بسم الله الرحمن الرحيم

IDENTIFICATION OF ROAD DISTRESSES AND TRAFFIC CONDITION THROUGH SMARTPHONE

BY

KAZI MASHUKUR RAHMAN

TANVIR ABEDIN

AHMAD QUTUB UL ALAM SINAN

FARAH BINTE FORHAD

Department of Civil and Environmental Engineering

ISLAMIC UNIVERSITY OF TECHNOLOGY (IUT)

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KAZI MASHUKUR RAHMAN (170051020)

TANVIR ABEDIN (170051037)

AHMAD QUTUB UL ALAM SINAN (170051061)

FARAH BINTE FORHAD (170051069)

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Project Report Approval

The thesis titled "**IDENTIFICATION OF ROAD DISTRESSES AND TRAFFIC CONDITION THROUGH SMARTPHONE**" submitted by **Kazi Mashukur Rahman** (170051020), **Tanvir Abedin** (170051037), **Ahmad Qutub Ul Alam Sinan** (170051061), **Farah Binte Forhad** (170051069) have been found as satisfactory and accepted as partial fulfillment of the requirement for the Degree Bachelor of Science in Civil Engineering.

SUPERVISOR

____

Dr. Nazmus Sakib
Assistant Professor
Department of Civil and Environmental Engineering (CEE)
Islamic University of Technology (IUT)
Board Bazar, Gazipur, Bangladesh.

Declaration of Candidate

This is to certify that the work presented in this thesis paper is the outcome of the research carried out by the candidates under the supervision of Dr. Nazmus Sakib, Assistant Professor of Civil and Environmental Engineering (CEE). It is also declared that, neither this thesis nor any part of the thesis has been submitted anywhere else for the award of any degree or any judgement.

Kazi Mashukur Rahman

Student ID-170051020

Tanvir Abedin

Student ID- 170051037

Farah Binte Forhad

Student ID-170051069

Ahmad Qutub Ul Alam Sinan

Student ID-170051061

<u>SUPERVISOR</u>

Dr. Nazmus Sakib

Assistant Professor

Department of Civil and Environmental Engineering (CEE)

Islamic University of Technology (IUT)

Board Bazar, Gazipur, Bangladesh

Dedication

This thesis work is dedicated to our respected parents who have been a constant source of support and encouragement and unconditional love during the challenges of graduation and life and whose good examples have taught us to work hard for the things that we aspire to achieve.

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This achievement would never come true without the help, support, and love of many wonderful people to whom we are always indebted.

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Abstract

Keywords:

Potholes, Bumps, Smartphone apps, Geometric Condition, Traffic Condition, 3-axis Accelerometer Sensor

One of the most serious issues in developing countries is road maintenance. Every year thousands of people lose life due to the failure in road maintenance. Road damage causes severe issues for drivers such as trip efficiency, car value, and even driving safety. In some circumstances, road degradation causes accidents that result in death. Currently, road damage detection research is expanding and presenting new ways such as the use of an accelerometer sensor. However, because of the inability to function in real-time and bad implementation, the implementations suffer from a lack of precision.

Well-maintained roadways contribute significantly to the country's economy. Identification of road distress, such as potholes and bumps, assists drivers in avoiding accidents and vehicle damage, as well as assisting authorities in road maintenance. A cost-effective technique with an appropriate level of accuracy and the least amount of labor is always ideal for road distress assessment study. And smartphones give all of these via various types of sensors.

The purpose of this study is to investigate the usage of smartphone apps to assess the discomfort of the road body, which directly reflects the road condition. The study investigates the source of vehicle trouble on the road. The research and observations obtained by the suggested approach for road condition evaluation were compared with a set of road infrastructure data collected by smartphone application employing sensors such as gyroscope, accelerometer, GPS, and so

Chapter 1: INTRODUCTION

1.1 General

Road distress is mostly measured by detecting speed bumps, potholes, road quality, and congestion (Srishyla K, 2021). This work is quite costly and time consuming. This is one of the major works for road maintenance. Negligence in road maintenance may result into adverse consequences. Smartphone sensors are being used to make this investigation more viable, cost-effective and efficient (Srishyla K, 2021). This study eases the way for road maintenance. After analyzing the acquired datasets with smartphones, we can be able to detect the overall condition of a road. Which includes -

1. Geometric Condition of road
2. Traffic Condition of road

A cost-effective system with acceptable level of accuracy & with least manpower is always preferable for a research work for road distress assessment (Uzaktan et al., 2020). And smartphone provides all of them through different types of sensors. Expenses in manpower has totally been minimized. Establishing a pattern of road distress through adequate datasets using X-axis, Y-axis and Z-axis acceleration of vehicles is one of the major tasks.

The goal of this research is to evaluate the use of smartphone apps to assess the distress of the road body which directly shows the road condition. So basically, after conducting the research, a whole overview of road will be stated. We can tell where the bumps, potholes are and also other anomalies. So, it is totally unnecessary to go to the road and conduct survey just to figure out the distress. Seeing the data from this study, it is easier to decide where the development of roads is needed. So Govt can be highly benefited by this study. The datasets are collected from moving vehicle. Then after analyzing the datasets, road distresses are shown through graphs which clearly indicates the inclination and degradation.

1.2 Background of the Study

Road maintenance is certainly one of the main regular tasks of a country. If the roads are not maintained in a systematic way and development tasks are not executed from time to time, there may occur different type of accidents. In fact, every year thousands of people lose their lives on roads in road accidents which occur due to damaged roads (ITF, 2021). A huge amount of money is spent by government in this field. A cost effective, time saving, efficient and sustainable solution to this issue can be the use of Smartphones. Road distress and traffic condition can be assessed by using Smartphones.

The main goal of the study is the maintenance of the road. Using smartphone sensors, datasets are collected from moving vehicle that are used for further analysis. After analyzing the datasets, road distresses can be measured. This gives us a clear concept about geometric and traffic condition of a specific road.

Potholes, bumps and defects of roads can be clearly detected after analyzing the datasets. After learning about all the distresses and defects of a certain road, it gets quite easier to conduct repair work or even road development related works. This study not only reduces the total costing but also minimizes the necessity of huge amount of manpower (Bills et al., 2014). This also eases the process of making budget for development work. Besides, proper maintenance of roads can pave the way of reducing untimely deaths and give us a great scenario of sustainable road development.

1.3 Objective of the Study

The following are the study's objectives:

- To identify the road distress and traffic condition which has to be assessed by smartphones.
- Identification of distress caused by potholes, speedbumps, traffic condition, traffic congestion, signals, stoppage will get measured by using accelerometer sensor and optically and taking videos.
- Establishing a pattern of road distress through adequate datasets using Z-axis acceleration of vehicles.
- Traffic related parameters can also be detected through this study.

Chapter 2: LITERATURE REVIEW

2.1 General

- L. Janani, V. Sunitha & Samson Mathew (2020) collected and used Smartphone accelerometer data, external tri-axis accelerometer data for sudden break detection, pothole detection, bump detection and patch detection (Janani et al., 2021). Their methodology included the use of z peak algorithm, z-sus algorithm and z-x algorithm. So, their research was conducted on smartphone accelerometer-based pavement distress detection. Their goal of the research was to evaluate the influence of surface distress in smartphone based IRI estimation. This paper investigates the feasibility of using smartphones equipped with highly efficient censors for pavement distress condition assessment.

- Piyasak Thiandee, Boonsap Witchayangkoon, Sayan Sirimontree, Ponlathep Lertworawanich (2019) collected acceleration data by using three different smartphones to measure the vibration for road roughness detection (Thiandee et al., 2019). The RMS and Machine Learning (ML) methods were used in this study. Then the results are compared to IRI observation. They found that ML method gives better result than RMS.

- Waleed Aleadelat, Khaled Ksaibati, Cameron H. G. Wright, Promothes Saha studied in evaluation of pavement roughness using android-based smartphone. In this research they used smartphones' 3D accelerometer for collecting vehicle data. Their methodologies included cross correlations, Welch periodograms, and variance analyses. AndroSensor app was used to collect data (Aleadelat et al., 2018).

- Junaid Mohammed (2015) studied on Pavement Performance measures using android-based smart phone application. The goal of this study was to investigate pavement roughness using android-based smartphone technology for improving the overall performance. Data were collected using combination of modern sensor technology with the help of an Android Smartphone (Uddin Mohammed et al., 2015). The result evaluates the structural and functional condition of pavement.

- Xiao Li, Daniel W. Goldberg used mobile crowd sensing system for road surface assessment. The methodology of this study includes built-in GPS receiver, accelerometer in smartphone, geo-referenced Z-axis accelerations of the road surface etc. This study represents a specialized mobile crowd sensing system for road surface roughness detection, which consists of a smartphone data-collecting equipment and a web-based data server component (Li & Goldberg, 2018).

- Marcin Staniek conducted his study on Road pavement condition diagnostics using smart phone-based data crowdsourcing in smart cities. The goal of the research was to analyze the effectiveness of a solution known as Road Condition Tool (RCT) based on data crowdsourcing from smartphones users in the transport system (Staniek, 2021).

- Sayna Firoozi Yeganeh, Ahmadreza Mahmoudzadeh, Mohammad Amin Azizpour, Amir Golroo conducted their study on validation of smartphone-Based pavement Roughness measures. In this study two main methods were used to collect the pavement roughness data. One is Manual and another one was Automated or semi-automated. The study actually helped to evaluate the acceptability of smartphone based sensor and their methodologies were fair enough and also left some future scope (Yeganeh et al., 2019).

