Evaluating Comfort for Public Buses in Dhaka City

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APPROVAL

The dissertation entitled "***Evaluating Comfort for Public Buses in Dhaka City***", by Mobasshir Rashid, Safkat Tajwar Ahmed and Noman Bin Kalam has beenapproved fulfilling the requirements for the Bachelor of Science Degree in Civil Engineering.

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DECLARATION

We hereby declare that the undergraduate research work reported in this thesis has been performed by us under the supervision of Assistant Professor **Dr. Moinul Hossain** and we have taken reasonable care to ensure that this work has not been submitted elsewhere for any purpose.

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ABSTRACT

In this research, a combined approach was undertaken to evaluate the comfort for public buses in Dhaka city. Public buses are the most used transport in Dhaka city. Though several studies were done before on the public buses in Dhaka on safety, cost, timeliness etc.; no comprehensive study had been done regarding comfort. This study is thus a pioneering step toward comfort analysis.

In this dissertation both the measurement of physical parameters through mechanical approach and subjective parameters through questionnaire survey were conducted. It was found that speed, temperature, noise and jerking were the most significant physical parameters influencing comfort. These physical parameters were translated to subjective feelings with numerical values by using multiple linear regression analysis. A comfort model for public bus was thus developed by correlating the subjective opinions of passengers to the objective physical parameters.

This research leads to a prime finding, where public buses in Dhaka are ‘slightly uncomfortable’ or ‘uncomfortable’. It also signifies the impact of temperature and jerking on the overall comfort feeling in public buses. A more in-depth analysis of the major routes of Dhaka city can be done for future researches to develop a more convenient model of comfortbased on this study. A comprehensive comfort model would aid at national level traffic comfort improvement through better design of public vehicles and traffic routes, which could help improve the overall bus service quality.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS

ADC Analog to Digital Converter
ADRAutomotive Dead Reckoning
BBS Bangladesh Bureau of Statistics
BMIBody Mass Index
BRTBus Rapid Transit
BRTA Bangladesh Road Transport Authority
CC Cubic Centimeter
CMS Comfort Measuring System
CNG Compressed Natural Gas
DCC Dhaka City Corporation
GPS Global Positioning System
ICSP In-Circuit Serial Programming
IRI International Roughness Index
JATD Jerk-Acceleration Threshold Detection
MEMSMicro-Electro-Mechanical Systems
MLR Multiple Linear Regression
PM Prime Minister
PMV Predicted Mean Vote
PPDPredicted Percentage of Dissatisfied
PWM Pulse Width Modulation
RH Relative Humidity
RHD Roads and Highways Department
RMMS Road Maintenance Management System
RMS Root Mean Square
SDSecure Digital
SPI Serial Peripheral Interface
SPL Sound Pressure Level
STP Strategic Transport Plan
TCThermal Comfort
TSThermal Sensation
UART Universal Asynchronous Receiver/Transmitter
USBUniversal Serial Bus
VDV Vibration Dose Value

NOTATIONS AND DEFINITION OF THE VARIABLES

T	Temperature
v	Speed
J’	Jerking
SPL	Sound Pressure Level
RH	Relative Humidity
L_{aeq}	A-weighted sound pressure level
Z_x	Vibration
J	Acceleration
ε	Error term
$\chi 2$	Chi-square test
H_0	Null Hypothesis
H_1	Alternative Hypothesis
e	Residual

Chapter 1

INTRODUCTION

1.1 Introduction

Dhaka is the capital of Bangladesh having a population of over 18 million as of 2016. With a density of 23,234 people per square kilometer, Dhaka is one the most densely populated city in the world (*World Population Review, 2017*).

Now-a-days, traffic is the most acute problem of Dhaka. Dhaka has nearly 3000km of road network, consisting of 200 km primary. Also, there are 110 km secondary,50 km feeder, 2640 km narrow roads and also few alternative connector roads (*Rabbani and Mahmud, 2012*).

The city is experiencing massive traffic congestion with the continued economic growth and development. Currently, there are approximately500,000 rickshaws, 964500 registered motor vehicles and another 400,000 unregistered motor vehicles operating on the roads of Dhaka (*RHD, 2013*).

With the increasing number of vehicles all over the city, the quality of travel is deteriorating rapidly. The comfort level along with the safety, timeliness, cost condition is going below at an alarming rate.

Given the present transportation situation in Dhaka city, it is a matter of great importance to define and analyze the comfort for different modes of transportations in Dhaka city and implement it thoroughly where it is needed.

Table 1.1: Number of Registered Buses in Dhaka (Year wise)

Sl.	Type of Vehicles	Upto-2010	2011	2012	2013	2014	2015	2016	Total
1	Bus	16783	1501	1218	971	1364	2221	2698	26756
2	Mini-Bus	9490	136	103	83	135	103	115	10165
	Total	26273	1637	1321	1054	1499	2324	2813	36921

(Data Source: BRTA, 2016)

1.2 Background

To ensure the development of a country's economy; it is important to maintain the quality of transportation system. A good transportation system can accelerate the economic growth and development of the society.

Quality of Travel depends on some factors such as- Speed, Travel time, Reliability, Cost, Safety, Accessibility, Staff behavior, Comfort etc. *(Kumar et al.,2004), (Castellanos and Fruett, 2014), (Lin et al.,2011)*.

Previously studies were mostly done on speed, travel time, reliability rather than comfort. For instance, Tim Lomax has measured Driver Variation, Road Segment Variation and Time of Day Variation for determining 'Reliability' of travel*(Lomax et al., 2003).*

Waiting Time at bus stops, Boarding Time, Time Consumed in Jam etc. variables were measured by Francesco D. d'OVIDIO for Timeliness *(D'Ovidioet al., 2014)*.

Tim Gates, Steven Schrock, and James Bonneson put forward a new method for measuring Speed for travel quality assessment which measures Fluctuation of Speed, Acceleration or deceleration*(Gates et al., 2004).*

Even though a lot of researches have been done based on Speed, Travel time, Reliability, Cost and Safety, very few studies has been done regarding "COMFORT". Passenger comfort and convenience were not considered priorities.

However, recently people all over the world has become more sensitive. Now-a-days, Travel comfort is a crucial factor in the mode choice of passengers. Therefore, comfort studies are becoming more popular day by day.

Comfort is a state of physical well-being and psychological satisfaction. In other words, it's the state of physical ease and freedom from pain or constraint. Comfort in transportation is essential as the transportation mode choice depends largely on it. As a result, the assessment and prediction of traffic comfort is of prime importance.

In developed countries, a good number of comfort studies have been undertaken following either Subjective or Mechanical approaches. Furthermore, some studies were done combining both the methods. The research of Ka Wing Shek and Wai Tin Chan in Hong Kong is an example of this where they used questionnaire survey and measured the physical parameters at the same time*(Shek and Chan, 2008).*

In developing countries, mechanical approach for comfort estimation is rather rare. Most of the cases, subjective methods such as questionnaire surveys are used*(Githui et al., 2009).*

1.3 Problem Statement

In recent years, a common scenery of Dhaka is the superfluous number of over-crowded and low fitness public buses roaming the streets and highways. To alleviate the situation, comfort studies should be given high priorities. Nevertheless, very few studies have been done regarding traffic comfort in Dhaka.

There are many problems that our study has addressed. The first problem is that for the dwellers of Dhaka city, traffic comfort has still not been defined. The definition of comfort can be very different from the perspectives of different persons. For example, a warm temperature may seem comfortable to a certain person while some other may find comfort in a cold weather. So, comfort must be defined to fit the varying perspectives.

Despite the detrimental quality of traffic, no comprehensive study has been conducted in Dhaka to measure comfort. Previous researches have touched on the crowded natureof buses in developing countries, but a comprehensive study for measuring comfort in public transportations is lacking.

In addition to the aforementioned, the mechanical approach is rather a new one in the context of Dhaka city. Earlier, Questionnaire Design and Pretesting with 7-point scales was done in a study *(Andaleeb et al., 2007)*, but integration of subjective and mechanical data is totally a new approach.

Even in the developed countries where mechanical approach has been adopted, using Arduino Micro-controllers for the measurement of comfort variables is rather rare. For instance, GPS and 3- axis accelerometer function of modern smartphones to measure comfort was proposed by Cheng-Yu Lin*(Lin et al., 2011).*

1.4 Purpose and Objectives

For the purpose of alleviation from the current situation and to solve the existing comfort related problems, it is of great importance to measure traffic comfort in a comprehensive method. As buses are the most used and significant public transportation of Dhaka city, special attention is to be given to public bus comfort. This thesis study contributes to develop a mechanical approach to measure various components of comfort in the public buses.

The specific objectives of this research are given below:

1. To measure Comfort data of public buses in Dhaka city.
2. To develop a Mechanical Approach to measure various components of Comfort such as Speed, Temperature, Jerking, Sound Pressure Level etc.
3. To evaluate different dimensions of comfort.
4. To determine the relationship between the different components of traffic comfort.
5. Establish a Comfort Estimation model in order to estimate comfort values by using Multiple Linear Regression.
6. To identify the dominating factors that influence the overall bus comfort.
7. To define how comfortable are the public buses in Dhaka by using a five-point scale.

1.5 Study Area and Scope of the Study

The study area selected for our study is from Mohakhali to Abdullahpur. Along this route, other important areas like Banani, Uttara, Khilkhet, Airport etc. is covered.

There are several reasons behind this selection.

