Cartography M.Sc.

Master's Thesis

Geovisualization and processing of mobility data to identify impact factors on mobility patterns

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Statement of Authorship

Herewith I declare that I am the sole author of the submitted Master's thesis entitled:

"Geovisualization and processing of mobility data to identify impact factors on mobility patterns"

I have fully referenced the ideas and work of others, whether published or unpublished. Literal or analogous citations are clearly marked as such.

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Abstract

Geovisualization represents the emerging technique to visualize the geographic data/information interactively. Through the integration of mobility data and geovisualization techniques, this thesis aims to develop the user interactive platform as a part of aCar Mobility project to facilitate the processing of raw data gathered in underdeveloped areas in Africa and visualize it. Different research institutes are involved to get the raw data. This data can be uploaded on a platform based on its type (pdf for raw data, jpg for image). The platform provides the user a way to structure and process the data on its own. After all these initial steps of data collection and processing, the derived mobility indicators can be visualized on a map with the option to selecting which indicators to show. The application is tested based on data provided by participants to see its efficiency and feasibility to use in real life.

Keywords: Mobility; Geovisulization; Mobility indicators, Processing of Data.

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Chapter 1: Introduction

This chapter includes the motivation & problem statement, research objectives, research questions and innovation intended which will help to understand the topic.

1.1 Motivation and Problem Statement

Africa is an economically growing continent. It has agricultural production and purification potentials. Most of the population live in rural areas but have less economic growth because of several reasons e.g. illiteracy, lack of proper machinery and the high onsite transportation costs & during the transportation of the goods (also known as: first and last-mile problem). A lot of initiatives have been taken for the economic growth in rural areas of Africa for example, Sub-Saharan Africa regions that have the potential for economic development to combat hunger and unemployment. German Federal Ministry for Economic Cooperation and Development (BMZ) has developed green innovation centers in those regions for agricultural food production.

The aCar Mobility project integrates into this initiative to significantly improve rural mobility by integrating new electric transport means. The project started in 2013 with development of electric vehicle in collaboration with KNUST University. Phase 2 of the project started in 2018 is related on-site electric vehicles production. Finally, Phase 3 of the aCar mobility project started in 2020 which is related to mobility patterns and their different impact factors for electric mobility in the target regions Ethiopia and Côte d'Ivoire.

This thesis will contribute to the aCar's vision to achieve long-lasting e-mobility frameworks. The main motivation to work on this topic is that it combines the research & development and focuses on electric mobility specifically which is of my interest. The result of this thesis will be a platform to provide a sustainable solution to users to identify the influential factors on mobility patterns for the Ethiopia region.

1.2 Target Area

The target region for this research is Ethiopia. The target areas in Ethiopia and Côte d'Ivoire are shown in figure 1.1.

Figure 1.1: Target Area

1.3 Research Objectives

This thesis aims to **make a user interactive and collaborative platform to upload, process the mobility data to identify and visualize impact factors on rural mobility patterns**.

As mentioned in the motivation statement regional impact factors on mobility need to be measured in this project. These factors can be derived out of very inhomogeneous geotagged data acquired by users for an on-site mobility assessment. This assessment, as well as the

post-processing of data needs to be centralized and reachable online so that the users can contribute in the different steps of data collection and transformation of this data to valuable information.

The goal of this work is to establish methods that give users the ability to upload, visualize and transform the acquired data interactively and referenced geographically. For this sake, post-processing interactions need to be integrated inside the GUI (Graphical User Interface) that allows the users to contribute to data transformation.

Finally, geo-referenced key indicators should be visualized and clustered to depict the influencing factors on the transportation system.

The concept workflow is shown in figure1.2.
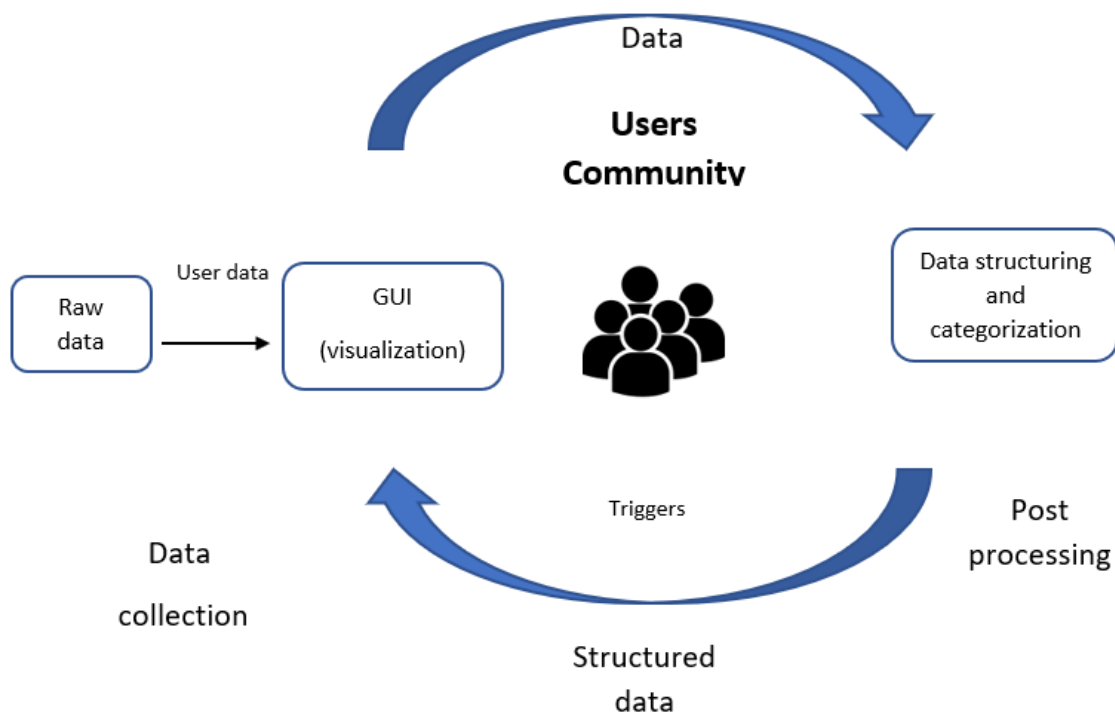
Figure 1.2: Concept Workflow

RO1: Data Collection & Processing

The data available for Africa regions are often very less and not refined. So, the first objective of this research thesis is to identify different (raw) data-source & -contributors that could take part in the platform. And they can upload data manually and engage in the processing step.

RO2: Methods for Processing and Categorization of data

This objective is to develop or find the existing methods to process (structure & categorize) the data-sources to map their collaborative engaged data transformation step (post-processing) to the mobility indicators that need to be derived.

RO3: Visualization of mobility data

This objective will lead to the visualization of the mobility indicators on a map which will enable the users for interactive exploration of uploaded raw data & possible mobility patterns. The mobility indicators will be the impact factors on mobility patterns for the ransportation system.

1.4 Research Questions

Before starting the research on this topic and to meet the research objectives there are some questions that need to be answered in a proper way to get good results for this work. These questions have been divided into three parts.

RQ1: What will be the sources and contributors for mobility data?

In Africa, there are not a lot of platforms that provide mobility data. So, the main concern will be the collection of raw data from users. This question is divided into the following sub-questions:

RQ1A: What kind of mobility data has to be collected and from which participants?

RQ1B: What would be the possible formats of data to be collected from the user?

RQ2: What will be the methods for processing the data?

This research question is related to the possible methods for the processing of collected raw data. These questions should be answered:

RQ2A: What are possible methods for data processing?

RQ2B: Do we need to develop new methods for data processing?

RQ2C: Which kind of mobility indicators can be derived from the structured data?

RQ2D: How would we correlate the user data with derived mobility indicators?

RQ3: What are the best cartographic techniques for visualization and platforms for the development of GUI?

As in this research the focus is on GUI (Graphical User Interface) for visualization which will be user interactive, where users will be able to see the results on the map in the form of different visualization techniques.

To show the mobility patterns on the map, thorough research about the available cartographic techniques has to be done which will give the idea of different ways of showing geographic features on a map.

To achieve this, these questions will be answered through research:

RQ3A: What should be the best cartographic techniques to show the mobility indicators on the map?

RQ3B: What is the best framework for frontend development?

RQ3C: What is the best framework for backend development?

RQ3D: What is the most suitable data base?

1.5 Research Innovation

This work is intended to create and describe a platform for collaborative data acquisition and processing into useful classified information. Moreover, finding out the way of visualizing the geographic data on a map could be easily interpreted by users. This work will have cartographic visualization which will communicate in a way to solve real-world mobility problems.

1.6 Thesis Outline

The thesis has five chapters in total. The second chapter is about related works to different part of the research. The third chapter talks about the adopted methodology for the implementation of application. In this chapter all the steps involved are explained in detail. Type of data, users, methodology of structuring and development of GUI are explained in it. In the fourth chapter, the final results are discussed. The fifth and last chapter is about the conclusion. The research outline is described in the workflow below figure1.3.

Figure 1.3: Research Workflow

Chapter 2: Literature Review & Theoretical Background

This chapter talks about the related work and theoretical background of the topic. The first part is about all the relevant work found in research including the similar developed applications/platforms. The second part explains the basic concept of mobility, mobility patterns and mobility data. The third part focuses on the type of users involved in data uploading and data structuring. Later, the data processing concept and available method for that are explained. Lastly, visualization of mobility data on a map and the development of GUI (Graphical User Interface) are discussed.

2.1 Related Work

Geisa Bugs et al. (2010) developed an application for public interaction by using an open-source tool for web mapping service. Using a suitable geospatial data layer where users can participate (e.g. comment). There is a database that stores the contribution in a format supported by GIS. The prototype itself is a valuable approach for engaging the public. It made a connection between users and decision-makers in an interactive way. It could be easily setup and understood by a common audience [1].

Lwin, Koko et al. (2014) researched real-time geotagged data collection and visualization on mobile phones. In their project they created a web GIS application where they provided a survey form to provide coordinate information, which improved the ability to find the locations and enter data during the survey. The web-GIS could collect, integrate and process all data entered in the fields. Due to the real-time information approach the results could be viewed, queried, and analyzed quickly. This concept can be used in various field data collection purposes [2].

In figure 2.1 you can see the GUI overview.