- Choirul Huda, Herman Tolle and Fitri Utaminingrum (2020) analyzed road damage (RODA) by using Built-in Accelerometer Sensor in Smartphone (Huda et al., 2020). This research was conducted by 3 gradual stages:
  Data Collection, Range Value Estimation,Road Damage Classification
  Experiments were taken along rural roads by driving the car for 30-40 minutes and occupied a specific distance. As a result, they collected fair enough data and later evaluated the damage.

2.2 Summary

From all these studies and research, we can see that, all the researchers were coming with new methodologies and new software-based research methods for the sake of using mobiles in road quality evaluation purpose.

Road quality evaluation was always a top priority in road management system and making it a handy and cost efficiency process was always on a try. So all these researches were conducted to modify the use of smartphone, evaluate the accuracy, rate the acceptability, improvise the methodologies, and create new scopes in this process.

Here we can see the use of lots of sensors, smartphone apps and different methodologies.

In conclusion these studies have created a lot of scopes for the new researchers to conduct new researches based on smartphone.

Chapter 3: METHODOLOGY

3.1 General

Data collection is done using smartphone sensors. Dhaka city is a fast-growing mega city and road network maintenance is a key factor for safe and fast travel. So, study area is selected so that it can replicate most of the scenarios of Dhaka city and the collected data can be applicable throughout the whole city. Data collection is done using the android-based smartphone which is equipped with various sensors like accelerometer, GPS, gyroscope form the factory. Different pre-developed application can be found which are suitable for this work. The application used is called Physics Toolbox Suite. It is a free to use software and can be easily downloaded from the google play store. The transportation methods for data collection work are kept limited to public transportation or bus services. It is to replicate to the natural scenario as closely as possible as majority of the people of Bangladesh commutes using public buses. Only one mode of transportation is used to keep error as minimum as possible. the position of the smartphone which is used for data collection work can also create error. So, the position is kept similar, which is in the passenger's pocket. It eliminates hand movement form the passenger and also the natural action of the human body to minimize the jerking caused by the bus. Several filed surveys are done to observe the condition of the route. Videos of the whole route were taken and photographs of the different road condition were taken. During a trip for data collection, video was taken simultaneously with the data so that the findings of this work can be established more accurately. This study regulates observational data instead of statistical or mathematical model. So, the collected data is comprehended and a correlation is stablished with the observational data. In order to do so, various graphs are used. First, the whole route is divided into five different zones. Average data of the trips are taken while establishing the graph.

3.2 Work Flow Diagram

The following work flow diagram is followed in this research work.

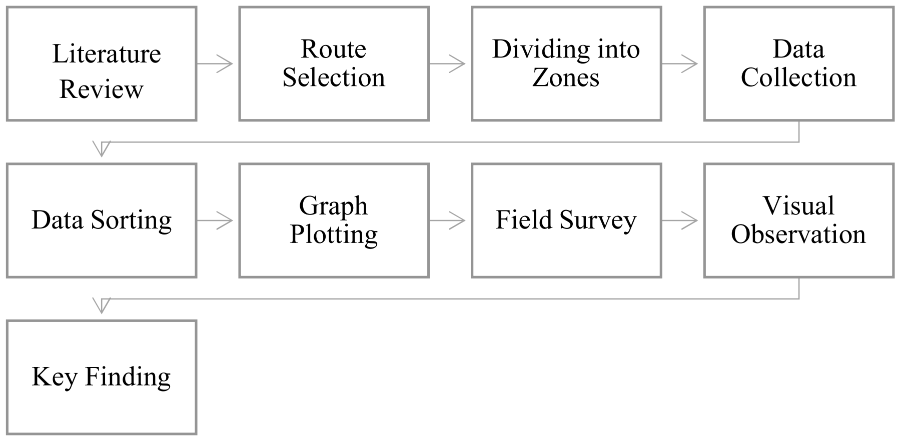


Figure 3-1: work flow diagram

3.3 Study Area

The study area for data collection work is a route in Dhaka city, starting from Asad gate bus stop in Mirpur Road, Dhaka and ending at Shainik club bus stand Dhaka via Khamar bari Goal Chottor, then right turn through Zia -Uddan and left turn from Bijoy Sharani and finally through Jahangir gate to Shainik club using Mohakhali flyover. The section of route is done meticulously considering different factors of the work. The route also represents the usual traffic scenario of Dhaka city. The total length of the route is 5.6 kilometers. The factors considered while taking this route are both congestion and congestion free vehicle movements can be observed, several turnings and bus stoppages, existence of potholes and speedbumps and an interchange where vehicle movement is faster, can be found in this route, which creates a diverse observation field as well as crates different data patterns.

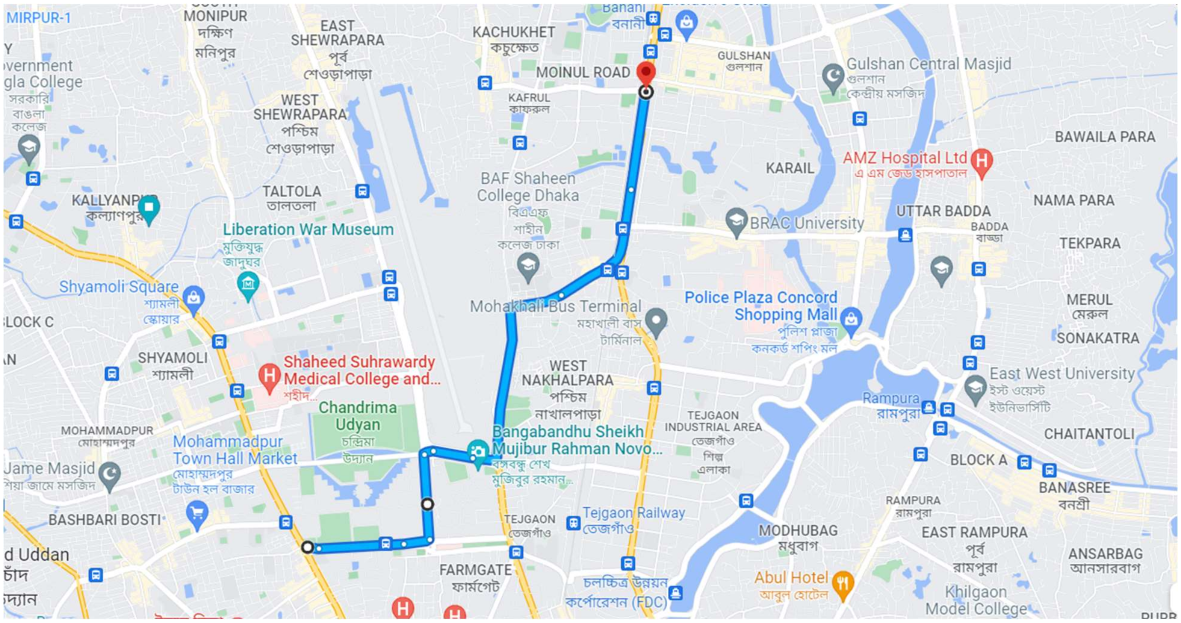


Figure 3-2: Data collection Route

The entire route is dived into five sections of road. The sectional division is done by separation the linear stretch of the road into each section. It is done in order to minimize the error in latitude and longitudinal coordination caused by the directional change. Turning changes, the direction of the vehicles which makes drastic changes in coordination, which can cause error in data of other parameters. So, the route is divided to linear segments. It also helps to organize the data while analyzing.

Table 3-1: Section of the route

Zone	Start point	End point	length
1	Asad Gate Bus stop	Khamarbari Goal-Chottor	950m
2	Khamarbari Goal-Chottor	Bijoy Sharani Circle	600m
3	Bijoy Sharani Circle	Bijoy Sharani	650m
4	Bijoy Sharani	Jahangir Gate	1200m
5	Jahangir Gate	Shainik Club	2200m

3.4 Data Collection

Data collection work consist several data parameters such as horizontal and vertical acceleration i.e., x-axis, y-axis, and z-axis acceleration, GPS coordination data i.e., latitude and longitudinal value of each point on the road, velocity of the vehicles, time. All of these data can be obtained from smartphones as modern smartphone is packed with various sensors such as accelerometer, gyroscope, GPS, camera sensors, etc. But these sensors cannot be accessed easily. In order to access the mobile sensors, mobile application is used. For the purpose of data collection various pre-developed application can be found. The application used is this study is “Physics Toolbox Sensor Suite”. It is a free application developed by Vieyra Software and can be downloaded and installed easily. The software is suitable for the work as it collects data of all necessary parameters, the software is easy to use and the laggings from sensor reading is very minimum. The collected data is stored in a separate folder in comma separated value format and is easily accessible.

The following image shows the app interface while data collection process.