First of all, a huge number of public bus service run along this route.

Secondly, all most all types of public buses can be found in these areas such as

- Local Buses
- Sitting Service Buses
- Gate-lock Buses
- Single Decker and Double Decker Buses
- Air Conditioned and Non-Air-Conditioned Buses
- Long Route Buses and Short Route Buses

Another reason for selecting this area is that people from diverse backgrounds use this route. This is important because the definition of comfort varies person to person which was mentioned earlier.

So, the scope of the study was well predefined. The study was done by travelling in all types of bus that are mentioned above. The opinion of passengers from various age, professions, mentalities and classes of the society was taken as feedback. The journeys were made during both day and night.

1.6 Organization of the Thesis

The thesis is organized into five chapters and each chapter consists of several sub-chapters. These chapters were divided based on the various activities that were done during this study. The sequence of the chapters is commensurate with the sequence in which the activities were performed.

Chapter 1: Introduction

This Chapter contains the main idea of this thesis. It is divided into six sub-chapters which are as follows:

1.1 Introduction

1.2 Background

1.3 Problem Statement

1.4 Purpose and Objectives

1.5 Study Area and Scope of the Study

1.6 Organization of the Thesis

Chapter 2: Literature Review

This chapter is the written overview of major writings and other sources on the selected topic. The sub-chapters are-

2.1 Introduction

2.2 Transportation System in Dhaka

2.3 Public Transportation in Dhaka

2.4 Importance of Comfort in Transportation

2.5 Measuring Comfort in Transportation Engineering

Chapter 3: Methodology

Methodology is a key part of this dissertation. It describes the broad philosophical underpinning to the chosen research method. It has following sub-chapters –

3.1 Introduction

3.2 Identification of Variables

3.3 Equipment Development

3.4 Survey Design

3.5 Multiple Linear Regression

Chapter 4: Analysis and Results

This chapter deals with the statistical methods used to evaluate the comfort model and check the validation of the created model. The sub-chapters are-

4.1 Introduction

4.2 Descriptive Statistics of Data

4.3 Comfort Model

Chapter 5: Conclusion

This is the final chapter that contains the findings and future scope of the research. It's divided into four sub-chapters-

5.1 Introductions

5.2 Major Findings

5.3 Limitations

5.4 Future Scopes

Chapter 2

LITERATURE REVIEW

2.1 Introduction

Comfort studies are of prime concern in the recent years. Many research have been conducted to measure comfort in various methods. Many theories have been proposed to explain what influences passenger comfort and how comfort should be measured. Although the literatures cover a wide variety of such theories, this review will mainly focus on four major variables which emerge repeatedly throughout the literatures reviewed.

These four main variables are Temperature (T), Speed (v), Jerking (J') and Sound Pressure Level (SPL). Some other variables are Relative Humidity (RH), Angular Rotation etc. which were not used in the study.

Although the literatures present these variables in a variety of contexts, this paper will primarily focus on the methods of their measurement and their impacts on passenger comfort in public transportations.

2.2 Transportation System in Dhaka

Dhaka is one of the fast-growing metropolitan cities in the whole world. It has a highly dense and increasing population that puts immense pressure on the existing transportation system.

The transportation system of Dhaka is mainly road based. Nonetheless, the amount of road network is far below the minimum requirement. There is a significant deficiency in the amount of road network.

- The total space occupied by roads of Dhaka City is only 9% of its total space.
- The total space occupied by pavement is only 6%.

According to *RMMS (2004)*, length of Primary roads is 61.45 km, which is 4.78% of the total area of Dhaka. The length of Secondary roads is 108.20 km (8.41%). The length of Connectors, Local roads and Narrow roads are 221.35 km (17.21%), 573.25 km (44.61%) and 321.27 km (24.98%) respectively.

The Primary roads area is 1.89 sq. km (15.67%). Furthermore, the area of secondary roads is 2.41 sq. km (19.94%). In addition to these, the area of Connectors, Local roads and Narrow roads are 2.47 sq.km (20.42%), 4.25 sq.km (35.19%) and 1.06 sq. km (8.8%) respectively. Ultimately, the total road area is 9.01% of total area of Dhaka which is very much less than 25% *(RMMS, 2004).*

For sustainable and comfortable transportation system, at least 25% of total area should be roads and streets while for Dhaka, it’s only 9%.

There are some serious problems in the transportation system of Dhaka. Some of them are-

- High Quantity of Narrow Road –
  Almost 36% of the total roads are narrow roads in Dhaka city.

- Huge Number of Link Missing –
  There are several discontinuities in the entire road network which has happened due to absence of proper planning.

- Large number of Staggered Junctions –
  There are many unwarranted staggered T-junctions formed in the main road. In this type of junction, a vehicle is forced to make two successive right turn within a short segment of road and thereby make junction operation very complicated.

- Lack of Continuity of Main Road –
  Many of the main roads have ended at an inappropriate location.

- Unacceptable Road Side Development –
  Many legal and illegal markets, shopping malls etc. have been built near the roads that hampers traffic flow movement.

- Unacceptable Railway Level Crossings–
  There are about 18 rail crossings in whole Dhaka city. During the passage of trains, these crossings interrupt the traffic.

- Lack of Bus Lay on Road –
  Designated places for the stoppage and boarding of buses are very few in Dhaka. Most of the time, buses don’t care about stoppage places and stops at anywhere in the roadsides.

- Lack of Overpass & Underpasses –
  Compare to the demand, the number of overpasses and underpasses are very low in Dhaka.

- Poor Road Sign and Marking –
  The traffic rules cannot be enforced properly because of poor road signs and markings.

- Insufficient Parking Space –
  A huge amount of space is taken by Car parking in the roads because of insufficient parking space.

- Lack of Utility Service Space in Road Side –
  There is no separate road side space for utility service line. So, for laying pipes and cables, the relative departments cut the roads which hampers traffic flow.

- No Sufficient Drainage Facility –

Because of insufficient drainage facility, water logging in streets has become a common scenario *(Mahmud and Haque, 2008).*

The transportation system of Dhaka consists of several types of vehicles such as Private Cars, Large Buses, Mini Buses, Utility Vehicles, Trucks, CNG auto-rickshaws, Rickshaw, Motor Bikes, Micro Buses, Pick-up vans, Lagunas etc.

2.3 Public Transportation in Dhaka

In Dhaka, the number of people having own auto mobiles is still few. Only 33 persons per 1000 persons own private auto mobiles *(Katz and Rahman, 2016)*. That's why public transports are very popular in Dhaka.

The main characteristics of the public transportation system in Dhaka are traffic congestion and delays, inadequate traffic management, unaffordable and inaccessible public transport for majority of the people, high accident rates and increasing air pollution problems.

The main road-based public transport modes of Dhaka are Bus and Rail. Buses can be categorized in some sub categories such as Double decker, Single deck large bus, Minibus and Collective transport which comprises of staff bus, school/college/university bus etc.

Few para-transits are available in order to supplement the main public transportation modes. They are Tempo/maxi, Auto-rickshaw, Taxi and Rickshaw.

The most important mass transit mode in Dhaka City is bus. According to *STP 2004*, the share of motorized and non-motorized vehicles in Dhaka are 49% and 51% respectively. The most dominant mode of transport is Bus which represents almost 31% of total trips. Among the non-motorized modes, with 29% trips, Rickshaw is the most used mode.

From 2003 to 2007, the number of bus has increased by 135.5% *(BRTA, 2007).*

The percentage of mini buses in Dhaka is 41%. Large buses and auto tempo share 13% and 12% of transports respectively. Lastly, staff and school buses are 4% of the total public vehicles in Dhaka *(STP, 2004).*

The number of bus is increasing day by day, yet it’s not sufficient to provide the ever-growing population of the city.

In 1965, total number of buses were around 100. In 1970 and 1980, the number of buses increased to around 141 and 173 respectively. The number of buses has increased significantly after 2000. In 2006, the total number of buses became 5070. According to *BRTA (2016)*, the number has reached around 26000.

In order to meet the increasing demand of transport facilities and to solve the problems of current public transportation system, several projects have been planned. Metro Rail project has been taken to connect Uttara to Motijheel, which will carry 60,000 passengers per hour. In order to improve the bus service from Gazipur to Mohakhali, BRT project is undertaken. It is designed to carry 25,000 passengers per hour. Some other small-scale projects have also been taken. They are Color coded bus service, smart cards etc. Dhaka Elevated Expressway will connect the Airport and Chittagong Road. Moreover, Water transport and Ride sharing etc. is being planned for future (*Dhaka Tribune, 2017).*

Recently, UBER taxi service has been introduced in Dhaka City which has gained success in a short time.

2.4 Importance of Comfort in Transportation

Transportation-comfort is defined as the transportation of passengers in a manner that the trip will be a pleasure and not a hardship. Passenger comfort is an important factor that affects the quality of public transport services.

- Comfort is a crucial indicator of service quality.
- Comfort is an important factor in choice of traffic mode*(Eboli and Mazzula, 2011).*
- Comfort is the key factor that significantly influences passenger satisfaction *(Eboli and Mazzula, 2007).*
- It influences the cost-benefit judgement of transport users with regard to mode selection.
- Comfort in the transportation improves public transportation perception and even attract some new passengers.

- Main reasons why people don’t use public transit in spite of having a good accessibility is due to inconvenience and discomfort.

