency' as the most significant attributes.

Specifically, Paratransit has become a vital mobility option in many developing countries, filling in gaps left unserved by public transit systems and providing efficient feeder connections *(12)*. Paratransit offers several advantages compared to other public transport modes, such as high accessibility and mobility, more beneficial operating cost for short trips, easy and unimpeded lane movement, and relatively low maintenance costs *(43)*. Paratransit supply is the best in meeting the transport requirements of the low income people in terms of fares and flexibility *(13)*. So improving SQ of paratransit is now a significant task of transport researchers, practitioners and transport agencies.

Assessing SQ of paratransit is a relatively new issue, and till this day very few studies are found on this topic. Among them, Stein *(44)* established several asymptotic models for estimating route length and average service time for a dial-a-ride system. However, the models were for extremely idealized conditions. Joewono and Kubota *(45)* evaluated the service quality of Indonesian paratransit using nine attributes. The nine attributes used are as follows: availability, accessibility, reliability, information, user service, comfort, safety, fare, and environmental impact. The study findings revealed that service quality had agreeing effects on both overall satisfaction and user loyalty, and overall satisfaction had a positive impact on user loyalty. Rahman et al. *(46)* analyzed a network of 21 potentially important factors using SEM method that affect customer satisfaction within the Dhaka City paratransit system. The results indicated that several factors had a direct influence on satisfaction, whereas others had an effect through intermediary variables. But that study also found several limitations of SEM and some misconceptions that it tends to elicit. Major themes emphasized were the problem of omitted variables, the importance of lower-order model components, potential limitations of models judged to be well fitting, and the inaccuracy of some commonly used rules of thumb.

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 paratransit. To the authors' best knowledge, this study is the first of its kind to use PNN and ANFIS to predict user based SQ of paratransit. The next two immediate sections depict the architecture of PNN and ANFIS accompanied by some broad information about these methods.

2.3 Artificial Neural Network (ANN)

The learning aptitude of human in making decision and applying it on changing situations can be simulated by ANN. ANN recognizes the characteristics from the defined variables based on existing data, although anomaly is present *(47)*. They can buffer the anomaly 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 networks, with their remarkable ability to derive meaning from complicated or imprecise data, can be used to extract patterns and detect trends that are too complex to be noticed by either humans or other computer techniques. A trained neural network can be thought of as an "expert" in the category of information it has been given to analyze. This expert can then be used to provide projections given new situations of interest and answer "what if" questions. Other advantages include:

1. **Adaptive learning:** An ability to learn how to do tasks based on the data given for training or initial experience.
2. **Self-Organization:** An ANN can create its own organization or representation of the information it receives during learning time.
3. **Real Time Operation:** ANN computations may be carried out in parallel, and special hardware devices are being designed and manufactured which take advantage of this capability.
4. **Fault Tolerance via Redundant Information Coding:** Partial destruction of a network leads to the corresponding degradation of performance. However, some network capabilities may be retained even with major network damage.

Neural network 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 are of several types such as Radial basis function network, Feed forward neural network, Recurrent neural network, Self-organizing Map. Among them feed forward neural network and a variant of Radial basis function network are used to carry out the research, and in this study Probabilistic Neural Network (PNN) is used for modeling the result.

2.3.1 Probabilistic Neural Network (PNN)

PNN can map any input pattern to any number of classifications. Itis a four-layered neural network which operates by minimizing the 'expected risk' function *(48).*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 *(49)* introduced a smooth and continuous class of estimators that asymptotically approach the real density. Later, Specht *(48)* 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. Figure2 shows a PNN architecture that recognizes classes to determine paratransit SQ by means of a set of user attributes. The first layer shows the input pattern consists of 22 user attributes.

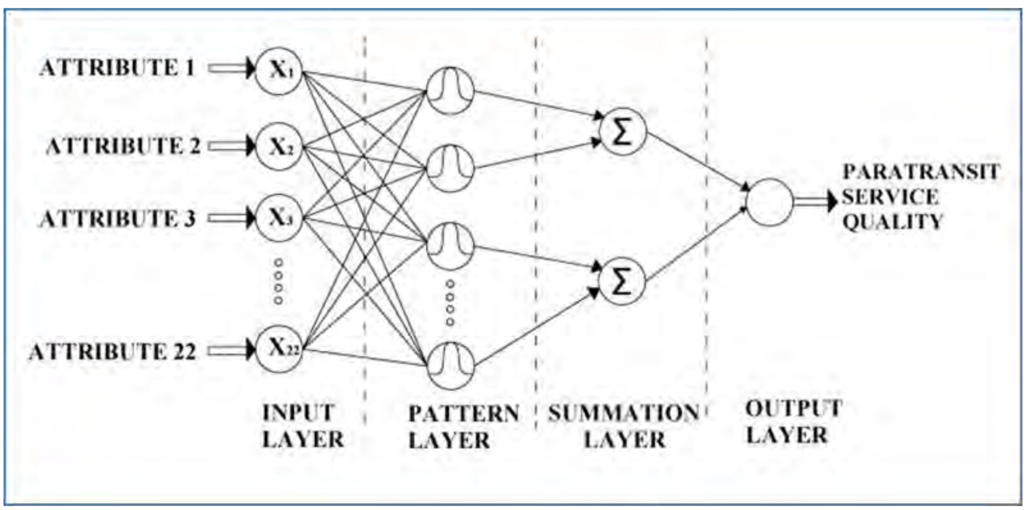


Figure 2.1 Architecture of PNN

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 *(50)*. 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 convergence criteria 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).

$$h_i = E_i F \qquad (1)$$

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

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

Where,

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

The smoothing parameter, γ is used to adjust the importance of the individual pattern units in the second layer. A properly chosen 'γ' produces less classification error and makes PNN insensitive to the change of its value.

2.4 Fuzzy Logic (FL) and Fuzzy Sets

Fuzzy logic was first introduced by Lotfi A. Zadeh, a professor at the University of California at Berkley. Zadeh (1965) *(51)* established the idea that data can occupy partial set membership rather than crisp set membership of non-membership. Professor Zadeh in his paper reasoned that people do not require precise, numerical information input, and yet they are capable of highly adaptive control. Basically, FL is a multivalued logic that allows intermediate values to be defined between conventional evaluations like true/false, yes/no, high/low, etc. Notions like rather tall or very fast can be formulated mathematically and processed by computers, in order to apply a more human-like way of thinking in the programming of computers *(52)*. Fuzzy Set theory also introduced by Professor Lotfi Zadeh in 1965 *(51)* is an extension of the classical set theory. In classical set theory an element either belongs to or does not belong to a set but in fuzzy set elements can take partial membership and sets are not necessarily bound by fixed boundaries or consist of binary membership characteristics. Human like interpretation and decision making processes are hard to simulate in machines as often these include some sort of vagueness and uncertainty. Fuzzy sets was particularly invented to represent such uncertain and vague notions *(53.)*

2.4.1 Fuzzy Inference System

The fuzzy inference system (FIS) is based on the concepts of fuzzy set theory, fuzzy if-then rules and fuzzy reasoning. FIS is a very popular technique and has been widely applied in different fields like data classification, automatic control, expert system, decision making, robotics, time series analysis, pattern classification, system identification etc. The basic structure of a fuzzy inference system consists of three principal components: a rule base comprising of the selected fuzzy rules, a database defining the membership functions of the fuzzy rules, and a reasoning mechanism which performs a fuzzy reasoning inference with respect to the rules so as to derive a reasonable output or conclusion.

2.4.2 Types of Fuzzy System

A fuzzy system may be of three principal types, namely:

1. **Mamdani fuzzy system:** Also known as linguistic fuzzy system.
2. **Singleton Fuzzy system:** The complexity of defuzzification of a linguistic fuzzy system can be simplified by restricting the output to a singleton membership function. Since no integration has to be carried out numerically, this results in reducing the computational demand for the evaluation and learning of the fuzzy system. Therefore a singleton fuzzy system is most widely applied in industry.
3. **Takagi-Sugeno Fuzzy system:** This system may be considered to be an extension of the singleton fuzzy system. Here the function f is not a fuzzy set. But the premise of a Takagi-Sugeno fuzzy system (1988) is linguistically interpretable. For a dynamic process modelling the Takagi- Sugeno models possess an excellent interpretation. A singleton fuzzy system can be recovered from a Takagi-Sugeno fuzzy system if the function f is chosen to be a constant. As the constant can be seen as a zeroth order Taylor series expansion of the function f, it is also called the zeroth order Takagi-Sugeno fuzzy system. However, in most of the applications, the first order Takagi-Sugeno fuzzy system is more common.

2.4.3 Adaptive Neuro Fuzzy Inference System (ANFIS)

ANFIS as proposed by Jang *(54)*, serves as a very powerful tool to construct fuzzy sets of 'if-then' rules automatically, taking the set of input-output data provided and generating membership functions (MFs), which are adjusted to the input-output dataset *(55)*. ANFIS uses back propagation or a combination of least-squares and back-propagation gradient descent method to tune the parameters of a Sugeno type fuzzy inference (FIS). The FIS consists of a rule base, database of MF used in the fuzzy rules, and a reasoning mechanism which uses the rules to provide an output from the given data. While neural networks recognize patterns and adapt to changing environments, fuzzy inference system can incorporate human knowledge. Combining these two techniques, ANFIS becomes a powerful tool capable of simultaneously self-learning and self-improving based on the given input-output dataset. In this study ANFIS toolbox in MATLAB is used for FIS training and testing.

To generate fuzzy rules by means of a given input-output dataset, ANFIS implements a Sugeno fuzzy inference system for a logical approach *(56)*. In the modeling process of ANFIS, the first step is the identification of the input and output variables. In a first-order Sugeno fuzzy model, two typical IF/THEN fuzzy rules can be expressed when a set of two inputs (x, y) and one output (f) is considered:

Rule 1: If x is A_1 and y is B_1, then $f_1 = p_1 x + q_1 y + r_1$ (3)

Rule 2: If x is A_2 and y is B_2, then $f_2 = p_2 x + q_2 y + r_2$ (4)

The ANFIS architecture consists of five-layers: fuzzification, fuzzy AND, normalization, defuzzification and output layer as shown in Figure 2.2. These layers are connected to each other through direct links and nodes. Nodes are the process units that comprise of some adaptive and fixed parameters. Adaptive parameters can be changed by setting learning rules and thus, the membership functions are reformed.

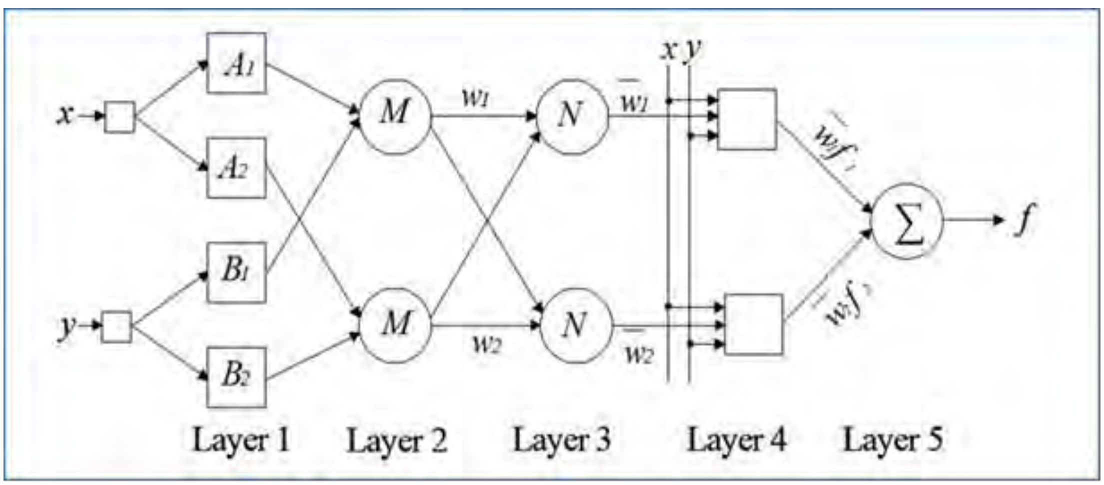


Figure 2.2 Adaptive Neuro-Fuzzy Inference System (ANFIS)

Layer 1: First layer is the fuzzy layer, in which all nodes are adaptive nodes. The membership relationship between the output and input functions of this layer can be expressed as:

$$O_i^1 = \mu_{A_i}(x); i = 1,2 \quad (5)$$

$$O_j^1 = \mu_{B_j}(y); j = 1,2 \quad (6)$$

Here, x and y are the input of nodes A_i and B_j respectively. A_i and B_j are the linguistic labels used in the fuzzy theory for dividing the membership functions.

The fuzzy membership function is generally chosen as a generalized bell-shape with upper limit and lower limit given by equal to 1 and 0. The generalized bell-shape function depends on three parameter sets a, b, and c as:

$$\mu_{Ai}(x) = \frac{1}{1 + [\left(\frac{x - c_i}{a_i}\right)^2]^{b_i}} \tag{6*}$$

Where the parameter b is usually positive. The parameter c locates the centre of the curve. The parameter sets in this first layer are named as premise parameters.

Layer 2: In the second layer all the nodes are fixed nodes. They perform as a simple multiplier and are labeled with M. The outputs of this layer are firing strengths which can be represented as:

$$\mathrm{O}_i^2 = w_i = \mu_{A_i}\mu_{B_j}(y); i, j = 1,2 \tag{7}$$

Layer 3: In the third layer, the nodes are also fixed nodes. They are labeled with N, indicating that they perform as a normalizer to the firing strengths from the previous layer. The outputs of this layer are called as normalized firing strengths which can be represented as:

$$O_i^3 = \bar{w}_i = \frac{w_i}{\Sigma w_i}; i = 1,2 \tag{8}$$

Layer 4: In the fourth layer, the nodes are adaptive nodes. For a first order Sugeno model, the output of each node in this layer is simply the product of the normalized firing strength and a first order polynomial. Hence, the outputs of this layer are given by:

$$O_i^4 = \bar{w}_i f_i = \bar{w}_i(p_i x + q_i y + r_i); i = 1,2 \tag{9}$$

Layer 5: In the fifth layer, the only one single fixed node performs the summation of all incoming signals that is labeled with ∑. Hence, the overall output of the model that comes from fifth layer can be expressed by:

$$O_i^5 = \sum_{i=1}^{2} \bar{w}_i f_i = \frac{\sum_{i=1}^{2} w_i f_i}{\Sigma w_i}; i = 1,2 \tag{10}$$

2.5 Conclusion

This chapter provided an overview on the previous studies on paratransit service quality assessment. Again this chapter described the two AI models (PNN and 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 paratransit SQ using PNN and ANFIS. Hence, this research work aimed at introducing above two models based on paratransit users' data which is expected to show the SQ of paratransit including most important attributes which is needed to improve for users' satisfaction.

Chapter 3

STUDY METHODOLOGY AND DATA COLLECTION

3.1 General

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

A stated preference questionnaire survey was conducted to collect the paratransit users' opinion. Collected data were then studied with the help of analyzing tools. This section also contains the location map of selected survey routes and general information about survey location.

The study procedure is chronologically outlined below.

3.2 Selection of SQ Attributes

The first component addressed SQ attributes selection process to perform a purpose-built questionnaire survey. This process mainly consisted two steps. Firstly, the analysis of the paratransit users' view. Secondly, the analysis of transit specialists' view towards service quality indicators. Primarily, all the SQ attributes were noted from the focus group discussions for both present and potential users. Another list was prepared from the consultations of transit experts and recommendations of previous researches *(2, 34, 56, and 57)*. Finally, a concise set of 22 SQ attributes was selected to carry out the study. The list of selected 22 attributes is given in table 5.1 along with the study results.