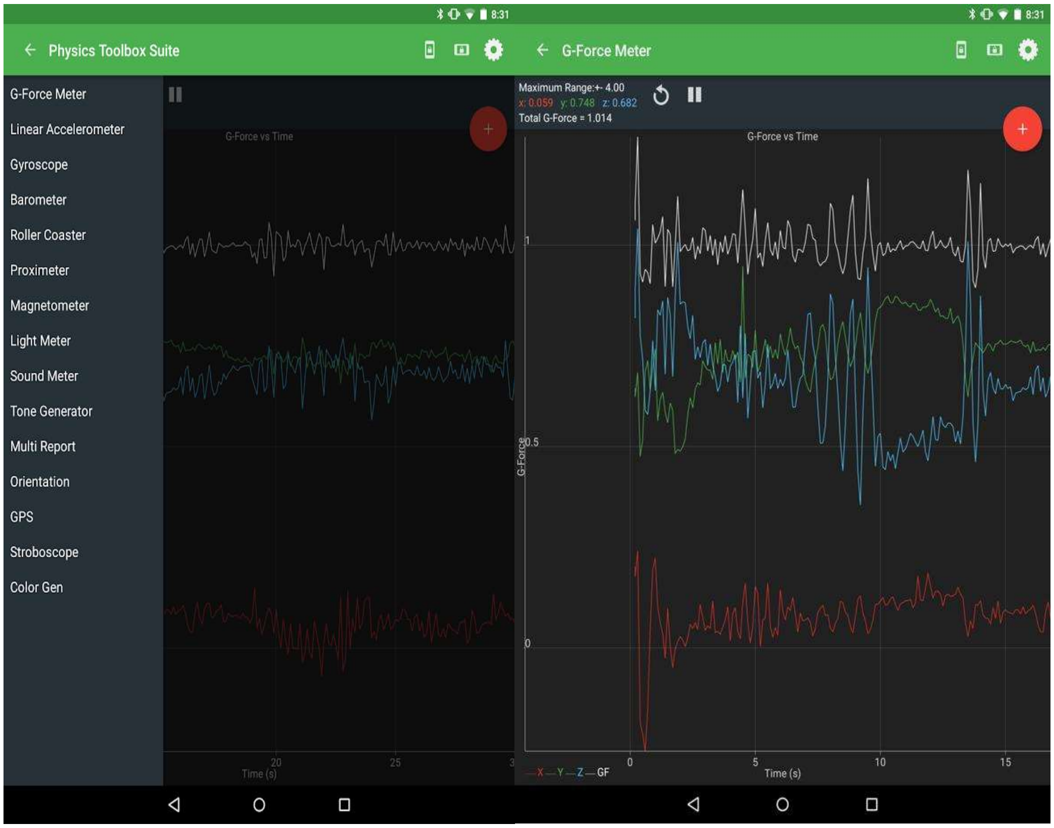


Figure 3-3: App Interface

The app collected real time data of vertical and horizontal acceleration in the three axes as well as GPS co-ordination and velocity of the vehicles. The range of data collected with respect to time is quite large. So, data sorting is done by taking the average value to each unique coordination points. The sample data set is represented by the following figure.

time	Average Ax	Average ay	Average Az	Latitude	Longitude	Average Speed	Unique Latitude	Unique Longitude
4.982165	-0.0941	0.042	0.0811	23.7585537	90.37498097	0.93000001	23.7585537	90.375
4.984115	-0.0941	0.042	0.0811	23.7585537	90.37498097	0.93000001	23.7585754	90.375
4.999536	-0.0941	0.042	0.0811	23.7585537	90.37498097	0.93000001	23.758556	90.375
5.001573	-0.0941	0.042	0.0811	23.7585537	90.37498097	0.93000001	23.7585521	90.375
5.003084	-0.0941	0.042	0.0811	23.7585537	90.37498097	0.93000001	23.7585757	90.375
5.019548	-0.0941	0.042	0.0811	23.7585537	90.37498097	0.93000001	23.7585676	90.375
5.021182	-0.1434	0.0549	-0.3568	23.7585537	90.37498097	0.93000001	23.7585561	90.375
5.022434	-0.1434	0.0549	-0.3568	23.7585537	90.37498097	0.93000001	23.758544	90.375
5.060109	0.0401	0.0543	-0.0028	23.7585537	90.37498097	0.93000001	23.7585424	90.375
5.061658	0.0401	0.0543	-0.0028	23.7585537	90.37498097	0.93000001	23.7585372	90.375
5.062667	0.0401	0.0543	-0.0028	23.7585537	90.37498097	0.93000001	23.7585322	90.375
5.063647	0.0401	0.0543	-0.0028	23.7585537	90.37498097	0.93000001	23.7585291	90.375
5.064839	0.0401	0.0543	-0.0028	23.7585537	90.37498097	0.93000001	23.7585274	90.375
5.065807	0.0401	0.0543	-0.0028	23.7585537	90.37498097	0.93000001	23.7585345	90.375
5.100796	0.0401	0.0543	-0.0028	23.7585537	90.37498097	0.93000001	23.7585417	90.375
5.103495	0.0105	0.0686	-0.0095	23.7585537	90.37498097	0.93000001	23.7585429	90.375
5.105656	0.0105	0.0686	-0.0095	23.7585537	90.37498097	0.93000001	23.7585427	90.375
5.120624	0.0105	0.0686	-0.0095	23.7585537	90.37498097	0.93000001	23.7585453	90.375
5.123357	0.0105	0.0686	-0.0095	23.7585537	90.37498097	0.93000001	23.7585503	90.375
5.125582	0.0105	0.0686	-0.0095	23.7585537	90.37498097	0.93000001	23.7585576	90.375
5.140848	0.0105	0.0686	-0.0095	23.7585537	90.37498097	0.93000001	23.7585656	90.375
5.143387	0.0105	0.0686	-0.0095	23.7585537	90.37498097	0.93000001	23.758575	90.375
5.14598	0.0472	0.0535	-0.018	23.7585537	90.37498097	0.93000001	23.7585827	90.375
5.180796	0.0472	0.0535	-0.018	23.7585537	90.37498097	0.93000001	23.7585889	90.375
5.183978	0.0472	0.0535	-0.018	23.7585537	90.37498097	0.93000001	23.758597	90.375
5.185618	0.0472	0.0535	-0.018	23.7585537	90.37498097	0.93000001	23.7585983	90.375
5.187669	0.0472	0.0535	-0.018	23.7585537	90.37498097	0.93000001	23.7585909	90.375
5.18954	0.0472	0.0535	-0.018	23.7585537	90.37498097	0.93000001	23.7585644	90.376
5.191451	-0.1481	-0.1256	0.3019	23.7585537	90.37498097	0.93000001	23.7585633	90.376
5.220817	-0.1481	-0.1256	0.3019	23.7585537	90.37498097	0.93000001	23.7585631	90.376
5.223824	-0.1481	-0.1256	0.3019	23.7585537	90.37498097	0.93000001	23.7585539	90.376
5.225503	-0.1544	-0.1242	0.2963	23.7585537	90.37498097	0.93000001	23.7585563	90.376
5.241188	-0.1544	-0.1242	0.2963	23.7585537	90.37498097	0.93000001	23.7585488	90.376
5.244353	-0.1544	-0.1242	0.2963	23.7585537	90.37498097	0.93000001	23.7585459	90.376
5.246874	-0.1544	-0.1242	0.2963	23.7585537	90.37498097	0.93000001	23.7585403	90.376
5.263091	-0.1544	-0.1242	0.2963	23.7585537	90.37498097	0.93000001	23.7585476	90.376
5.266245	-0.1544	-0.1242	0.2963	23.7585537	90.37498097	0.93000001	23.7585472	90.376
5.268224	0.1166	0.0432	0.1174	23.7585537	90.37498097	0.93000001	23.7585444	90.376
5.302256	0.1166	0.0432	0.1174	23.7585537	90.37498097	0.93000001	23.7585407	90.376
5.305208	0.1166	0.0432	0.1174	23.7585537	90.37498097	0.93000001	23.7585372	90.376
5.30717	0.1166	0.0432	0.1174	23.7585537	90.37498097	0.93000001	23.7585426	90.376
5.308912	0.1166	0.0432	0.1174	23.7585537	90.37498097	0.93000001	23.7585492	90.377
5.310626	0.0778	-0.0015	-0.1007	23.7585537	90.37498097	0.93000001	23.7585488	90.377
5.313373	0.0778	-0.0015	-0.1007	23.7585537	90.37498097	0.93000001	23.7585564	90.377
5.341195	0.0778	-0.0015	-0.1007	23.7585537	90.37498097	0.93000001	23.7585599	90.377
5.344278	0.0874	0.0095	-0.1009	23.7585537	90.37498097	0.93000001	23.758567	90.377
5.346584	0.0874	0.0095	-0.1009	23.7585537	90.37498097	0.93000001	23.7585744	90.377
5.363281	0.0874	0.0095	-0.1009	23.7585537	90.37498097	0.93000001	23.7585731	90.377
5.365627	0.0874	0.0095	-0.1009	23.7585537	90.37498097	0.93000001	23.7585879	90.377
5.367232	0.0874	0.0095	-0.1009	23.7585537	90.37498097	0.93000001	23.7585881	90.377

FINAL DATA | DATA FOR GRAPH | GRAPHS | SD | ZONE 1 | ZONE 2 | ZONE 3 | ZONE 4 | ZONE 5

Figure 3-4: Sample Data Table

Chapter 4: ANALYSIS & KEY FINDINGS

4.1 Analysis

The whole route is divided into five zones and the zones are then divided into further smaller segments so that data pattern in those segments can establish the condition of that part of the road. Which in terms can represent and will be hugely similar to other roads with similar conditions. This is the core strategy of this study as the purpose of the study is to identify road condition using collected data.