2.5 Measuring Comfort in Transportation Engineering

Considering the facts mentioned above in chapter 2.4, it can be said that comfort is one of the crucial factors that influence travel quality. Therefore, comfort studies are becoming popular day by day. There are two aspects of comfort studies - One is measuring comfort by Qualitative approach and the other is by Mechanical approach.

2.5.1 Mechanical Approach

Kai Zhang, Kan Zhou and Fangzhou Zhang have developed a combined comfort model using some environmental parameters like noise, vibration, thermal comfort and the acceleration. They used USB5935 machine to measure noise(L_{aeq}), thermal comfort(PPD), vibration(Z_x) and acceleration(J) during 241 bus journeys. Then they used multiple linear regression to predict the comfort value. The problems they faced were that the samples they gathered were somewhat changeable by season and area. Air quality was another problem as it was not assessed in the study (*Zhang et al., 2014).*

Optimal thermal comfort during a cool day was measured by Velt and Daanen. They used an iButton with humidity sensor (DS1923, Maxim Integrated Products Inc. Sunnyvale, CA, USA) to measure the bus temperature and used Volt-craft IR-230 infrared thermometer to measure the hand and face temperatures of passengers. They also developed a relationship between Body Mass Index (BMI), Thermal Sensation (TS) and Thermal Comfort (TC). The problem that they faced was not every passenger could provide their respective height, weight and clothing insulation information (*Velt and Daanen, 2017*).

*Alahmer et al. (2012)*evaluated thermal sensation and thermal comfort using a Thermal Manikin in different vehicle environments. In this regard, they used Fanger's PMV and PDD. They concluded that thermal comfort is affected heavily by relative humidity. They found that the comfort zone could be reached faster if the relative humidity was controlled.

*Pala and Oz (2015)*installed a bus in a climatic chamber at 20 degrees Celsius and performed a warm up experiment from-20^{0}C to 20^{0}C in 90 min and built a model based on it.

Shek and Chan (2008) measured three thermal parameters which are air temperature, relative humidity and air velocity and three air parameters which are carbon monoxide, carbon dioxide and respirable suspended particulates for measuring thermal comfort and air quality in public transportbuses in Hong Kong.They also conducted questionnaire survey on bus passengers and usedcorrelation analyses to make a combined comfort model. The limitation was the question of clothing insulation was notincluded in the questionnaire because it might take a long time for completing the survey.

Siebert et al. (2017) used fixed base driving simulator to measure the vehicle to vehicle distance thresholds for self-reported subjective risk and comfort was researched. Ascending and descending time headway sequences were given to the participants. They concluded that time headway thresholds do not significantly differ for different speeds.

*Castellanos and Fruett (2013)*used the ESCM sensor node, which contains a 32-bit microcontroller, a GPS module, a digital tri-axial MEMS accelerometer, a temperature sensor, awireless communication module to 900 MHz and finally a socket for a Secure Digital (SD) memory. They measured jerking by JATD method.

A new Comfort Measuring System (CMS) was adopted *by Lin et al. (2011)* for public transportations. CMS consists of the GPS, 3-axis accelerometer functions of modern smart phones and VProbe tool.

*Cantisani and Loprencipe (2010)*constructed a mechanical calibrated model to represent the dynamics of a real vehicle on an uneven surface. They found correlations between subjective perception of ride quality and the international roughness index IRI at various speeds.

*Eboli et al. (2016)*stated that kinematic parameters can be considered as significantly affecting passenger comfort. They used A specific smart phone app named Torque that recorded the acceleration (longitudinal, lateral and vertical accelerations) and speed values by adopting a frequency of 1 hertz, together with the instantaneous bus position (latitude and longitude).

2.5.2 Qualitative Approach

*Wahlberg (2006)*undertook a field study to determine whether bus passenger comfort is influenced by driving style. Data was gathered by passengerquestionnaire survey on the city buses. The questionnaire contained five-step scales questions on how jerky, uncomfortable, noisy and dangerous the bus ride was.

In the research of *Prashanth et al. (2013)*, the passengers' subjective opinion was obtained to quantify the difficulty in reading a national newspaper on a running bus to evaluate vibration comfort. The questionnaire was used for self-rating of the performance and feeling from disturbances from noise, vibration, jerks etc. in the buses. The questions were formulated using both preference and magnitude scaling techniques in order to obtain qualitative and quantitative information. The correlation between IRI and kurtosis and the Vibration Dose Value (VDV) was calculated at the same time.

The data was collected via telephone survey by *Fellesson and Friman(2008)*. The participants were asked about various aspects of citizen satisfaction with public transportation. They collected data from 1,000 respondents in each city. The local survey institutes performed the job of translating the questionnaire into the local language. Following scales were used for rating: (1) don't agree at all, (2) hardly agree,(3) neutral, (4) partially agree and (5) fully agree.

*Dell'Olio et al. (2011)*conducted surveys both on the buses and atthe bus stops. A focus group was used to deducethe most significant variables for the users of public transport before beginning the survey. The users were categorized according to age, sex, incomelevel or the frequency they used public transport. Information about variables of desired quality: waiting time,journey time, vehicle occupancy, level of cleanliness, driver kindness and comfort was obtained.

*Eboli and Mazzulla (2007)*conducted a survey on 763 students of University of Calabria. Respondents were asked to provide information about their socioeconomic characteristics and bus service quality. They were asked about 16 service attributes and rated on a scale from 1 to 10.

Chapter 3

METHODOLOGY

3.1Introduction

In this chapter, discussion about data collection and methodology adopted for the Comfort Evaluation has been introduced. The sources of data used for this study are described first and then the mathematical formulation of the selected statistical model is discussed. The methodology is followed by identifying variables, building equipment, collecting data and theoretical framework of construction of Comfort model by Multiple Linear Regression (MLR) respectively. The development of the model will assist us to understand how the model can be used to fulfill the objectives of the study; i.e. developing a mechanical approach to measure components of Comfort and evaluating comfort model for public buses in Dhaka city. The overall workflow diagram of the methodology is shown in the following figure:

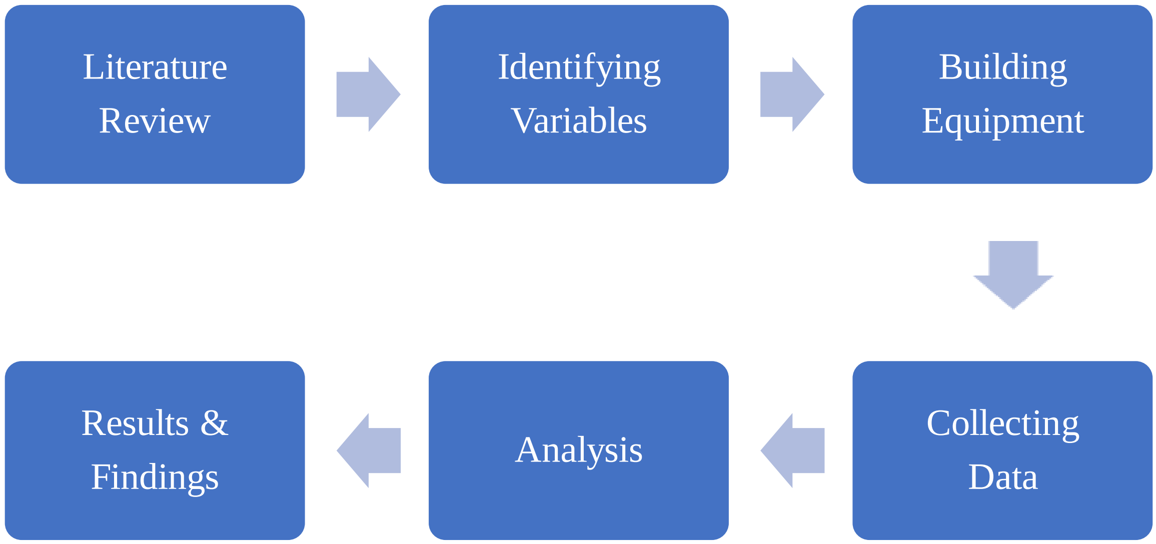

Figure 3.1: Work Flow Diagram

3.2Identification of Variables

A variable is a characteristic or feature that varies, or changes within a study. The opposite of variable is constant: something that doesn't change. There are two types of variables: "dependent" and "independent" variables. The "independent" variables can be manipulated and its effect on the dependent variables can be measured. On the other hand, the "dependent" variable is the outcomeof an experiment. Hence, we are evaluating Comfort model for buses, our dependent variable is comfort. Furthermore, the identification of the independent variables is discussed below:

3.2.1 Temperature (T)

Temperature is the key independent variable that manipulate traffic comfort. Temperature can be experienced; either hot or cold; in different ways. The main distinction is made between thermal sensation (TS) and thermal comfort (TC). TS is the measurement of how hot or how cold a person feels. TC is the condition of the mind that expresses satisfaction with the thermal environment *(Velt and Daneen, 2017).*

3.2.2 Speed (v)

Bus riding smoothness is one of the key aspects regarding traffic comfort. According to *Seredynski et al. (2014)* by smooth ride we mean avoiding stop-and-go driving pattern, excessiveacceleration/breaking and idling at traffic lights. Smooth riding also reduces fuel consumption of bus. Incidentally all of these facts indicate that speed can also manipulate traffic comfort.