Figure 2.1: Web-based GUI for user interaction [2]

Lwin et al. (2014) worked on public participation in the field of GIS using mobile applications. They described three processes with different scales and purposes. The context is urban monitoring & planning, and tourism optimization. Open-source architecture was used in each case. Which allowed public to use their mobile devices for the field data collection. Later on, the data was made publicly available [3].

Poorazizi et al. (2008) developed a system in which they were collecting, integrating, analyzing and visualizing spatial and aspatial information in the electric industry. The examination of mobile GIS architectures, components of the mobile GIS and their impact on data collection. The important features in their system are data access in the field, capturing the data entered in the field, adding positional information in the captured data and run the GIS functionality in the field. The collected data in the field contains the photos and the text values [4].

Jing et al. (2019) researched the overview of the historical background of dashboard, technologies and applications in the smart city. They discussed the visualization model and the ability of the model for a decision support system. They have done the research on how geospatial dashboard can be used to examine the performance of smart cities. In that paper they talked about the conceptual architecture for the geospatial dashboards. According to this paper the same architecture is adopted by many geospatial dashboards, which consists of data, analysis and the presentation of the data. Below is the figure you can see the three-tier architecture. The data layer deals with the spatial data and non-spatial data. The data model

is responsible for data management and organization. The model layer is showing the analysis done on the data which calculates the indicators. The third layer is the presentation layer showing the indicators on the map [5].
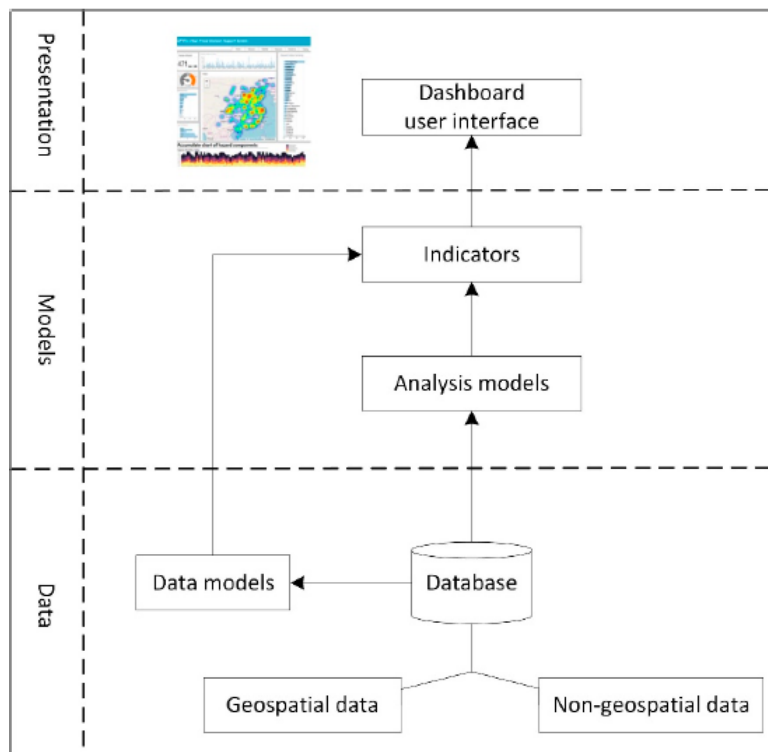
Figure 2.2: Architecture for geo spatial dashboards [5]

Al-Saiyd, Nedhal. (2015) presented a generic and comprehensive methodology to save the geographical data and eliminate geospatial data redundancy. This methodology enables to store the important data and reduces the storage space by avoiding redundant data to achieve a good quality of data. The representation of the stored data and the selection of application software selection was a big issue in it. The data from many sources was integrated and the data documents, maps and services were stored in the metadata. In their model the data is collected, maintained, classified and represented perfectly. The geospatial data and non-spatial data were accessed by the GIS web. The users could apply queries on the data and generate the map [6].

Krykewycz, et al. (2011) talked about the web-based crowd sourcing approach to improve bikeability scoring. This paper also includes the lessons learned from the developers considering the same applications. The bikeability data was maintained online by participation of the site visitors. Location-based comments were shared with the consultants for the preparation of the new bike master plan. This work is about adding the crowds' opinion for the development of the plan for bikeability [7].

Cignetti, et al. (2019) proposed an infrastructure that is based on open source free software and internationally recognized standards. They created an instrument to collect, manage, visualize and share the multisource and multi-sensor data. The data could be downloaded and used by anyone for reprocessing. The data which is openly available for anyone could be used for research and development purposes [8].

Serena Pastore (2013) researched the possible availabilities to handle the data. She created a platform that could be able to hold a large amount of both unstructured and structured data that could be published on the web platforms accessible by mobile devices [10].

Aydın, Y. E. (2006) proposed a web-based data collection method for effective and accurate geocoding. This system enables users to enter real-time data. This platform is a multi-participant platform. In which users engaged for data acquisition. The application is crime-based application showing the data collected by police stations [9].

Publication	Data Source	Data collection method
Geisa Bugs et al. (2010)	Public participation	HTML survey form
Lwin, Koko et al. (2014)	Public participation	HTML survey form
Lwin et al. (2014)	Public participation	HTML survey form
Poorazizi et al. (2008)	Public participation	HTML survey form
Jing et al. (2019)	Public participation	HTML survey form
Al-Saiyd, Nedhal. (2015)	Public participation	HTML survey form
Krykewycz, et al. (2011)	Public participation	HTML survey form
Cignetti, et al. (2019)	Public participation	HTML survey form
Serena Pastore (2013)	Public participation	HTML survey form
Aydın, Y. E. (2006)	Public participation	HTML survey form

Table 1: Related work overview

The table above shows the all related research work summarized. In all of these works HTML survey form was used as the data collection method in the development of application and the reason behind was the user participation. This makes these research works very important input for this thesis that also includes the development of user interactive GUI.

2.2 Mobility Studies

This section talks about all relevant topics related to this thesis that includes mobility, sustainable mobility, mobility patterns.

2.2.1 Mobility

Travelling is one of the biggest necessities of human since the beginning. In this era, we analyzed the importance of mobility in community development because of infrastructure development and higher population.

Eltis says mobility is the possibility for movement and it is the ability to move from one place to another using different modes of transportation to meet their daily needs. Mobility is the result of social activities like living, relaxing, production and trade [11].

The ARTS project also describes mobility as the movement of people or goods from one place to another. It also states the modes of urban mobility. Those modes include cycling, public transport, and private cars [15].

So, mobility covers all the aspects of movement placed in our daily life. Driving factors of movement include tourism, transportation, and migration. Merriman P. (2009) researched geographical mobility. He mentioned that mobilities are important in our life for the functioning of our societies and economies [12].

From these studies, the importance of mobility is understandable. Mobility is happening every second. Students are going to schools, colleges and universities. Workers go to offices for their work. Tourists are making trips. Everyone is moving by different transport mode including cars, motorbikes, carts, bicycles and buses.

2.2.2 Mobility Patterns

During the movement of human beings, they move in an equal way which then can be unveiled by certain patterns that show the human travelling behavior on the ground from origin to the target point. The mobility patterns are the outcomes of the human movement analysis. The increase in the availability of mobile-phone records, GPS data and other datasets (which capture the human traces) have revealed numerous human mobility patterns. According to the observation of human mobility patterns, the human mobility is random, but patterns and randomness do not fit to each other in some way [13]. Large spatial scale includes international movements and small scale includes movements within the cities that could be predicted by the population in the city [13]. Similarly, there are movements in urban areas and rural areas as well. There is a lot of work done by many researchers for finding mobility patterns.

Liu et al. (2009) mobility landscape has researched urban mobility patterns in South China where they used real-time data which includes floating car data of 5000 cars and data of five million smart cars. They quantified, visualized and examined the urban mobility patterns [14].

2.2.3 Sustainable Mobility

As in this research work major aim is to develop the GUI that enables users to visualize the impact factors on mobility. For achieving that aim I need to find out the mobility indicators that could be found by understanding of sustainable mobility.

There are a lot of definitions of sustainable mobility. But there is no global definition of it. The definition of sustainable mobility can be derived from sustainable development. The definition contains three aspects i.e. economic, environmental, and social. The shift towards the sustainable mobility needs a shift in transport planning [16]. Therefore, transport researchers normally focus on three aspects for the sustainable mobility. As it is also stated by Brůhová (2020) that transport widely affects the sustainability and quality of life in the cities [16].

The European cities are supported by European governments to develop sustainable urban mobility plans. In Etlis up from 2013 the need of sustainability in the urban mobility and the new approaches to urban mobility planning are used in urban mobility climate. Because of people's willingness to use new modes of transport the urban mobility is evolving. The 2013 Urban mobility package is set as a concept of sustainable urban mobility plans used by many planners across the European Union later on [17]. If we talk about Europe they came up with SUMP (Sustainable Urban Mobility Plans) which is used as the standard for sustainable mobility.

As sustainable mobility is considered very important in the context of development. Most researchers agreed on transport systems that have services and have social, environmental, and economic impacts too [18].

Salvatore et al. (2011) researched indicators of sustainable urban mobility in which they classified data into three categories i.e. economic, social, and environmental [18].

2.2.3.1 Mobility Indicators

There are some indicators in each category of mobility data that are important for analyzing the mobility pattern in urban or rural area. In this section, a set of mobility indicators are proposed. These indicators are based on transport services due to displacement within the area.

Tafidis et al. (2017) reviewed the huge number of sustainable mobility indicators from literature and examined the data availability. In the end, he summed up an efficient, realistic and comprehensive indicator system as an evaluation tool for checking mobility conditions in the Greek Urban areas [19]. All the indicators which he found during the study are shown in figure 2.3 and figure 2.4.