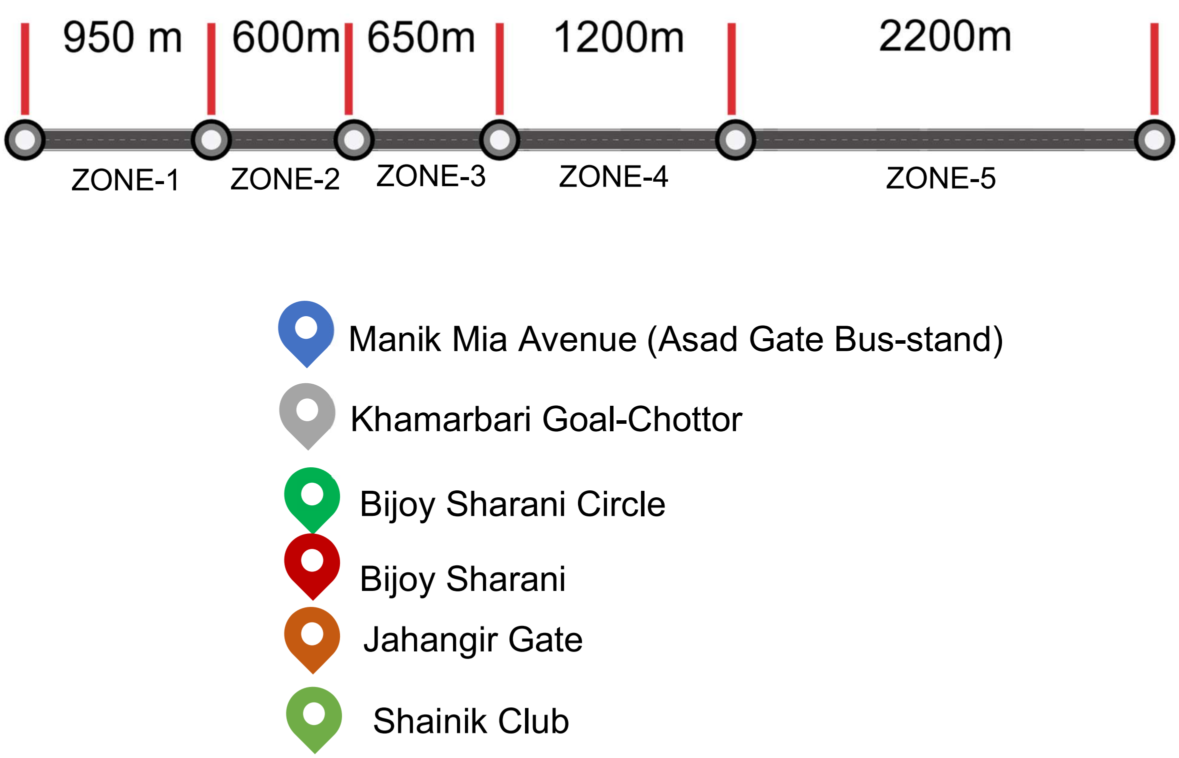


Figure-division of routes

The first one shows average Z axis acceleration versus distance and the second one shows speed versus distance. The first graph is used to determine road distress and traffic condition. For better understanding and precise result, we used the speed graphs as well.

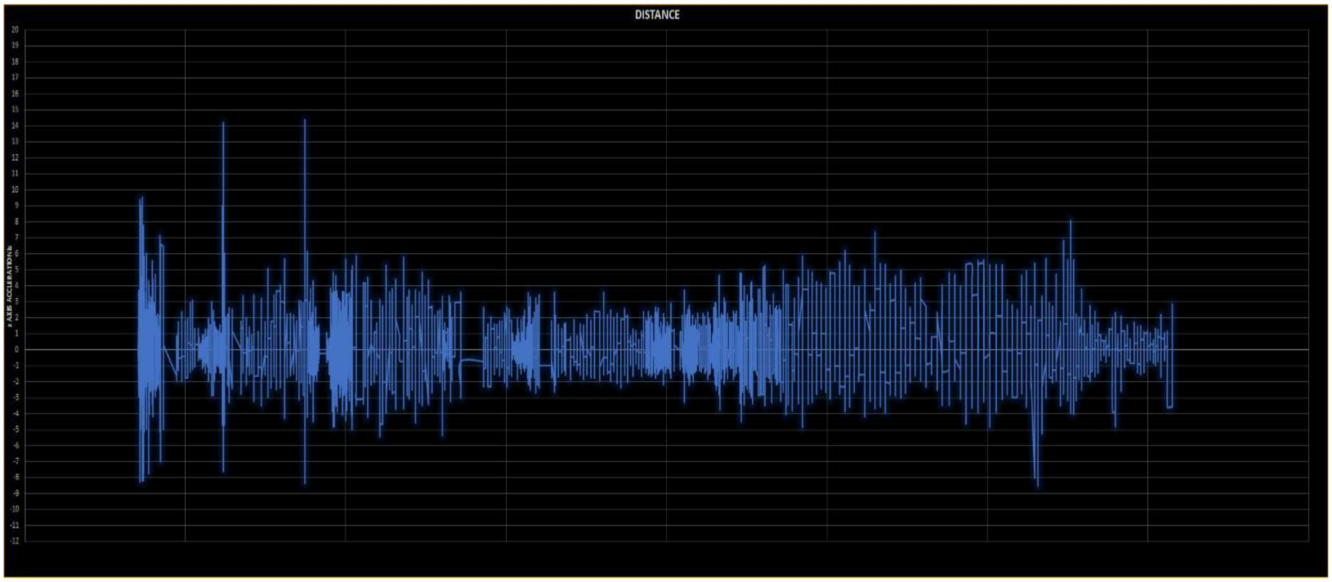


Figure 4-1:Average Z axis acceleration versus distance

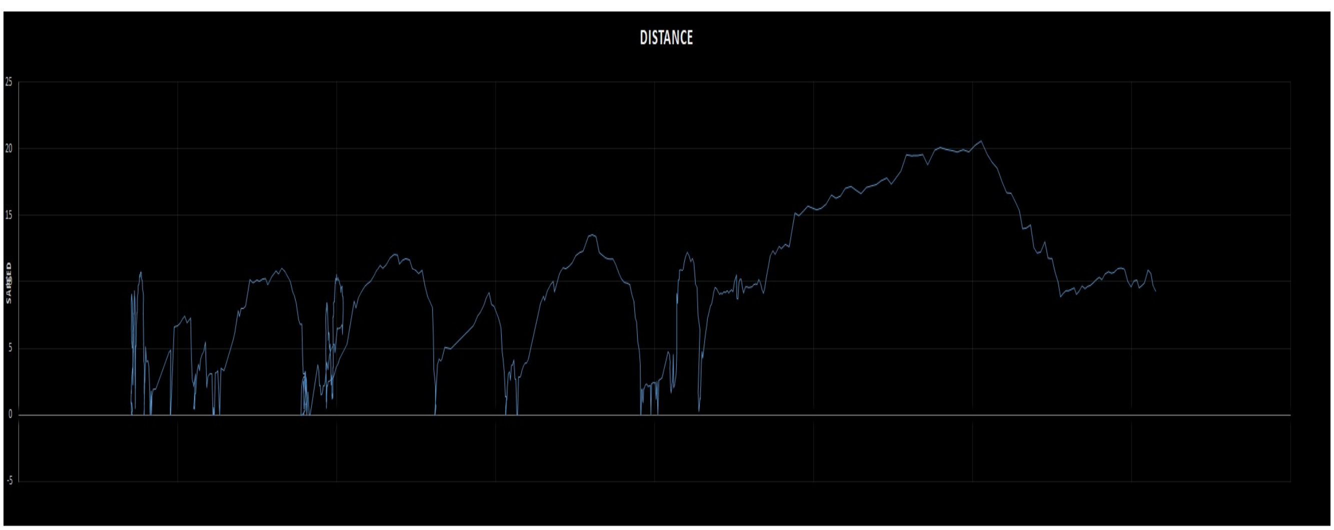


Figure 4-2:Speed versus distance

The total length of trip is divided into five linear sections in the next step.

