Identification of Road Distress and Traffic Condition Through Smartphone

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Abstract.

One of the most serious issues in developing countries is road maintenance. Every year thousands of people lose lives 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 labour is always ideal for road distress assessment study. 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 on.

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

1 . Introduction

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 in 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 -

- Geometric Condition of the road
- Traffic Condition of the road

A cost-effective system with an acceptable level of accuracy & and with the least manpower is always preferable for research work for road distress assessment (Uzaktan et al., 2020). Smartphone provides all of them through different types of sensors. Expenses in manpower have totally been minimized. Establishing a pattern of road distress through adequate datasets using the 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 the road will be stated. We can tell where the bumps and potholes are and other anomalies. So, it is totally unnecessary to go to the road and conduct a 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 highly benefit from this study. The datasets are collected from moving vehicles. Then after analyzing the datasets, road distresses are shown through graphs which clearly indicate the inclination and degradation.

1.1 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 types of accidents. In fact, every year thousands of people lose their lives on roads in road accidents that occur due to damaged roads (*ITF Transport Outlook 2021*, 2021). A huge amount of money is spent by the government in this field. A cost-effective, timesaving, efficient, and sustainable solution to this issue can be the use of Smartphones. Road distress and traffic conditions 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 vehicles that are used for further analysis. After analyzing the datasets, road distress can be measured. This gives us a clear concept of the geometric and traffic condition of a specific road.

Potholes, bumps, and defects in 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 cost but also minimizes the necessity of a huge amount of manpower (Bills et al., 2014). This also eases the process of making the budget for development work. Besides, proper maintenance of roads can pave the way for reducing untimely deaths and give us a great scenario of sustainable road development.

Objective of the Study

The following are the study's objectives:

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

1.2 Literature Review

Janani et al. (2020) collected and used Smartphone accelerometer data, and 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. The 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.

Thiandee et al. (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 the ML method gives better result than RMS.

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

Mohammed (2015) studied Pavement Performance measures using Android-based smartphone application. The goal of this study was to investigate pavement roughness using android-based smartphone technology for improving overall performance. Data were collected using a 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.

Li and Goldberg (2018) used mobile crowd-sensing system for road surface assessment. The methodology of this study includes a built-in GPS receiver, accelerometer in smartphones, 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 smartphone data-collecting equipment and a web-based data server component (Li & Goldberg, 2018).

Another study was conducted by Staniek (2018) on Road pavement condition diagnostics using smartphone-based data crowdsourcing in smart cities. The goal of his 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).

Yeganeh et al. (2019) conducted their study on validation of smartphone-based pavement Roughness measures (Yeganeh et al., 2019). 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.

Huda, et al. (2020) analyzed road damage (RODA) by using Built-in Accelerometer Sensor in Smartphone (Huda et al., 2020).

2 Methodology

This research was conducted in 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 occupying a specific distance. As a result, they collected fair enough data and later evaluated the damage. From all these studies and research, we can see that all the researchers were coming up with new methodologies and new software-based research methods for the sake of using mobiles for road quality evaluation purposes.

Road quality evaluation was always a top priority in the road management system and making it a handy and cost-efficient process was always a try. So, all this research was conducted to modify the use of smartphones, 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 scope for new researchers to conduct new research based on smartphones.

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, the 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 an accelerometer, GPS, and gyroscope from the factory. Different pre-developed applications can be found which are suitable for this work. The application used is called Physics Toolbox Suite. It is free-to-use software and can be easily downloaded from the Google Play Store. The transportation methods for data collection work are limited to public transportation or bus services. It is to replicate the natural scenario as closely as possible as most of the people of Bangladesh commute using public buses. Only one mode of transportation is used to keep errors as minimal as possible. The position of the smartphone which is used for data collection work can also create errors. So, the position is kept similar, which is in the passenger’s pocket. It eliminates hand movement from the passenger and the natural action of the human body to minimize the jerking caused by the bus. Several field surveys are done to observe the condition of the route. Videos of the whole route were taken, and photographs of the different road conditions were taken. During a trip for data collection, the video was taken simultaneously with the data so that the findings of this work could be established more accurately. This study regulates observational data instead of statistical or mathematical models.

So, the collected data is comprehended, and a correlation is established with the observational data. 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.

2.1 Workflow Diagram

The following workflow diagram is followed in this research work.