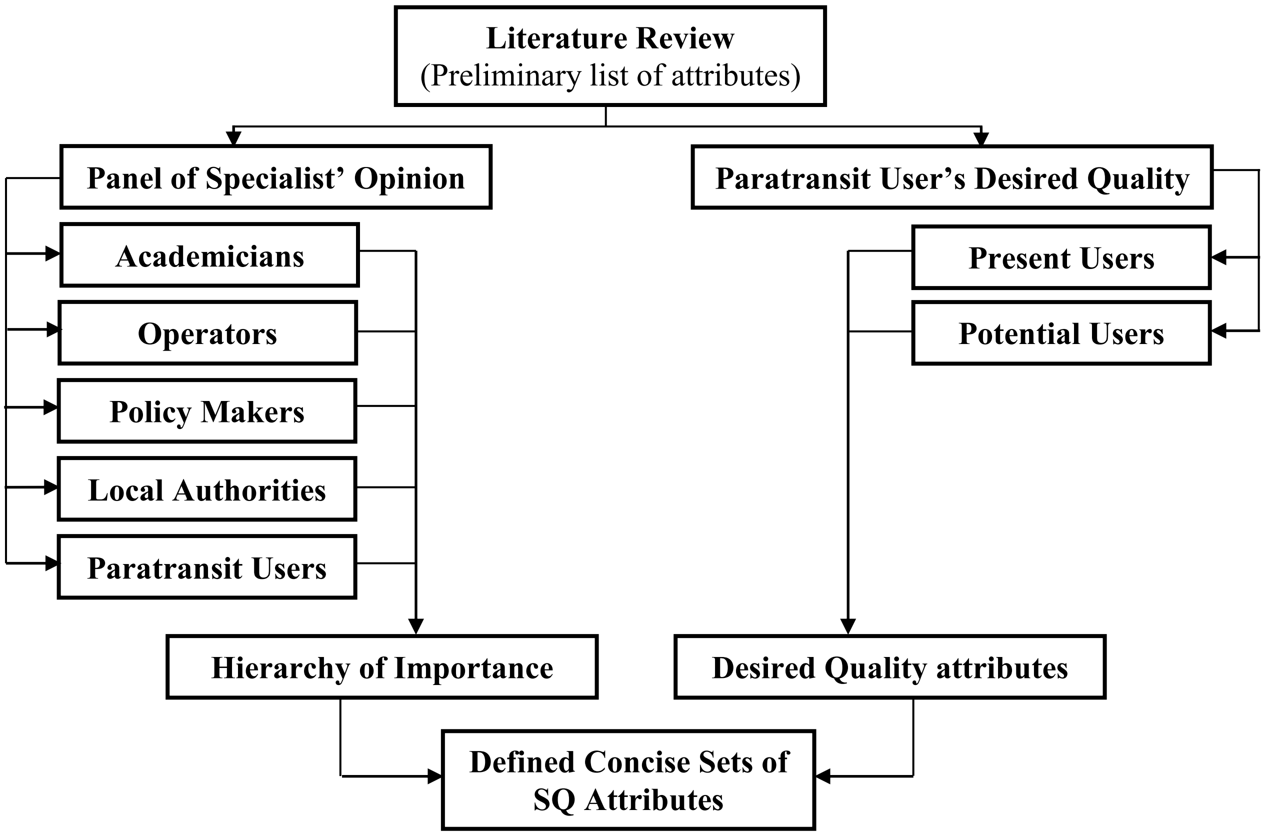


Figure 3.1 Framework for SQ Attributes Selection

3.3 Procedure of Questionnaire Survey

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

Survey locations were selected based on available paratransit routes in Dhaka. Table 3.1 shows the available paratransit routes in Dhaka City.

Table 3.1 Available Paratransit Routes in Dhaka City

Sl. No	From	To
01	Gulistan	New Market
02	Gulistan	Azimpur
03	Gulistan	Madartek/Bashabo
04	Gulistan	Goran
05	Gulistan	Sipahibag
06	Gulistan	Mugdapara
07	Gulistan	Pilkhana (BGB 1 No. Gate)
08	New Market	Zigatola

Sl. No	From	To
09	New Market	Chak Bazar
10	Zigatola	Mohammadpur
11	Zigatola	Shyamoli
12	Farmgate	Mohammadpur
13	Farmgate	New Market
14	Farmgate	Mohakhali (Railgate)
15	Farmgate	Nabisco (Mohakhali)
16	Farmgate	Zigatola
17	Farmgate	Shyamoli
18	Farmgate	Mirpur-10
19	Mohakhali	Mirpur-10
20	Mohakhali	Gabtoli
21	Mohakhali	Mohammadpur
22	Shyamoli	Shiya Mosjid (Mohammadpur)
23	Mohammadpur	Badda (Link Road)
24	Mohammadpur	Gabtoli
25	Mohammadpur	Mirpur-10
26	Shiya Mosjid (Mohammadpur)	Mirpur-1
27	Malibag	Mugdapara
28	Malibag	Khilgaon
29	Rampura	Demra (Staff Quarter)
30	Rampura	Madartek
31	Rampura	Meradia
32	Rampura	Sipahibag

These are the available routes of paratransit in Dhaka city. Fifteen survey locations were selected from the above routes to cover the maximum area of paratransit service.

The table 3.2 shows the locations those are selected for survey.

Table 3.2 Locations for Questionnaire Survey

Sl. No	From	To
01	Farmgate ↔ New Market	Beside Ananda Cinema Hall
02	Zigatola ↔ Shyamoly	Zigatola (Beside JBFH)
03	Shyamoly ↔ Shiya Moszid (Mohammadpur)	Beside Shyamoly Cinema Hall
04	Farmgate ↔ Mohammadpur	Beside Tejgaon College
05	Farmgate ↔ Nabisco (Mohakhali)	Beside Tezturi Bazar
06	Mohammadpur ↔ Mirpur -10	Beside Mohammadpur Bus Stand
07	Shiya Moszid ↔ Mirpur-1	Beside Shiya Moszid
08	Gulistan ↔ New Market	Beside Gulistan Mazar
09	Gulistan ↔ Azimpur	Beside DSCC office
10	Gulistan ↔ Khilgaon / Bashabo	Beside Gulistan Stadium

Sl. No	From	To
11	New Market ↔ Chak Bazar	Beside Home Economics College
12	New Market ↔ Zigatola	West Side of Nilkhet Mor
13	Mohakhali ↔ Mirpur-10	Mohakhali (Railgate)
14	Mohakhali ↔ Gabtoli	Mohakhali (Amtoli Mor)
15	Rampura ↔ Madartek	Rampura Beside Canal

After selection of survey locations, a survey schedule was prepared to complete the survey properly. Table 3.3 shows the schedule of questionnaire survey.

Table 3.3 Questionnaire Survey Schedule

Sl. No	From	Date	Time	To
01	Farmgate ↔ New Market	14/06/2015	8.00 am	Beside Ananda Cinema Hall
02	Zigatola ↔ Shyamoly	14/06/2015	12.00 pm	Zigatola (Beside JBFH)
03	Shyamoly ↔ Shiya Moszid (Mohammadpur)	15/06/2015	8.00 am	Beside Shyamoly Cinema Hall
04	Farmgate ↔ Mohammadpur	16/06/2015	8.00 am	Beside Tejgaon College
05	Farmgate ↔ Nabisco (Mohakhali)	16/06/2015	3.00 pm	Beside Tezturi Bazar
06	Mohammadpur ↔ Mirpur - 10	29/06/2015	4.00 pm	Beside Mohammadpur Bus Stand
07	Shiya Moszid ↔ Mirpur-1	29/06/2015	8.00 am	Beside Shiya Moszid
08	Gulistan ↔ New Market	30/06/2015	12.00 pm	Beside Gulistan Mazar
09	Gulistan ↔ Azimpur	30/06/2015	4.00 pm	Beside DSCC office
10	Gulistan ↔ Khilgaon / Bashabo	01/07/2015	8.00 am	Beside Gulistan Stadium
11	New Market ↔ Chak Bazar	01/07/2015	4.00 pm	Beside Home Economics College
12	New Market ↔ Zigatola	02/07/2015	4.00 pm	West Side of Nilkhet Mor
13	Mohakhali ↔ Mirpur-10	02/07/2015	8.00 am	Mohakhali (Railgate)
14	Mohakhali ↔ Gabtoli	05/07/2015	12.00 pm	Mohakhali (Amtoli Mor)
15	Rampura ↔ Madartek	05/07/2015	4.00 pm	Rampura Beside Canal

3.4 Detail Information about Selected Routes and Study Locations

1. Farmgate ↔ New Market: It is one of the busiest routes of Paratransit in Dhaka City. Figure 3.2 shows the location map of this route. The map was developed through GIS (geographic information system) software using GPS (global information system).

Figure 3.2 Location Map of Farmgate to New Market Route.

Farm Gate (Beside Ananda Cinema Hall) was considered as one the survey locations in this study. Figure 3.3 shows the existing condition survey location at Farm gate.

(a) **(b)**

Figure 3.3 Existing Condition of paratransit system at Farm Gate (Beside Ananda Cinema Hall)

2. Zigatola ↔ Shyamoli: This is another popular route of paratransit. People from Dhanmondi & Zigatola Residential area are the main user of this route. They use this route for their services or businesses or education purpose. The location map of this route shown in Figure 3.4.

Figure 3.4 Location Map of Zigatola to Shyamoli Route.

Questionnaire survey was conducted at Zigatola (Beside Japan Bangladesh Friendship Hospital). Figure 3.5 shows the existing condition of paratransit at that point.

(a) **(b)**

Figure 3.5 Existing Condition of paratransit system at Zigatola (Beside JBFH)

3. Shyamoli↔Shia Masjid (Mohammadpur): Shyamoli is one of the busy traffic points of Dhaka city. It is connected to whole Dhaka city for the availability of various business or service here. Shyamoli to Shia Masjid is another busy route for paratransit. Figure 3.6 shows the Location Map of this route.

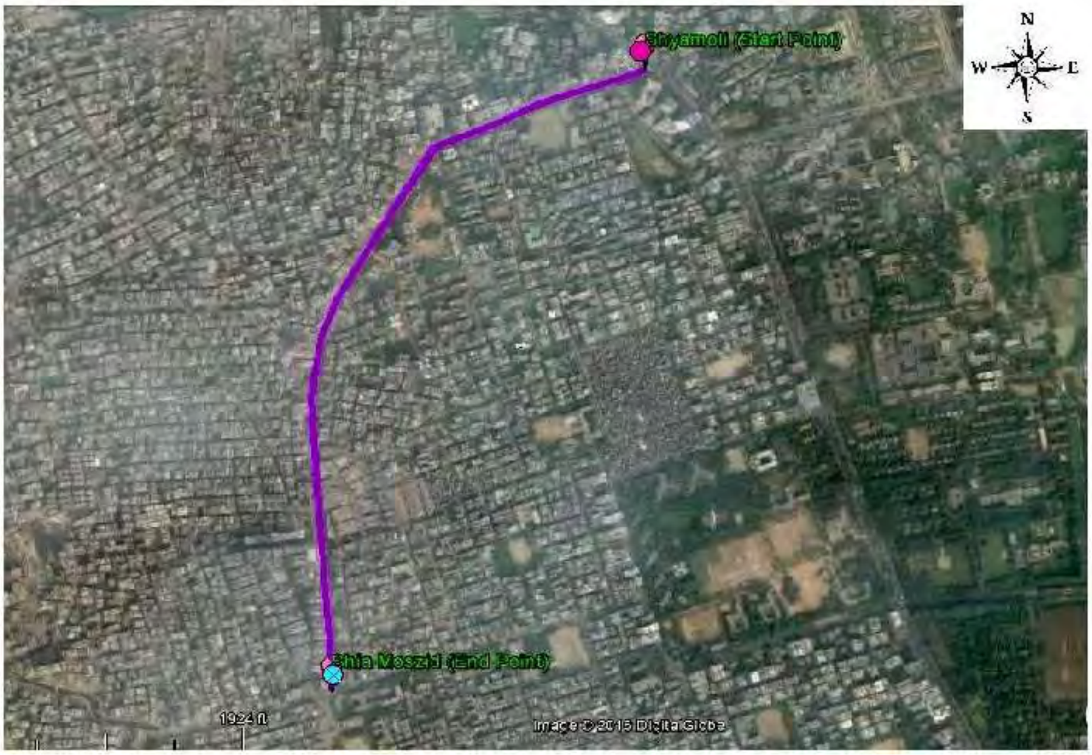


Figure 3.6 Location Map of Shyamoli to Shia Masjid Route.

Shyamoli bus stand was selected as a questionnarie survey location because it was a starting point of shyamoli- shia masjid route. Figure 3.7 represents the existing condition of paratransit system at shyamoli (beside cinema hall).

(a) **(b)**

Figure 3.7 Existing Condition of Paratransit System at Shyamoli (Beside Cinema Hall)

4. Farm Gate ↔ Mohammadpur Bus Stand: Farmgate to Mohammadpur is another busy route of paratransit. Bus services are also provided in this route but some people specially the women and students use paratransit service to avoid travelling hazards. The Location Map of this route shown in Figure 3.8.

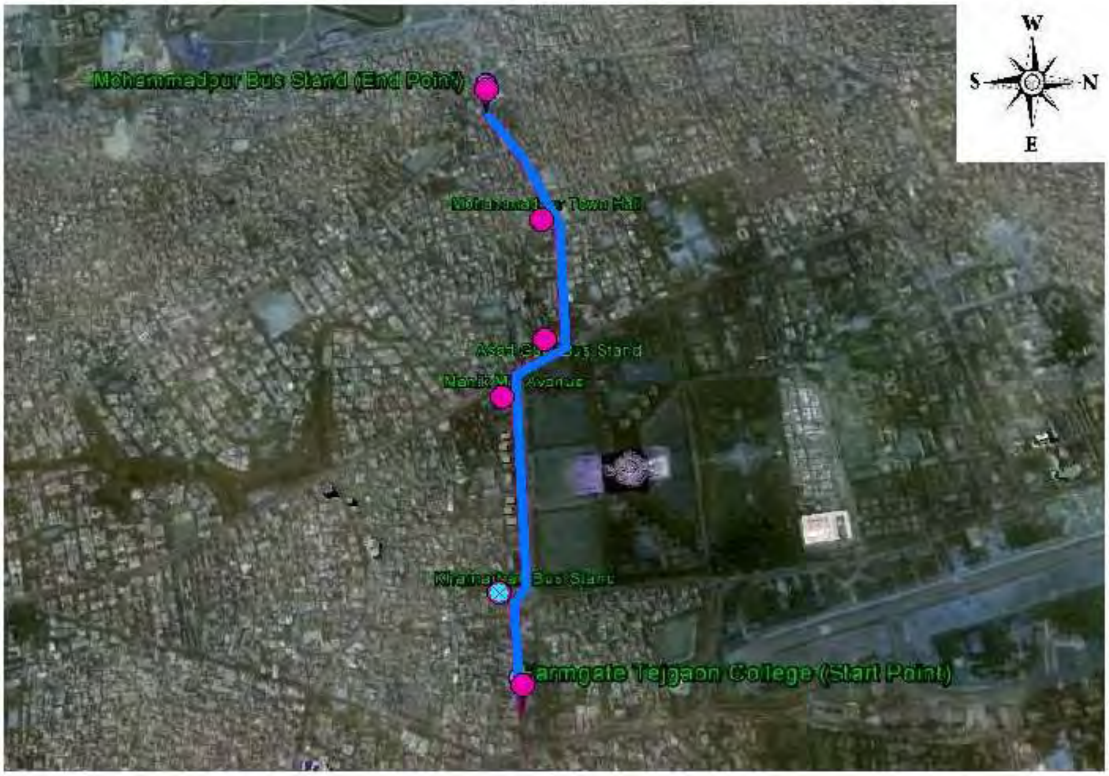


Figure 3.8 Location Map of Farmgate to Mohammadpur Bus Stand Route.

Survey for Farmgate to Mohammadpur route was done at Farm Gate (Beside Tejgaon College) as it was the starting point of this route. Figure 3.9 shows existing condition of paratransit vehicles at this point.

(a) **(b)**

Figure 3.9 Existing Condition of Paratransit Vehicles at Farm gate (Beside Tejgaon College)

5. Farmgate ↔ Nabisco (Mohakhali): The roads are narrow in this route so paratransit is more suitable than buses. People are using this route to save time also. The Location Map of this route is Figure 3.10 below:

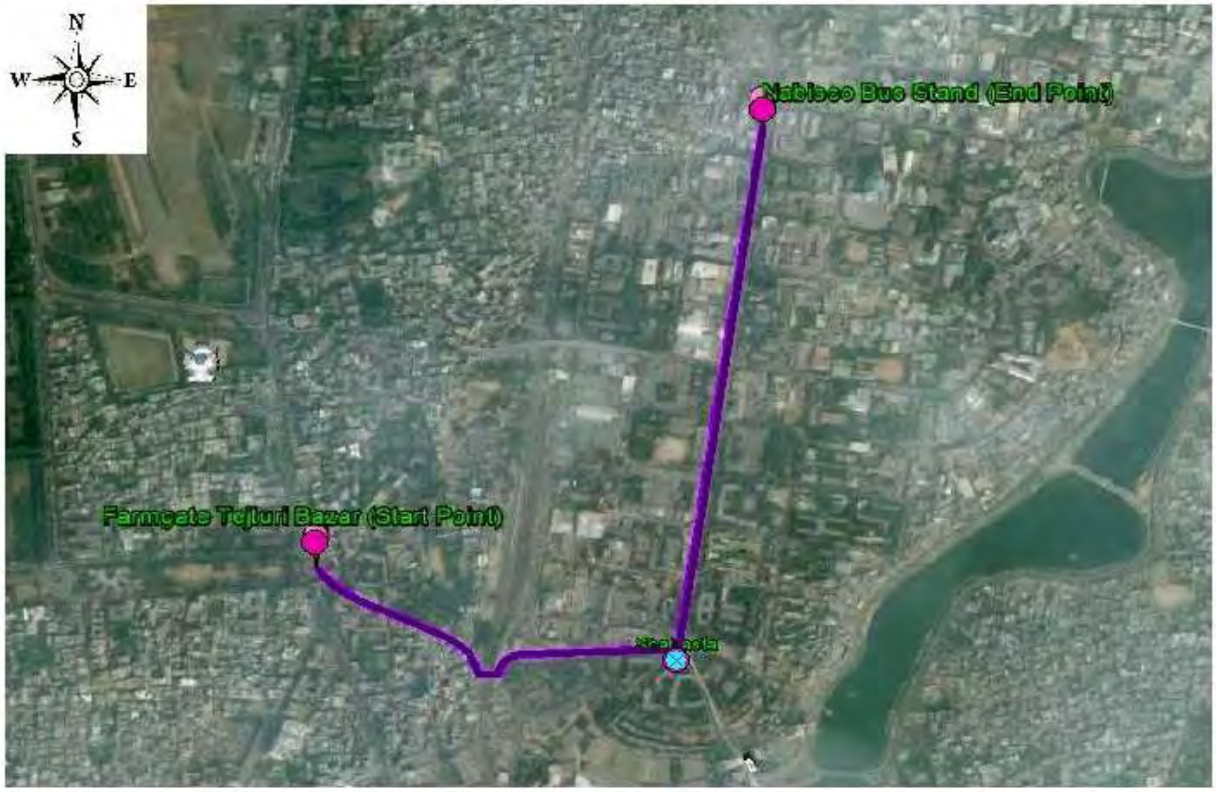


Figure 3.10 Location Map of Farmgate to Nabisco Bus Stand Route.