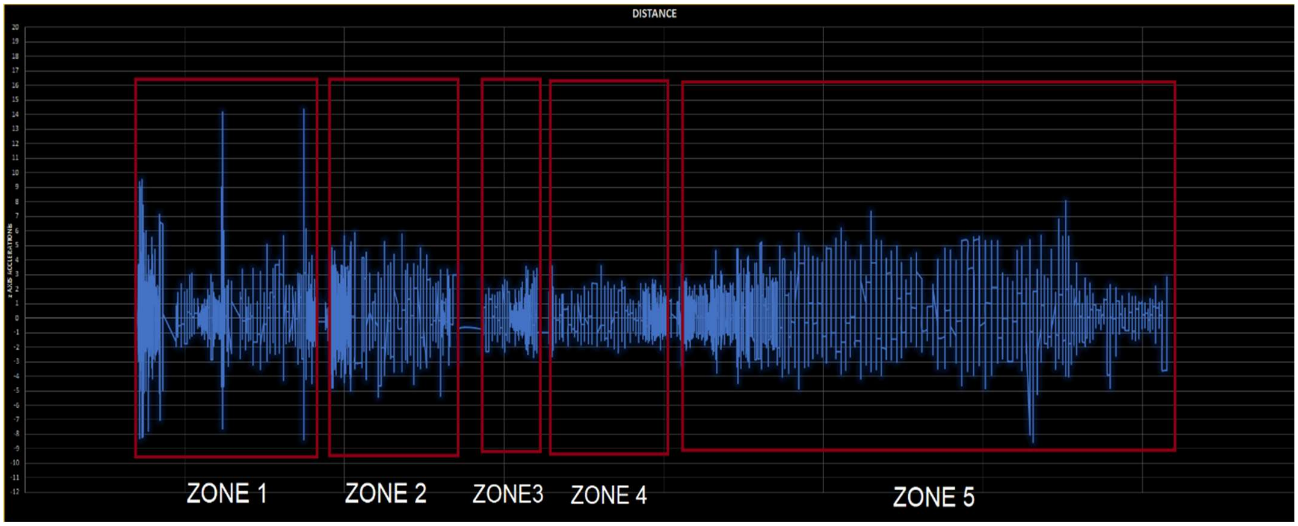


Figure 4-3: Dividing the graph into five zones

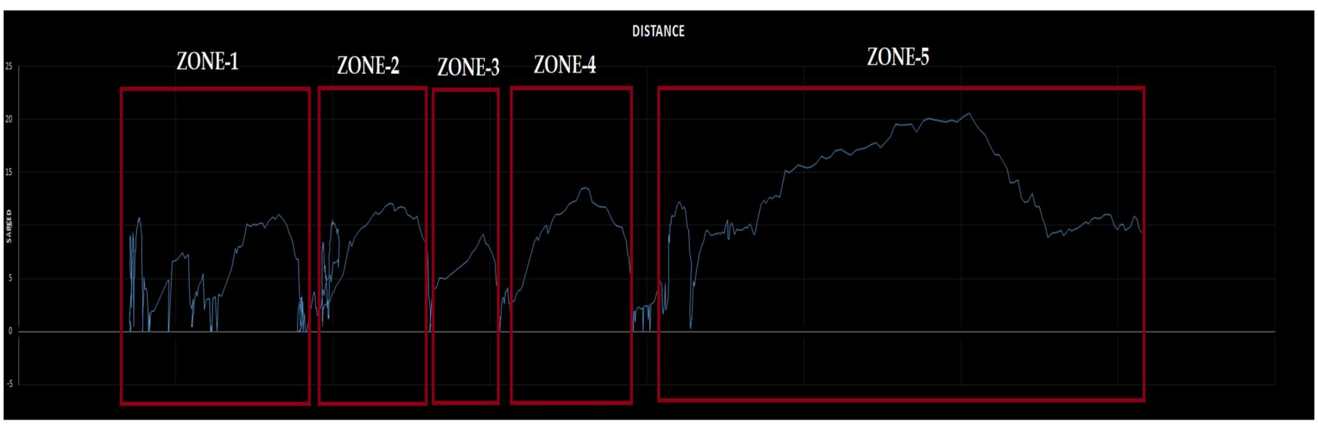


Figure 4-4:Zone-wise segment of the graph

In a Nutshell, we collected the data through smartphones Then sorted out the data to plot the graph. After that we did several field surveys to justify the Graph and divided the routes into five zones for better understanding of the anomalies.

4.1.1 Zone 1

Zone 1 Started from Asad Gate and ended at Khamar bari Goal Chottor and the Distance was 950 meters. We came across two speed bumps in this zone and on average data collection for several days for this zone was the second highest congested area in our route. The reason behind the congestion is there are two bus stops at the start and end of this zone and because of this here the data is denser compared to other zones.

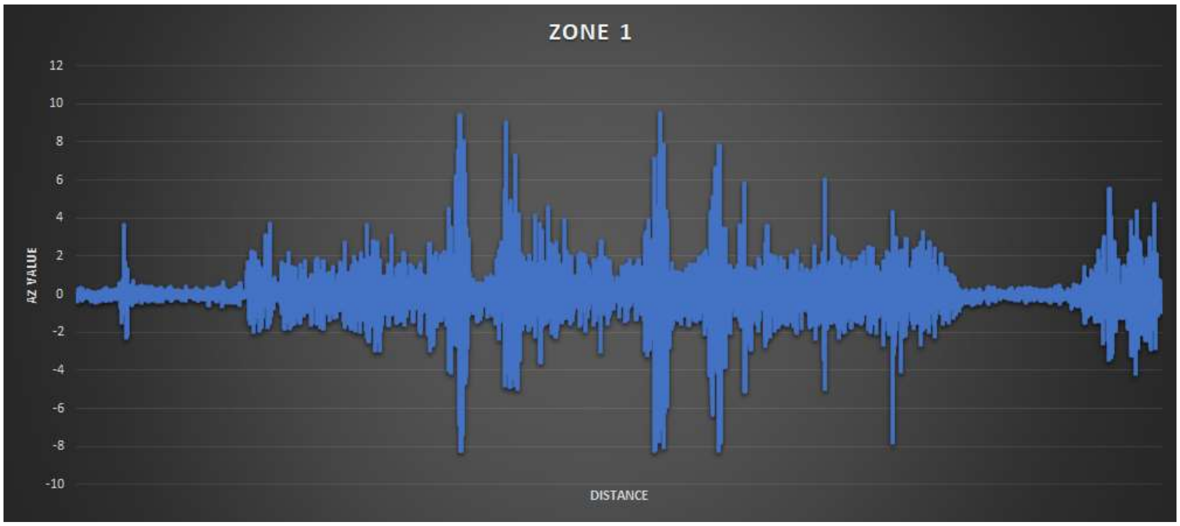


Figure 4-5:average Z axis acceleration versus distance for zone 1

Here we also have also found some peak value those are basically speed bumps that is justified by field survey

Figure 4-6: Speed-bump at Manik Mia Avenue

4.1.2 Zone 2

Zone 2 started from Khamarbari goal chottor to Bijoy shoroni circle and the distance is 600 meters. We came across a higher congestion at the starting of the zone due to bus stops.

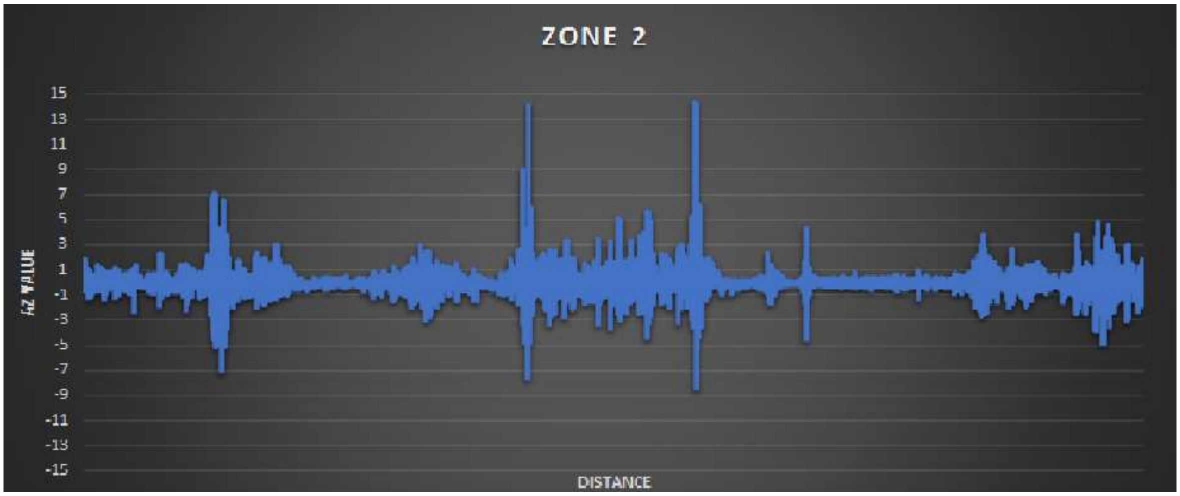


Figure 4-7:average Z axis acceleration versus distance for zone 2

Since there are no fixed bus stops at these areas and the bus stops at random that's why the congestion is significant in some areas. Besides that, other parts of the zone are regular.

Figure 4-8:Random congestion due to temporary stoppage

4.1.3 Zone 3

Zone 3 started from bijoy shoroni circle to bijoy shoroni and the distance is 650 meters.

Figure 4-9:average Z axis acceleration versus distance for zone 3

We didn’t find any significant or unique anomalies in this area rather this area was quite normal. However, we found high rise of congestion at Bijoy shoroni. Reason behind the congestion is this road is headed towards and being connected to the Dhaka-Mymensingh highway. Congestion can be found in this section through the day, turning to heavy congestion during peak hour such as office going time and office ending time. In regular travel period however, the traffic congestion is not as severe. But congestion can be seen almost throughout the day.

4.1.4 Zone 4

Zone 4 started from Bijoy shoroni to Jahangir gate and the distance is 1200 meters.

Figure 4-10:average Z axis acceleration versus distance for zone 4

This zone is by far the most congested Zone in the entire route. Reason behind the congestion is Jahangir gate is the connecting point of numerous roads. That's why here Traffic is significantly higher than any other roads.

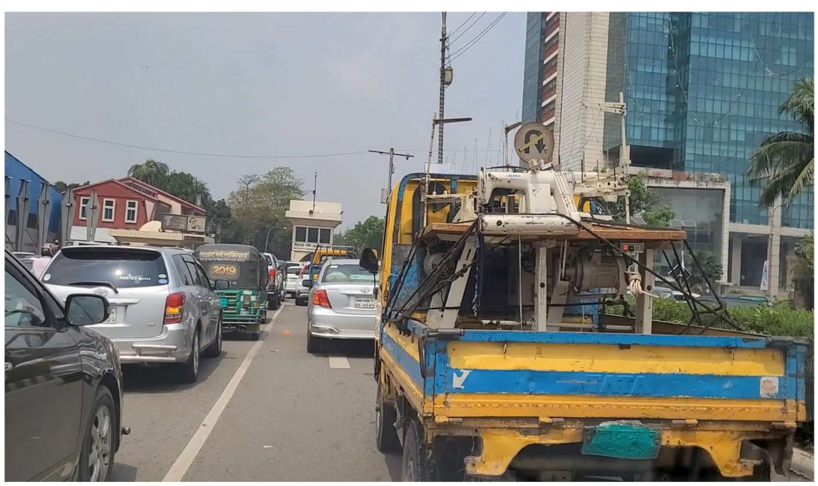


Figure 4-11:Congestion at Jahangir Gate

4.1.5 Zone 5

Zone 5 started from Jahangir gate to Shainik club and the distance is 2200 meters. This zone is the longest among all five zones.