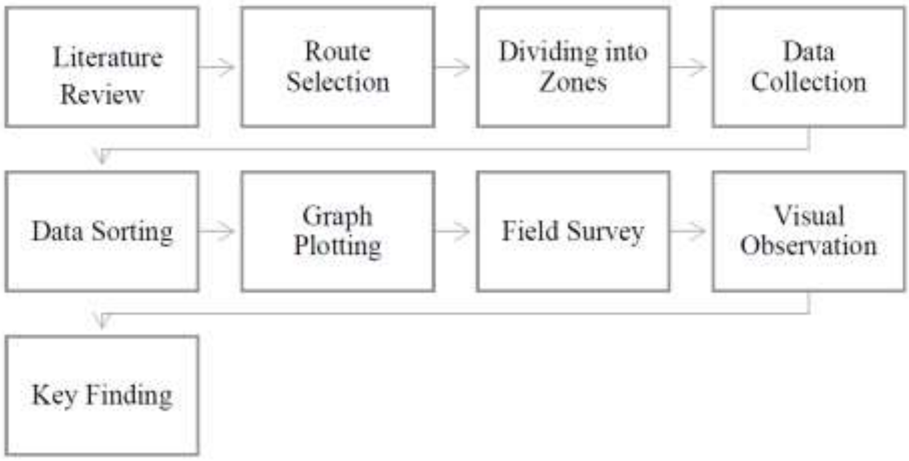

Figure 1: Workflow diagram

2.2 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 Shoroni and finally through Jahangir gate to Shainik club using Mohakhali flyover. The section of the 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, the 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.

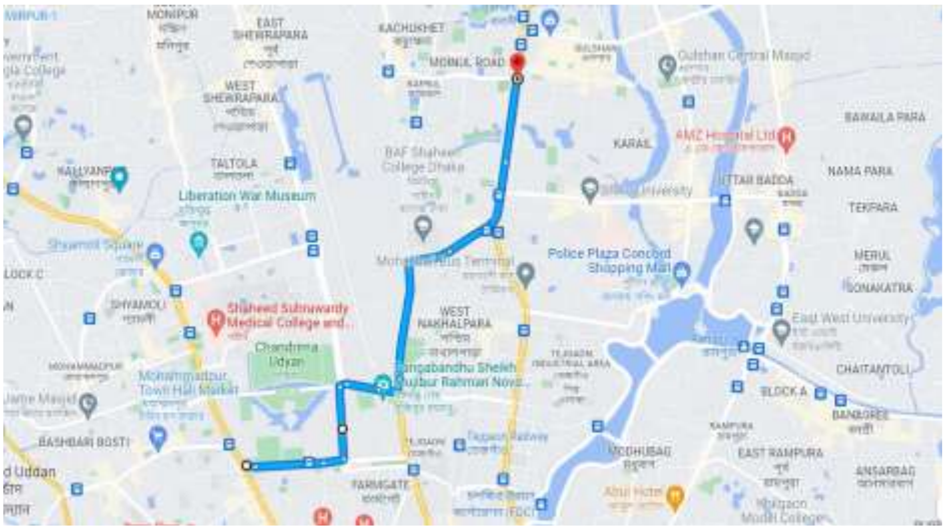

Figure 2: data collection route

The entire route is divided into five sections of road. The sectional division is done by separating the linear stretch of the road into each section. It is done 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 errors in data of other parameters. So, the route is divided into linear segments. It also helps to organize the data while analyzing.

. 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

2.3 Data Collection

Data collection work consists of 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, the velocity of the vehicles, and time.

All this data can be obtained from smartphones as the modern smartphone is packed with various sensors such as accelerometers, gyroscopes, GPS, camera sensors, etc. However, these sensors cannot be accessed easily.

To access the mobile sensors, a mobile application is used. For data collection, various pre-developed applications can be found. The application used in 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 are very minimal. 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 of the data collection process.