Questionnaire survey was done at Tejturi Bazar, Farmgate. Figure 3.11 shows the existing condition of paratransit system at this point.

(a) **(b)**

Figure 3.11 Existing Condition of Paratransit System at Farm gate (Tejturi Bazar)

6. Mohammadpur ↔ Mirpur-10: This is also a busy route of paratransit. Everyday lots of people are travelling from Mohammadpur to Mirpur-10 or Mirpur-10 to Mohammadpur for their daily needs. The Location Map of this route is presented in Figure 3.12.

Figure 3.12 Location Map of Mohammadpur to Mirpur-10 Bus Stand Route.

Mohammadpur and Mirpur-10 both locations has bus stand and regular bus service is available but people use paratransit because of saving travel time and the service availability. Usually service holder, students, housewives are travelling in this route. Questionnaire survey was conducted at the point of Mohammadpur bus stand. Figure 3.13 shows the existing condition of this point.

(a) **(b)**

Figure 3.13 Existing Condition of Paratransit System at Mohammadpur Bus Stand

7. Shia Moszid (Mohammadpur) ↔ Mirpur-1: Shia Masjid is an important place situated in Mohammadpur which is mainly a residential area; on the other hand Mirpur-1 is one of the busiest commercial area of Dhaka. Questionnaire survey was done at Shia masjid area because generally people starts their journey from here. The location map of this route and the existing condition of Shia Masjid point are presented in 3.14 and 3.15 respectively.

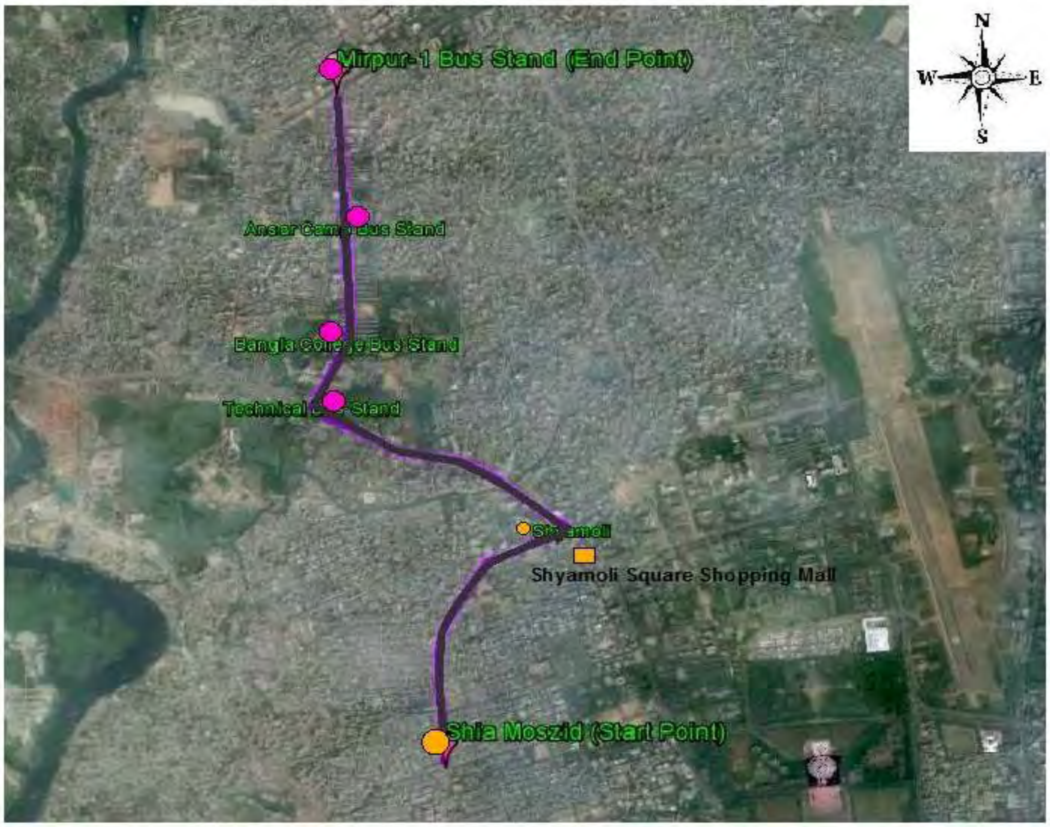


Figure 3.14 Location Map of Shia Masjid (Mohammadpur) to Mirpur-1 Bus Stand Route.

(a) **(b)**

Figure 3.15 Existing Condition of Paratransit System at Shia Masjid (Mohammadpur)

8. Gulistan ↔ New Market: Gulistan and New Market both are the busy commercial areas of the city, a number of people travel from here to there daily by paratransit. There are also bus services in this route but users' choose paratransit for its flexibility. This route starts from Gulistan and ends in New Market via Banga Bazar, Chankharpul and palashi. The location map of this route is shown in figure 3.16.

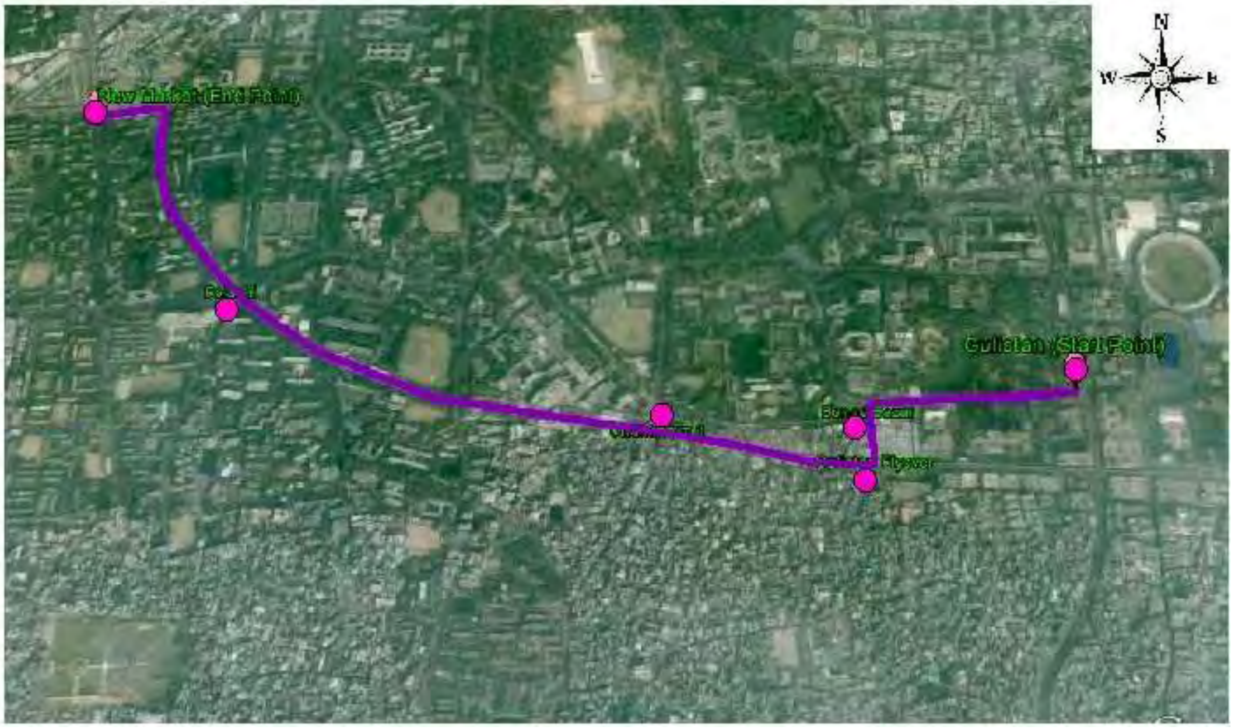


Figure 3.16 Location Map of Gulistan to New Market Route

Questionnaire survey was conducted at Gulistan point (Beside Golap Shah Mazar). The existing condition of this point is presented in figure 3.17.

(a) **(b)**

Figure 3.17 Existing Condition of Paratransit System at Gulistan (Beside Golap Shah Mazar)

9. Gulistan ↔ Azimpur: Gulistan to Azimpur is another route of paratransit service in this area. Sometimes paratransit of Gulistan to New Market route use this route. Figure 3.18 shows the location map of this route.

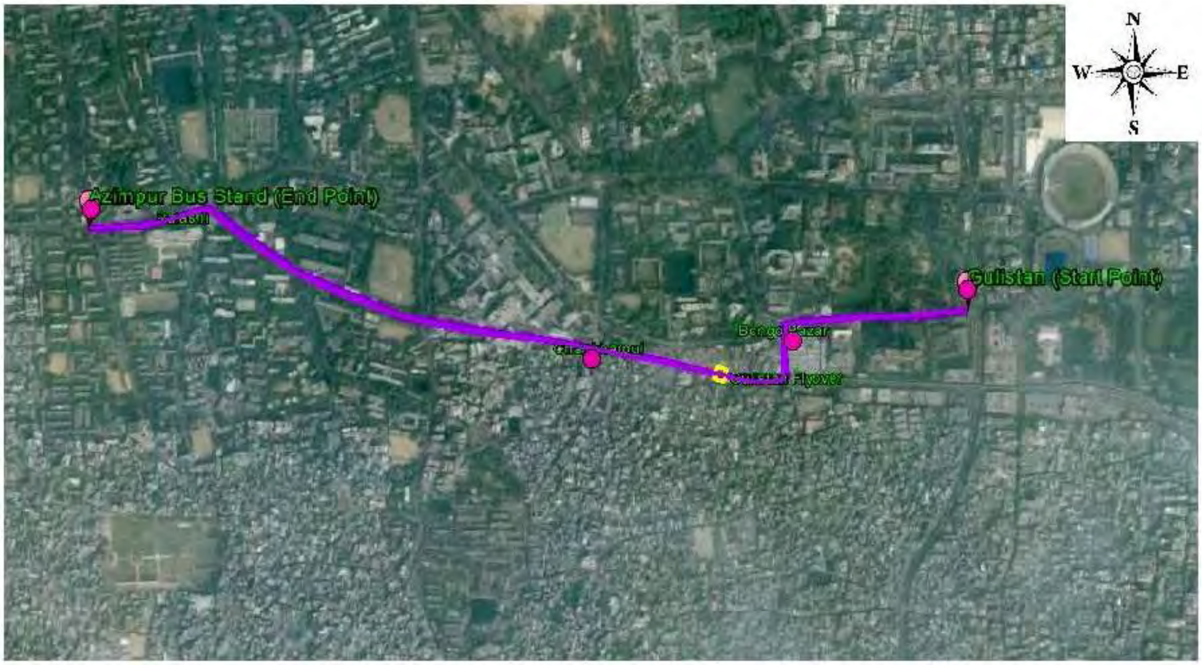


Figure 3.18 Location Map of Gulistan to Azimpur Route.

Azimpur is a residential area from where people come to Gulistan daily for their work and other purposes. Most of the vehicles of this route stands at Gulistan so questionnaire survey was conducted at Gulistan (besides DSCC building) to know the actual condition of the service. Figure 3.19 shows the Existing Condition of paratransit system at Gulistan.

(a)

(b)

Figure 3.19 Existing Condition of Paratransit System at Gulistan (Beside DSCC Building)

10. Gulistan ↔ Khilgaon / Bashabo: Gulistan is the busiest commercial area of the city, so people come here daily from all around the city. People from Bashabo and Khilgaon area also use paratransit services to come Gulistan. The location map of this route and Existing Condition of paratransit system at Gulistan (Beside Stadium) are shown in figure 3.20 and 3.21 respectively.

Figure 3.20 Location Map of Gulistan to Khilgaon / Bashabo Route

(a) **(b)**

Figure 3. 21 Existing Condition of Paratransit System at Gulistan (Beside Stadium)

11. New Market ↔ Zigatola: There are several buses running in this route but paratransit service is also running here because of its availability and flexibility. Questionnaire survey was done at New Market (West Side of Nilkhet Mor). The location map of New Market-Zigatola route and the existing Condition of paratransit system at this point are presented in figure 3.22 and 3.23 respectively.

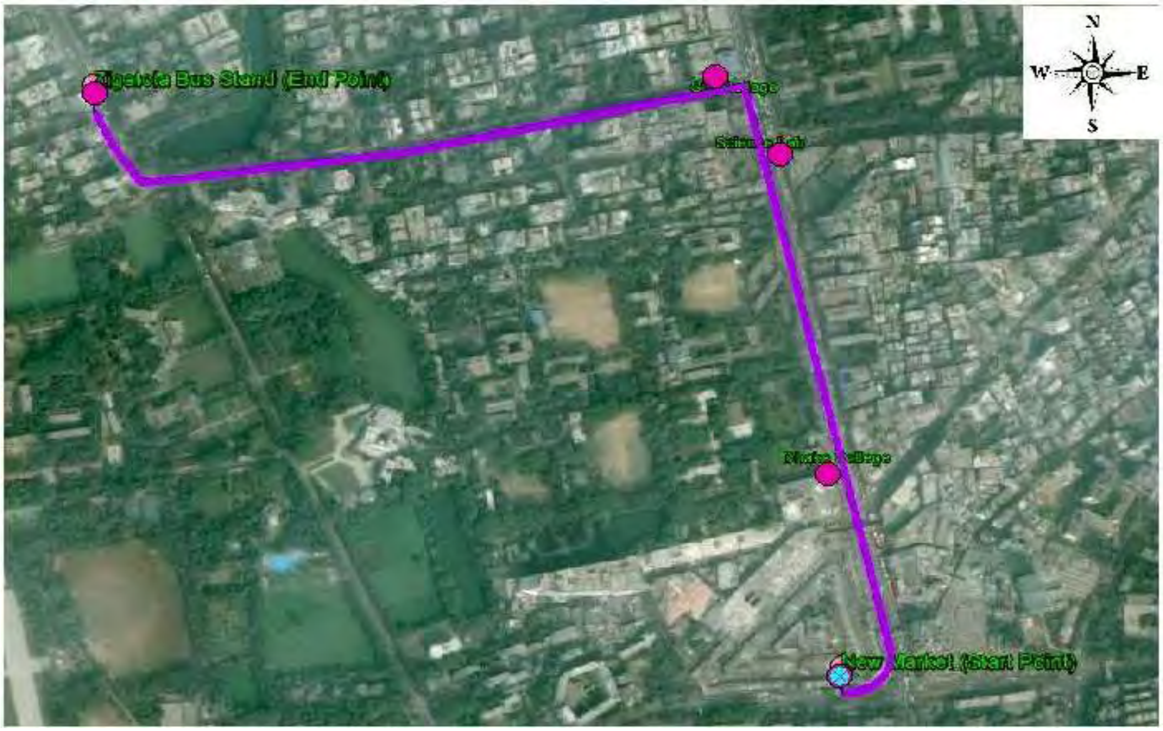


Figure 3.22 Location Map of New Market to Zigatola Route

(a) **(b)**

Figure 3.23 Existing Condition of Paratransit System at New Market

(West side of Nilkhet Mor)

12. New Market ↔ Chakbazar: This is another route of paratransit in New Market area. Survey was conducted at New Market Side (Beside Home Economics College). Figure 3.24 and 3.25 shows the location map and the existing condition of this route respectively.

Figure 3.24 Location Map of New Market to Chak Bazar Route

(a) **(b)**

Figure 3.25 Existing Condition at New Market (Beside Home Economics College)

13. Mohakhali ↔ Mirpur-10: Mohakhali and Mirpur-10 both are commercial areas and a lot of people travel these locations daily through paratransit services. Questionnaire survey was done at Mohakhali Rail gate. Location map and the existing condition are presented in figure 3.26 and 3.27 respectively.