Objective	Indicator	Availability	Frequency	Reliability	Data source
Integration of land use / transport planning	Change in land use by transport infrastructure	3	1	4	LA, Un & RC
	Land take by transport infrastructure mode	3	4	5	LA, Un & RC
	Land use mix	3	1	4	LA, Un & RC
	Population Density	5	1	5	ELSTAT
	Rate of use of urban land	3	1	4	LA, Un & RC
Accessibility	Access to basic services	3	1	4	LA, Un & RC
	PT network coverage	3	4	4	OASTH, THITA
	PT size in relation to population	5	4	4	OASTH, THITA, ELSTAT
	Quality of transport for disadvantaged people	3	2	4	Un & RC
	Share of PT vehicles and stops which are wheelchair accessible	3	4	4	OASTH, THITA
Increased mobility	Average passenger travel time	3	5	2	Un & RC
	Average speed of private vehicles	3	5	3	Un & RC
	Capacity of Park and Ride facilities	3	4	5	LA, Un & RC
	Condition of transport networks	3	3	3	LA
	Daily or annual passenger-km by means of PT	3	4	2	OASTH, THITA, ELSTAT
	Daily or annual passenger-km by private vehicles	3	5	2	UN & RC
	Length of paved roads	3	4	4	LA, Un & RC
	Occupancy rates of private vehicles	3	1	4	LA
	Passenger transport trends by mode (Modal split)	5	2	2	Un & RC, THITA
	Private car ownership	3	4	3	ELSTAT, Un & RC, OI & Cp
	Road network density	3	4	5	LA, Un & RC
	Road network length	3	4	5	LA, Un & RC
	Traffic congestion	3	5	3	Un & RC
Promotion of non-motorised means	Bicycle network density	3	4	5	LA, Un & RC
	Bicycle network length	3	4	5	LA, Un & RC
	Cycle parking availability	3	4	4	LA
	Pedestrian network density	3	4	5	LA, Un & RC
	Pedestrian network length	3	4	5	LA, Un & RC
	Share of streets with traffic calming measures	3	4	3	LA, Un & RC
Encouragement of PT	Average PT speed	3	4	4	OASTH, THITA
	Number of means of PT	5	4	5	THITA
	PT comfort	3	3	3	OASTH, THITA
	PT frequency during peak-hour	3	4	5	OASTH, THITA
	PT occupancy	3	4	4	OASTH, THITA
	PT reliability	3	4	4	OASTH, THITA
	PT security	3	4	3	OASTH, THITA
Environmental concerns	Average age of PT fleet	3	4	5	OASTH, THITA
	Average age of vehicle fleet	3	5	5	MEnv, OI & Cp
	Cases of chronic respiratory diseases due to vehicle pollution	1	-	-	-
	CH_4 emissions (per capita)	5	5	4	MEnv, OI & Cp, ELSTAT
	CO emissions (per capita)	5	5	4	MEnv, OI & Cp, ELSTAT
	CO_2 emissions (per capita)	2	5	3	OI & Cp

Figure 2.3: Indicators for sustainable mobility Tafidis et al. (2017) [19].

	Indicator				
	Final energy consumption by the transport sector referring to the urban level	3	4	1	MEnv, Un & RC
	Fuel consumption of private vehicles	3	4	1	MEnv, Un & RC
	Fuel efficiency of PT fleet	3	4	5	OASTH, THITA
	Greenhouse gas emissions deriving from the transport sector	5	5	4	MEnv, OI & CP, ELSTAT
	Habitat and ecosystem disruption	1	-	-	-
	NO_x emissions (per capita)	5	5	4	MEnv, OI & Cp, ELSTAT
	O_3 concentration (per capita)	5	5	4	MEnv, OI & Cp, ELSTAT
	PM_{10} and $PM_{2.5}$ emissions (per capita)	5	5	4	MEnv, OI & Cp, ELSTAT
	Population exposed to air pollution deriving from the transport sector	1	-	-	-
	Population exposed to transport noise ⩾ 65 dB	3	2	2	ELSTAT, Un & RC
	Share of vehicle fleet meeting certain air emission standards	2	4	5	OI & Cp
	SO_x emissions (per capita)	5	5	4	MEnv, OI & Cp, ELSTAT
	Structure of road vehicle fleet	3	5	5	MEnv, OI & Cp, ELSTAT
	Transport-related waste and related recovery rates	1	-	-	-
	Type of fuel used in PT fleet	3	4	5	OASTH, THITA
	Use of renewable energy sources & biofuels	3	5	5	MEnv, OI & Cp
Economic welfare	Affordability (share of income devoted to transport)	1	-	-	-
	Contribution of transport sector (by mode) to employment growth	3	4	2	OASTH, ELSTAT
	Direct subsidies to PT	3	4	4	MEc, OASTH
	Direct user cost referring to travel by private vehicles	1	-	-	-
	Direct user cost referring to travel by PT	5	4	4	MEc, OASTH
	Fuel prices and taxes	5	5	4	MEc
	GDP per capita	5	4	5	ELSTAT, IMF
	Internalization of costs	1	-	-	-
	Investment in transport infrastructure (per capita and mode as share of GDP)	3	4	2	LA, MEc
	PT affordability (share of households' income devoted to trips by means of PT)	1	-	-	-
	Share of GDP contributed by the transport sector	3	4	4	MEc
	Social cost of transport	1	-	-	-
	Taxation of vehicles	5	4	5	MEc
	Total expenditure on pollution prevention and clean-up	1	-	-	-
	Total per capita transport expenditures	1	-	-	-
	Trends in PT prices	5	4	4	MEc, OASTH
Road safety	Index of incidence of injuries and fatalities from road transport	3	4	3	TPD, ELSTAT
	Road safety and vulnerable users	3	4	3	TPD, ELSTAT
	Road traffic fatalities	3	4	3	TPD, ELSTAT
	Traffic accidents involving injuries	3	4	3	TPD, ELSTAT

Figure 2.4: Indicators for sustainable mobility Tafidis et al. [19].

In figure 2.3 and figure 2.4, there is a huge number of indicators from which 16% of the indicators are excluded because of the estimation difficulties due to less amount of data. In this list we can see different categories of indicators that could be measured on a national level but not on a regional level. Some of indicators could be available on the internet easily. Most of them (49 out of 80) needs special permission to measure on the specific region or area [19].

Dominique et al. (2016) have done intensive research and gave a systematic overview of mobility indicators that covers different aspects of sustainable mobility [20]. They have found 22 indicators during their research shown in the figure 2.5

Indicators for the Sustainability of Urban Mobility	Short Name	Dimension
Emissions of greenhouse gases	GHG	Global environment
Energy efficiency	Energy efficiency	Global environment
Net public finance	Public finance	Economic success
Congestion and delays	Congestion	Economic success
Economic opportunity	Economic opportunity	Economic success
Commuting travel time	Travel time	Economic success
Mobility space usage	Space usage	Quality of life
Quality of public area	Public area	Quality of life
Access to mobility services	Access	Quality of life
Traffic safety	Safety	Quality of life
Noise hindrance	Noise hindrance	Quality of life
Air polluting emissions	Air pollution	Quality of life
Comfort and pleasure	Comfort and pleasure	Quality of life
Accessibility for mobility impaired groups	Accessibility for the impaired	Mobility system performance
Affordability of public transport for poorest group	Affordability	Mobility system performance
Security	Security	Mobility system performance
Functional diversity	Functional diversity	Mobility system performance
Intermodal connectivity	Intermodal connectivity	Mobility system performance
Intermodal integration	Intermodal integration	Mobility system performance
Resilience for disaster and ecologic/social disruptions	Resilience	Mobility system performance
Occupancy rate	Occupancy rate	Mobility system performance
Opportunity for active mobility	Active mobility	Mobility system performance

Figure 2.5: Indicators for sustainable-mobility Dominique et al. (2016) [20].

To define the set of indicators the literature research has been done for each sustainable mobility dimension. These indicators are covering all the relevant aspects. The result is a combination of classic criteria such as greenhouse gas emission and other innovative criteria such as quality of the public area, traffic safety [20].

2.3 Application Development Studies

This section aims to cover available data collection methods, data processing and geovisualization techniques that would help for the implementation of GUI.

2.3.1 Data Collection

Data collection is the process of collecting, measuring and analyzing data insights for a research by use of standard validated techniques [21]. Data collection is an important step in this topic. The major issue is that data is not acquired everywhere, and it is very time intensive to do this locally on your own. The other issue is how we can speed up the process of data collection drastically. Nowadays data collection is not so difficult because of high technological advancements and public engagement through the internet. For example, some of the researchers and government agencies are working on data collection. They upload the collected data on an online platform from where anyone can get the paid or free data. In other cases, if any research institute wants to do it by itself it is also easy for them to capture data by using advanced technologies.

There are four important choices of data collection i.e. in person, mail, phone and web/online [21]. As mentioned earlier the target area is Harar so the data collection in the context of the African region should be kept in mind.

2.3.1.1 African Context

In developed countries like Europe it is easy to collect data but in under-developing countries it is quite tough. Fragility and conflicts affect the data collection for researchers in various ways. There is a very limited capacity for doing surveys and analysis in these areas.

Researchers have very limited resources for data collection. If they do a survey, they could hardly cover the entire region which leads to the lack of data. In some cases, there are infections in those areas. During the Ebola, enumerators could not travel and talk face to face because of the risk of infection. Data collection in plenty of areas is also affected by poor road quality and bad telecommunication infrastructure. The reason for these problems is because of the conflict in the areas that are physically distant from the administrative center and have few public services [22].

If we want to focus on the area which could not be reachable by normal means or physically distant from the administrative center, then the public doesn't participate in the data collection part because of few resources in their area. Due to all these factors involved public and administrative centers are not reliable for data collection in Africa.

2.3.1.2 Participants

For data collection we need those participants who are already researching this topic. Ngongalah et al. (2018) did research on data collection in the African region. They included some participant during their research. By knowing the toughest challenges of Africa, they decided to include research professionals, research groups (institutes) and research students. They asked them to fill the survey forms. In the end they got 424 responses from their participants [23].

The article by Linda Nordling (2021) mentioned that during their research studies on genome they asked the public to fill the form so that they can use their data. But some of researchers said that this can make distrust between the public and the researchers. That is why they created a research group in 2019 in which the African Academy of Sciences and African Union Development Agency were included. The report says that engaging the public in data collection is vulnerable to exploitation. That is because of illiteracy, diseases and poor access to medical care. So, public involvement in those areas could not be possible but we can engage some of the research institutes together [24].

aCar mobility project is collaborating with the ASTU (Adama Science and Technology University), INPHB and TUM (Technical University Munich). And this developed platform will be used by these institutes [25]. These institutes have professional researchers and students. They will be able to collect data in the African region and share it.

2.3.2 Data Files

Any kind of computer file containing information but not code that is only used to read, view and write is the data file. There are some data files including a web page, a document file written in a word processor and a text file. Even programs also depend on data files to get the information. For example, the data file contains the setting information which needs to be implemented for the program [26].