3.2.3 Jerking (J')

It has been found that both driving style and bus environment heavily influence the bus comfort *(Hensher et al., 2003).* Road pavement roughness is an expression of the surface irregularity and includes both localized and diffuse unevenness; it causes vibration phenomena on the user's whole body during motion of bus *(Cantisani and Loprencipe,2010).* Thus, jerking is also a key variable in measuring comfort. Traffic comfort is mainly manipulated by road roughness or jerking *(Cantisani & Loprencipe, 2010).*

Jerking is measured as a derivative of acceleration. From the machine, 3-axis acceleration data was obtained. Then the RMS (root mean square) value of these 3 values are obtained. Meanwhile, the frequency of data collection of our machine is 1 second; so we divide the difference of the RMS values by 1 second. Thus, jerking value was obtained for 1 second of each individual journey.

3.2.4 Sound Pressure Level (SPL)

Excessive sound in bus is always undesirable. It is found that the continuous exposure of people to road traffic noise leads to suffering from various kinds of discomfort thus reducing appreciably the number of their well-being elements.*(Ouis, 2002).* Therefore, SPL can also manipulate comfort evaluation.

We choose temperature, speed, jerking and sound pressure level, while air quality was not involved in our study. Because our Arduino micro-controller was not able to measure air quality properly.

3.3 Equipment development for measuring comfort

We have used Arduino; an open-source electronics platform based on easy-to-use hardware and software. It's a micro-controller which consists of several parts:

1. Arduino mega 2560
2. GPS sensor
3. GPS antenna
4. Accelerometer sensor
5. Bread Board
6. SD card slot

The detailed diagram of the prototype is shown below:

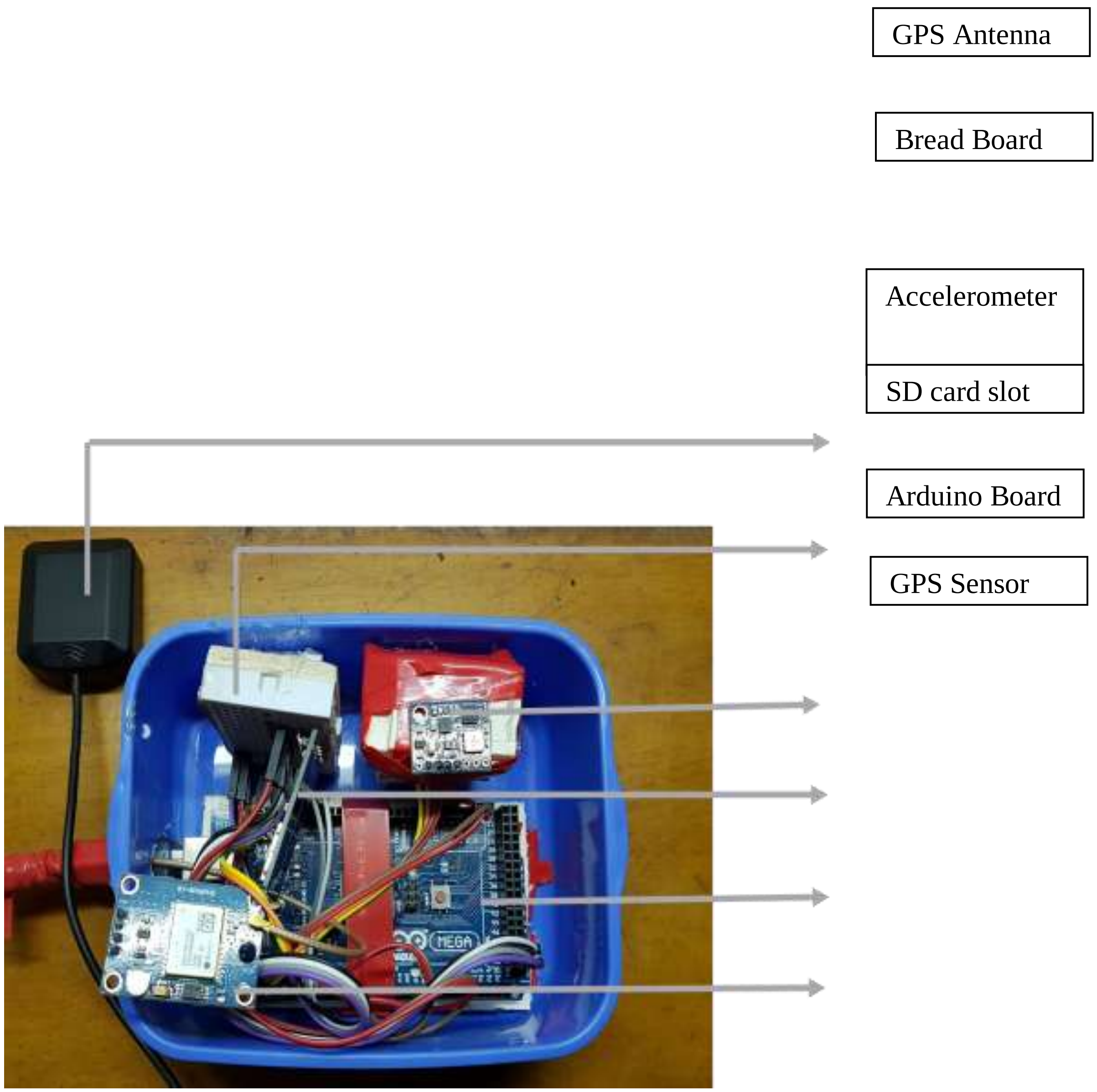

Figure 3.2: Detailed Diagram of the Prototype

3.3.1 Arduino Mega 2560

It is a microcontroller board based on the ATmega2560. It has 54 digital input/output pins (of which 15 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button.

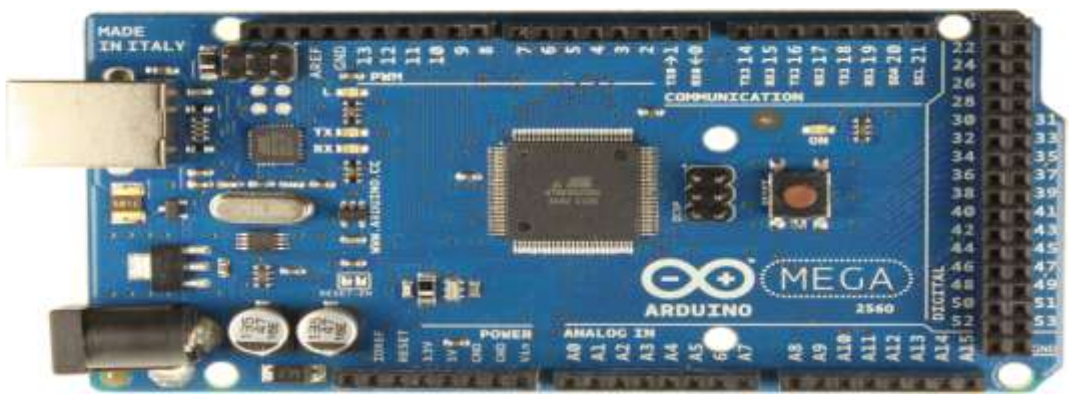

Figure 3.3: Arduino Mega 2560

3.3.2 U-blox Neo-6M GPS

U-blox' ADR solution combines GPS and sensor digital data using a tightly coupled Kalman filter. This improves position accuracy during periods of no or degraded GPS signal. The NEO-6M provides ADR functionality over its software sensor interface. A variety of sensors are supported, with the sensor data received via UBX messages from the application processor. Using this sensor, we can get the exact location with time and date of our bus and its speed at that specific time.

Figure 3.4: GPS Sensor

3.3.3 Gyroscope sensor MPU- 6050

This sensor gives us information about bus temperature and acceleration for each journey. From the acceleration value, total jerking is calculated in addition which will be discussed later. In addition, Gyro sensorsalso known as angular rate sensors or angular velocity sensors, are devices that sense angular velocity. Angular velocity is generally expressed in deg/s (degrees per second) consequently.

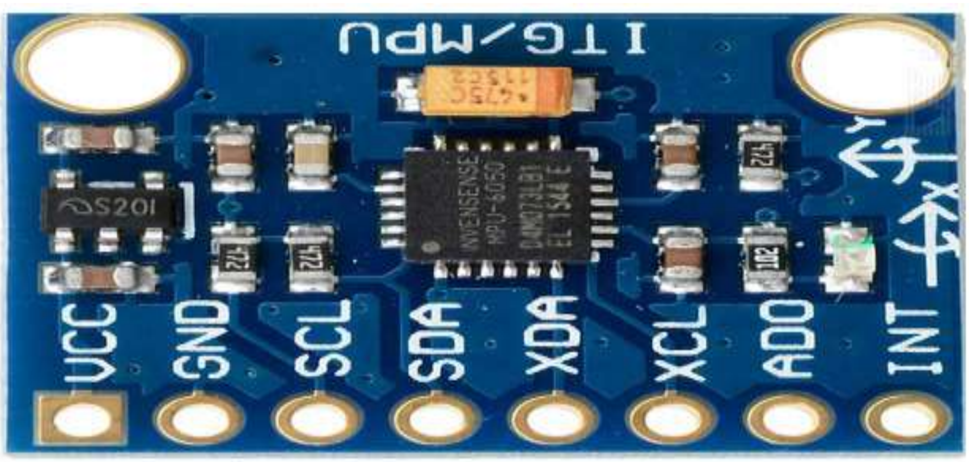

Figure 3.5: Accelerometer Sensor

3.3.4 Sparkfun Electret Breakout

This small breakout board couples an Electret microphone (100Hz–10kHz) with a 60x mic preamplifier to amplify the sounds. Each breakout comes fully assembled and works from 2.7V up to 5.5V.