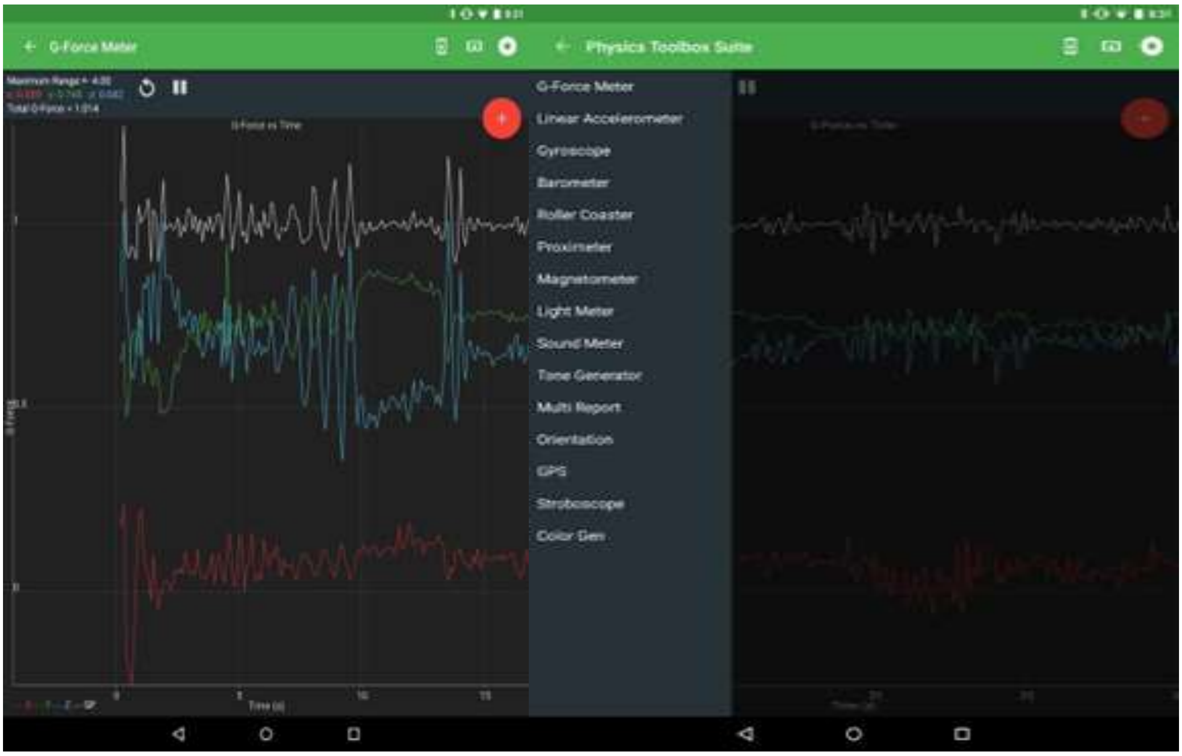

Figure 3 : App Interface

The app collected real-time data of vertical and horizontal acceleration in the three axes as well as GPS coordination 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 of each unique coordination point. The sample data set is represented by the following figure.

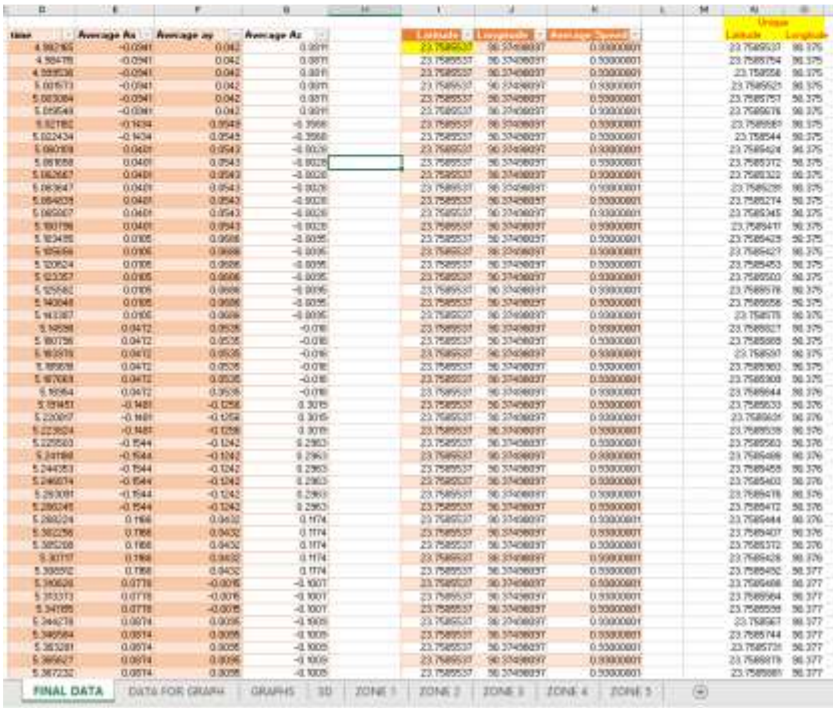

Figure 4 : Sample Data Table

3 Analysis & Key Findings

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

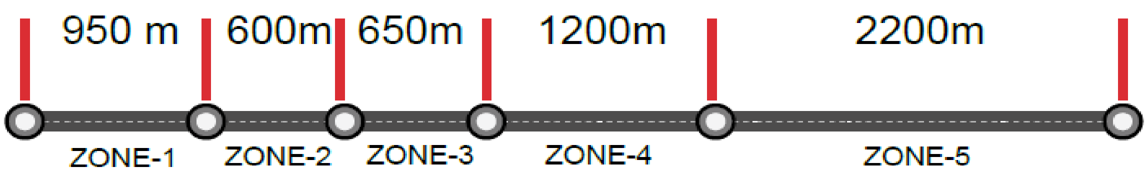

Figure 5: Division of routes

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 conditions. For better understanding and precise results, we used the speed graphs as well.