2.3.2.1 Types of Data

Oregon States University (2021) have researched the data type and supported data formats for each data type. They came up with some specified data types and their formats [27].

1. Qualitative tabular data with extensive metadata in which we have variable labels, code labels and defined missing values. The pre-defined formats of file include SPSS portable format (.por), Delimited text and command MS Access (.mdb/.accdb). SPSS, Stata, SAS, etc. contain metadata.

2. Quantitative tabular data having minimum metadata have a matrix of data. Sometimes columns headings and variable names are not present and no metadata or labelling. The formats of the file include comma-separated values (CSV) file, tab-delimited file (.tab).
3. Geospatial Data which contains vector and raster data. The file formats are ESRI shapefiles (.shp, .shx, .dbf, sbx), geo-referenced TIFF (.tif,tfw), CAD data (.dwg), tabular GIS attribute data.
4. Qualitative data contains textual information. Which has file-formats including extensible markup language (XML), Rich text format (.rtf), plain text data and UTF-8.
5. Digital Image data is showing the image information inside it. The acceptable formats are JPEG (.jpeg, jpg), TIFF, Adobe Portable Document Format (PDF/A, PDF) (.pdf).
6. Digital audio data contains some voice information that supports only Free Lossless Audio Codec (FLAC), Waveform Audio Format (WAV) and MPEG-1 Audio layer 3 (.mp3).
7. Digital video data contains some animated information. It has MPEG-4 High profile and motion JPEG 2000 (.jp2) formats.
8. Documentation and scripts contain the mixture of text and images inside it. Supported formats for this data type are Rich text format (.rtf). HTML, plain text (.txt), xlx/. Xlsx and PDF (.pdf).
9. Chemistry data can show the contours representing the intensity and peak positions. It has some specific formats including convert NMR, IR, Raman, UV and Mass Spectrometry files to JCAMP.

In the given figure 2.6 you can see detailed information about the data types and predefined formats for storing the data.

Digital image data	TIFF version 6 uncompressed (.tif)	• JPEG (.jpeg, .jpg) • TIFF (other versions; .tif, .tiff) • JPEG 2000 (.jp2) • Adobe Portable Document Format (PDF/A, PDF) (.pdf)
Digital audio data	• Free Lossless Audio Codec (FLAC) (.flac) • Waveform Audio Format (WAV) (.wav) • MPEG-1 Audio Layer 3 (.mp3) - spoken word audio only	• MPEG-1 Audio Layer 3 (.mp3) • Audio Interchange File Format (AIFF) (.aif)
Digital video data	• MPEG-4 High Profile (.mp4) • motion JPEG 2000 (.jp2)	JPEG 2000 (.mj2)
Documentation & Scripts	• Rich Text Format (.rtf) • Open Document Text (.odt) • HTML (.htm, .html)	• plain text (.txt) • widely-used proprietary formats, e.g. MS Word (.doc/.docx) or MS Excel (.xls/ .xlsx) • XML marked-up text (.xml) according to an appropriate DTD or schema, e.g. XHMTL 1.0 • PDF/A or PDF (.pdf)

Figure 2.6: Types and formats of data file (Adapted to [27]).

2.3.2.2 File Types

There are some file types that have specific file extensions to open them on different programs or software. Some of file types were discussed in the above section 2.3.1. In this section the focus is on document file type and image file type.

2.3.2.2.1 Document file types

There are a lot of document file formats as we saw in the above discussion. According to Casey Schmidt (2012) and file stack there are some document file types including [28] [29]:

1. DOC and DOCX are the production of the Microsoft word software [28].

2. XLS/XLSX are products of the Microsoft Excel which have spread sheets in it [29].
3. PDF file format is product of Adobe which is frequently used on web today [28].
4. HTML stands for Hypertext Markup Language which is capable of opening on web browsers [29].
5. ODT are similar to the DOCX files. These files can open on word processor program [29].
6. ODS is also the spread sheet. These files can be opened with open source programs [29].
7. PPT and PPTX are the common file formats for the Microsoft power point [29].
8. TXT files are very basic plaintext file formats. TXT files can be created as the text-based documents without formatting, font style and text color [29].

2.3.2.2.2 Image file formats

There are ten types of Image file extensions. Which includes JPEG/JPG (Join Photographic Experts Group), PNG (Portable Network Graphics), GIF (Graphics Interchange Format), TIFF (Tagged Image file), PSD (Photoshop document), PDF (Portable Document Format), EPS (Encapsulated Postscripts), AI (Adobe Illustrator Document), INDD (Adobe InDesign Document) and RAW (Raw Image Formats) [30].

2.3.2.2.3 Audio file formats

Canto describes seven popular audio file types [28].

1. M4A is mpeg-4 audio file format. It is the compressed audio file.
2. FLAC is free lossless Audio Codec.
3. MP3 audio file is very famous among all kind of devices i.e. mobile, computers and tablets.
4. MP4 is used for audio and video both.
5. WAV file format can store the waveform of the data.
6. WMA is an alternative to MP3. Which is used only in Windows.
7. AAC is advanced audio coding which provides high quality sound and increased by using advanced coding.

2.3.2.2.4 Video file formats

Video file contains audio, video, subtitles and Meta data inside it. There are eight common video file formats [31].

1. MP4 is the very earliest video file format. Most of the devices supports MP4.
2. MOV is the video file format provided by Apple.
3. WMV is created by Microsoft and it is commonly used in windows media player.
4. FLV is provided by the Adobe Flash player.
5. AVI is provided by Microsoft and still popular these days.
6. AVHD is associated with the HD video playback and digital recording.
7. WebM is created by Google by keeping in mind the present and future state of internet.
8. MKV file contains audio, video, and subtitles in one file.

2.3.2.3 File formats for website

Normally there is always a confusion in the selection of file formats for the website which would not create loading or appearance problems for websites. There are few file formats which user can upload on website [32]. The most compatible file types and their file formats/extensions for website will be discussed.

2.3.2.3.1 Image file formats

John Hughes (2020) by Themeisle wrote an article in which he talked about the best image formats for the website. There are normally various types of image formats but when we talk about website we normally stick to JPEG/ PNG and GIFs. The type of image used usually affects the websites. These images affect performance, appearance and scalability. Some images take so much memory which could affect the website loading times. Some images are not good in quality which could affect the appearance. When user stretch or shrink the web page it could affect the equality of image as well [33].

After keeping in mind all three affecting factors we came up with three major image formats on websites. These formats are perfect for any kind of website [33]. John Hughes concluded with three best image formats for the websites such as:

1. JPEG is useful because it can show millions of colors and it's perfect for the high compression levels. It is more suitable to show complex photographs which has a lot of colors inside it. It is idea for any kind of photograph.
2. PNG are also famous as JPEG for websites. This file format also supports huge number of colors and transparency.
3. GIF is also famous for websites in which user shows animation.

2.3.2.3.2 Documents file formats for web

There are some documents which can be downloaded and viewed by users. But usually users upload the documents file in word document format which enables users to edit and change the documents. However, using word document sometimes is not good which could lead users to remove or destroy the real shape of data. That is why using PDF (Portable Document format) is good to upload on website which is non-editable and contains all the pages of the document in one file [32].

2.3.2.3.3 Audio file formats for web

Here is another file type which can be uploaded to website. It could contain the voice messages or some useful information in form of voice recordings. The easiest and most useful file format which can be uploaded to webpage is MP3. This file format is playable on any kind of device including computer, mobiles, and tablets [32].

2.3.2.3.4 Video file formats for web

Sometimes user wants to show the real view of their work in term of videography which contains audio plus video effects inside that file. The most suitable file format to upload on website is MP4. This file format is accessible on any kind of devices [32].

2.3.3 Data Processing

2.3.3.1 Spatial data structuring

The enormous raw spatial data should be systematically structured. From the mapping point of view geoinformation is composed of geographic entities, spatial reference, semantic

properties, symbols, scales. The large quantity of geodata and their structure enables users to extract useful information from the data. It has been realized that structuring the geodata is very important for the visualization of the data on the map. For the extraction of the information and the knowledge hidden in geodata, re-organization and the labeling of geodata should be done. Which needs an adaptive system with the capability of self-learning and explanation. The categorization of data should be incorporated to structure the data [35].

Technologically geodata is not obtained directly from the measurements. But it is obtained after the post-processing of the data. It consists of different types of data in a single complex form. And shows the existing relationships in different areas. There is a workflow of the geodata organization which consists of five stages including the gathering of initial data, classification of the data into classes and structuring the data, then spatial information-based integration and in the last step is the stratification of the integrated complex. In the figure 2.7 the steps are explained [36]. After getting the data it is classified into three classes economic, geographic and social.
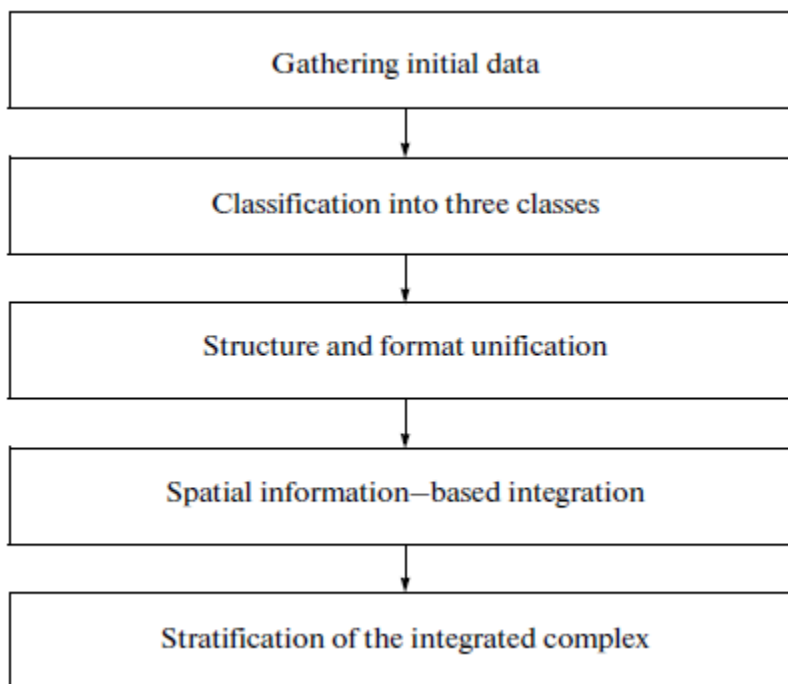
Figure 2.7: Steps of data processing [36].