The Electret Mic Breakout translates amplitude by capturing sound waves between two conducting plates in the microphone and converting them into electrical waves. These electrical signals are then amplified and picked up by your microcontroller's ADC.

Figure 3.6: Sound Pressure Sensor

3.3.5 SD card Slot

The communication between the microcontroller and the SD card uses SPI, which takes place on digital pins 11, 12, and 13 (on most Arduino boards) or 50, 51, and 52 (Arduino Mega). Additionally, another pin must be used to select the SD card. This can be the hardware SS pin - pin 10 (on most Arduino boards) or pin 53 (on the Mega) - or another pin specified in the call.

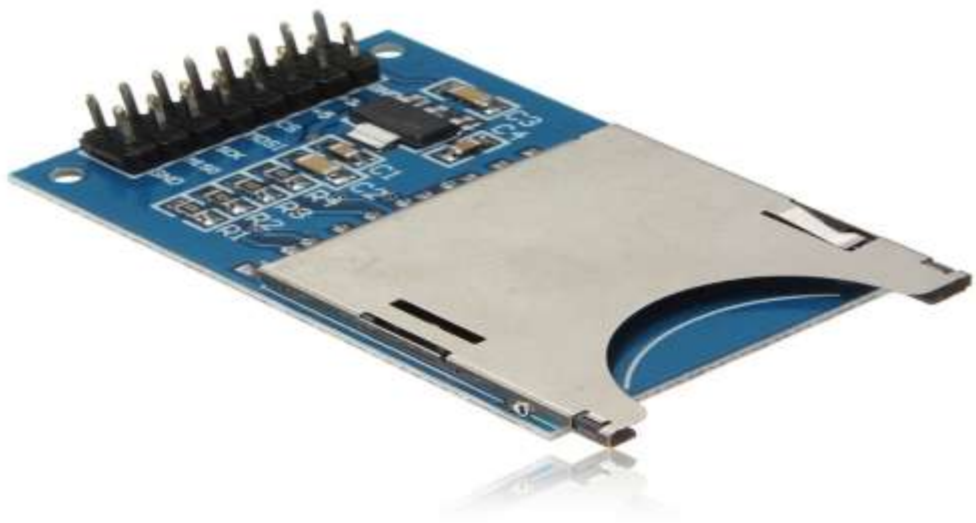

Figure 3.7: SD card slot

3.4 Survey Design

Most of the known attempts trying to assess passenger comfort have used a "questionnaire," or subjective approach. *(Hoberock,1977*). Meanwhile, the approach is mechanical approach, so main focus was given on the data collection from the machine. Only 1 question was included in the Questionnaire. The question is-

- "How comfortable was your overall journey?"

The passenger can give then answer from the following range:

Table 3.1: Comfort Value Range

Level of Comfort	**Comfort Values**
Very Comfortable	0
Comfortable	1
Slightly Uncomfortable	2
Uncomfortable	3
Extremely Uncomfortable	4

First some pilot survey was done in Tongi area before moving to Dhaka city. The pilot survey was done for 2 days and the students got some idea on data collection procedure. Then some corrections were done in the process.

3.5 Multiple Linear Regression

Multiple regression analysis is one of the most popular statistical estimation procedures (Hakim, 1984). Multiple linear regression is the most common form of linear regression analysis. It is a predictive analysis. MLR is used to explain the relationship between one continuous dependent variable and two or more independent variables. It establishes the relationship between two or more explanatory variables and a response variable by fitting a linear equation. Here, every value of the independent variable x is associated with a value of the dependent variable y.

MLR is given by

$$y = a + bx_1 + cx_2 + dx_3 + ex_4 + \varepsilon$$

Where,

y= overall comfort

x_1= speed

x_2 = temperature

x_3 = SPL

x_4 = jerking

a = intercept

ε = error term

b, c, d, e = regression coefficient

Total sample size was 45, It mainly consists of 45 individual journeys by bus and the data was collected by machine and stored in the SD card. This data will then be used in statistical analysis and to build the overall comfort model.

3.5.1 F test

F test is used to test the equality of mean of two populations. It is simply a ratio of variances of the two populations. It can also assess the equality of variances. So, it becomes a very flexible test by changing the variances that are included into the ratio. Our two hypotheses are-

Null HypothesisH_0: Overall comfort is independent of speed, temperature, SPL and jerking.

Alternative Hypothesis H_1: Overall comfort is dependent of speed, temperature, SPL and jerking.

3.5.2 Goodness of Fit test

It is based on chi-square distribution. It is used to compare the observed sample distribution with the expected probability distribution. It gives us an idea on how the observed value of a given comfort value is significantly different from the expected comfort value. It mainly compares the observed sample distribution with the expected probability distribution. The hypotheses are -

Null HypothesisH_0: There is no significant difference between the observed and the expected comfort value.

Alternative Hypothesis H_1: There is a significant difference between the observed and the expected comfort value.

3.5.3 Residual Plots

It a graph that shows the residuals on the vertical axis and the independent variable on the horizontal axis. When the points in a residual plot are randomly dispersed around the horizontal axis, we can say that linear regression model is appropriate for the data; otherwise, a non-linear model is more appropriate.

$$e = y - \hat{y}$$

where,

e = Residual

y = Observed comfort value

$\hat{y}$ = Predicted comfort value

3.5.4 Model Evaluation

The model will then be evaluated by Model verification test. From the 45 samples, two datasets will be created. One dataset contains 1st 22 samples, similarly; another dataset contains the rest of 23 samples.

From the 1st dataset; a multiple linear regression (MLR) model will be established. Then the values from the 2nd dataset will be put into the model and comfort values will be derived from the model. If all the statistical parameters are within acceptable limit then the model is valid. On the other hand; if all statistical parameters are not within acceptable range then the model will be established again by applying some corrections and validation will be checked again. Thus, a valid overall comfort model will be established.

Chapter 4

ANALYSIS & RESULTS

4.1 Introduction

In this chapter, discussion will be limited to describe comfort model with all independent variables that have significant effect on overall comfort of bus. A statistical model is a mathematical model, which stores a set of assumptions concerning the generation of some sample data, and similar data from a larger population.Furthermore, a statistical model can also give us an idea whether the collected data is satisfactory or not. In this study, overall bus has been taken as dependent variable. Then Bus speed, jerking, temperature and sound pressure level have been taken as independent variables. And therefore, a multiple linear regression model has been run for all the bus journeys to see the effect of included independent variables on the dependent variable. Furthermore, the model validation will be discussed in this chapter.

4.2 Descriptive Statistics of Data

For our model, 45 bus journeys are taken as sample data. Our study area is from Mohakhali to Abdullahpur. In this pathway we also considered Uttara, Airport, Badda, Gulshan etc. As our approach is mechanical approach, we collect our data with the help of Arduino micro- controller. The machine mainly collects the data of –

- ❖ GPS location
- ❖ Time and Date
- ❖ Speed
- ❖ Acceleration (in 3-axis)
- ❖ Temperature
- ❖ Sound Pressure Level

Table 4.1: Units of Variables

Variables	Unit
Speed	m/s
Acceleration	m/s^2

Temperature	Degree Celsius
Sound Pressure Level	dB

4.2.1 Sample Data

Total 45 bus journey data are recorded in the spreadsheet. The data were collected from the various sensors of micro-controller and retrieved from the micro SD card. The sample data are shown in appendix 3 and 4.

4.3 Comfort Model

4.3.1 Multiple Linear Regression Model for Comfort Estimation:

A regression model is used to check the inter- dependency between variables. Meanwhile, this comfort model will be established to check the dependency of overall comfort to other independent variables such as speed, temperature, sound pressure level and jerking etc. The significance level for the regression model is 5%.

Table 4.2: Regression Statistics

R Square	0.97
Adjusted R Square	0.96
Standard Error	0.05
Observations	45

From the table, it is found that Multiple R is 0.98 which means that the linear relationship is strong. The R-squared value is 97%, it means that all the variability of the overall comfort is around their mean value. The adjusted R Square value is also less than the R Square value. The standard error value is also very low which indicates that the predictions of the model are adequately accurate.

Table 4.3: ANOVA Test

	df	SS	MS	F	Significance F

Regression	4	3.66	0.91	293.24	0.000
Residual	40	0.12	0.01		
Total	44	3.79			

The F value is very higher which indicates the variance between means of two population are significantly different. The Significance F value is also very low.

Table 4.4: Regression Output

	Coefficients	Standard Error	T Stat	P- value
Intercept	-1.87	0.22	-8.18	0.000
Speed	-0.02	0.01	-22.53	0.000
Temperature	0.11	0.01	28.64	0.000
SPL	0.01	0.01	2.10	0.04
Jerking	0.15	0.02	6.98	0.000

The standard error value for each independent variable is also very low which indicates that the prediction of the model is adequately accurate. The T stat value is also larger than +2 or -2 which means that the coefficient is significant with 5% significance level.