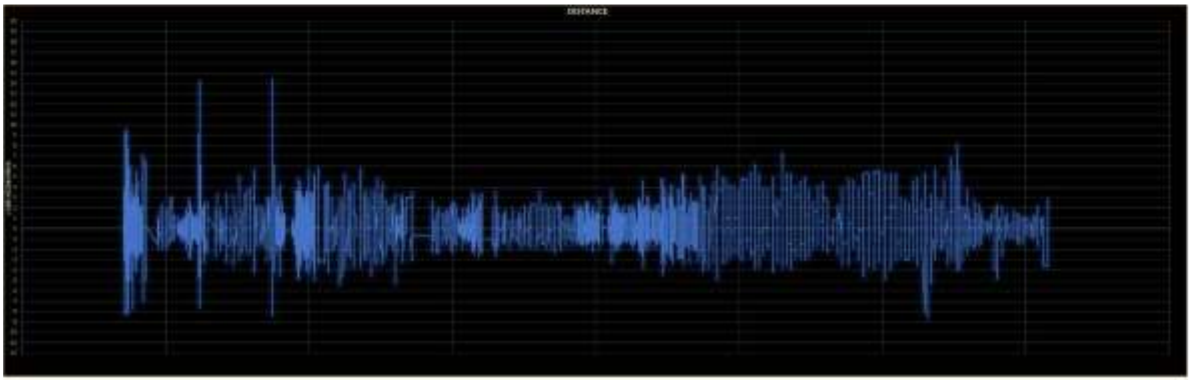

Figure 6: Average Z axis acceleration vs. distance

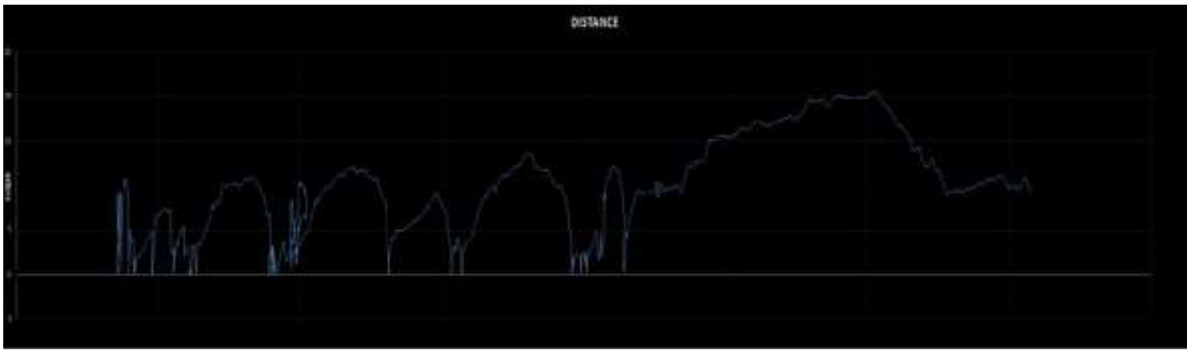

Figure 7: Speed vs. Distance

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

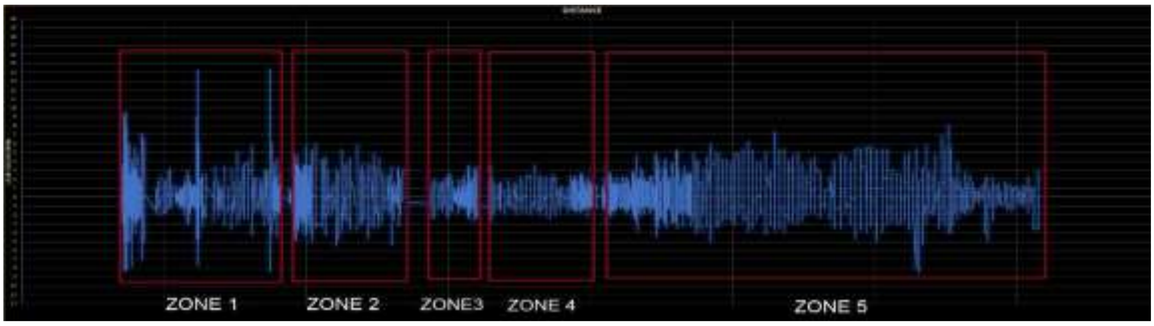

Figure 8: Dividing graph into five zones

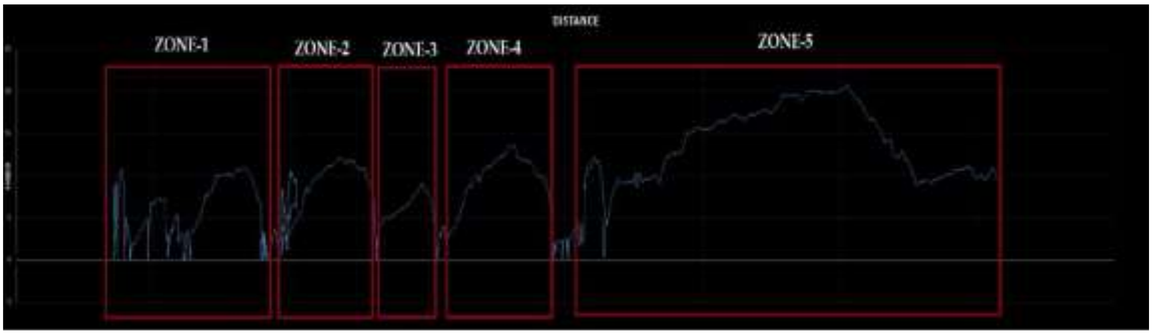

Figure 9: Zone-wise segment of the graph

In a Nutshell, we collected the data through smartphones and 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 a better understanding of the anomalies.

Comprehensive Analysis:

Individual Zone serves as a focal point in our study, representing a specific geographic segment within the surveyed area. Our comprehensive analysis of different zones aims to delve deeply into various aspects, shedding light on distinctive features and patterns, ultimately contributing to a nuanced understanding of road distress and traffic conditions.

Traffic Flow and Congestion:

Within individual Zones, we meticulously examined the dynamics of traffic flow and congestion. By closely analyzing data points related to vehicle speed, acceleration, and deceleration, we gained insights into the patterns that contribute to congestion. This information is crucial for devising strategies aimed at optimizing traffic flow and reducing congestion-related road distress.

Vertical Acceleration Patterns:

One key focus of our analysis in individual zones was the vertical acceleration patterns of vehicles. Understanding how vehicles respond to road irregularities, bumps, or potholes provides valuable data for assessing road distress. Our findings in this area contribute to a better comprehension of the impact of road conditions on vehicle behavior.