2.3.3.2 Available methods for data structure
To achieve all these goals, methods available for the data the processing need to be searched.

2.3.3.2.1 Data Structuring Languages

Serena Pastore (2013) was structuring the collected data using the open and interoperable language which allows publishing on the web page. She considered three languages including XML, JSON and RDF and decided to use different representations in each of these languages according to the kind of the collected data. Aside from the structuring she focused on the storage and management of the data. She preferred to use the cloud-based solution.

She did a comparison of these three languages by keeping in mind the data model, syntax, security and processing requirements [10]. In figure 2.8 the detailed comparison is shown.

	Data Structuring Languages		
	XML	RDF	JSON
Data Model	Tree	Graph	Data Object Notation
Syntax	Elements/ Attributes	Triples (subject/predicat e/object)	Key/value
Security Support	Yes	Yes	No
Processing requirements	High	Medium	Low

Figure 2.8: Data structuring languages [10].

2.3.3.2.2 Machine learning based model

Ledur et al. (2015) proposed an external Domain-Specific Language (DSL) which allows the huge input of the raw data and provides the dictionary with keywords for the visualization. It also supports the data filtering and generating the HTML, JS files to visualize the maps on the web. They proposed a fully automated system. In which the raw data is entered in their DSL system and it will do preprocessing and convert it to library format data and generate the HTML and JS file to show them on a web. In the figure 2.9 the comparison of two ways to do data processing has been explained. One is a traditional way in which raw data is collected and the data is processed manually to visualize on the map. On other hand the proposed new method is fully automated which just asks for the raw data file and does everything by the DSL system [37].

Traditional Visualization Creation

Raw Data

.a

Data Preprocessing → Library Format Data → Generation of the Visualization → Display

Proposed DSL

Raw Data

.b

Data Preprocessing → Library Format Data → Generation of the Visualization → Display
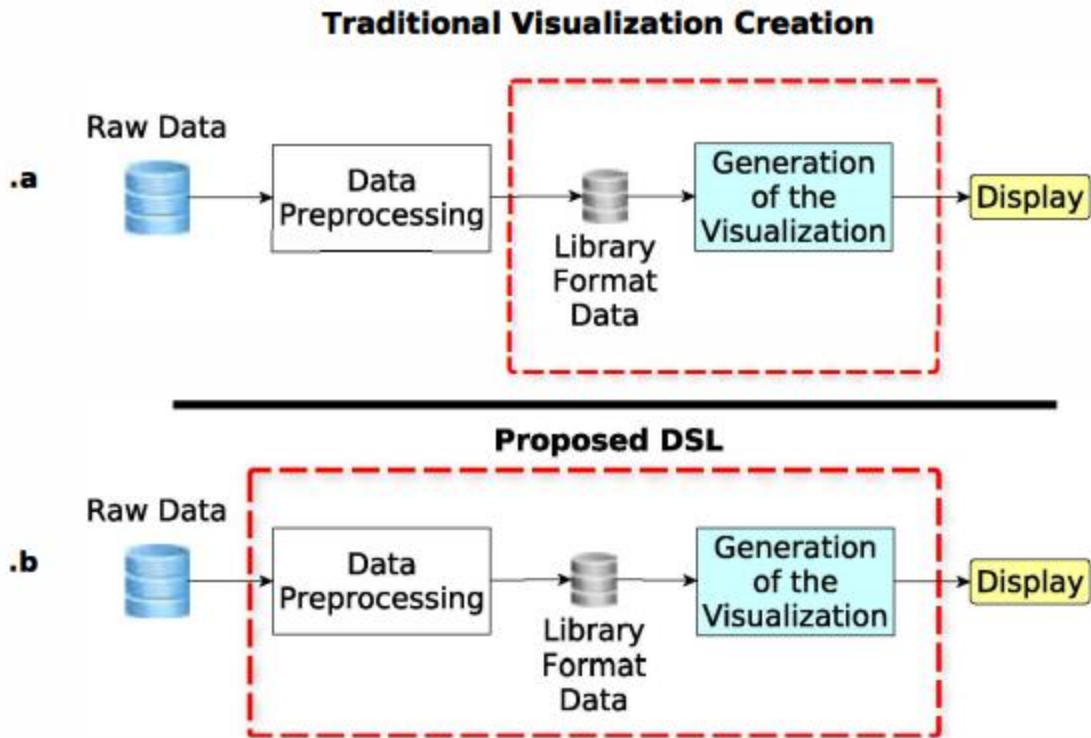
Figure 2.9: Data processing methods Ledur et al. [37].

2.3.3.2.3 Manual user input forms

Aydın, Y. E. (2006) used the user input web form for the crime point incidents collection. Some of the fields are automatically generated but some of the fields are asked to fill by the users. Some crime incidents are fixed, and users are asked to select the option on the tabular input panel. Hence, he used the user input form for the collection of the points and then these points were transferred to the database in an organized way so later they can visualize those points on the map [9].
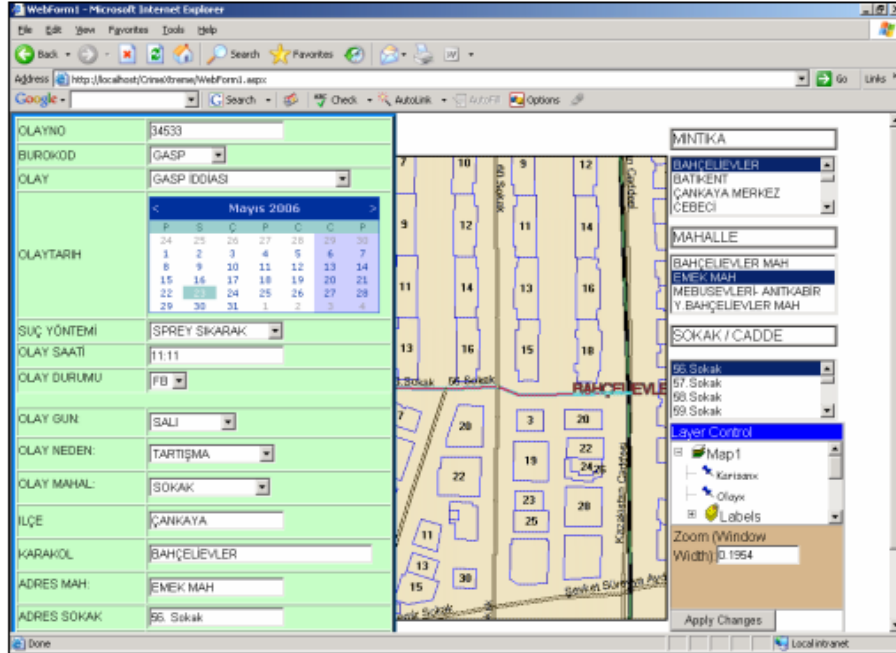
Figure 2.10: Input value via web form Aydın, Y. E. (2006) [9].

Tasoulas et al. (2013) Developed a GIS application which is an independent window application. The application focuses on urban forestry management planning. In that application they have the option of visualizing the forest-relevant entities. They can also add new trees and polygon showing the covered area by trees. For the data entry they are also providing the input field form [38]. In figure 2.11 the form is shown.
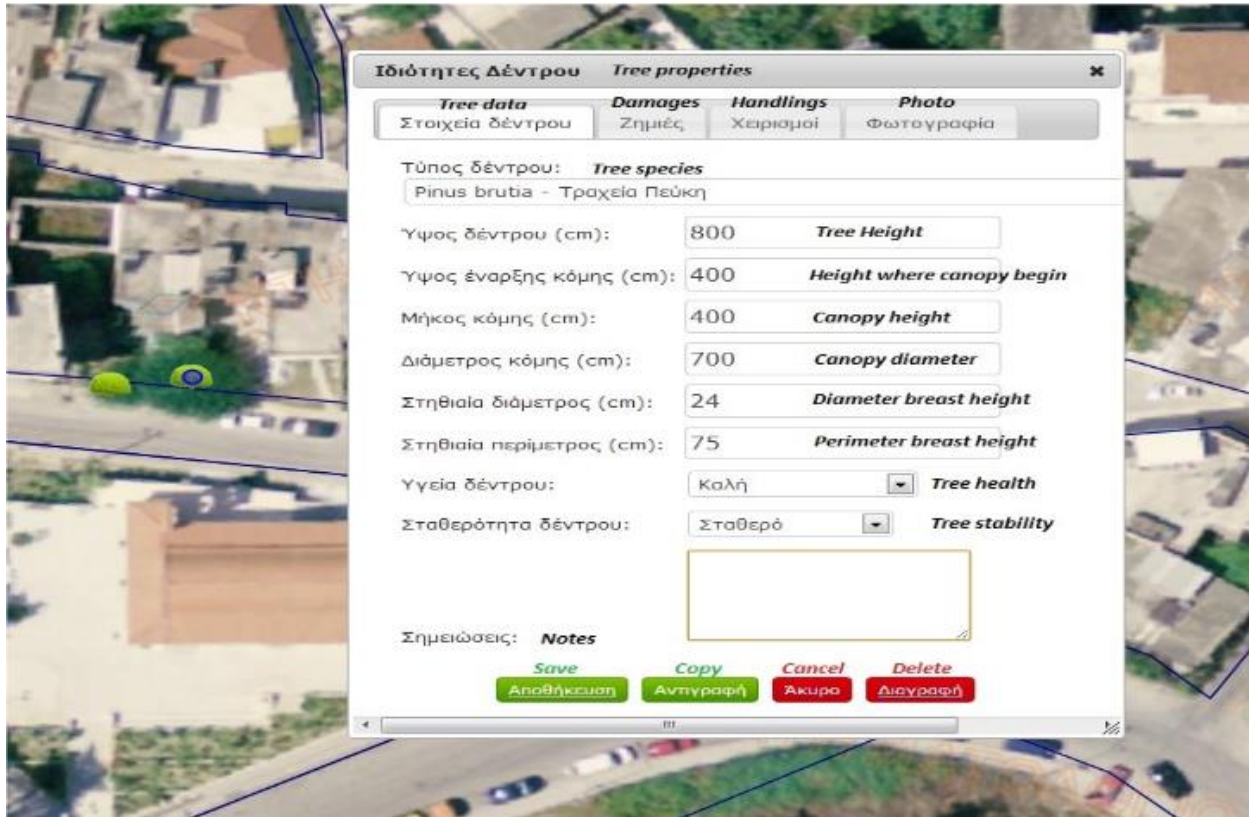
Figure 2.11: Web from for data processing Tasoulas et al. (2013) [38].