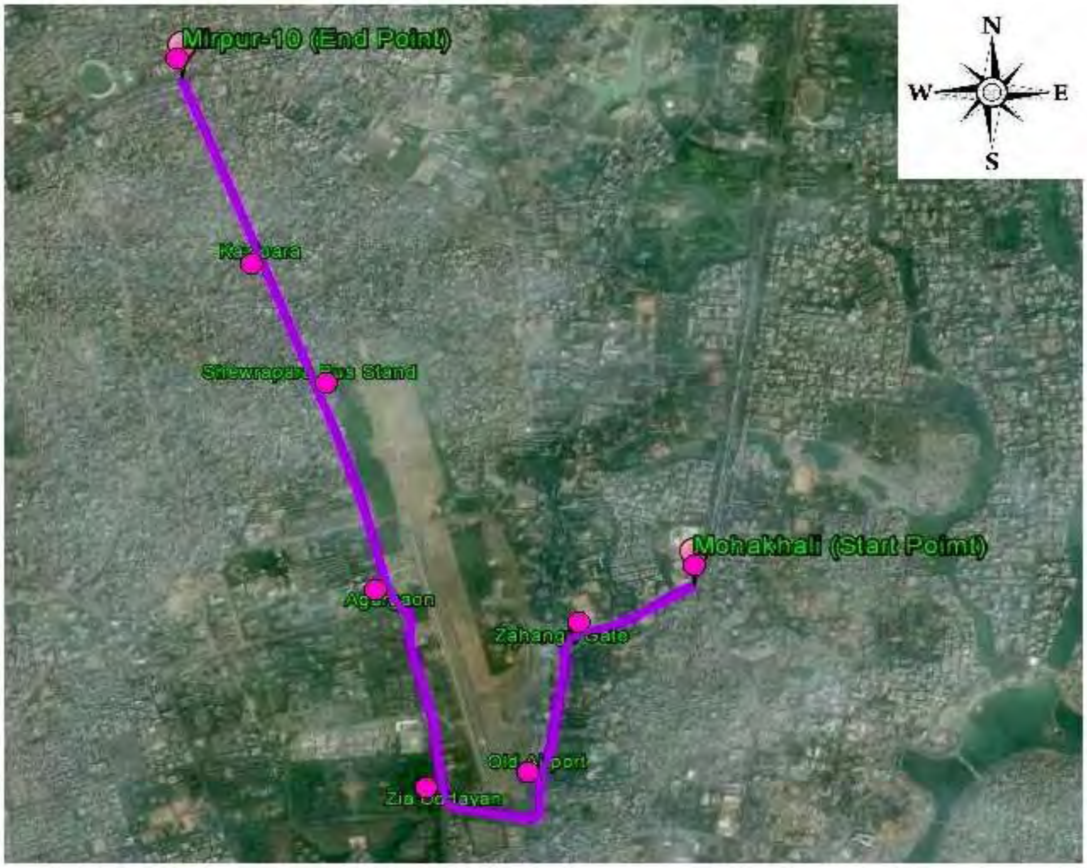


Figure 3.26 Location Map of Mohakhali to Mirpur-10 Route

(a) **(b)**

Figure 3.27 Existing Condition of Paratransit System at Mohakhali Rail gate

14. Mohakhali ↔ Gabtoli: Mohakhali to Gabtoli is another busy route of traffic and paratransit also. People usually come to mohakhali and gabtoli for their works. Students also travel in this route for their educational purposes. Survey was done at Mohakhali (Amtoli Mor) which is one of the starting point of this route. Figure 3.28 and 3.29 represents the location map of this route and the existing condition at Mohakhali (Amtoli Mor) respectively.

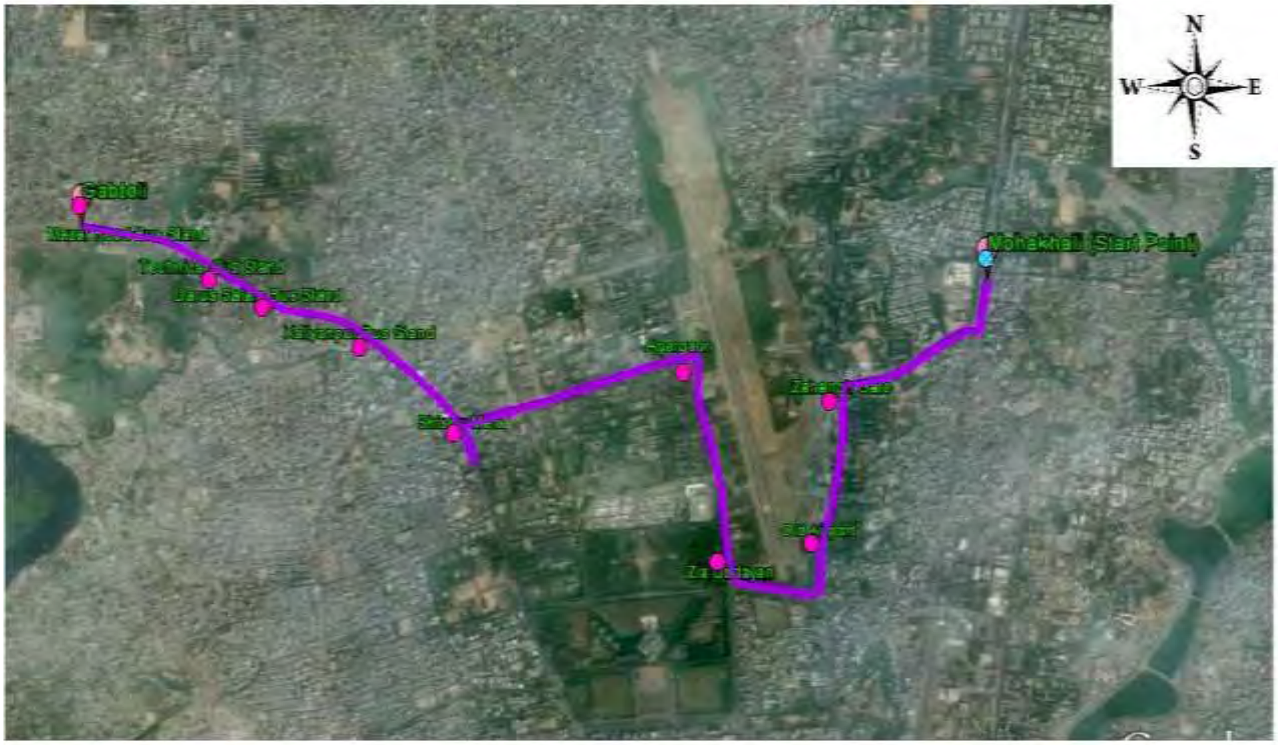


Figure 3.28 Location Map of Mohakhali to Gabtoli Route

(a) **(b)**

Figure 3.29 Existing Condition of Paratransit System at Mohakhali (Amtoli Mor)

15. Rampura ↔ Madartek: This is another important route of paratransit in the city. Thousands of people travel in this route daily. Questionnaire survey was done at Rampura (Beside canal). The location map and existing condition are presented in figure 3.30 and 3.31 respectively.

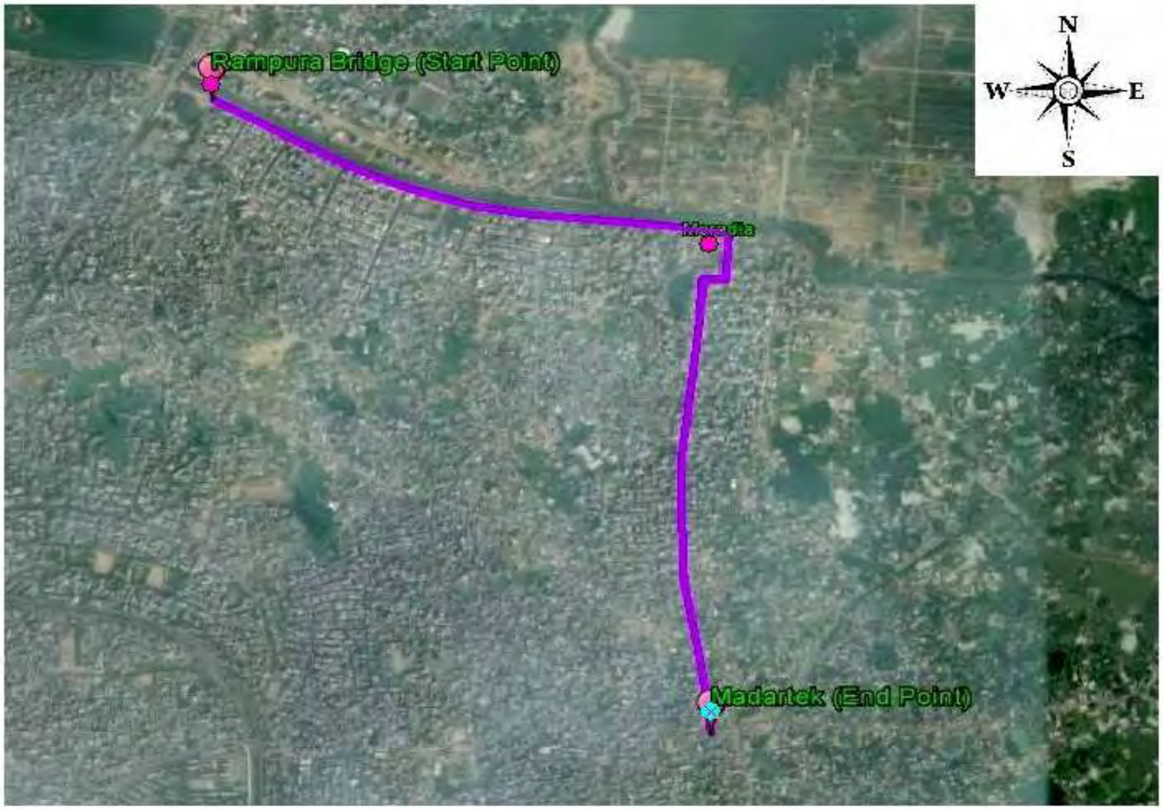


Figure 3.30 Location Map of Rampura Bridge to Madartek Route.

(a) **(b)**

Figure 3.31 Existing Condition of Paratransit System at Rampura (Beside TV Center)

3.5 Data Collection

Thirty five (35) skilled enumerators carried out face-to-face interviews at main paratransit stops around Dhaka city throughout the month of June and July, 2015. There were two sections in the survey questionnaire. The first section was aimed to get personal and socioeconomic information (age, gender, occupation) of commuters and the reason for using paratransit mode. The second section was focused on 22 attributes that are accountable for the evaluation of paratransit service quality. 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 were 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 2500 samples. However, reluctance to participate from the users, rush hour movements, and other un-expected situations restricted the random data samples to 2200. After filtering the anomalies, outputs from 2008 data samples were used in this study.

3.6 Model Development (Training)

In this study, PNN and ANFIS were introduced and the out-of-sample forecasting technique was applied to examine the predictive power of those models. The accuracy of a prediction model was tested by comparing its predicted outputs with corresponding observed targets. The training and forecasting sets contained 1606 (80% of whole sample) and 402 (20% of whole sample) observations, respectively. MATLAB was 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 were 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 PNN and ANFIS for Paratransit SQ Prediction Models

PNN		ANFIS	
Number of input variables	22	Number of input variables	22
Number of layers	4	Number of layers	5
Initial function	initlay	Number of membership function	885
Performance function	mse	MF type	Gaussian
Performance parameter	regularization	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-

PNN		ANFIS	
			propagation
		Training cycles, epochs	10
		Training goal	0.01

Four layered neural networks were created by using the PNN whereas in ANFIS there were five layered neural networks. Every network had an input layer and an output layer. The SQ attributes were applied as input variable and the paratransit SQs as output. Some properties have to be defined to build the models to get best performance which are shown in above table. ANFIS was defined with two hidden layers, 885 membership functions, *tansigmoid* transfer function of hidden layer, *linear* transfer function of output layer, *normalization* as scaling method, 0.01 as training goal and training cycle (epochs) is 10.

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

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

3.7 Conclusion

This research aimed at developing the PNN and ANFIS models for the prediction of paratransit SQ of Dhaka city. For this high-resolution data was the prerequisite. The current chapter introduce the study location with details of the adopted stated preference data collection method. It then briefly discussed the GIS image of the test site and the development of PNN and ANFIS model. The collected high-resolution data is used for the analysis and evaluation of the model in the subsequent chapters.

Chapter 4
DATA ANALYSIS AND RESULTS

4.1 General

This Chapter represents the analysis of paratransit user data collected from stated preference survey. It contains a questionnaire that have 2 parts as followings; 1) general characteristics such as personal details (gender, age, education, occupation, monthly income, car ownership) and reason of choosing paratransit, 2) twenty two (22) paratransit service quality attributes. This chapter illustrates the details information about the general characteristics of paratransit user. It also describes the details description of users' perception for quality of service of paratransit.

4.2 General Characteristics of Paratransit User

Two thousand and Eight (2008) respondents were selected randomly from fifteen different locations in Dhaka City. Table 4.1 illustrates the general characteristics of the respondents collected from survey.

Table 4.1 General characteristics of the Paratransit User

Characteristics	***Statistics***	***No. of Respondents***	***Percentage***
Gender	Male	1667	83%
	Female	341	17%
Age	< 20 Years old	201	10%
	20~29 Years old	783	39%
	30~39 Years old	643	32%
	40~49 Years old	281	14%
	50~59 Years old	100	5%
	>59 Years old	20	1%
Education	Uneducated	522	26%
	Primary	763	38%
	SSC/HSC/Graduate/Post Graduate	723	36%
Occupation	Service	422	21%
	Business	281	14%

Characteristics	Statistics	No. of Respondents	Percentage
	Worker	241	12%
	Housewife	181	9%
	Student	582	29%
	Others	301	15%
Monthly Income	No Specific Income	763	38%
	< 5,000 Tk	100	5%
	5,000~10,000 Tk	141	7%
	10,000~15,000 Tk	241	12%
	15,000~20,000 Tk	402	20%
	> 20,000 Tk	361	18%
Motivation of Choosing Paratransit	Necessity	1004	50%
	Demand Responsive	663	33%
	Economical Reason	221	11%
	Non-Work Based (Recreational)	120	6%

The questionnaire surveys were composed of a sample data of 2008 paratransit users of Dhaka city. In this study, users have expressed their preferences on the prevailing service quality of paratransit. From the above statistical analysis, it was found that the sample was composed of 341 females and 1667 males. The age range was between 16 and 59, but 39% of the sample was between 20 and 29 and 32% was in between 30 to 39. In case of income (in BDT) distribution, 5 percent of the respondents income was less than 5000, 7 percent was in between 5000 to 10000, 12% was in between 10000 to 15000 , 20 percent was in between 15000 to 20000, 18.0% was more than 50000 and about 38% respondents have no specific income. Occupation type revealed that 21 percent of the respondents was job holder (different service holder, government employee, teacher etc.), 29 percent was student, 14 percent was businessman and 9 percent was housewives. Among various options, respondents were asked to tick the most tracking reason behind picking paratransit as their mode of travel. 50% of the respondents described necessity as their motivation, 33% respondents use paratransit as the service is demand responsive than other modes, 11% respondents use paratransit for the economical reason and remaining 6% of the respondents choose paratransit for occasional travel (non-work based; mainly recreational) trips.

4.3 Statistical Approaches for Users' Satisfaction Ratings about Paratransit Service in Dhaka City

1. Service Quality Rating based on Users' Perception:

What is your idea about the prevailing paratransit quality?

In this question respondents were asked about the existing condition of paratransit service quality. Major portion (42%) of the respondents said that overall quality of paratransit service was satisfactory while 30% users' opined that existing condition was good.

Figure 4.1 shows the users' perception about prevailing paratransit quality.

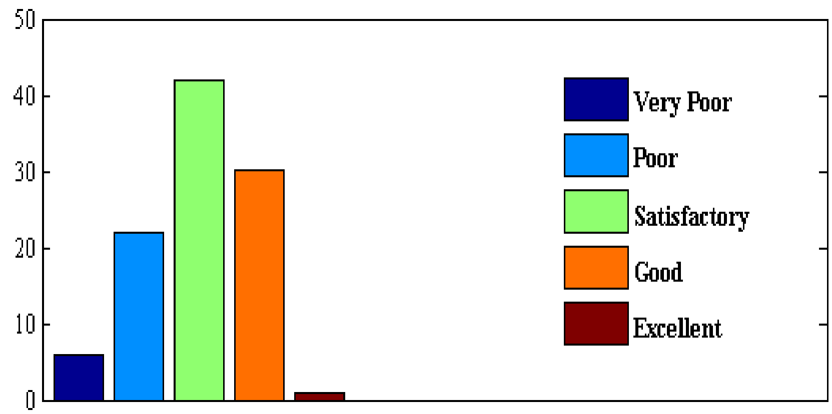


Figure 4.1 Users' Perception about Prevailing Paratransit Service Quality

2. Attribute Rating based on Users' Perception:

Attribute 1: Seat Comfort Level inside Paratransit

In the poorest cities, where vehicles unsuited for passenger transport are overloaded to meet the demand for mobility, the word 'comfort' hardly applies. Though paratransit is the important mode for transport users and a major portion of people use it but in less constrained situations, paratransit vehicles generally provide seating, unlike institutional transport vehicles. However, paratransit vehicles are often overloaded and passengers must share seats. This makes boarding and the journey itself particularly difficult. That's why, the seat comfort level of paratransit mode also become one of the types of complaint that is sent by passengers. From the stated preference survey, following results was found for paratransit seat comfort level.