<u>The regression model is:</u>

Overall Comfort = -1.87 - 0.02*(Speed) + 0.11*(Temperature) +0.01*(SPL) +0.15*(Jerking)

4.3.2 Line Fit Plot

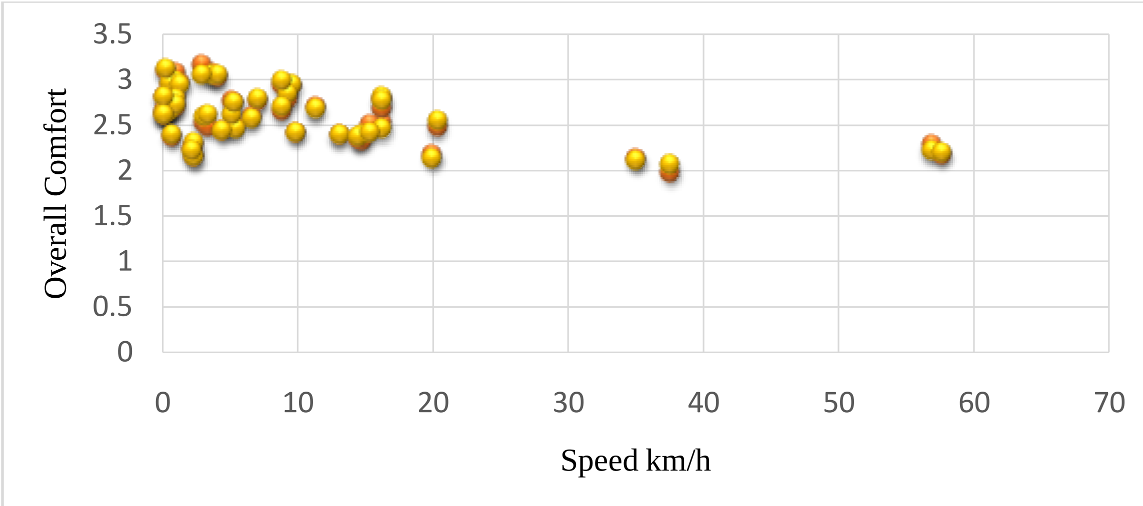

Figure 4.1: Speed Line Fit Plot

The overall comfort value lies between 2 and 3, that means the journey is slightly uncomfortable to uncomfortable with respect to Speed.

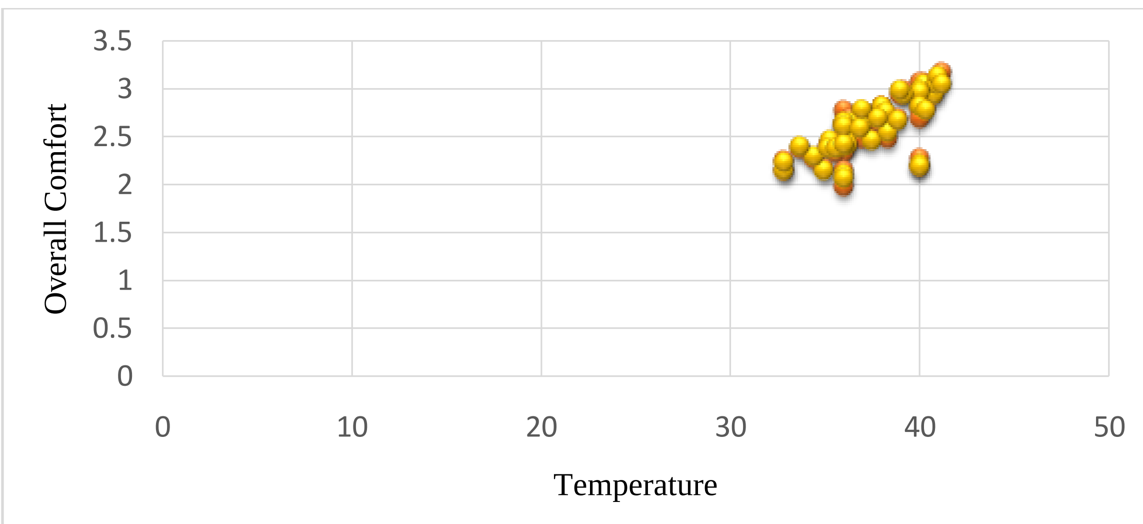

Figure 4.2: Temperature Line Fit Plot

The overall comfort value lies between 2 and 3, that means the journey is slightly uncomfortable to uncomfortable with respect to Temperature.

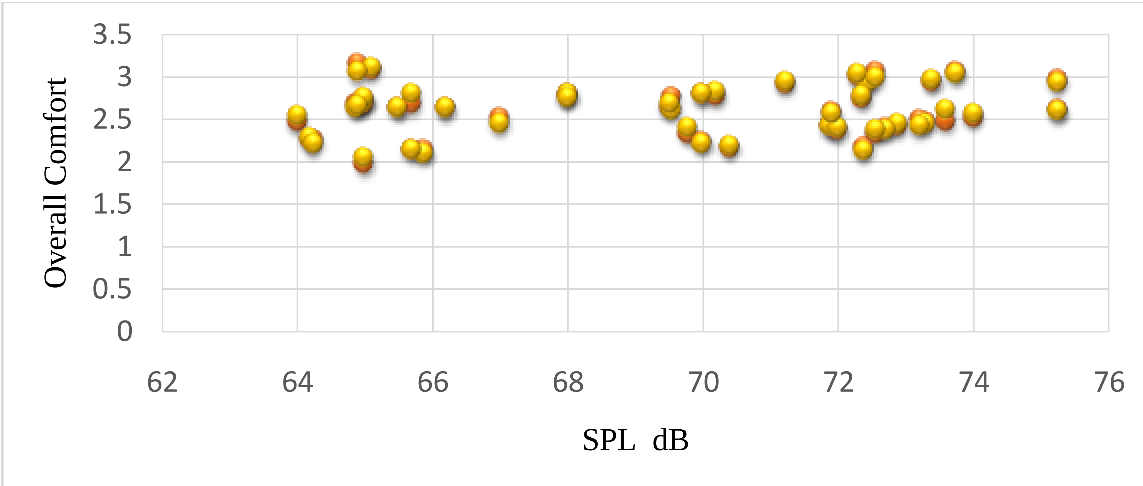

Figure 4.3: SPL Line Fit Plot

The overall comfort value lies between 2 and 3, that means the journey is slightly uncomfortable to uncomfortable with respect to Sound Pressure Level.

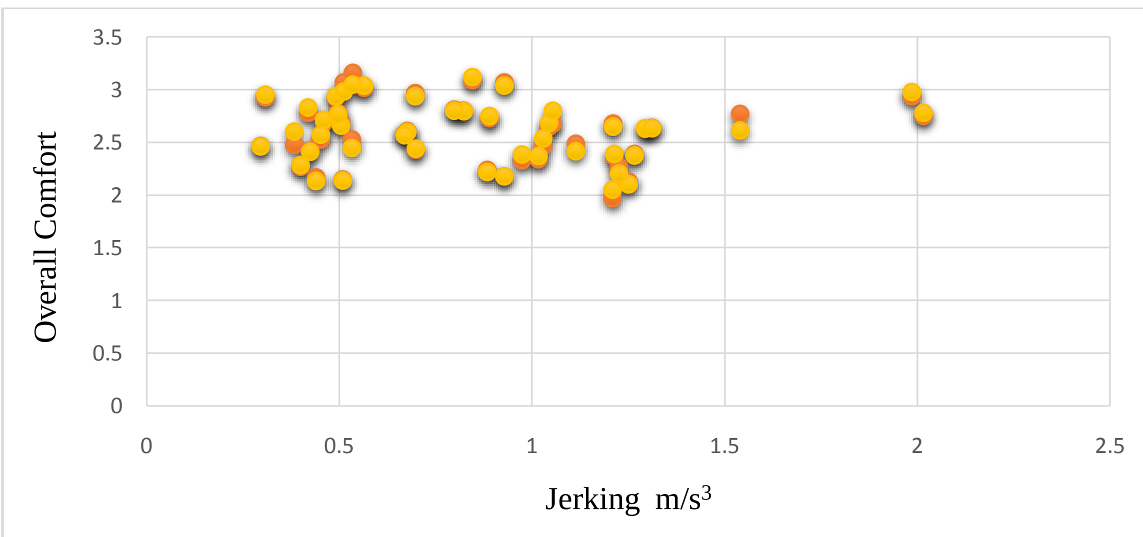

Figure 4.4: Jerking Line Fit Plot

The overall comfort value lies between 2 and 3, that means the journey is slightly uncomfortable to uncomfortable with respect to Jerking.

4.3.3 Model Validation

From the 45 observations, first 22 samples are taken and linear regression model is established. These samples are shown in appendix 1.

Table 4.5: Regression Statistics for validation model building

R Square	0.97
Adjusted R Square	0.97
Standard Error	0.06
Observations	22

Table 4.6: Regression Output for validation model building

	Coefficients	Standard Error	T Stat	P- value
Intercept	-2.15	0.31	-6.97	0.000
Speed	-0.02	0.01	-13.56	0.000
Temperature	0.11	0.01	17.27	0.000
SPL	0.01	0.01	1.98	0.06
Jerking	0.22	0.04	6.05	0.000

The regression equation is:

Overall Comfort = -2.15 -0.02*(Speed) + 0.11*(Temperature) +0.01*(SPL) +0.22*(Jerking)

Then, the independent values of the last 23 samples are put into this regression model and overall comfort values are measured from that model. These 23 samples are shown in appendix 2.

Again, a linear regression model is established with this data.