Forms are one of the most famous types of interactions for users on the website. This is means to an end that enables users to interact with the websites. Through the form user can enter data that will work with the web application to show useful information [52].

In many applications forms are major component that allow users to provide the data and interact with the system. Users can fill the form by understanding the field's name mentioned [52]. There is a lot of research on applications where they let the users engage with system to structure their data.

Cooper et al. (2006) mates they worked on a web interface in which they involved users for collection of the data via a web interface. They created a web application in which they integrated the data entry, data management, and data tables to store the data. After this kind of development, the data processing and analysis were accelerated. They have created a questionnaire in which they specified the specific fields in the form. So, they used the form for the data entry and the data structuring [53]. In figure 2.12 below you can see the questionnaire database management web page.

Figure 2.12: Web from Cooper et al. (2006) [53].

In the above image you can see the form in which they asked for specific information. Each field is connected to the SQL server data base. The entered data value is going back to the database table in the corresponding attribute field. For example, field Item No. is taking value-form user and storing it to the corresponding column field in the table of SQL database. They have formally divided the sections to make it easy for the users to fill in.

Bhagdev et al. (2008) introduced forms and search for supporting the distributed and shared knowledge accusation, retrieval, management and sharing. They have used the form-based solution to get their product. They said that form-based knowledge is very famous for users. They are publishing the forms on the internet to give access to users. The target users could easily understand the fields and fill them accordingly. For example, a mechanical engineer can diagnose a fault in a vehicle [54]. The form is shown in figure 2.13.

Figure 2.13: Web form Bhagdev et al. [54].

Goritz, A.S., Birnbaum, M.H. (2005) worked on a generic HTML forum processor in which he was collecting the data from the users via HTML forums and then storing that data into MySQL database. Where he used PHP for sending the data into the data base. The script was developed to process the data coming from the HTML form input fields. He created the columns in the data base and the corresponding entered input values were stored in those fields. In summary he was getting values via web forms and then organizing and storing them in the data base via PHP [55]. In figure 2.14 and figure 2.15 below you can see the web form and the organized data in the database.

Figure 2.14: Data entry form Goritz, A.S., Birnbaum, M.H. (2005) [55].

Figure 2.15: Data entry form Goritz, A.S., Birnbaum, M.H. (2005) [55].

Deo SS et al. (2005) created a web-based data base management system in which she was collecting, managing and analyzing data of diabetes patients. The system was a

searchable, client-server and relational database type application. That software was providing the ability to access, enter, update and analyze the patient data to the healthcare providers. It also enables user to query on the data. The data is taken from a web form, which is later stored in the data base. She provided different sections related to data. First, she provided a section which is accessed after login to the page. In the main page user has options of viewing data, inserting data and printing data. If user see the view option, the user can see the patient records and the find option can display all details of particular patient by entering the id. The graph option can enable user to print the graphs. And in add option user can add patient information which goes to backend and stored in the data base. So, in the web interface the information was getting by using the web form having the input fields inside it. Where the values of corresponding fields were stored in the specific field of database [56]. In figure 2.16 the form is shown where she is asking for the diabetes relevant information from the user.

Figure 2.16: Web Form by Deo SS et al. (2005) [56].

Here you can see the fields of weight, height, gender and pulse etc. These fields are storing in the corresponding fields of tables of the database. Which could then be retrieved by the same field name.

Different data processing methods used in the research work have been summarized alongside the reason behind using the methods in the table 2 below. As the platform has to be user interactive and user participation is needed. It is evident from the table which method is most feasible for this research work.

Methodologies	Publications/Research work	Reason
Data Structured Languages	Serena Pastore (2013)	No user participation
ML-based Model	Ledur et al. (2015)	No user participation. Totally automated
Manual user input form	Aydın, Y. E. (2006), Tasoulas et al. (2013), Cooper et al. (2006), Bhagdev et al. (2008), Birnbaum, M.H. (2005), Deo SS et al. (2005)	User participation.

Table 2: Available data structure techniques

2.3.4 Geovisualization

Geovisualization is used in many fields including cartography, image analysis, scientific visualization and geographical information science to give theoretical explanation and methods for visual exploration, analysis and presentation of data containing geographical information. For the support of geovisualization, the art and science of cartography have been developed. This has happened because of the efforts of cartographers to support map use and with the commissions of international cartographic associations on map use and visualization. For a long time, ICA commissions have focused on the use of maps by many experts to enable them for the discovery of unknowns in complex spatial data sets. By the passage of time, the techniques for visualization have become available and information has been more accessible. Users are using more interactive techniques to get insight from different kinds of spatial data sets for a large amount of geospatial information. So now-a-days, because of the higher demand for visualization of spatial data, geovisualization has become an essential element of the 21st century. [39]

The major question about the representation of geographical phenomenon has become one of the great challenges. Creating and developing meaningful graphics to represent the large Spatio-temporal data has an importance in the domain of geovisulaization. [39]

2.3.4.1 Types of geovisualization techniques

Later, there was a lot of research on geospatial data to visualize the spatial patterns on the map. In all those researches they have presented the maps in which they showed the representation of geographic data on a map. They have discussed some major types of geovisualization techniques.

2.3.4.1.1 Point-based visualization technique

Chris Weaver (2006) has researched visualization of census data of the United States. He showed the country-level demographic data collected from the 2000 United States Census. There is the capability of modification and extension during ongoing exploration. The visualization of the census is the result of all the processes including designing, development and exploration. The visualization shows the census data of the United States which includes the shapefiles and DBF database gathered from the National Atlas that describes the states, counties, cities, urban areas, roads, railway lines and airport locations. Demographics of the county contains population, population density, gender

percentages, percentage changes and age categories of residents [40]. In figure 2.17 the overview of the map with a list of states and territories is shown.
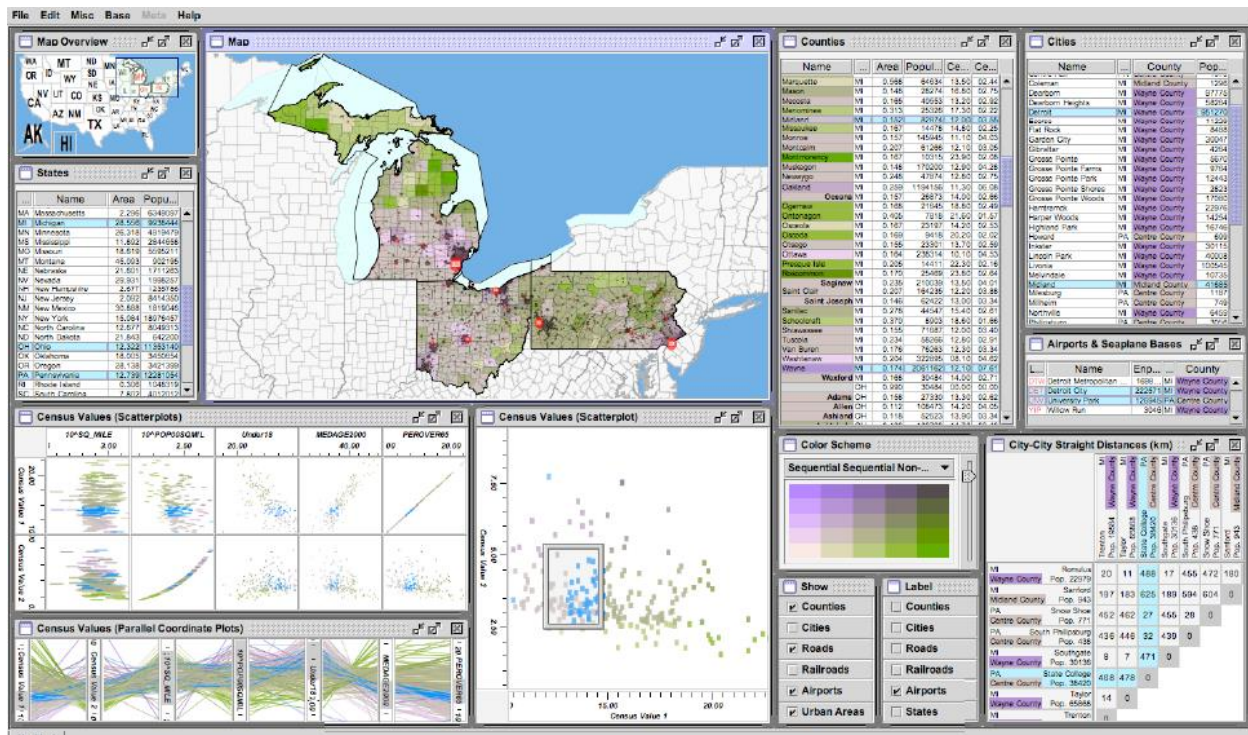
Figure 2.17: Visualization of census data by Chris Weaver (2006) [40].

The map is showing various natural and artificial areas of the states as checked by the users. Where the color pellet is showing the population percentage. The users can also change the color scheme over here.

In appendix VI-A the population percentage as oval size with the edge of red color is shown. The bigger the size of the circle, the higher the population percentage in that region. So, the size is directly proportional to the percentage of the population. Hence the map is sized based on data visualization which is showing circles of different sizes [40]. The numeric geospatial data can be represented in shape of the circles which could vary in size. The size variations show the variation in the numeric value of the geospatial attribute.

There is another map which is giving the idea of showing the numeric value of the map. In the given figure 2.19 the values in the form of circles are represented. Higher the circle, the higher the value of incoming or outgoing calls value. A blue circle is showing the outgoing handover and the red color is showing the incoming handover. The outgoing and incoming calls are visualized simultaneously, and the size of the circle is representing the number of the calls [41].