Attribute	Users' Perception Rating	
	Scaling Method	Percentage
Seat Comfort Level	Excellent	0
	Good	5
	Satisfactory	24
	Poor	51
	Very poor	20

Figure 4.2 shows the graphical representation of user's perception about seat comfort level of paratransit.

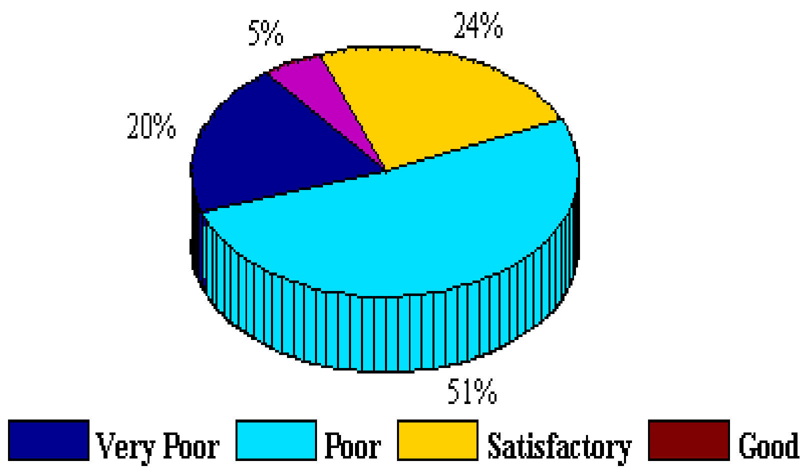


Figure 4.2 User's Perception about Seat Comfort Level of Paratransit

Attribute 2: Fitness of paratransit vehicle

Respondents were asked about the fitness condition of paratransit vehicles. From the stated preference survey, following results was found for paratransit seat comfort level.

Attribute	Users' Perception Rating	
	Scaling Method	Percentage
Fitness of Vehicle	Excellent	0
	Good	7
	Satisfactory	20
	Poor	48
	Very poor	25

Figure 4.3 **s**hows the graphical representation of users' perception about fitness of paratransit vehicle.

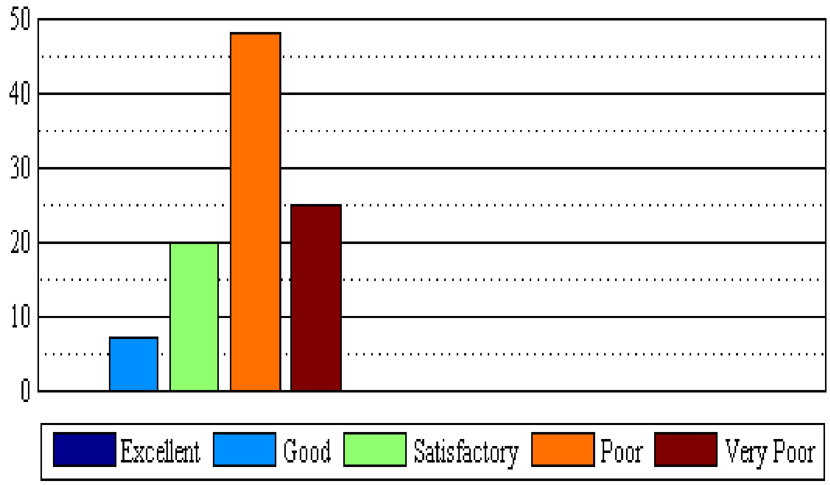


Figure 4.3 Users' Perception about Fitness of Paratransit Vehicle

Attribute 3: Noise Condition of paratransit.

It was found that the noise condition of paratransit was not good enough. The overall satisfaction level of users were given below.

Attribute	**Users' Perception Rating**	
	Scaling Method	**Percentage**
Noise Level	Excellent	0
	Good	9
	Satisfactory	33
	Poor	45
	Very poor	13

Figure 4.4 shows the graphical representation of users' perception about noise condition of paratransit

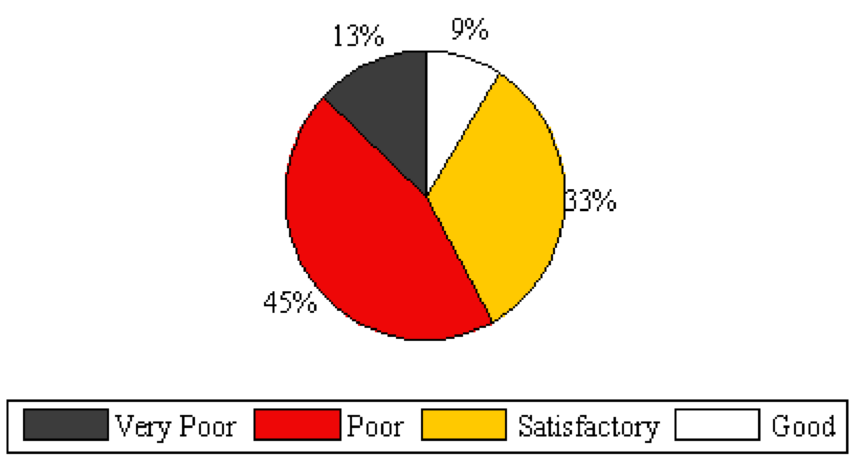


Figure 4.4 Users' Perception about Noise Condition of Paratransit

Attribute 4: Lighting facilities of paratransit.

Most of the time there is a small lighting facility available in a vehicle which is not sufficient for passenger. Sometimes passengers have to travel a vehicle which has no lighting system. Passengers feel unsafe at night due to insufficiency/absence of proper lighting system inside paratransit. From the stated preference survey, following results was found for lighting facilities of paratransit.

Attribute	Users' Perception Rating	
	Scaling Method	**Percentage**
Lighting Facility	Excellent	1
	Good	16
	Satisfactory	33
	Poor	39
	Very poor	11

Figure 4.5 shows the graphical representation of users' perception about lighting facility of paratransit.

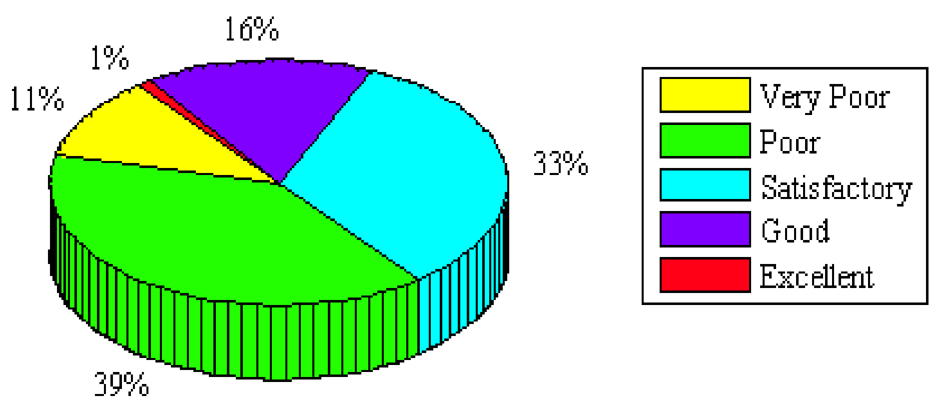


Figure 4.5 Users' Perception about Lighting Facility of Paratransit

Attribute 5: Cleanliness of paratransit

Cleanliness of the vehicle was found satisfactory according to the users' rating. The overall satisfaction level of users were given below:

Attribute	Users' Perception Rating	
	Scaling Method	**Percentage**
Cleanliness	Excellent	0
	Good	15
	Satisfactory	42
	Poor	35
	Very poor	8

Figure 4.6 shows the graphical representation of users' perception about cleanliness of paratransit.

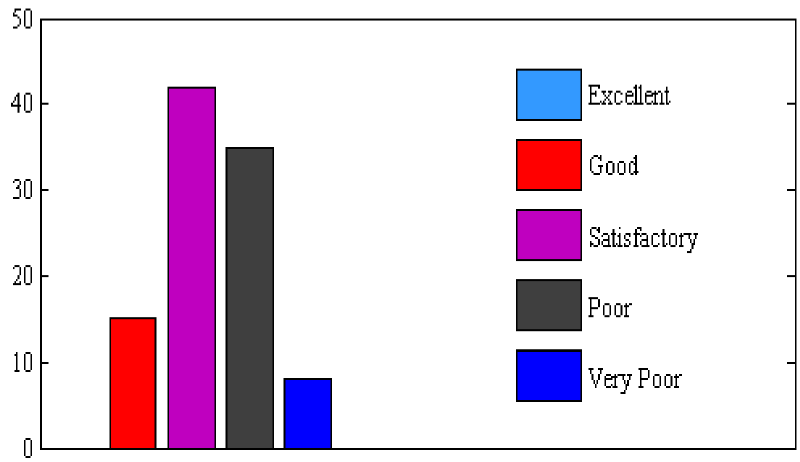


Figure 4.6 Users' Perception about Cleanliness of Paratransit

Attribute 6: Ticketing system (Fare collection)

Basically there is no standard ticketing system in paratransit service. People pay fare on board based on distance. From the stated preference survey, following results was found for ticketing system in paratransit.

Attribute	**Users' Perception Rating**	
	Scaling Method	**Percentage**
Ticketing system (Fare Collection)	Excellent	1
	Good	21
	Satisfactory	30
	Poor	40
	Very poor	8

Figure 4.7 shows the graphical representation of users' perception about ticketing system of paratransit.

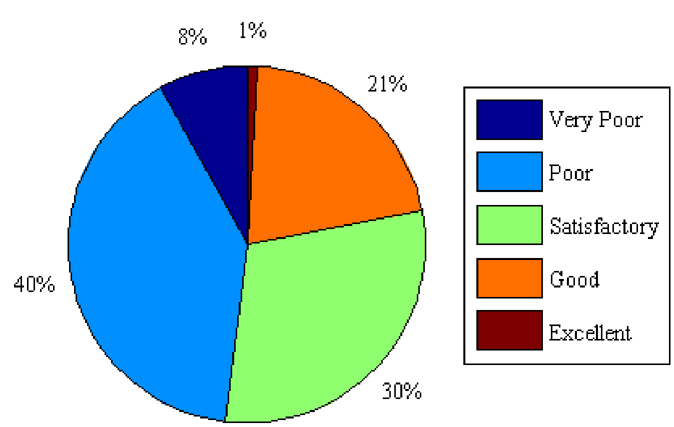


Figure 4.7 Users' Perception about Ticketing System of Paratransit

Attribute 7: Ease of entry-exit in paratransit

As the aspect of paratransit is small so its' entry-exit arrangement is not good enough. Users identified that it is one of the major limitation/disadvantage of travelling by paratransit. Followings are the perception rating given by the users.

Attribute	Users' Perception Rating	
	Scaling Method	Percentage
Ease of Entry and Exit	Excellent	0
	Good	2
	Satisfactory	18
	Poor	55
	Very poor	25

Figure 4.8 shows the graphical representation of users' perception about ease of entry-exit system of paratransit.

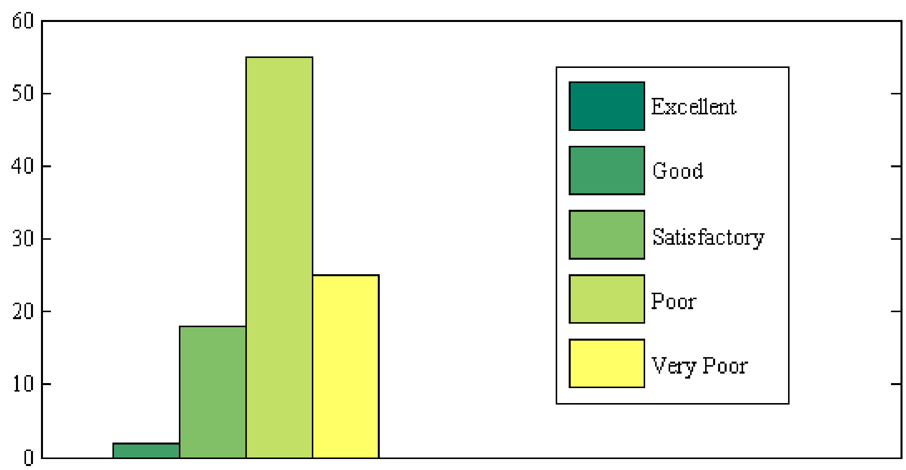


Figure 4.8 Users' Perception about ease of Entry-exit System of Paratransit

Attribute 8: **S**itting arrangements in paratransit.

One of the main problems of travelling by paratransit in our country is its sitting arrangements. It's always so congested that passengers can not able to move even for paying their fare. Users' perception rating are as follows:

Attribute	Users' Perception Rating	
	Scaling Method	Percentage
Sitting Arrangement	Excellent	0
	Good	2
	Satisfactory	14
	Poor	48
	Very poor	36

Figure 4.9 shows the graphical representation of users' perception about sitting arrangements in paratransit

Figure 4.9 Users' Perception about Sitting Arrangements in Paratransit

Attribute 9: Movement flexibility in paratransit.

As the sitting arrangement is not good enough to the passenger so the movement flexibility is also not satisfactory. From the stated preference survey, following results was found for movement flexibility in paratransit.

Attribute	Users' Perception Rating	
	Scaling Method	Percentage
Movement Flexibility	Excellent	1
	Good	5
	Satisfactory	17
	Poor	42
	Very poor	35

Figure 4.10 shows the graphical representation of users' perception about movement flexibility in paratransit

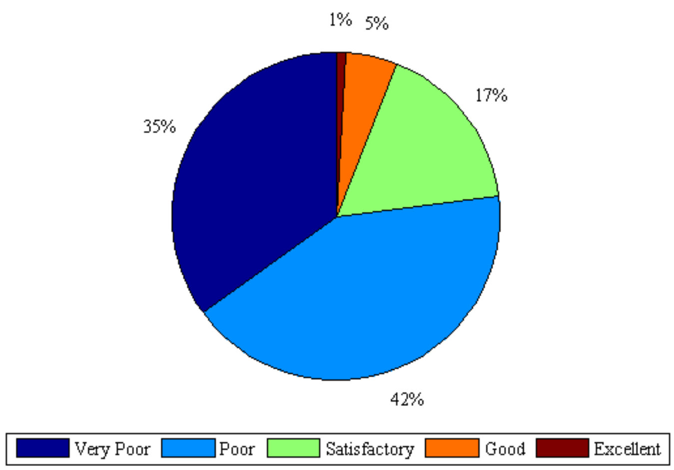


Figure 4.10 Users' Perception about Movement Flexibility in Paratransit

Attribute 10: Quality of driver of paratransit

As in our country there is no special training on driving vehicles so the driving skill of vehicle driver is questionable. Users' perception rating are as follows:

Attribute	Users' Perception Rating	
	Scaling Method	Percentage
Quality of Driver	Excellent	2
	Good	19
	Satisfactory	24
	Poor	34
	Very poor	21

Figure 4.11 shows the graphical representation of users' perception about driver's quality of paratransit.

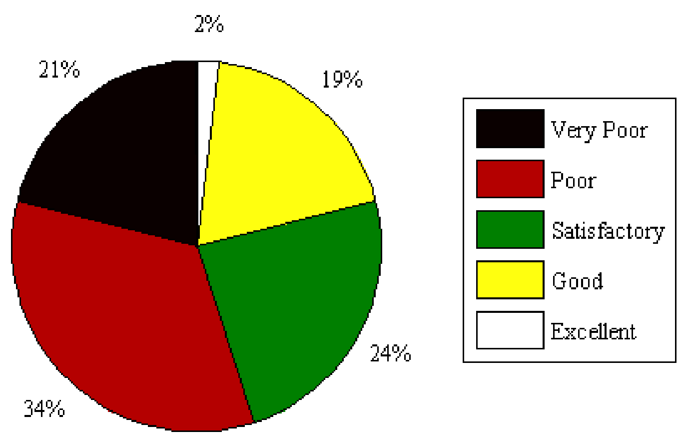


Figure 4.11 Users' Perception about Driver's Quality of Paratransit

Attribute 11: Speed of paratransit

Speed is one of the most important factors that influence users' to choose paratransit service in Dhaka city. Because of their size paratransit vehicle (Tempo, Leguna) can move faster than buses. Therefore, it is considered as one of the attributes for measuring service quality of paratransit. The user's perception rating are as follows:

Attribute	Users' Perception Rating	
	Scaling Method	Percentage
Speed of Paratransit	Excellent	4
	Good	41
	Satisfactory	38
	Poor	12
	Very poor	5

Figure 4.12 shows the graphical representation of users' perception about speed of paratransit vehicle.