Table 4.7: Regression Statistics for validity check

R Square	1
Adjusted R Square	1
Standard Error	0.000
Observations	23

Table 4.8: Regression Output for validity check

	Coefficients	Standard Error	T Stat	P- value
Intercept	-2.15	0.000	-6.55E+14	-6.55E+14
Speed	-0.02	0.000	-3.14E+15	-3.14E+15
Temperature	0.11	0.000	2.39E+15	2.39E+15
SPL	0.01	0.000	3.10E+14	3.10E+14
Jerking	0.22	0.000	1.077E+15	1.07E+15

From the regression statistics, it is found that Multiple R is 1 which means that the linear relationship is strong. The R-squared value is 100%, it means that all the variability of the overall comfort is around their mean value. The adjusted R Square value is also equal to the R Square value. The standard error value is also very low which indicates that the predictions of the model are adequately accurate. So, the model is valid.

4.3.4 Residual Plots

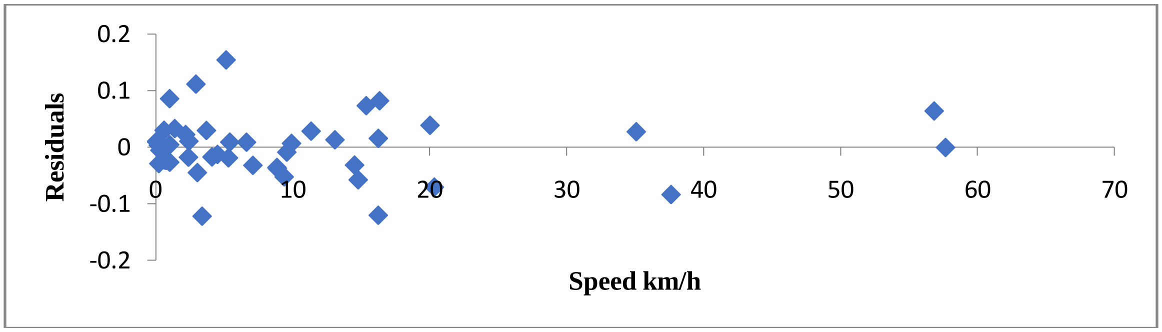

Figure 4.5: Speed Residual Plot

From the residual plot, all the points are almost close to zero. All the points in the residual plot are randomly dispersed around the horizontal axis, this means that the linear regression model is appropriate with respect to speed.

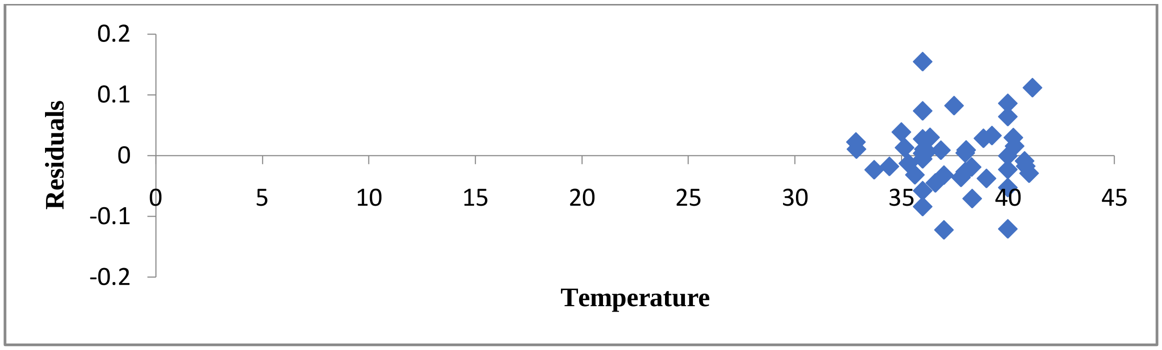

Figure 4.6: Temperature Residual Plot

From the residual plot, all the points are almost close to zero. All the points in the residual plot are randomly dispersed around the horizontal axis, this means that the linear regression model is appropriate with respect to temperature.

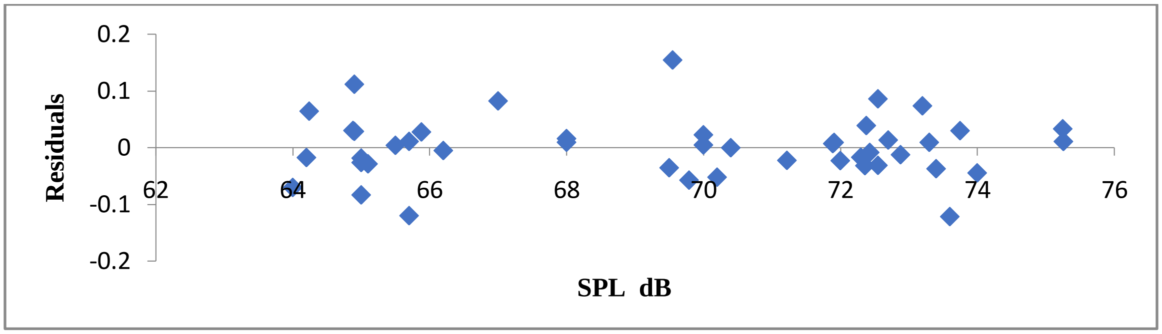

Figure 4.7: SPL Residual Plot

From the residual plot, all the points are almost close to zero. All the points in a residual plot are randomly dispersed around the horizontal axis, this means that the linear regression model is appropriate with respect to Sound Pressure Level.

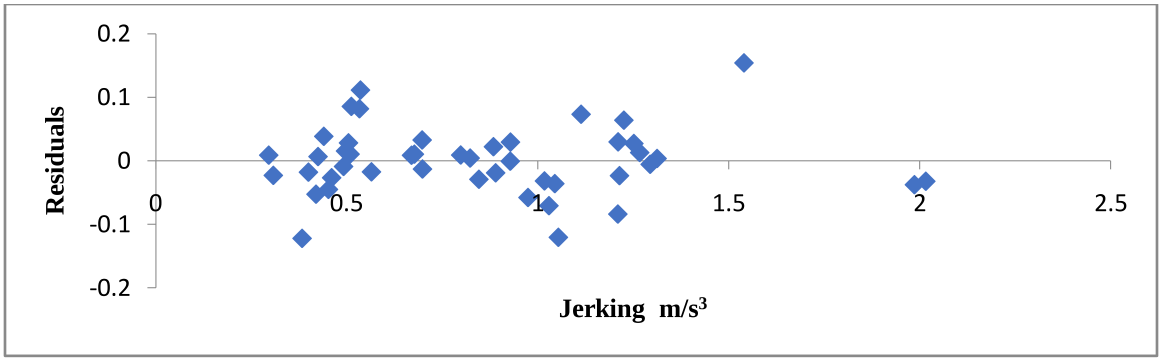

Figure 4.8: Jerking Residual Plot

From the residual plot, all the points are almost close to zero. All the points in a residual plot are randomly dispersed around the horizontal axis, this means that the linear regression model is appropriate with respect to jerking.

Chapter 5
CONCLUSION

5.1 Introduction

The principal objective of this study is to measure comfort for public buses in Dhaka city and establish a Comfort Estimation Model. In order to achieve this objective, some steps were needed to be taken i.e., identifying the variables, building up the microcontroller, collecting data from various route, analyzing the data and finally finding out the result. There are several research studies related to reliability, cost, speed, safety and timeliness. However no comprehensive study has been conducted to measure travel comfort for Dhaka. The mechanical approach has gained popularity in recent times.In the context of Dhaka city, the mechanical approach is rather a new one. This study will help us identify the important variables which dominate the overall comfort value.

Comfort is an important factor in the cost-benefit judgement of transport users with regard to mode selection. This study aims to quantify comfort of passengers of public transport by taking into consideration the key variables that have impact on comfort. It also takes into consideration the variation of comfort requirements of different types of passengers for instance an old passenger may opt for a warm temperature compared to that of a young passenger.

This chapter gives an overview of the important findings of this research. The findings are discussed in detail. This is followed by suggestions for precautionary measures to be taken to enhance safety as well as suggestions for future research.

5.2 Major Findings

1. The response obtained from passengers after conducting the questionnaire survey yielded two very common level of comfort. The Comfort level for Public Buses varied between “Slightly Uncomfortable” and “Uncomfortable”. Hence in the graph all the values lie within 2 and 3.

2. The level of significance for our study had been set at 5%. After conducting it has been found that the values are coherent with our 5% significance level. Hence the model is satisfactory for 5% significance level.

3. During conducting the survey, the climate was humid and warm. The road from which the data were obtained was in a bad condition. Therefore, temperature and jerking mainly dominated the Overall Comfort Value estimation.

5.3 Limitations

Conducting this thesis, it was found out that it had quite a number of limitations.

- For the common dwellers of Dhaka city, comfort is still not defined. There are no supporting studies to determine the extent of comfort of different people having different social, economic and physical standards. It is difficult to assess the idea of comfort since it varies from passenger to passenger and it is not a parameter that can be effectively quantified.

- No comprehensive study has been conducted to measure travel comfort. In Bangladesh there are no previous information regarding travel comfort which is an important factor that determines mode selection.
- Usually studies involved subjective data collection by means of questionnaires which has limited the results to perception of passengers. No mechanical data were analyzed in order to understand the factors which influenced such passenger response. The subjective and mechanical data may be effectively integrated to yield a relationship between these two data sets. This will help develop ways to improve comfort for passengers.
- The mechanical data obtained in this study were the first of its kind in Bangladesh. There are no relevant study or data with which the mechanical data could be compared for evaluation *(Prashanth et al.,2013).*
- The instrument used to obtain the mechanical data was prone to questioning due to its outlook. Often the buses were reluctant to let us conduct the experiment since the wired set-up made them feel uncomfortable. Many passengers were

eager to know about the study and often interrupted during data collection. Again, there were also many passengers who did cooperate during our data collection.