Comprehensive analysis involves considering external factors that may influence road distress. We scrutinized environmental variables such as signage, and road surface quality. These factors play a significant role in understanding the broader context of road distress and traffic conditions.

Anomalies and Outliers:

Our analysis involved the identification of anomalies and outliers in the collected data. These instances, whether related to sudden accelerations, decelerations, or irregular traffic patterns, were thoroughly investigated. Pinpointing these anomalies aids in recognizing potential areas of concern and implementing targeted solutions.

By providing a comprehensive analysis of different zones, we aim to offer a detailed understanding of the intricate interplay between various factors influencing road distress and traffic conditions. This knowledge forms the basis for informed decision-making and the development of effective strategies for road maintenance and safety enhancement.

3.1 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, the data is denser compared to other zones.

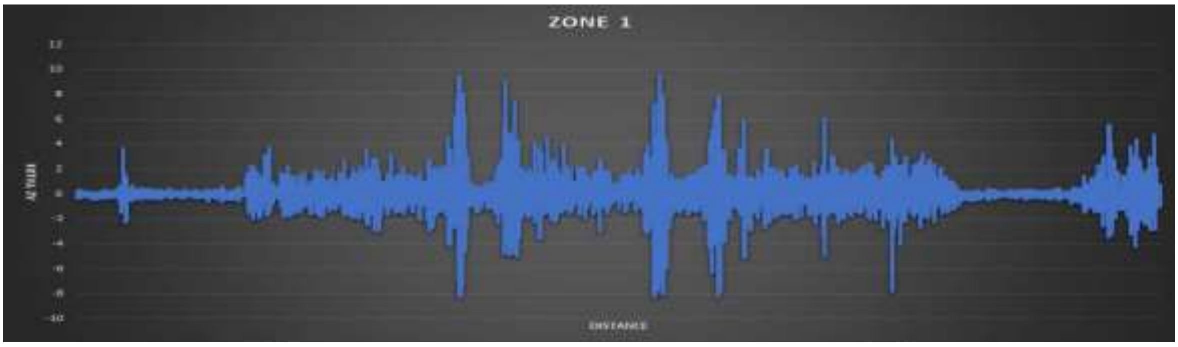

Figure 10: Average Z axis acceleration vs. distance for zone 1

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

Figure 11: Speed-bump at Manik Mia Avenue

3.2 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 start of the zone due to bus stops.