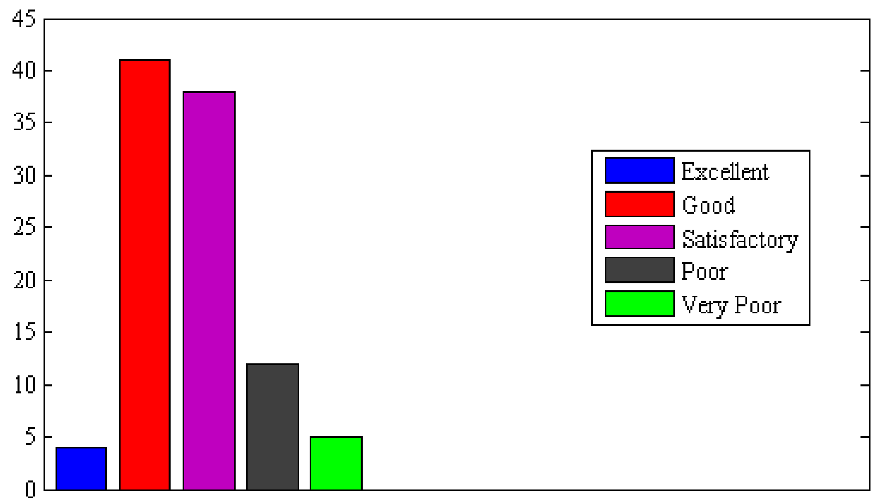


Figure 4.12 Users' Perception about Speed of Paratransit Vehicle

Attribute 12: Availability of paratransit.

Availability of paratransit vehicle varies with the demand. It is more available in off-peak time than office time because the demand is decreased.

Attribute	Users' Perception Rating	
	Scaling Method	**Percentage**
Availability	Excellent	1
	Good	37
	Satisfactory	47
	Poor	12
	Very poor	3

Figure 4.13 shows the graphical representation of users' perception about availability of paratransit vehicle.

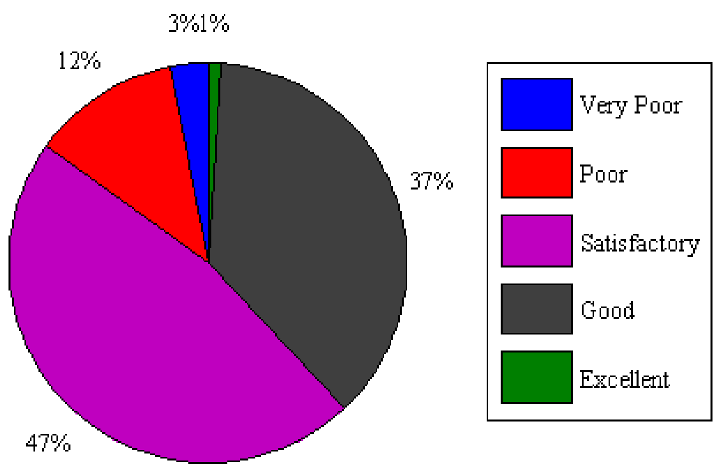


Figure 4.13 Users' Perception about Availability of Paratransit Vehicle

Attribute 13: Travel time (office days) by paratransit

Travel time (office days) depends on traffic volume on the road. In Sunday and Thursday, traffic volume is high, therefore it takes abundant time to go somewhere.

Attribute	Users' Perception Rating	
	Scaling Method	**Percentage**
Travel Time (Office Days)	Excellent	3
	Good	18
	Satisfactory	31
	Poor	32
	Very poor	16

Figure 4.14 shows the graphical representation of users' perception about travel time (office days) by paratransit.

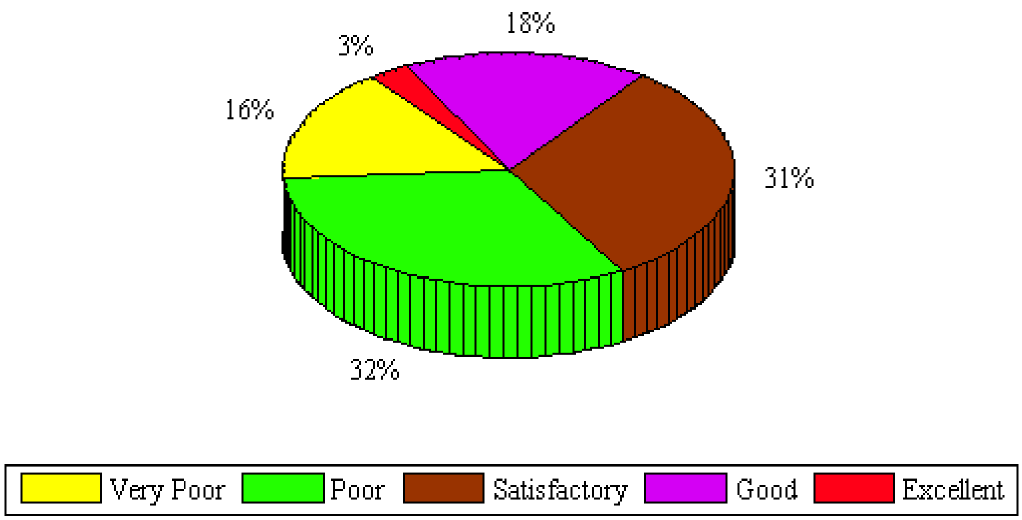


Figure 4.14 Users' Perception about Travel Time (Office Days) by Paratransit

Attribute 14: Travel time (holidays) by paratransit.

Paratransit users are satisfied about in travelling by it during holidays because the traffic volume remains very low. From the stated preference survey, following results was found for travel time (holidays) in paratransit.

Attribute	Users' Perception Rating	
	Scaling Method	**Percentage**
Travel Time (Holidays)	Excellent	13
	Good	43
	Satisfactory	36
	Poor	7
	Very poor	1

Figure 4.15 shows the graphical representation of users' perception about travel time (holidays) by paratransit.

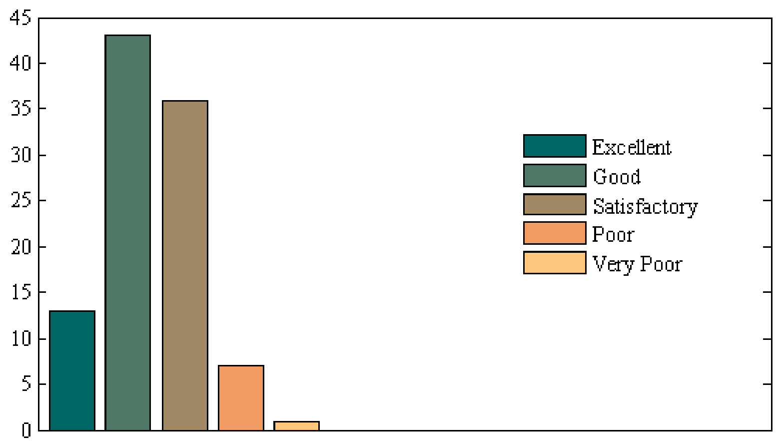


Figure 4.15 Users' perception about Travel Time (Holidays) by Paratransit

Attribute 15: Integration with supporting modes

As paratransit is vital mobility option than other transport, so most of the paratransit user is satisfied with the integration of supporting modes. The overall satisfaction level of users were given below:

Attribute	Users' Perception Rating	
	Scaling Method	Percentage
Integration of Supporting Modes	Excellent	1
	Good	37
	Satisfactory	55
	Poor	6
	Very poor	1

Figure 4.16 shows the graphical representation of users' perception about integration with supporting modes.

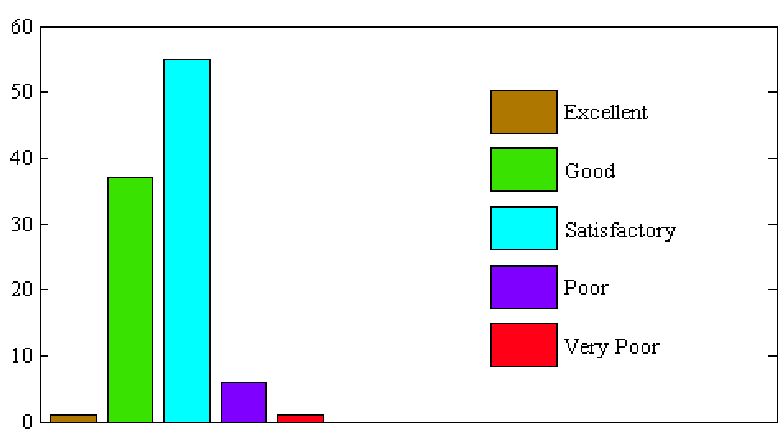


Figure 4.16 Users' Perception about Integration with Supporting Modes

Attribute 16: Security of goods

From the stated preference survey, following results was found for security of goods inside paratransit.

Attribute	Users' Perception Rating	
	Scaling Method	**Percentage**
Security of goods	Excellent	1
	Good	13
	Satisfactory	44
	Poor	35
	Very poor	7

Figure 4.17 shows the graphical representation of users' perception about security of goods inside paratransit.

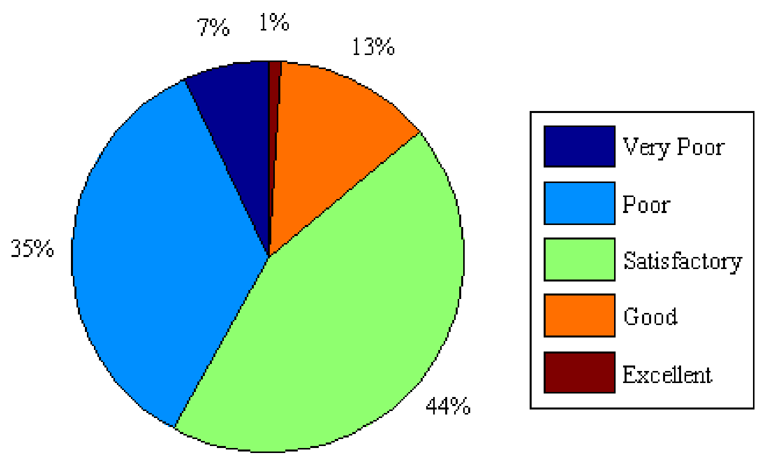


Figure 4.17 Users' Perception about Security of Goods inside Paratransit

Attribute 17: Security of passengers in paratransit.

Security of passenger is not quite good in paratransit service as it is not safe at late night. The overall satisfaction level of users were given below:

Attribute	Users' Perception Rating	
	Scaling Method	**Percentage**
Security of passengers	Excellent	0
	Good	8
	Satisfactory	39
	Poor	41
	Very poor	12

Overall percentage of respondents' opinion is shown in figure 4.18.

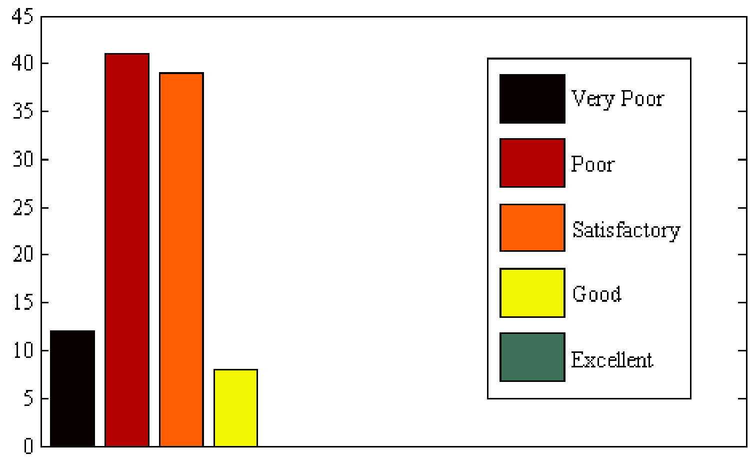


Figure 4.18 Users' Perception about Security of Passengers inside Paratransit

Attribute 18: Riding safety of paratransit

There is no specific riding safety features available in paratransit service in our country. From the stated preference survey, following results was found for riding safety of paratransit.

Attribute	Users' Perception Rating	
	Scaling Method	Percentage
Riding Safety	Excellent	0
	Good	5
	Satisfactory	31
	Poor	44
	Very poor	20

Overall percentage of respondents' opinion is shown in figure 4.18.

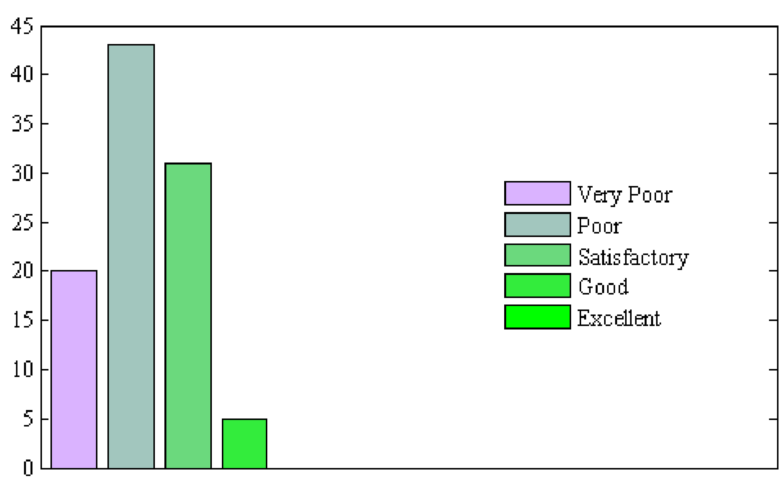


Figure 4.19 Users' Perception about Riding Safety of Paratransit

Attribute 19: Travel cost comparing with other transport

Travel cost is another important factor for what users choose paratransit service. It is much less than rickshaw or CNG auto rickshaw but little bit more than bus. Most of the time, respondents use the service instead of bus to save travel time. Following table and figure 4.20 show the perception rating on travel cost of paratransit service.

Attribute	Users' Perception Rating	
	Scaling Method	**Percentage**
Travel Cost	Excellent	1
	Good	27
	Satisfactory	53
	Poor	17
	Very poor	2

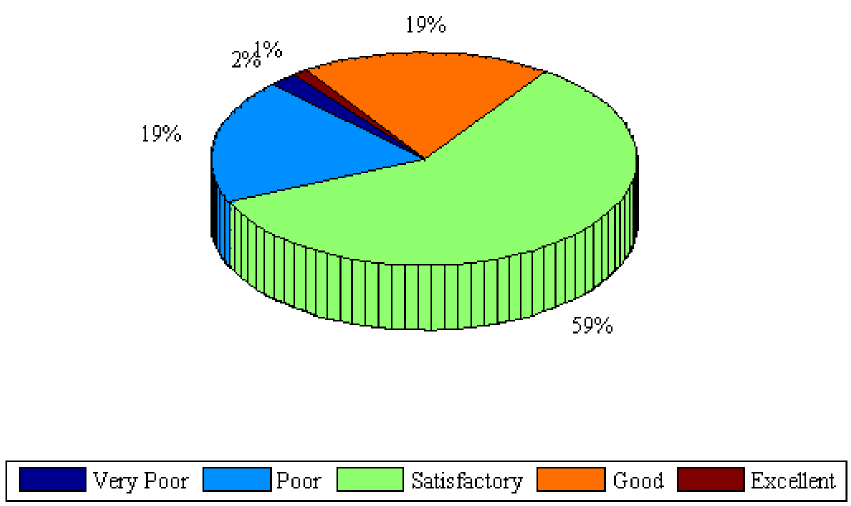


Figure 4.20 Users' Perception about the Travel Cost Comparing with other Transport

Attribute 20: Service features

The rating of service features of paratransit were as follows:

Attribute	Users' Perception Rating	
	Scaling Method	**Percentage**
Service Features	Excellent	5
	Good	45
	Satisfactory	50
	Poor	0
	Very poor	0

Figure 4.21 shows the graphical representation of users' perception about the service features comparing with other transport.

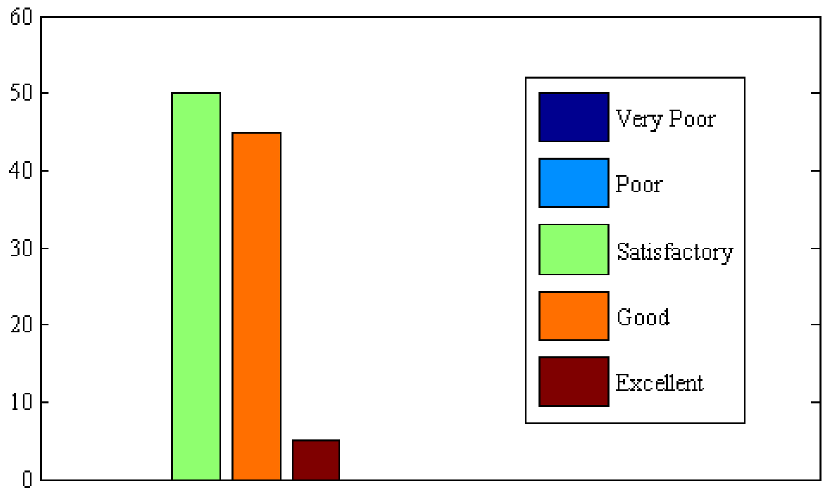


Figure 4.21 Users' Perception about the Service Features Comparing with other Transport

Attribute 21: Performance for long route movement

Performance for long route movement of paratransit service found poor according to the users' perception.

Attribute	Users' Perception Rating	
	Scaling Method	**Percentage**
Performance for Long Route Movement	Excellent	0
	Good	10
	Satisfactory	25
	Poor	52
	Very poor	13

Figure 4.22 shows the graphical representation of users' perception about performance for long route movement.