- At different points in ride, the GPS signals were relatively poor which created problems of location data collection. Initial synchronization of the instrument took a significant amount of time which hampered data collection at times.
- Temperature sensors were used to obtain data related to temperature. The sensors were accommodated in a plastic box which may induce secondary temperature values due to its materialistic Thermal Conductivity characteristics. Plastic is a poor conductor of heat; therefore, it couldn't effectively measure the temperature changes.
- Equipment carrying problem due to congestion was an issue. Jerking values may have been induced due to jerking of the person holding the instrument.
- The GPS Sensor had poor signal which caused it to malfunction during certain periods in certain places. It had to be adjusted before resuming the data collection.

5.4 Future Research Scopes

We measured only four comfort variables i.e.,Speed, Temperature, Sound Pressure Level and Jerking. But there are scopes of measuring several other comfort variables such as humidity, air flow etc. These parameters may be integrated with our study which will enable us to better understand the influence of factors on comfort of passengers.
Some category variables may also be introduced. Age, sex, stuff behavior, standing or sitting position in the bus, timeliness etc. are the variables that can be integrated in the future studies.

This study is based on measuring comfort for travelling only in buses. There is possible scope of study by measuring the comfort for other public transport modes i.e.,Para-Transit (Laguna), Motorized Vehicle (Private Car, CNG), Non-Motorized Vehicle (Rickshaw) etc. These data may be integrated to conduct a comparative study.
After measuring comfort value from different modes, correlation between comforts of these modes could be determined. ANOVA test, t-test, f-test and several otherstatistical

operations may be performed to show a relation between the different modes of transportation and their relative effect on comfort of travelling. The values obtained from different modes may also be used to conduct a comparative study and help understand how different modes effect the concept of comfort in transportation.

This study only measures comfort of passengers. Comfort of drivers was not taken into consideration. In future, studies may be conducted to evaluate the comfort of drivers of different modes of transport. Different factors that affect comfort of drivers may be identified and integrated in the overall comfort study.

The results of this study may be implemented on a national level to improve comfort of passengers traveling in public transportation modes. This study will pave the way for future researchers to study the influence of different factors and transportation modes on the comfort of passengers.

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APPENDIX A

Appendix A 1

Speed m/s	Temperature	SPL dB	Jerking m/s^3	Overall Comfort
3.697062133	40.25981873	73.75	0.9285112	3.07
9.57	40.78654292	72.43	0.491636	2.93
4.104224147	40.83982684	72.3	0.564613724	3.02
9.37953624	40	70.2	0.419485898	2.78
1.008059362	40	72.55	0.512000525	3.07
0.637904342	40	71.22	0.307715775	2.93
1.384382969	39.25490196	75.25	0.697329	2.97
3.035989212	36.59848485	74	0.452010504	2.53
5.405473022	36.1349481	73.3	0.295742746	2.47
3.383695683	37	73.6	0.383051765	2.48
9.913402828	36.20845921	71.89	0.424809785	2.42
4.505721053	35.32894737	72.88	0.698159721	2.43
20.0311229	35	72.38	0.439901097	2.17
14.78463436	36	69.79	0.974429466	2.33
5.136238531	36	69.55	1.539705756	2.77
0.297205066	36	66.2	1.294186542	2.63
0.606662026	36.34709931	64.88	1.210276412	2.68
0.1852	36	65.5	1.312267834	2.64
35.09934149	36	65.88	1.251439419	2.13
37.64171321	36	65	1.2095619	1.97
2.385741631	34.43776824	64.2	0.39968436	2.27
2.417361444	32.8898917	65.7	0.508655175	2.15

Appendix A 2

Speed m/s	Temperature	SPL dB	Jerking m/s^3	Overall Comfort
2.179186667	32.86538462	70	0.883922337	2.242905603
0.75932	33.72277228	72	1.213859443	2.452054001
16.34652759	37.4744186	67	0.533187683	2.406270347
1.0186	38	70	0.822962119	2.808758918
1.01648526	38	65	0.460432819	2.681887412
0.07408	38.04278075	68	0.798210985	2.805165323
5.308294405	38.3	65	0.889647302	2.739925276
20.34612296	38.32534247	64	1.029207459	2.516757177
8.874412318	38.99653979	73.4	1.985888886	3.079389783
13.08656599	35.14854111	72.7	1.266758827	2.422581022
14.52075078	35.63605442	72.55	1.017500002	2.394958303
0.067991934	36.05801105	75.26	0.676997718	2.627955069
15.37239729	36	73.2	1.113417722	2.448050101
6.625545382	36.85714286	71.91	0.669466978	2.574671879
7.09316	37	72.36	2.015635126	2.888022757
8.852052603	37.80136986	69.5	1.044580393	2.702917766
11.3473569	38.8553616	64.9	0.504491394	2.613792
16.25001229	40	65.7	1.053858243	2.78815063
56.85974723	40	64.24	1.225321745	2.143380267
57.6898	40	70.4	0.927972284	2.119488611
16.25560394	40.31830986	68	0.496735761	2.719123227

0.22224	41	65.1	0.845942395	3.109603205
2.931551378	41.1578	64.9	0.53587766	3.010896885

Appendix A 3

Date and time	Latitude	Longitude	Speed	Ac_x	Ac_y	Ac_z	T	SPL	RMS	Jerking
5:55:29-:2:10:2017	23.82143	90.4185	50.80036	-6.07	2.17	5.53	40	473	8.493215	0.184888
5:55:29-:2:10:2017	23.82143	90.4185	50.80036	-3.93	4.53	5.75	40	880	8.308327	0.056436
5:55:29-:2:10:2017	23.82143	90.4185	50.80036	-6.88	-0.83	4.48	40	881	8.251891	0.545325
5:55:29-:2:10:2017	23.82143	90.4185	50.80036	-7.97	-0.74	3.65	40	882	8.797215	0.626903
5:55:29-:2:10:2017	23.82143	90.4185	50.80036	-6.2	-0.66	5.28	40	825	8.170312	0.437649
5:55:29-:2:10:2017	23.82143	90.4185	50.80036	-7	-0.89	4.93	40	625	8.607961	0.030771
5:55:45-:2:10:2017	23.82159	90.41876	50.80036	-7	-0.81	4.89	40	883	8.577191	1.295205
5:55:45-:2:10:2017	23.82159	90.41876	50.80036	-7.92	-0.53	5.87	40	883	9.872396	1.534273
5:55:45-:2:10:2017	23.82159	90.41876	50.80036	-6.81	-0.11	4.81	40	940	8.338123	1.3971
5:55:45-:2:10:2017	23.82159	90.41876	50.80036	-5.56	-0.61	4.11	40	304	6.941023	2.222606
5:55:45-:2:10:2017	23.82159	90.41876	50.80036	-7.4	-0.4	5.39	40	220	9.163629	0.984804
5:55:45-:2:10:2017	23.82159	90.41876	50.80036	-8.13	-0.73	6.03	40	114	10.14843	5.175135
5:55:45-:2:10:2017	23.82159	90.41876	50.80036	-4.02	-0.58	2.87	40	347	4.973299	4.688518

13:57:52-:29:9:2017	23.87342	90.40046	9.88968	-3.7	-4.49	7.13	36	881	9.202554	1.46634
13:57:52-:29:9:2017	23.87342	90.40046	9.88968	-3.16	-3.47	6.15	36	884	7.736214	1.380836
13:57:52-:29:9:2017	23.87342	90.40046	9.88968	-3.79	-4.06	7.23	36	881	9.11705	0.216932
13:57:52-:29:9:2017	23.87342	90.40046	9.88968	-5.16	-3.89	6.12	35	882	8.900118	1.542693
13:57:52-:29:9:2017	23.87342	90.40046	9.88968	-3.68	-3.58	5.27	35	883	7.357425	1.733076
13:57:52-:29:9:2017	23.87342	90.40046	9.88968	-5.16	-4.04	6.3	36	883	9.090501	0.458548
13:57:52-:29:9:2017	23.87342	90.40046	9.88968	-4.43	-4.29	6.04	35	881	8.631952	0.465245
13:57:52-:29:9:2017	23.87342	90.40046	9.88968	-4.57	-4.71	6.3	35	883	9.097197	0.135717
13:57:52-:29:9:2017	23.87342	90.40046	9.88968	-4.49	-4.71	6.55	36	883	9.232914	1.183347
13:57:52-:29:9:2017	23.87342	90.40046	9.88968	-4.68	-5.44	7.55	36	882	10.41626	2.86397
13:57:52-:29:9:2017	23.87342	90.40046	9.88968	-3.89	-4.05	5.05	35	882	7.552291	0.966823
13:57:52-:29:9:2017	23.87342	90.40046	9.88968	-3.66	-5.21	5.66	36	882	8.519114	2.394918
13:57:52-:29:9:2017	23.87342	90.40046	9.88968	-6.2	-4.85	7.56	36	883	10.91403	3.240682
13:57:52-:29:9:2017	23.87342	90.40046	9.88968	-4.01	-4.11	5.09	35	883	7.67335	0.965124

Appendix A 4