In contrast to visualization of the numerical data on a particular location, the circle shapes are useful and easy to understand for the viewer. So, the point-based visualization can represent the location, the mobility indicator with the specified value. The color and size of the point representation are used for the illustration of mobility data attributes which could include the accident, number of vehicles and deaths, etc. [42].
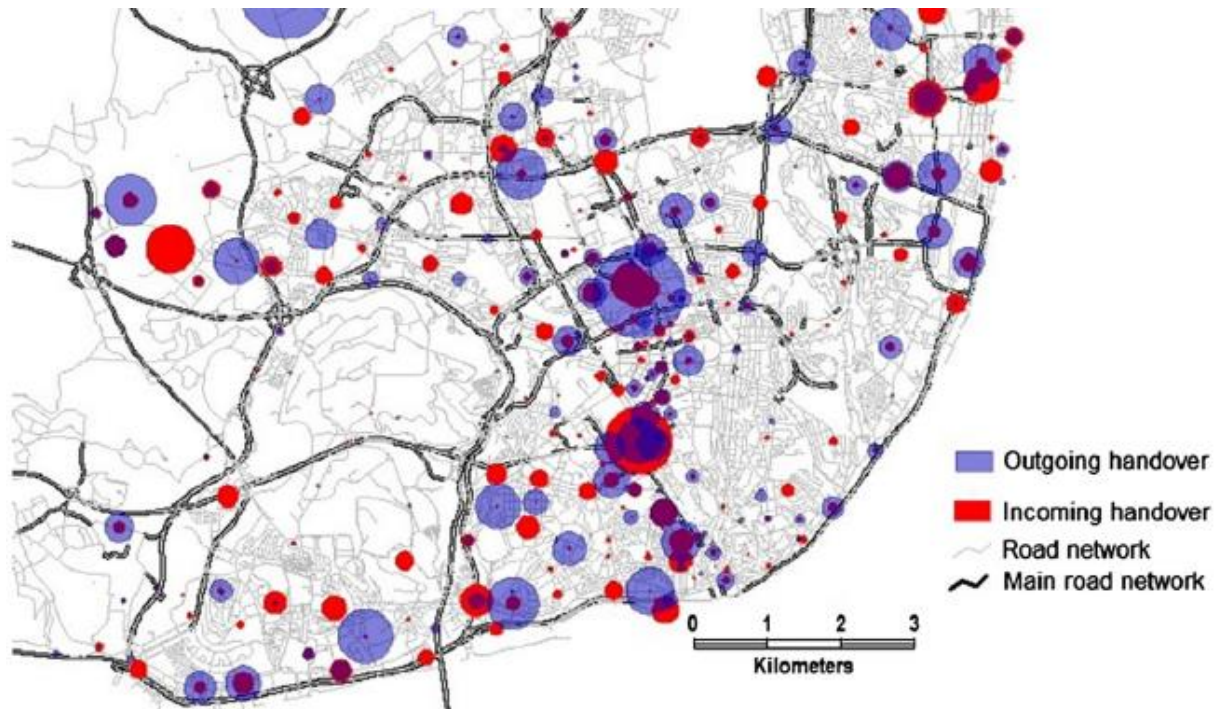
Figure 2.18: Point visualization by Chris Weaver (2006) [41].

J. Wood et al. (2007) did an analysis on visualization where they proposed a mash-up technique which follows the conventions of web application hybrid. He integrated wide applications using website-based technologies to make a new application. Where they came up with an interface having map. In that map they are showing the data as points place markers with the labels on them. The description of markers indicates spatial distribution. The attribute values were compared with the data set provided by Google Earth. In this development they used Google Earth for the visual synthesis of encoding created using the PHP (For linking the data base and the server and then creating output from it), MYSQL (for storage of all data and then querying on that data), and LandSerf (for surface processing and calculating the spatial parameters). In figure 26 below the visualization of the points showing the zip codes of the places is shown. The zip code in the data set made the basic comparison of the users who are performing the query on the dataset. Here they also imported another zip code data set for doing the comparison. In figure 2.20 some markers have yellow color but there is one zip code that is wrongly placed has orange color. So, the different markers having different colors show specific information [43].

These markers are also useful in regard to show any indicator on the map. The indicator could use any symbol which is self-explaining. The pin markers can be used for the comparison of the values in different regions. These pins can have detailed information about that region which could be displayed in any interactive way. In some cases, this information is shown by clicking on the markers. And that information is coming directly coming from the data base [42].
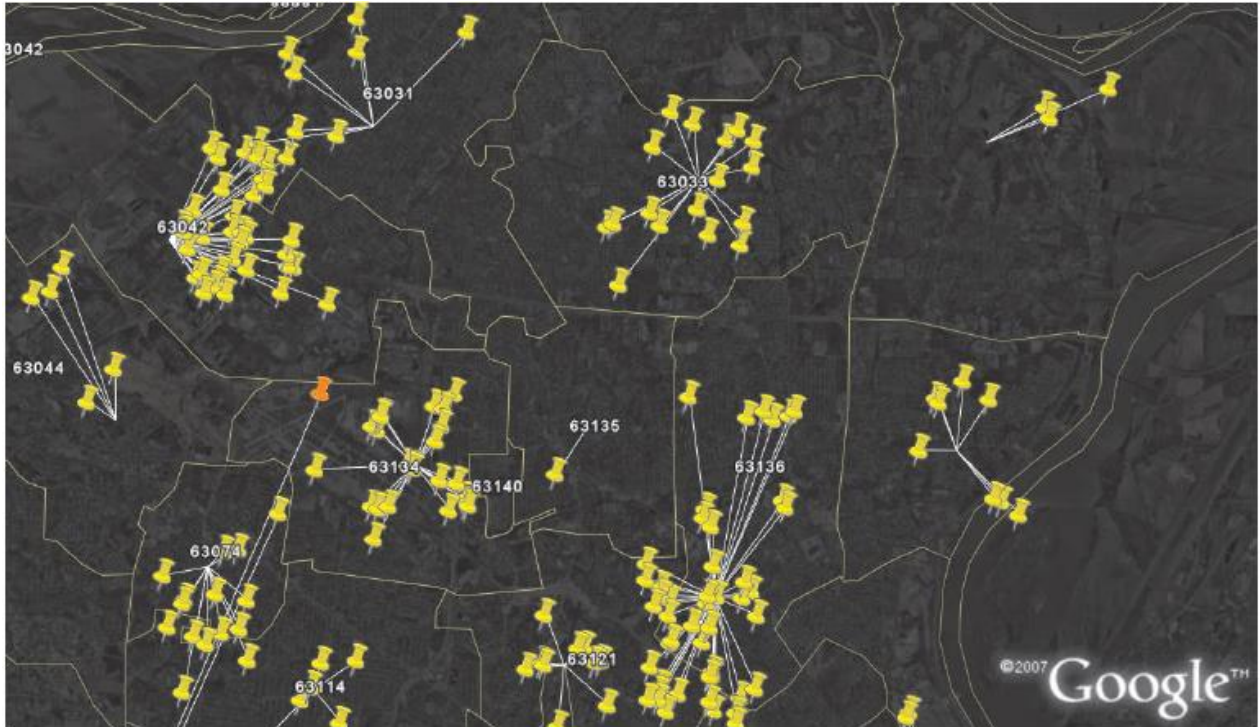
Figure 2.19: Point visualization by J. Wood et al. [43].

The quantity data can be show by heat points as well. The appendix VI-B (Yin et al, 2015) shows the analysis of irregularities of the number of passengers on the bus stations by using the metaballs visualization techniques. They are showing the average number of the passengers at bus stop throughout the day. The figure is showing the point based metaballs giving a clear view of the stops with the irregularities. The red and green color show the above average and below average deviations respectively.

Heat maps are very useful for huge amount of point-based data sets. In which they reduce the visual clutter. But in case of the line-based, visualization could create a conflict with road network recognition. Heat maps are not useful in case of line, where we want to show the precise spatial locations along the road [42].

Sobral, T et al. (2019) did research on the visualization of urban mobility data. They researched about the related studies and then analyzed which topics of mobility were addressed and their related phenomenon. And they found the adopted visualization techniques. They discussed about different methods of showing the traffic flows on map. First in the appendix VI-C the rose diagrams for spatial temporal analysis are used. Where they used circular segments to represent the number of traffic jams and size of each circular segment shows the duration of traffic jams. In this visualization type they are majorly focused on the temporal perspective. This kind of visualization is based on the same percentage value of the traffic jams [41].

The quantity of anything could be represented by the covered space of any shape. Like in this case the covered circle segment is representing the value of congestion. More covered circle segment means the congestion is more. Similarly, we can implement this kind of visualization in terms of showing the quantitative value of that region in different perspective either its environmental variable or social variable [42].

2.3.4.1.2 Line-based visualization technique

Kirk Goldsberry did research on traffic visualization which was divided into three parts: data collection, application development, and map reading. He visualized the traffic data combining the thematic and navigational maps. During his development he kept in mind the legibility of the map on every kind of device including computers, tablets and mobile phones and vehicle displays. This map is like a bridge which removes the gap between the map readers and the traffic data base. He showed the congestion of the roads on map where he categorized the level of congestion into three levels: high, medium and light. He used five colors green, red, grey, yellow and black. Higher congestion is shown by red color, no congestion by green and moderate is represented by yellow color, grey color is showing missing data and black color is showing stops. In his map he did not use the legends as it is self-descriptive map which any user can understand easily [44]. In the given figure 2.23 the map showing the traffic condition on the selected region is shown.