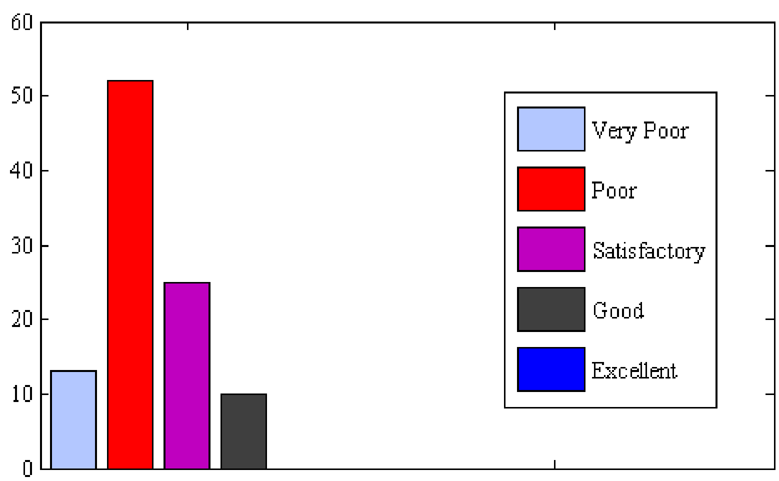


Figure 4.22 Users' Perception about Performance for Long Route Movement

Attribute 22: Movement flexibility in any road

Paratransit users think that the movement flexibility in any road is not good for paratransit service. It is better for the roads with medium width (20-40 ft). It is not good in highways because of bus and not good at narrow roads because of rickshaw. From the stated preference survey, following results was found for movement flexibility in any road.

Attribute	Users' Perception Rating	
	Scaling Method	**Percentage**
Movement Flexibility in any Road	Excellent	1
	Good	17
	Satisfactory	27
	Poor	43
	Very poor	12

Figure 4.23 shows the graphical representation of users' perception about the movement flexibility in any road.

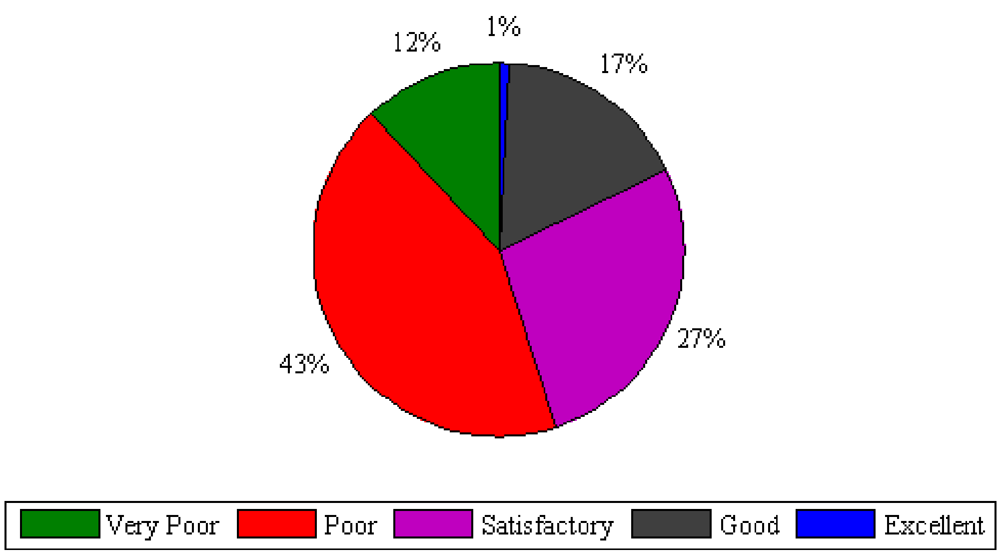


Figure 4.23 Users' Perception about the Movement Flexibility in any Road

Above section shows the 22 attributes that influences the overall quality of paratransit. It also illustrates the users' perception rating of those attributes. The rating were collected by respondents during questionnaire survey.

4.4 Summery about Users' Perception about Paratransit Service

Twenty Three (23) questions (among them 22 used as paratransit attributes and one used for gathering information about the quality of paratransit service) were used in this study to know the users' perception about paratransit service. Respondents were asked to provide a rating which reflects their opinion about different features of paratransit. They rated the questions as "Excellent", "Good", "Satisfactory", "Poor" or "Very Poor". Table 4.2 represents the summery of overall users' perception ratting for different factors of paratransit service in Dhaka city.

Table 4.2 Summery of Users' Perception about Paratransit Service

Sl. No	***Attributes***	***Rating***
01	Seat Comfort Level	Excellent (0%), Good (5%), Satisfactory (24%), Poor (52%), Very Poor (19%)
02	Fitness of Vehicle	Excellent (0%), Good (7%), Satisfactory (20%), Poor (48%), Very Poor (25%)
03	Noise Level	Excellent (0%), Good (9%), Satisfactory (33%), Poor (45%), Very Poor (13%)
04	Lighting Facility	Excellent (1%), Good (16%), Satisfactory (33%), Poor (39%), Very Poor (11%)
05	Cleanliness	Excellent (0%), Good (15%), Satisfactory (42%), Poor (35%), Very Poor (8%)
06	Ticketing system (Fare Collection)	Excellent (1%), Good (21%), Satisfactory (30%), Poor (40%), Very Poor (8%)
07	Ease of Entry and Exit	Excellent (0%), Good (2%), Satisfactory (18%), Poor (55%), Very Poor (25%)
08	Sitting Arrangement	Excellent (0%), Good (2%), Satisfactory (14%), Poor (48%), Very Poor (36%)
09	Movement Flexibility	Excellent (1%), Good (5%), Satisfactory (17%), Poor (42%), Very Poor (35%)
10	Quality of Driver	Excellent (2%), Good (19%), Satisfactory (24%), Poor (34%), Very Poor (21%)
11	Speed of Paratransit	Excellent (4%), Good (41%), Satisfactory (38%), Poor (12%), Very Poor (5%)
12	Availability	Excellent (1%), Good (37%), Satisfactory (47%), Poor (12%), Very Poor (3%)
13	Travel Time (Office Days)	Excellent (3%), Good (18%), Satisfactory (31%), Poor (32%), Very Poor (16%)
14	Travel Time (Holidays)	Excellent (13%), Good (43%), Satisfactory (36%), Poor (7%), Very Poor (1%)
15	Integration of Supporting Modes	Excellent (1%), Good (37%), Satisfactory (55%), Poor (6%), Very Poor (1%)
16	Security of goods	Excellent (1%), Good (13%), Satisfactory (44%), Poor (35%), Very Poor (7%)

Sl. No	Attributes	Rating
17	Security of passengers	Excellent (0%), Good (8%), Satisfactory (39%), Poor (41%), Very Poor (12%)
18	Riding Safety	Excellent (0%), Good (5%), Satisfactory (31%), Poor (44%), Very Poor (20%)
19	Travel Cost	Excellent (1%), Good (27%), Satisfactory (53%), Poor (17%), Very Poor (2%)
20	Service Features	Excellent (5%), Good (45%), Satisfactory (50%), Poor (0%), Very Poor (0%)
21	Performance for Long Route Movement	Excellent (0%), Good (10%), Satisfactory (25%), Poor (52%), Very Poor (13%)
22	Movement Flexibility in any Road	Excellent (1%), Good (17%), Satisfactory (27%), Poor (43%), Very Poor (12%)

4.5 Conclusion

This chapter aimed to acquire information regarding socioeconomic characteristics of passengers (gender, age, occupation) and purpose of travelling. From the above questionnaire survey, paratransit users' perception rating were found about quality of transport, service quality, service reliability, safety and security of the service etc. From the table 4.2, the idea of actual condition of the perception of paratransit user on individual attribute which affects the quality of service of paratransit was obtained. Existing condition of paratransit service was found satisfactory: i) Cleanliness of the vehicle, ii) Availability of vehicle, iii) Integration with supporting modes, iv) Security of goods, v) Travel cost and vi) Service Feature. Two parameters were found in good condition during survey which are: i) Speed of the vehicle and ii) Travel time in Holidays. There were some parameters that found in poor condition like- i) Seat comfort level, ii) Fitness of the vehicle, iii) Ticketing system (fare collection), iv) Quality of Driver, v) Ease of entry-exit system, vi) Sitting arrangements, vii) Lighting facilities, viii) Travel time (Office Days), ix) Noise condition, x) Security of passenger during off-peak period, xi) Movement flexibility inside vehicle, xii) Riding safety xiii) Performance for long route movement and xiv) Movement flexibility in any roads.

Chapter 5
MODEL FORMULATION AND RESULTS

5.1 General

The evolution of advanced technologies and their application to complex transportation problems require, in most cases, Artificial Intelligence (AI) paradigms. Computational intelligence (CI) is one the branches of AI, which includes such methods as neural networks (NN), fuzzy systems (FS), and evolutionary computing. In this study two AI (PNN and ANFIS) are used for predicting SQ of paratransit. The present chapter aims at comparing the performances of a PNN and ANFIS models developed in the previous chapter, This Chapter also shows the model performance of PNN and ANFIS for paratransit SQ. It also reveals the attribute ranking and find the significant attributes for improving SQ of paratransit.

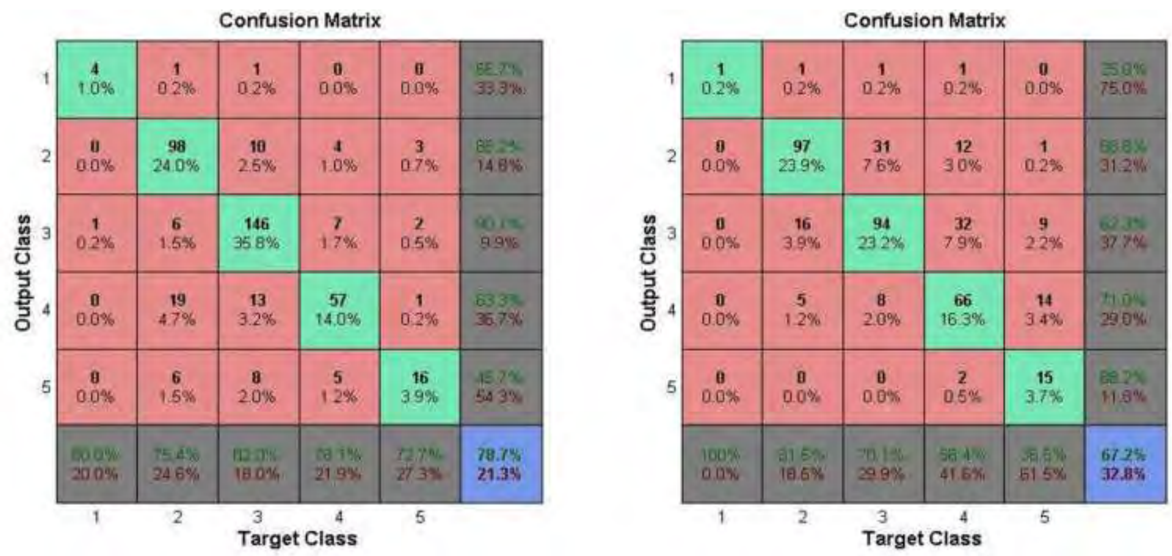
The details are chronologically outlined below.

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), correlation co-efficient (R).

5.2.1 Confusion Matrix

A *confusion matrix*, also known as a contingency table or an error matrix, is a specific table layout that allows visualization of the performance of an algorithm, typically a supervised learning one (in unsupervised learning it is usually called a matching matrix). Each column of the matrix represents the instances in a predicted class while each row represents the instances in an actual class (or vice-versa). The name stems from the fact that it makes it easy to see if the system is confusing two classes (i.e. commonly mislabeling one as another). 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 5.1 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) **(b)**

FIGURE 5.1 Confusion Matrix for Model Evaluation: (a) PNN; and (b) ANFIS

The predicted classifications of developed PNN and ANFIS models are shown in Figure 5.1 by means of confusion matrix. It is seen that, PNN and ANFIS have 78.7% and 67.2% accuracy in prediction, respectively. In quantitative term, PNN has shown accuracy in 321 predictions out of 401, which implies that 321 predictions match with the actual SQ value. ANFIS has shown accuracy for 273 prediction out of 401, which implies that 273 predictions match with the actual SQ value recorded from the survey.

5.2.2 Correlation Coefficient (R)

Correlation – often measured as a correlation coefficient – 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:

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

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.

5.2.3 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 modelled. 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:

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

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

Comments can be made on the model performances based on the R and RMSE values between the predicted and actual SQ of the forecasting sample (402 data). The R value of PNN and ANFIS prediction were 0.702 and 0.442, respectively. Whereas, the RMSE values for those models were 0.745 and 0.929, respectively. It was seen that R value of PNN model is greater than ANFIS model. Whereas, RMSE value of PNN model was smaller than ANFIS model. It showed that based on user stated preferences, PNN performs better than ANFIS in SQ prediction of paratransit.

5.3 Attribute Ranking

This study used twenty two (22) attributes in PNN and ANFIS models to estimate the paratransit 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 was followed for ranking the significant paratransit attributes which is shown in following section.

5.3.1 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), root-mean-square error (RMSE) and correlation coefficient (R).However, in this study the last two methods were used to assess the effects of attributes. These measures were compared for both PNN and ANFIS models in table 5.1. Here, the higher the value of 'R' and lower the value of 'RMSE', the corresponding attribute was more significant and vice versa. As an example, in case of the model developed by including 'Ticketing system (Fare Collection)' only, the prediction was most accurate. Because, among all the other models, this model had the highest R-value and the lowest RMSE. It was meant that this variable had significant control on the paratransit SQ determination. Conversely, 'Travel Time (Holidays)' was less important due to the corresponding R and RMSE values.

The sequences of relative significance within first ten of the SQ attributes revealed by the models were important for SQ of paratransit. However, slight variations in the relative importance of the attributes were found in different models. These could be occurred due to the model behavior on paratransit attributes. Table 5.1 shows the ranking of the attributes based on their effect on the SQ prediction.

Table 5.1 Attributes Ranking Comparison among PNN and ANFIS

ATTRIBUTES	PNN			ANFIS		
	R	RMSE	Rank	R	RMSE	Rank
Seat Comfort Level	0.246	0.881	9.000	0.575	0.989	10
Fitness of Vehicle	0.446	0.888	10.000	0.442	1.194	19

ATTRIBUTES	PNN			ANFIS		
	R	RMSE	Rank	R	RMSE	Rank
Noise Level	0.588	0.986	18	0.480	1.012	13
Lighting Facility	0.282	1.032	22	0.328	1.212	20
Cleanliness	0.572	0.954	17	0.316	0.954	9
Ticketing system (Fare Collection)	0.411	0.851	2	0.624	0.823	1
Ease of Entry and Exit	0.667	0.924	14	0.513	1.155	17
Sitting Arrangement	0.187	0.912	13	0.238	1.000	12
Movement Flexibility	0.457	0.868	7	0.260	0.930	8
Quality of Driver	0.542	0.842	1	0.467	0.875	3
Speed of Paratransit	0.245	0.928	15	0.641	1.180	18
Availability	0.044	0.904	12	0.361	1.086	16
Travel Time (Office Days)	0.694	0.981	20	0.111	1.266	21
Travel Time (Holidays)	0.238	0.999	21	0.283	1.387	22
Integration of Supporting Modes	0.406	0.871	8	0.368	1.069	15
Security of goods	0.622	0.899	11	0.610	0.916	7
Security of passengers	0.622	0.852	3	0.620	0.845	2
Riding Safety	0.357	0.857	5	0.468	0.896	6
Travel Cost	0.086	0.859	6	0.518	0.885	4
Service Features	0.058	0.941	16	0.327	1.021	14
Performance for Long Route Movement	0.169	0.856	4	0.479	0.895	5
Movement Flexibility in any Road	0.481	0.993	19	0.442	0.993	11

Fare collection system was found to be the most concerning fact to the users while deciding whether a service was satisfactory or not. Currently, because of the short travel time, service providers prefer to deal with cash money rather than any paper based ticket systems. This gives the service providers a scope to increase or change the fare rate to any route at any time. Also, some paratransit routes do not have fixed stations/stoppage points, and therefore, passengers sometimes feel overcharged as they decide to stop at any location before the regular stoppage point. From the users' perception rating, this attribute was also identified as a concerning issue for improving paratransit SQ. It means, model shown similar prediction with the respondents' rating.

Driver quality was found to be the next most important attribute. It is understandable as a good portion of the paratransit drivers (especially legunas) are very young and they are often found to drive in an immature way on the busy roads. This driving attitude makes the passenger feel unsafe and therefore has significant impact on user stated service quality.

The third most important attribute was found to be the 'Security of passengers', which implies the security inside the vehicle. A significant portion of the users are female (35%) and therefore security is a major concern for the user group as a whole while using different paratransit modes.

'Performance for Long Route Movement' was another significant attribute. As sometimes paratransit covers a long route travelling so this service needs to be smoother and well performed. Whereas the scenario is totally different and the long route performance of paratransit is not comfortable to the users. That's why, it has also major impact on user stated SQ.