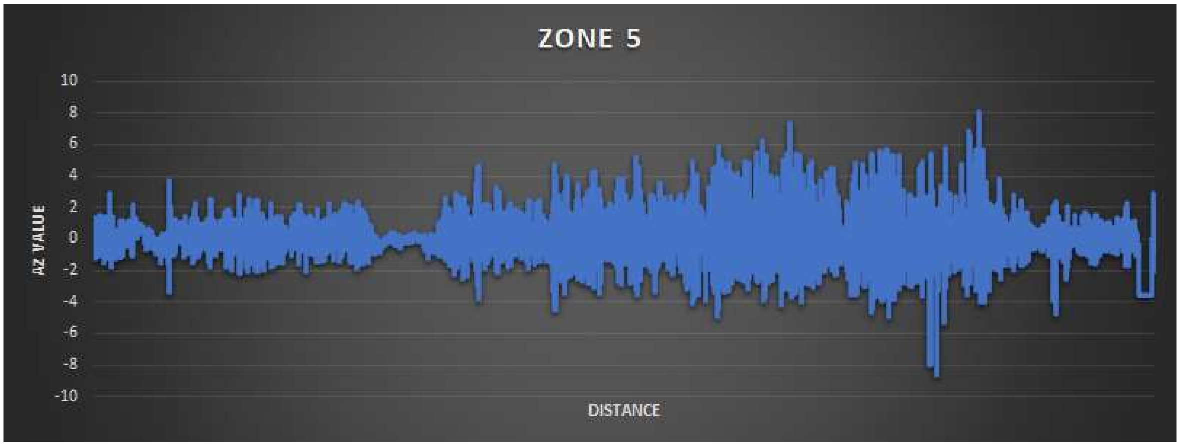


Figure 4-12:average Z axis acceleration versus distance for zone 5

In this zone we came across a flyover which is the Mohakhali flyover. We found consequential amount of congestion at the starting point of the flyover because not all vehicles go across the flyover. Some vehicles go across the road of the flyover and that is the reason behind the congestion.

Figure 4-13:Expansion Joints of Mohakhali Flyover

We also found several expansion joints at the flyover and lastly, we encountered a pothole at the end of the flyover.

Figure 4-14:Pothole After flyover before Shainik Club

4.2 Key Findings

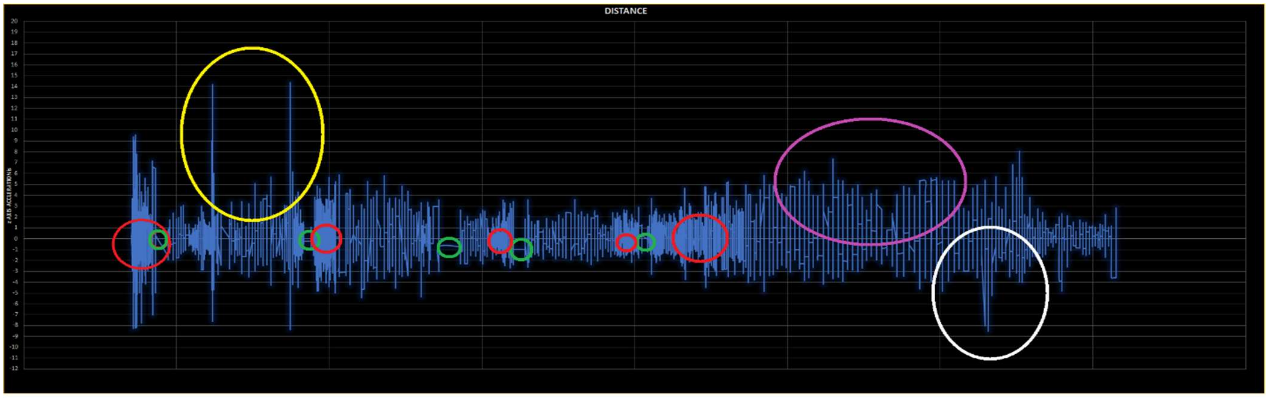


Figure 4-15:average Z axis acceleration versus distance

In the figure above (figure 4-15),

- **Red Circle** - congestion
- **Green Circle** - Turning Points
- **White Circle** - Pothole
- **Yellow Circle** - Speed bumps
- **Purple circle** - Expansion joints at flyover

Here Red circle indicates congestion which give us a clear view about the density of vehicles moving on that road. Green circles stand for turning points for which we get linear pattern on our graph

Here the white circle indicates the potholes that shows a sudden degradation on our analysis. Yellow circle shows the speed bumps which is due to the sudden jump of vehicle movements. Purple circle gives the idea about the pattern of expansion joints on flyover

Figure 4-16:average velocity versus distance

And in the figure 4-16,

- Green Circle-Turning Points
- Yellow Circle-Speed bumps

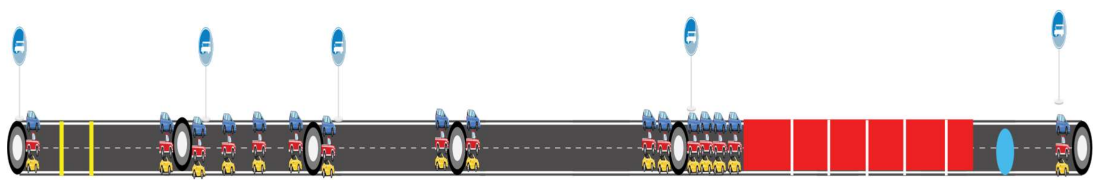
From the speed graph we can observe the fluctuations of speed at each zone.

If we look into it carefully then we can find that at the turning point the speed is gradually decreasing then increasing

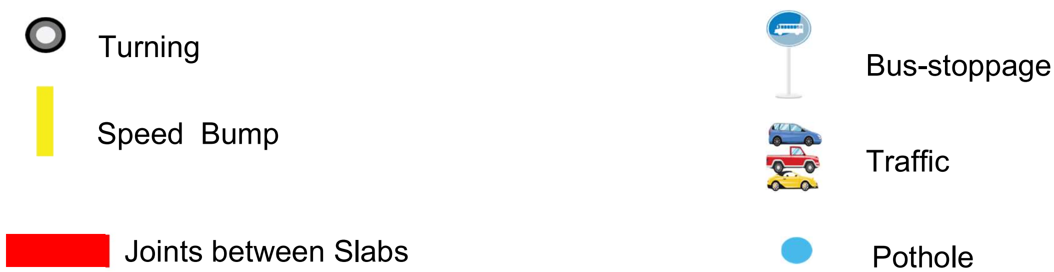
At turning points there may occur 2 things. One of the reasons is for banking angle and the other reason is there are no fixed bus stops at these areas and the bus stops at random that's why the congestion is significant in some areas.

At the starting point of the Mohakhali flyover there is a drastic change of speed and on throughout the trip the highest speed can be seen over the flyover.

4.3 Visual Statistical Observation



LEGENDS



This is the visual sketching of our whole route where we have represented the key finding after our analysis part. Here we have found turnings, speed bumps, Joints between slabs, bus-stoppage, traffic and pothole that we have determined from our collected data sets

4.4 3D Profiling

A 3D profile corresponding to the collected data and road condition is created in order to get a through visual understanding. 3D profile is an oriented contour in the three-dimensional space. A 3D profile is oriented based on the orientation of the elements used for defining the profile (a work plane, work surface, face or a set of edges) (Kondiparthi, 2013).

A 3D profile can be created based on a parametric 2D contour located on a work plane page. This allows propagating parametric properties of two-dimensional drawings into the realm of solid modeling. Sweeping a profile by any means in the space is the base operation for a solid body creation.

In a general case, a 3D profile is a sheet geometry element. For working convenience, profiles in the 3D scene are usually rendered as a wireframe, that this is a set of bounding lines (contours). However, one can set the 3D profile display mode is a sheet body.

3D profiles created from the elements of 2D drawings are widely used in creation of 3D models. To create a profile, one can use hatches, text and graphic entities located on work plane and work surface pages. When using a 2D element lying on a work plane page, the resulting 3D profile will be flat. A 3D profile created from a 2D element on a work plane will repeat the shape of the underlying surface (Mandapalli et al., 2019).

When creating 3D profile, its plane (surface) coincides with the work plane or a surface, whose page contains the originality

A flat 3D profile (can be repositioned in space. This can be done by using a 3D node through which the plane of the profile being created should pass. If that is not sufficient, one can refine the position of the 3D profile in space by specifying a 2D node, to which the selected 3D node should be snapped.