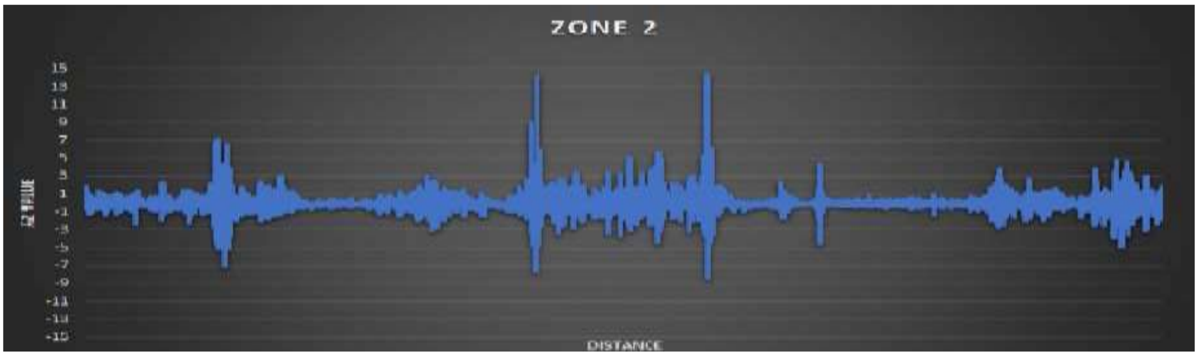

Figure 12: Average Z axis acceleration vs. distance for zone 2

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

Figure 13: Random congestion due to temporary stoppage

3.3 Zone 3

Zone 3 started from Bijoy Shoroni circle to Bijoy Shoroni and the distance is 650 meters.

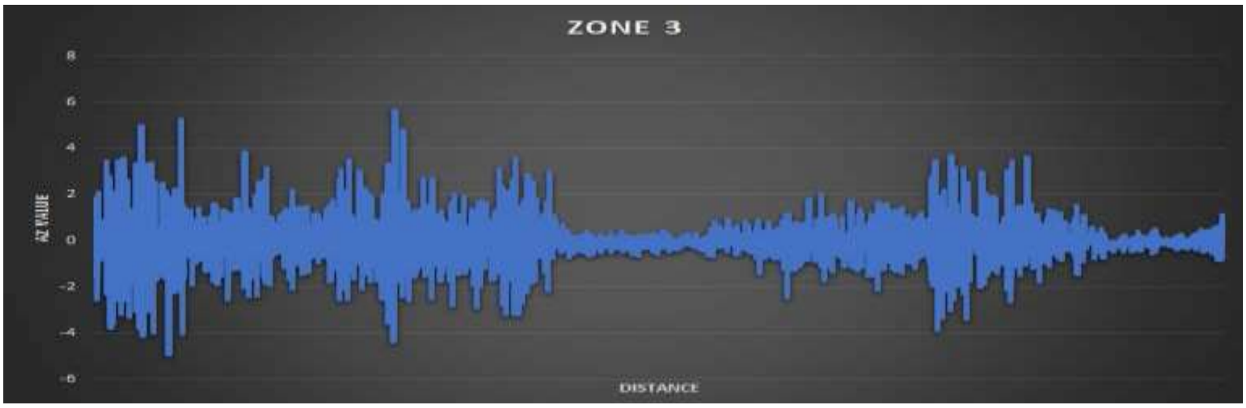

Figure 14: Average Z axis acceleration vs. distance for zone 3

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

3.4 Zone 4

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

Figure 15: Average Z axis acceleration vs. distance for zone 4

This zone is by far the most congested Zone in the entire route. The 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 16: Congestion at Jahangir Gate

3.5 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 17: Average Z axis acceleration vs. 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 18: Expansion joints at Mohakhali flyover