There is no specific riding safety features available in paratransit service in Dhaka city. Therefore, 'Riding Safety' was found one of the most concerning attributes.

It is seen that decreasing 'Travel Time' (both during office days and holidays) increases 'Travel Cost'. This signifies vehicles that need lower trip time charge higher fares. From the models, 'Travel Cost' was obtained one of the important attributes to the users.

'Movement Flexibility' was also other significant SQ attribute of paratransit that has a great impact on SQ. All these results match with the real scenario quite remarkably.

5.4 Conclusion

The current chapter focused on the development and evaluation of empirical models (PNN and ANFIS) for predicting the SQ of paratransit service in Dhaka city. For this, at first the models were systematically developed based on the paratransit data collected earlier. From the analysis, the performance of these models were checked and compared through RMSE and coefficient of correlation values. Based on the performance of the two models, it was concluded that PNN shows the best fit with the measured paratransit data and it outperforms the ANFIS model. Next, based on the models analysis, some most suitable attributes was found that have significant impact on SQ of paratransit such as Fare collection system, Driver quality, Security of passengers' etc. And improving these attributes will help transit operators to attract more people for using paratransit service.

Chapter 6
CONCLUSIONS & RECOMMENDATIONS

6.1 General

This research work was conducted to understand users' perception on paratransit service quality (SQ). In this context, a stated preference survey on paratransit users of different routes in Dhaka city was conducted. With the collected data, two empirical models were developed, which can be utilized to assess or predict paratransit SQ based on several attributes related to this mode. The study also identified significant attributes that greatly affects the paratransit SQ. The major findings of this study and future recommendations are summarized in the following sections.

6.2 Research Summary

Paratransit has become a vital mobility option in many developing countries, filling in gaps left unserved by public transit systems and providing efficient feeder connections. Paratransit offers several advantages compared to other public transport modes, such as high accessibility and mobility, more beneficial operating cost for short trips, easy and unimpeded lane movement and relatively low maintenance costs. Paratransit supply is the best in meeting the transport requirements of the low income people in terms of fares and flexibility. Although a lot of people in Dhaka city are traveling everyday by this mode, but the service is not advanced according to their expectations. Specifically, most of these vehicles are indigenously manufactured to fit the market needs; as such, they have various forms and are ill-equipped and non-standardized. Due to some lack of this service, it sometimes causes accident in the roads. Therefore, the number of passengers a paratransit is able to attract and retain is the measure of success of this system. To this end, SQ is a very important feature of this particular public transportation mode. However, it depends on a series of features relating to the mode.

As the customers are the sole judges of SQ, appropriate perceptions of the users about the service on a regular basis are vital to establish efficient transportation strategies. Measuring from the customer's perspective, transit quality depends on the passengers' perceptions about each attribute characterizing the service. Therefore, the first objective of the study aims to explore the users' perception regarding the paratransit SQ. To achieve the study objectives, thirty five (35) skilled enumerators carried out face-to-face interviews at main paratransit stops around Dhaka city throughout the month of June and July, 2015. A total fifteen (15) routes of paratransit were surveyed to carry out the assessment. The subjective assessment was made using a rating scale of excellent, good, satisfactory, poor, very poor. In this regard, the respondents were asked to give their rating on the quality of service of paratransit in Dhaka City.

After collecting the data, the sample size set forth in this research was 2008. There were two sections in the survey questionnaire. The first section was aimed to get personal and socioeconomic information (age, gender, occupation) of commuters and the reason for using paratransit mode. Out of 2008 respondents, 83% were male and 17% were female. In case of income (in Bangladeshi taka or BDT) distribution, 5 percent of the respondents income was less than 5000, 7 percent was in between 5000 to 10000, 12% was in between 10000 to 15000 , 20 percent was in between 15000 to 20000, 18.0% was more than 50000 and about 38% respondents have no specific income. The ages of the respondents were between 16 to more than 59 years. To be particular, 10%, 39%, 32%, 14%, 5% and 1% of the respondents fall in the category of 16 to 19 years, 20 to 29 years, 30 to 39 years, 40 to 49 years, 50 to 59 years and more than 59 years of age, respectively. Among various options, respondents were asked to tick the most tracking reason behind picking paratransit as their mode of travel. 50% of the respondents described necessity as their motivation to use paratransit.

The second section of the stated preference survey was focused on twenty three (23) questions regarding paratransit SQ (twenty-two SQ attributes and a question about overall paratransit SQ) to know the actual conditions of this mode in Dhaka City. It was found that major portion (42%) of the respondents rating overall quality of paratransit service 'satisfactory' while 30% users' think that existing condition is good and 22% opined that it is in poor condition. Based on users' perception and the stated ratings (22 paratransit SQ attributes), it was found that majority of the user opined that the following factors are the advantages of using paratransit service: (i) Cleanliness of the vehicle; (ii) Speed of the vehicle; (iii) Availability of vehicle; (iv) Travel time (Holidays); (v) Integration with supporting modes; (vi) Security of goods; (vii) Travel cost and (viii) Service feature. However, there were some following factors identified by the user, which are the main limitations of paratransit: (i) Meager seat comfort level of paratransit; (ii) Substandard fitness of the vehicle; (iii) Dissatisfactory noise level of the service; (iv) Insufficient lighting facilities; (v) Inconvenient ticketing system (fare collection) to the users; (vi) Unskilled paratransit drivers; (vii) Risky entry-exit system; (viii) Congested sitting arrangements for passengers; (ix) Inadequate movement flexibility in the vehicle; (x) High travel time during office day; (xi) Not enough security of the passenger during off-peak period; (xii) Poor riding safety; (xiii) Ordinary performance of long route movement; (xiv) Low graded movement flexibility of vehicles in any road.

The authority should improve consider these limitations to improve the ridership of the paratransit users. At present, transportation researchers and practitioners are highly concerned about solving operating problems, adapting appropriate new technologies and introducing innovations into the transit systems. Modeling of the complex information in this regard from collective data sets have become very much popular. As the prediction of SQ based on users' perception is a non-linear process, Artificial Intelligence (AI) is a dependable tool to model such process. Particularly, the study implemented two AI models, namely, (i) Probabilistic Neural Network (PNN); and (ii) Adaptive Neuro Fuzzy Inference System

(ANFIS) to predict the overall paratransit SQ based on 22 attributes. The PNN, is used primarily because of its one-pass fast learning algorithm when dealing with large data sets; whereas, ANFIS is a computationally efficient, well-adaptable with optimization and adaptive technique.

In modeling with PNN, the training algorithm used was radbas (RB) as PNN is a special design of the Radial Basis Function (RBF) for dichotomous outputs. Moreover, the PNN classification framework follows the same principles as the RBF that is transforms the data nonlinearly into a high-dimensional hidden space. 80% (1606) and 20% (402) of the entire sample set were used as training and testing sample for modeling PNN, respectively. Again, the inputs of it were normalized to the range [0 1]. The normalization is carried out by subtracting the vector minimum from the vector and dividing it by its range (i.e. the difference between the vectors' maximum and minimum). This normalization is essential for the accurate performance of it as the input variables are combined in the network via a distance kernel function. In modelling, training data and testing data must be in a similar range due to overcome the similar relative changes in the results. As PNN has one free parameter (smoothing parameter/spread) to estimate, so the default smoothing parameter was used here to model the PNN for predicting paratransit SQ.

By contrast, in ANFIS, the input membership functions type was set as Gaussian, while constants were used for the rule outputs (a zeroth-order Sugeno model). The Gradient descent algorithm particularly known as back-propagation algorithm was selected as the learning algorithm. Tansigmoid was used as a transfer function in hidden layer. Data sets used in this model as same as described in PNN model. The parameters for training options have been selected; 10 epochs were used to stop the training process and the training goal (step size) was 0.01.

From the analysis of these two models, a comparison was made based on the confusion matrix, coefficient of correlation (R) and root mean square error (RMSE) values to find a network that shows best fit for paratransit SQ prediction. It was found that PNN and ANFIS show 78.7% and 67.2% matches with the collected SQ data. Besides, the R value of PNN and ANFIS prediction were 0.702 and 0.442, respectively. Whereas, the RMSE values for those models were 0.745 and 0.929, respectively. It was seen that R value of PNN model is greater than ANFIS model. Whereas, RMSE value of PNN model was smaller than ANFIS model. Therefore, it can be concluded that PNN outperforms ANFIS in SQ prediction. This could be due to the fact that PNN executes neural network algorithm, which is well classifier, faster and accurate in predicting heterogeneous data than any other models.

Moreover, using the above models, an evaluation of paratransit SQ attributes according to their importance was conducted. The most prominent attributes were ranked from 1 to 22 based on the coefficient of correlation (R) and root mean square error (RMSE) values. According to the ranking, 'Fare collection' system was found to be the most concerning factor to the users as both models showed lowest RMSE than other attributes (PNN: 0.842, ANFIS: 0.875). Driver quality was found to be the next most important attribute because of their RMSE values (PNN: 0.851, ANFIS: 0.823). The third most important attribute was found to be the ‘Security of passengers’ and the RMSE values are 0.852 for PNN and 0.845 for ANFIS. Based on the models, ‘Performance for Long Route Movement’, ‘Riding Safety’, ‘Travel Cost’, and ‘Movement Flexibility’ were found some of the other significant paratransit SQ attributes.

6.3 Conclusions

From the analysis of my thesis, following conclusions can be summarized into 6 parts. These are:

- In this study, based on the users’ perception and the stated ratings, the overall paratransit service quality (SQ) was evaluated and it was found satisfactory.

- Study revealed the advantages of using paratransit identified by the users are: availability of paratransit, speed of the vehicle, integration with supporting modes, travel time etc.

- A list of limitations was found in this research considering users’ stated ratings, which has major impact on paratransit SQ: seat comfort level of paratransit, ease of entry-exit system, sitting arrangements, movement flexibility, security of the passenger, riding safety, performance of long route movement etc.

- In this study, two models (PNN and ANFIS) were developed involving all the 22 SQ attributes. Study revealed that PNN exhibited superior prediction (78.7%) than ANFIS (67.2%), which implies PNN outperformed ANFIS in SQ prediction capability.

- Based on stepwise approach (using R and RMSE values of developed models), study ranked the three key attributes that significantly affecting the paratransit SQ: ‘Fare collection’ system, ‘Driver quality’, and ‘Security of passengers’.

- The study findings can help the paratransit service providers and the public transport authority to identify and improve the quality of significant attributes, and thereby, increase paratransit ridership.

6.4 Recommendations

Paratransit is a vital mobility option in Dhaka city as an alternative of public transportation. It is contributing a striking percent of traffic flow while being able to transport more than 50 percent of passenger trips. Due to the meteoric increase in population, the existing paratransit service is incapacitating to meet the increasing travel demand. To this end, a clear perception about understanding and improving the overall paratransit SQ is provided in this study. Specifically, it relates users’ expectation on the overall paratransit SQ. The results of this study will carry some vital information to the service providers, operators, policy makers and transportation officials about how to improve the paratransit SQ. With the inadequate resources, developing countries like Bangladesh will find it difficult to invest in improving all of the significant attributes' quality as were found from this study at once. This investigation provides guidance for a stepwise development which will start with the most important attribute.

Since, from this study, PNN model are found to be the best approaches in paratransit SQ estimation. Therefore, this approach can be applied to other cities of developing countries reliably. However, the model parameters need to be calibrated for that particular scenario.

6.5 Future Research

Although Users' perception on public transport specially paratransit 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 driver population, vehicle components and traffic environment. In this section some recommendations are provided for future research following the study carried out in this dissertation. These are listed below.

1. The data set used in this study represents the paratransit user group of Dhaka, the capital city of Bangladesh. Although the sample size is sufficient, however, a further research can be done with a larger data set which will more boldly represent the paratransit user of a city with over 15 million populations. Research 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 paratransit SQ.

2. Moreover, data was collected from fifteen (15) paratransit routes, whereas the available paratransit routes in Dhaka city are thirty two (32). Thus, a possible extension to this research approach would be to develop the models using the data collected from all available routes in this city.

3. PNN is proven to be very powerful when used for prediction and classification problems. Particularly, the accuracy of this model depends on smoothing parameter. Though the prediction accuracy of paratransit SQ was satisfactory in the study, therefore, higher accuracy could be achieved with the further tuned smoothing parameter through trial and error basis. Future research should be conducted utilizing proper background knowledge in the areas from choosing input pattern, optimizing the network structure and tuning the smoothing parameter to making the prediction more profitable.

4. The performance of the ANFIS is greatly influenced by various parameters such as: membership function, learning algorithm and so on. This study revealed that the accuracy of the model is not up to standard level. Therefore, to obtain better result further

researches may be carried out utilizing other membership function which can be triangular, trapezoidal, or other shapes. Again, an investigation of additional learning algorithm (resilient propagation, nonnegative least square etc.) may be used for improved performance of ANFIS.

5. Two models were checked for finding paratransit SQ. However, for superior results, other modeling techniques such as Structured Equation Modeling (SEM) and SERVQUAL method may be applied in predicting SQ of this service.

6. The prediction capabilities of PNN and ANFIS found in this research 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 PARATRANSIT SERVICE AT DHAKA CITY

Users Information

Age:
Occupation:
Income Range: 5000 tk-10000 tk / 10000 tk-15000 tk / 15000 tk-20000 tk / More than 20000 tk
Survey Location:
Users Most Used Route:

QUALITY OF TRANSPORT

A. What is your idea about the prevailing paratransit quality? (Put a tick mark)
(1) Excellent
(2) Good
(3) Satisfactory
(4) Poor
(5) Very Poor

B. How about seat comfort level:
(1) Excellent
(2) Good
(3) Satisfactory
(4) Poor
(5) Very Poor

C. Fitness of paratransit vehicles.
(1) Excellent
(2) Good
(3) Satisfactory
(4) Poor
(5) Very Poor

D. Noise level of the paratransit:
(1) Excellent
(2) Good
(3) Satisfactory
(4) Poor
(5) Very Poor

E. **Lighting facilities of paratransit:**

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

F. **Cleanliness of para transit:**

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

Do you have any other comments related to paratransit quality of transport? If "Yes" then put your comments.

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<u>SERVICE QUALITY</u>

G. **What do you think about the ticketing system?**

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

H. **Ease of entry-exit:**

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

I. **What is your comment about the sitting arrangement?**

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

J. **How is the movement flexibility?**
(1) Excellent
(2) Good
(3) Satisfactory
(4) Poor
(5) Very Poor

K. **Quality of driver:**
(1) Excellent
(2) Good
(3) Satisfactory
(4) Poor
(5) Very Poor

L. **What is your idea about the speed of paratransit?**
(1) Excellent
(2) Good
(3) Satisfactory
(4) Poor
(5) Very Poor

Do you have any other comments related to paratransit service quality? If "Yes" then put your comments.
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<u>RELIABILITY</u>

M. **Availability of paratransit:**
(1) Excellent
(2) Good
(3) Satisfactory
(4) Poor
(5) Very Poor

N. **Travel time (official days):**
(1) Excellent
(2) Good
(3) Satisfactory
(4) Poor
(5) Very Poor

O. Travel time (holidays):
(1) Excellent
(2) Good
(3) Satisfactory
(4) Poor
(5) Very Poor

P. Integration with supporting modes:
(1) Excellent
(2) Good
(3) Satisfactory
(4) Poor
(5) Very Poor

Do you have any other comments related to paratransit service reliability? If "Yes" then put your comments.
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SAFETY & SECURITY

Q. Security of goods inside paratransit:
(1) Excellent
(2) Good
(3) Satisfactory
(4) Poor
(5) Very Poor

R. Security of passengers during off peak period:
(1) Excellent
(2) Good
(3) Satisfactory
(4) Poor
(5) Very Poor

S. Riding safety of paratransit:
(1) Excellent
(2) Good
(3) Satisfactory
(4) Poor
(5) Very Poor

Do you have any other comments related to paratransit service safety & security? If "Yes" then put your comments.

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ECONOMY

T. What do you think about the travel cost comparing with other transport?

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

U. How is the service features comparing with other transport?

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

TRAFFIC MANAGEMENT

V. How is the performance for long route movement?

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

W. How is the movement flexibility in any road?

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

APPENDIX B

Related publications

Followings are the list of publications resulted from my M.Sc. Thesis.

Publication in International Journals

1. M R Islam, M Hadiuzzaman, R Banik, M M Hasnat, S R Musabbir & S Hossain (2016), "Bus service quality prediction and attribute ranking: a neural network approach". Public Transport, Volume 8, Issue 2, pp 295-313.

2. R Banik, I U Ahmed, M M Hasnat, M Hadiuzzaman, T Z Qiu, & F Rahman (2016), "Probabilistic Neural Network and Adaptive Neuro Fuzzy Inference System Based Paratransit Service Quality Predicting and Attribute Ranking", Accepted for presentation at the 96th Annual Meeting of Transportation Research Board.

3. M Hadiuzzaman, I U Ahmed, R Banik, F Rahman & M M Rahman (2016), "Modeling user perception of paratransit service quality based on artificial neural network approach", submitted for publication to Public Transport (PUTR).