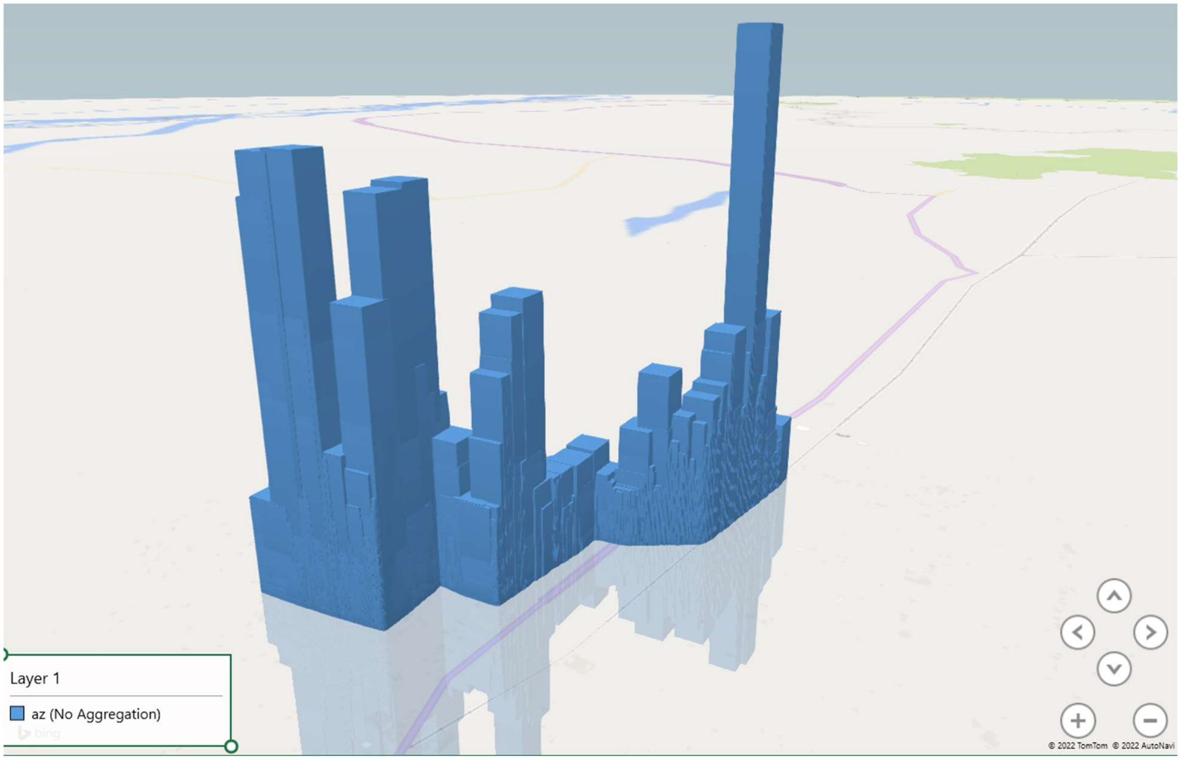


Figure 4-17: 3D representation of the route

These illustration shows the 3D profiling of the collected data of as value with no aggregation.

The image shows the vertical movement in a visual dimensional way which creates a clear image of the respective routs and helps to understand the distress profile more easily.

The image shows that the turbulence was quite consistent from Asad Gate bus stand to Khamarbari goal chottor. The az values were more from khamarbari to Bijoy Shoroni circle. And it became the highest while crossing the Mohakhali flyover. From our field survey we could also relate this profile with the actual scenario.

The 3D profiling can be illustrated by using other parameters, variables and dimension to understand the scenario with different perspectives.

Figure 4-18: 3D representation using average data

This is another perspective of the 3D profiling of our rout. This shows the profiling with aggregation.

This is as significant as the one with no aggregation in respect of better understanding the data turbulence and the fluctuation from the previous one. This also illustrate the corresponding values of our rout.

This one also shows how the as value is higher in the rout of Asad Gate to Khamarbari Gol Chottor. Also higher as value is observed on Mohakhali Flyover.

The 3D profiling also can be illustrated by the mean of minimum, maximum and average as values which will be helpful for better understanding the rout profile.

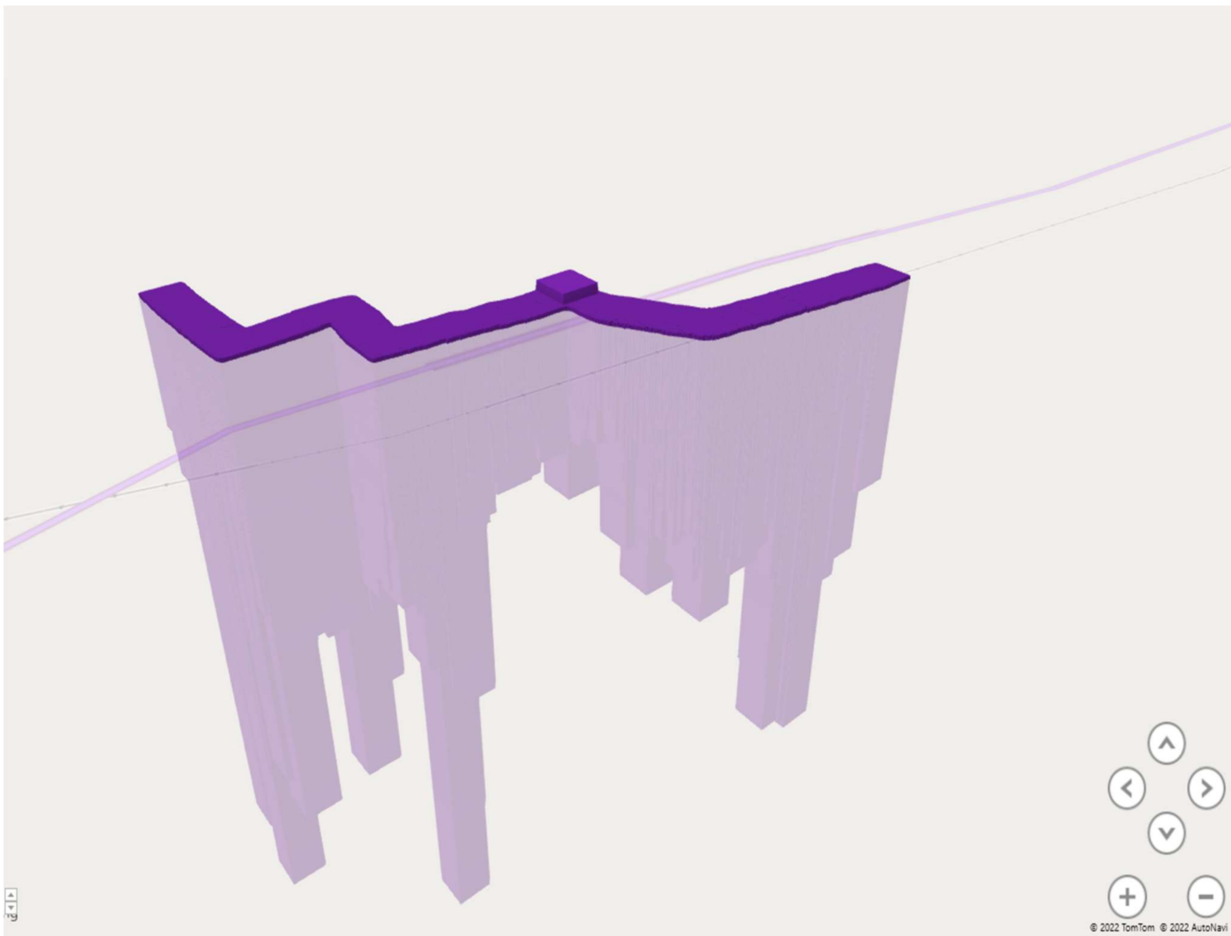


Figure 4-19: 3D representation of the reverse value

This 3D profiling illustration shows the compilation of minimum as values which makes it easier to better understand the corresponding comparison of as values of different rout and thus it helps to evaluate the rout in respect of distress and smoothness.

From the profiling it can be seen that the minimum as value is observed on the point of Jahangir Gate. This means that the fluctuation is lower there and it got smoothness.

As the minimum value compilation, another 3D profile can be plotted by using the maximum as values.

Figure 4-20: 3D representation using maximum value

This 3D profile is illustrated by using the maximum as values of corresponding routs which makes it easier to understand and observe the maximum turbulence and data fluctuation of the rout.

From this image it can be seen that the highest as data are concentrated mainly from Asad Gate to Khamarbari Gol Chottor and also on the rout of Mohakhali flyover.

As we got the minimum values and maximum values, it is also possible calculate average as data and also a 3D profile can be plotted.