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

Figure 19: Pothole after flyover before Shainik Club

4 Key Findings

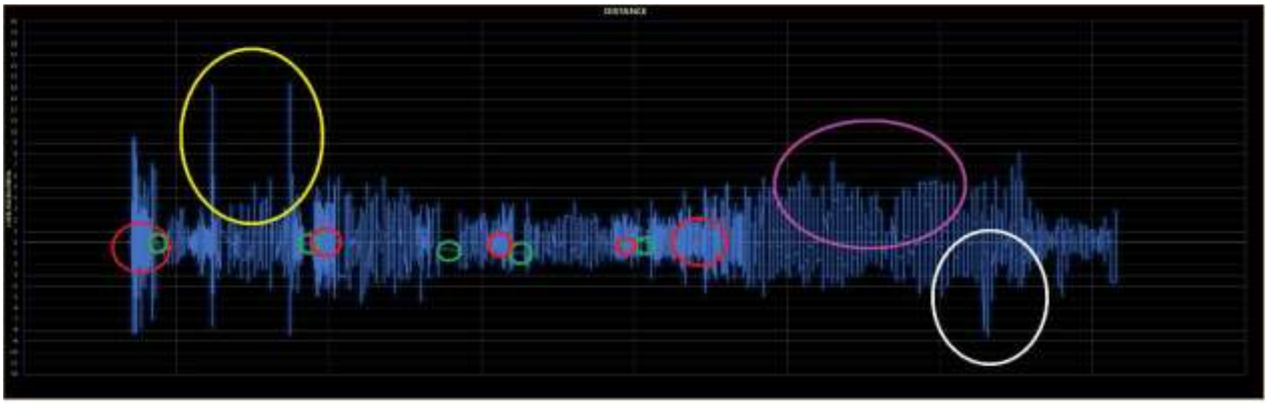

Figure 20: Average Z axis acceleration vs. distance

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 gives 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 show a sudden degradation in our analysis. The yellow circle shows the speed bumps which are due to the sudden jump of vehicle movements. The purple circle gives the idea about the pattern of expansion joints on the flyover.

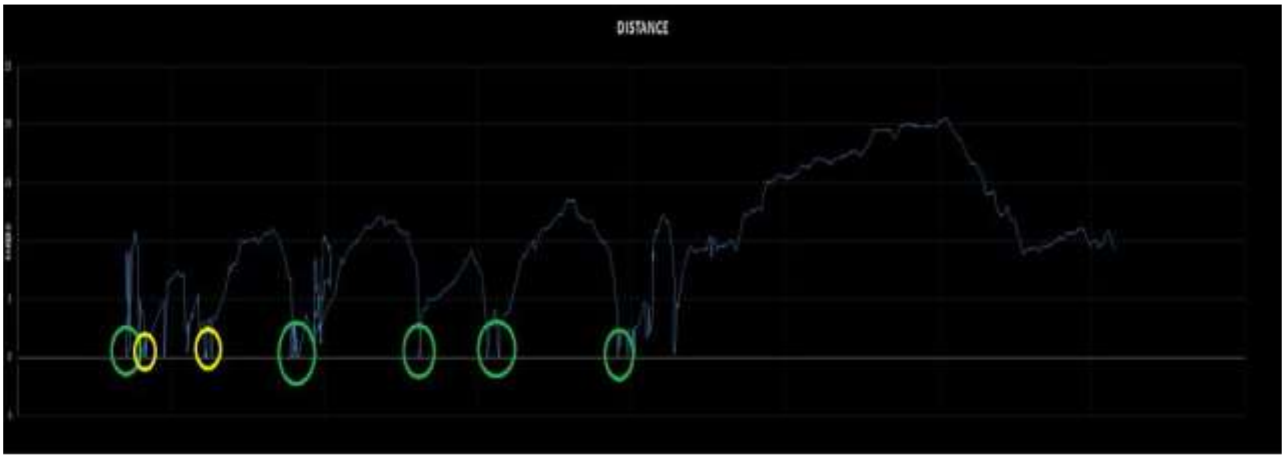

Figure 21: Average velocity vs. distance

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 in each zone.

If we investigate 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 the banking angle and the other reason is there are no fixed bus stops in 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 in speed and throughout the trip, the highest speed can be seen over the flyover.

5 Visual Static Observation

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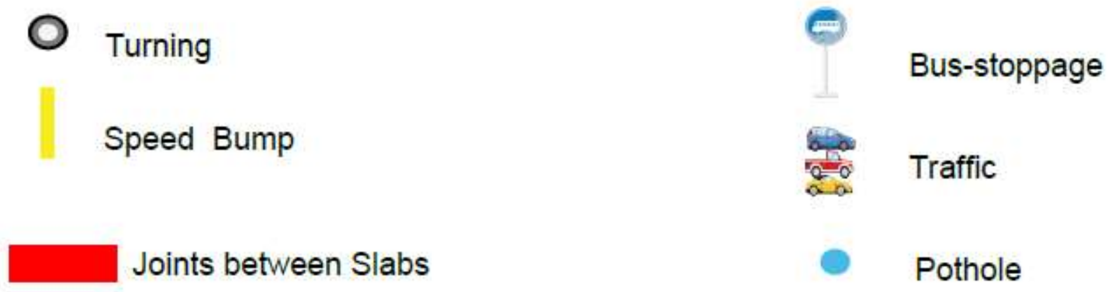

This is the visual sketching of our whole route where we have represented the key finding after our analysis part. Here we have found turnings, speed bumps, Joints between slabs, bus-stoppage, traffic, and pothole that we have determined from our collected data sets Standard Deviation

1.Turnings:
In the visual sketch, turning are identified points where the direction of the road changes significantly. The application of Standard Deviation in this context involves measuring the variation in vehicle movement at these turnings. A higher Standard Deviation may indicate more pronounced fluctuations in speed or acceleration, highlighting potential areas of interest such as sharp turns or intersections.

2. Speed Bumps:
Standard Deviation is employed to assess the consistency of speed data. In the context of speed bumps, areas with a notable increase in Standard Deviation may indicate irregularities in vehicle speed, suggesting the presence of speed bumps. These deviations from the average speed serve as indicators of road features affecting vehicle movement.

3. Joints Between Slabs:
Joints between slabs in the road surface can be detected through variations in vertical acceleration. Standard Deviation is applied to the vertical acceleration data to identify points where the road surface changes, indicating joints between slabs. Higher Standard Deviation values in these areas signify.

4. Bus Stoppage:
Bus stops are discerned by analyzing patterns in speed and acceleration data. Standard Deviation helps identify anomalies in vehicle behavior, such as sudden stops or variations in speed that coincide with bus stop locations. These deviations serve as markers for the presence of bus stops along the route.

5. Traffic Congestion:
Using Standard Deviation in speed data, areas with unusually high deviations can be indicative of traffic congestion. Peaks in Standard Deviation highlight segments where vehicles experience fluctuations in speed, suggesting the presence of congestion or slower traffic flow.

6. Potholes:
Potholes are identified through irregularities in vertical acceleration data. Standard Deviation is employed to pinpoint areas with significant variations in vertical movement, indicating potential pothole locations. Higher Standard Deviation values in these areas signal the likelihood of road distress in the form of potholes.

In summary, the application of Standard Deviation across various parameters in the visual sketch enhances the precision of identifying key features along the route. By examining deviations from the norm, we can pinpoint specific elements such as turnings, speed bumps, joints between slabs, bus stoppages, traffic congestion, and potholes, providing a nuanced understanding of road conditions and contributing to effective road maintenance strategies.

5.1 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 standard deviation calculations 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.

The standard deviation is calculated by determining each data point's deviation related to the mean value.

For understanding the Fluctuation measurement, if the result of the 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 us as values by using the above formula where x is the corresponding as value, $\bar{x}$ is the mean value, and 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 was fluctuating or not, which indicates if different types of vehicles or the same type of vehicles were used to collect the data. It also

indicates if the traffic condition was avoidable and unavoidable. This kind of indicator 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.

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

From our mathematical calculation we got our result value of standard deviation **1.242039** 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.

6 Conclusion

Vertical acceleration data has been meticulously collected and analyzed in this study, seamlessly integrated with visual statistics to unveil patterns indicative of road distress and traffic conditions. The careful sorting of data not only reveals the current state and quality of the road but also underscores the robustness of the methodology employed. The visual correlation adds another layer of assurance, showcasing the accuracy of the smartphone app and the sensors pivotal to studies of this nature. A comprehensive field analysis, leveraging both software algorithms and direct human involvement, further validates the acceptability and reliability of the study.

The inclusion of mathematical analysis and data scrutiny has allowed for a nuanced understanding of the fluctuations inherent in the data sorting process. The use of standard deviation to gauge the speed variations among different vehicles during the study serves as a tangible indicator of the precision of the data collection process.

The amalgamation of data sorting, analysis, and the elucidation of graphical or mathematical patterns brings to light the multifaceted reasons behind road distress. This discernment becomes instrumental in distinguishing between traffic and geographical conditions, providing insights into which challenges are avoidable and which are inevitable.

Through meticulous sorting and analysis, this study offers a vivid illustration of the road's condition. It pinpoints areas where vehicles encounter congestion, experience vertical movement, or altogether face road distress. Consequently, the findings pave the way for informed decision-making and proactive measures to alleviate avoidable distress conditions. Moreover, the study's ability to detect traffic conditions opens avenues for designing congestion-free road patterns and formulating pertinent traffic regulations.

Notably, the reliance solely on a smartphone application and basic sensors renders this road distress evaluation process not only accessible but also a practical solution. It emerges as a cost-effective and user-friendly approach, minimizing the financial burden associated with road distress studies and demanding minimal human resources. The ease and efficiency of this analysis make it an asset in the realms of road maintenance, traffic safety, and overall improvement in the quality of road travel. experience.

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