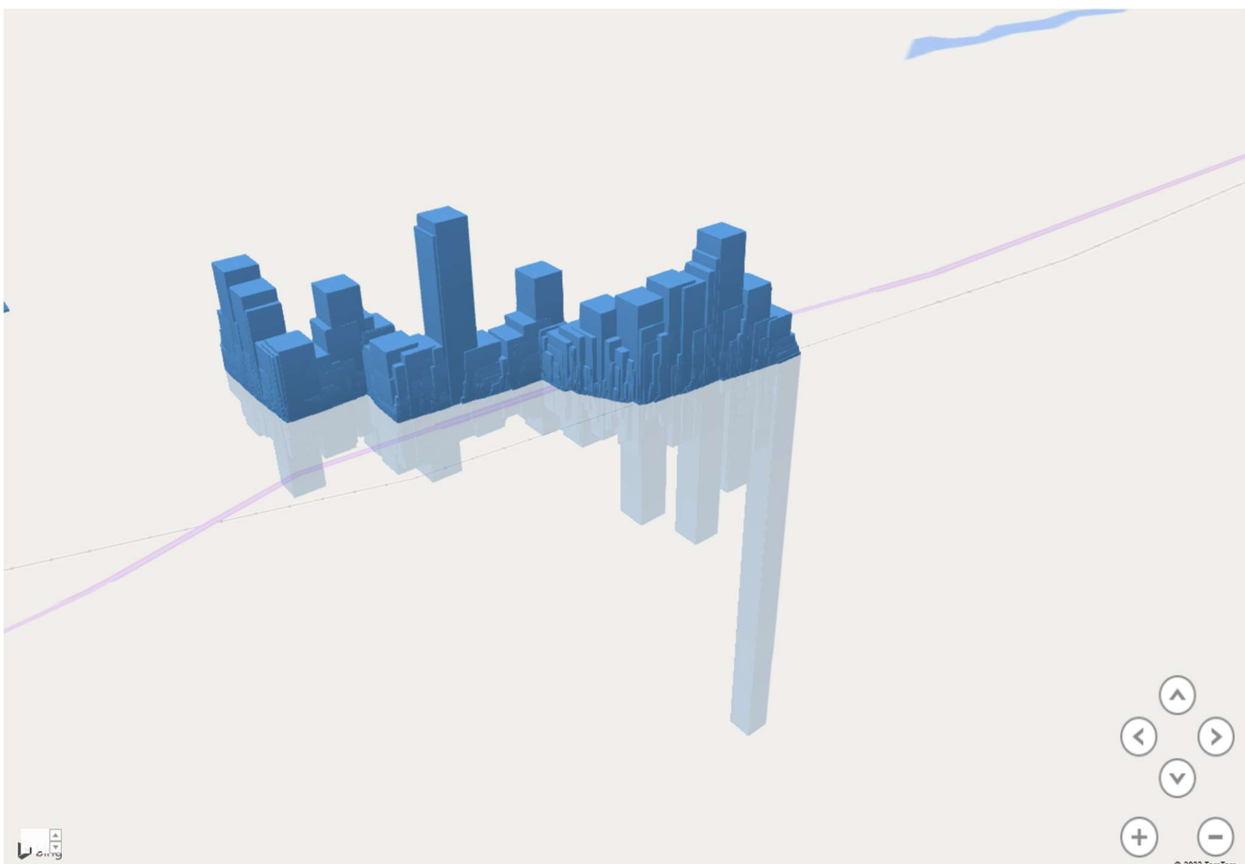


Figure 4-21: 3D representation with no aggregation

This one is illustrated by using the average as values which are extracted from the maximum as values and minimum as values of corresponding locations.

This one help to illustrate a moderate average image of vertical turbulence of the rout. From the average data compilation, it can be said that the rout is moderately smooth and goy least vertical distress than other problematic routs.

So, all this 3D profile helped us to understand the rout in a easy way and also helped us to evaluate the rout.

4.5 Standard Deviation

For any kind of data analysis research, it is important to rate the fluctuation of the collected data. Also, some mathematical analysis is needed to get the relevant information through the data set. As a part of our mathematical analysis, we conducted out standard deviation calculation to better understand the fluctuation of our collected data set.

Standard deviation is a statistic that calculates the fluctuation and dispersion of a data set related to its mean value and is calculated as the square root of the variance (Rouaud, 2013). The standard deviation is calculated by determining each data point's deviation related the mean value.

For understanding the Fluctuation measurement, if the result of standard deviation is high, then the deviation value will be larger too. If the standard deviation is smaller, that means the fluctuation of the data set from the mean value is quite negligible.

$$s = \sqrt{\frac{\Sigma\,(X - \bar{x})^2}{n-1}}$$

We have calculated the standard deviation of our as values by using the above formula where x is the corresponding as values, $\overline{x}$ is the mean as value, n is the number of our data set.

In our case standard deviation was needed to know the fluctuation of our collected data. It would also help us to know if the speed of the vehicles were fluctuating or not which indicates if different types of vehicles or same type of vehicles were used to collect the data. It also indicates if the traffic condition was avoidable and unavoidable. This kind of indicators help us to illustrate a relevant distress pattern and will help us to know if the traffic condition was avoidable or manmade. That also leads us to state the result of our study and evaluate the distress pattern.

STANDARD DEVIATION

Table 4-1:Zone wise standard deviation

ZONE	MEAN	STD.DEVATION
ZONE-1	0.016108	1.411927811
ZONE-2	0.006429	1.141665392
ZONE-3	0.00101	1.081123327
ZONE-4	0.036503	0.973026886
ZONE-5	0.057743	1.513998244

The table 3-2 show the standard deviation and mean of the zone-wise data of the route. From our mathematical calculation we got our result value of standard deviation **1.242039** of the whole route which is a very small value.

As we said before the greater the value is, the more fluctuation from the mean value. And the smaller the value is, the less the fluctuation from the mean value.

As we got a very small value, we can say that our data fluctuated very little. And this fluctuation rate will help us to take many mathematical and analytical decision regarding to the road distress study.

Let us check those decisions.

As the value of standard deviation is smaller, the fluctuation from mean value is small.

Lower rate of fluctuation indicates that the data were collected by using quite same type of vehicle. And it actually was. We have collected our data by using local bus mostly. If we collected our data by using different vehicles, there was a chance to get larger fluctuation value or standard deviation.

Also, this value indicates that the speed of the vehicles was quite consistent. That also indicates using same type of vehicle or facing same type of traffic conditions regularly.

It also indicates if the traffic condition was avoidable or unavoidable. If the value was larger, we could say that at different times the vehicles are behaving differently, which indicates that some of the vehicles are stopping for no reason and some are going smooth. This kind of phenomena happens when the traffic congestion condition is avoidable.

If the fluctuation rate is low, then it can be said that all the vehicles are behaving the same in the same congestion phenomena. That means that all the vehicles are obliged to stop or move slowly in same conditions. Which indicates that the traffic condition is unavoidable.

And as we got small standard deviation value, that means that the different kind of vehicles used for data collection were facing same type of congestions which are unavoidable.

So, the standard deviation helped us to know the data collection vehicle priority and also evaluate the distress pattern if they were avoidable or unavoidable and if they were geographic condition or traffic condition.

Chapter 5: CONCLUSION AND FUTURE SCOPE

5.1 Conclusion

Vertical Acceleration data has been collected and analyzed in this study and incorporated with visual statistics to identify the road distress and traffic condition. The sorting of data shows the patterns of the road distress and these relates the current condition and quality of the road. The visual correlation also shows the accuracy of the smartphone app which can evaluate the acceptability of such apps and sensors used in such studies. The field analysis also helped to ensure the accuracy of the methodology used for this study. Software and direct man force both were used to ensure the acceptability of the study.

Also, mathematical analysis and data analysis were conducted to measure the fluctuation of the data sorting process. Standard deviation was used to measure the fluctuation of the speed of different vehicles during the study which shows the accuracy of data collection process.

Data sorting and analysis and graphical or mathematical pattern or deviation also shows the different reasons of road distress. It helps to distinguish between the traffic condition and geographical condition. Which later may indicate that which conditions are avoidable and which are unavoidable.

After all these sorting and analyzing we got an illustration of the road condition. This shows where the vehicle is facing congestion, where it is facing vertical movement, or altogether where it is facing road distress and how.

Thus, this study can help to take necessary steps to reduce the distress of avoidable conditions. Also, as it detects the traffic condition, it may help in taking necessary steps in designing a congestion free road pattern and making necessary traffic rules for that specific road.

All these things can be detected by using only a smart phone application and some simple sensors. So, anyone can easily measure the road distress. Thus, it can become a handy solution of regular road distress evaluation and observation process.

This is a probable solution to minimize the cost of road distress study as a part of maintenance of the road. Also, it ensures least man power. So, this may estimate as the easiest road distress evaluation process with low cost, least man power and for a hassle-free data collection process.

This analyze can be very useful in road maintenance, traffic safety and good riding experience.

5.2 Future Scopes

The current road distress situation of Bangladesh shows the necessity of regular road evaluation and maintenance. The daily growing vehicle number, insufficient road network, funding limitations and many other obstacles have created the prioritization of regular road distress evaluation.

Road distress and roughness data is one of the key factors for maintenance planning. Road maintenance process needs data, distress pattern and the overall traffic condition assessment which may be achieved by using these sensors and smartphone apps. Thus, it may not only save large amount of money but it will also make easier the data collection process.

Though the app is fair enough, there are some other scopes for making this kind of study more fruitful, accurate and self-sufficient.

Incorporation of Artificial Intelligence and Machine Learning process may boost up the overall process for remote road condition observation and maintenance. It will also ensure the accuracy and reduce the rate of fluctuation from actual data.

IOT based automotive sensing may also be incorporated in this kind of study to maintain the consistency and accuracy of data sorting and collection process.

Traffic Control in feasible way using Smartphone Sensors may also be included. This may ensure the acceptability of the output of traffic distress measurement and rule maintenance process.

There also scopes for Cost effective methods road maintenance, sustainable road construction and repair works. Several study may conduct to ensure more cost effective and energy saving evaluation process.

Scopes of using other handy and accurate software is always there. We have only used some of them. Many other of them may give more accurate output.

Also, there are scopes for understanding the distress pattern by those excel graphs and direct field studies. Corona situation hampered the direct data collection process which could have been more enriched by collecting more sets of data. So, there is always scope for better work.

So more consistent data collection and more accurate sorting process may be recommended.

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