The given scenario below is helpful in showing any line information in the target region. Which is normally in form of the roads or streets information. It is showing the continuous value of the line segment in geographical space. This line-based representation is frequently used for the urban traffic attributes. These attributes include the condition of the roads in terms of structural condition or traffic condition [42].
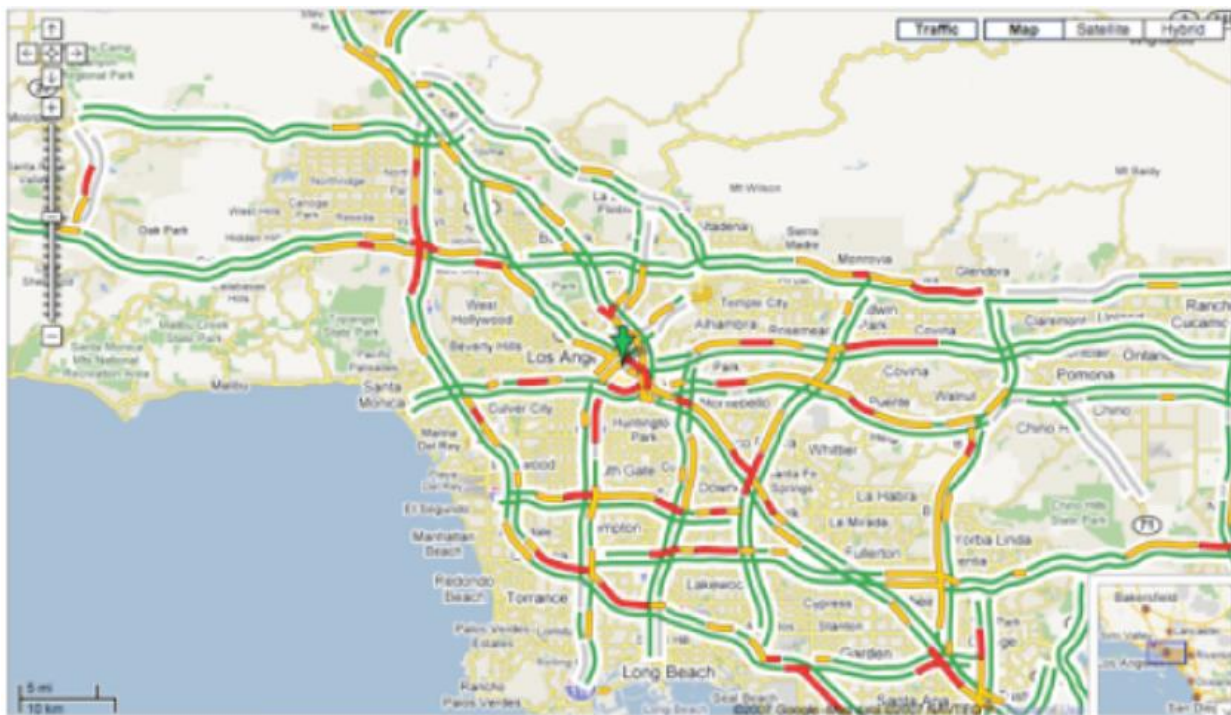
Figure 2.20: Road congestion visualization by Kirk Goldsberry [44].

The other form of representation is heat maps in which they calculated the values of congestion and then created the scale according to the congestion level. Afterwards, they assigned the heat value to corresponding congestion value. Represented colors show the congestion level. The congestion level was categorized in some colors: red, yellow, orange, and blue [41]. The map is shown below figure 2.24.
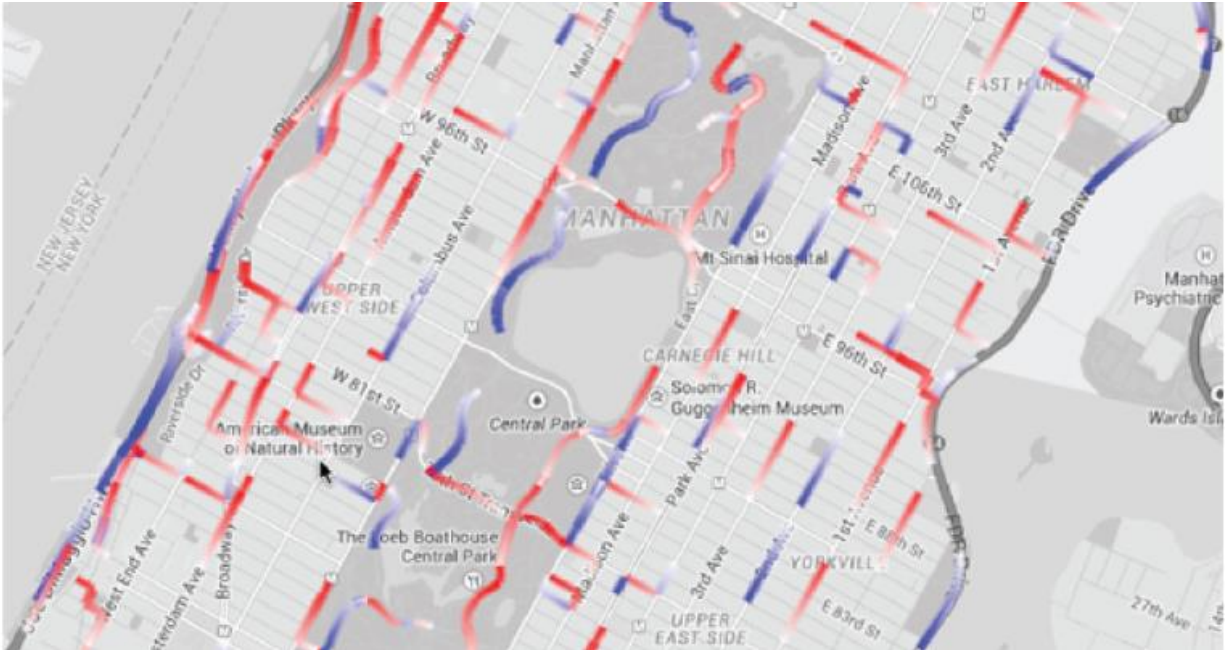
Figure 2.21: Line visualization by Sobral, T., Galvão, T., & Borges, J. (2019) [41].

There is another way of visualization in which the mean speed on road links are shown. In which the arrowhead is showing the direction of flow of traffic and the color scheme is showing the average speed on each road. In the appendix VI-D arrows on each road can be seen [41].

The lined based visualization is also useful in traffic to show the flow direction of the traffic or the movement direction of the people. The color and line width are used to represent the variation in the geographic data. This kind of visualization is useful for the trajectory data visualization. It has the capability of showing the continuous data on the line segment. It is famous for showing the traffic intensity, vehicle speed, time of journey and traffic direction [42].

2.3.4.1.3 Polygon-based visualization technique

The polygon-based visualization normally came from the point and line-based data which are spread on the regions such as counties and other kind of administrative boundaries. The polygon-based data visualization is famous and useful to get an overview of data and understand the pattern on macro level. They could be beneficial for the comparison between different regions. They could be used for different mobility attributes e.g. death rate in different regions.

In the given figure 2.26 Yin et al. (2015) visualized the accessibility indexes and the travel times by using heat map and choropleth over the Chicago city blocks [45] [46]. In which they provided the tool to compare between two distinct transportation network scenarios.
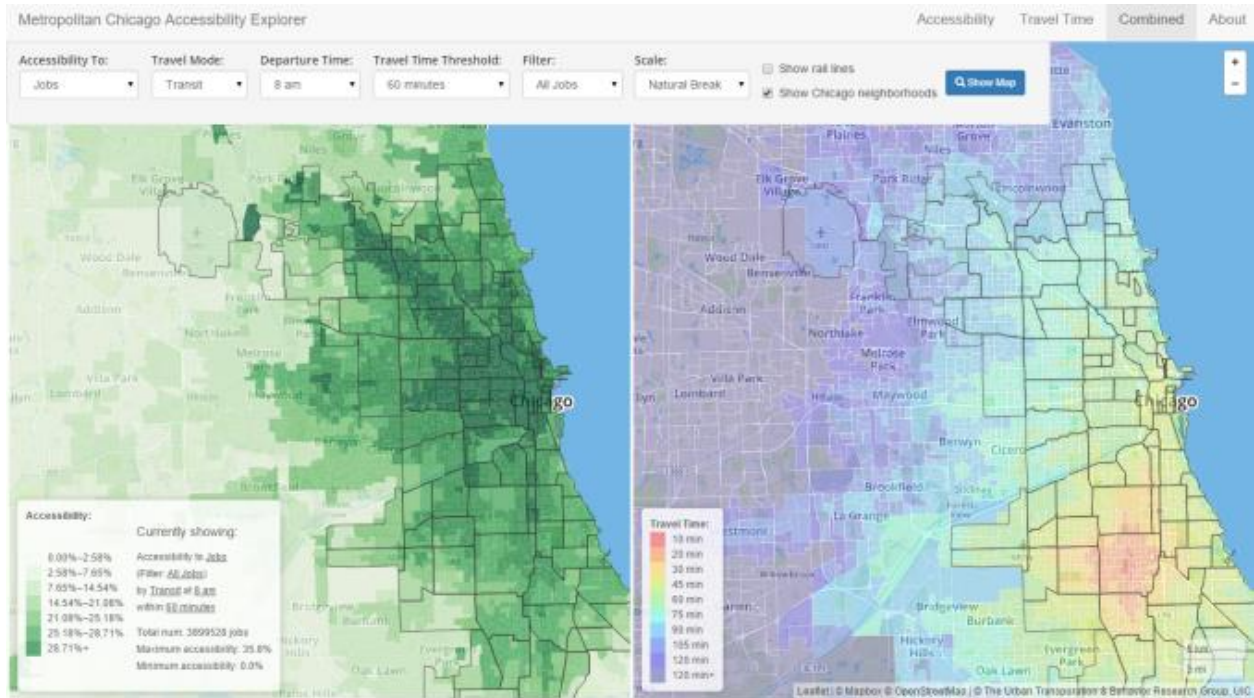
Figure 2.22: Polygon based visualization by Yin, S.; Li, M., Tilahun, N., Forbes, A, Johnson (2015) [41].

Different geovisualization techniques used in the research work have been summarized alongside the reason for using the methods in the table 3 below. As my platform is visualizing the numeric values and the line-based information on the map that is why point-based and line-based visualization are used in my research work. It is evident from the table which geovisualization technique is most feasible for this research work.

Publication	Visualization technique	Reason
Chris Weaver (2006), J. Wood et al. (2007), Sobral, T et al.	Point-based Visualization	Used for Numeric Values and points
Kirk Goldsberry,	Line-based Visualization	Used for Roads, continuous values of lines
Yin et al. (2015)	Polygon-based Visualization	Used for Value spread on whole region

Table 3: Geovisualization techniques

Chapter 3: Methodology

This chapter is describing about the development of the platform/GUI. In this chapter, the complete methodology adopted to develop the GUI will be discussed. This will include the selected data types most feasible for GUI, possible participants who can upload the data and process the already available data in the storage, possible formats of the data which could be uploaded in platform, mobility indicators which will be visualized on the map and the used languages, SDKs & frameworks for the development of GUI.

3.1 Mobility Data

The mobility data consists of four major classes containing environmental, economic data, social and geographical data. These classes will have the data of interest for the processing and visualization in the Graphical User Interface.
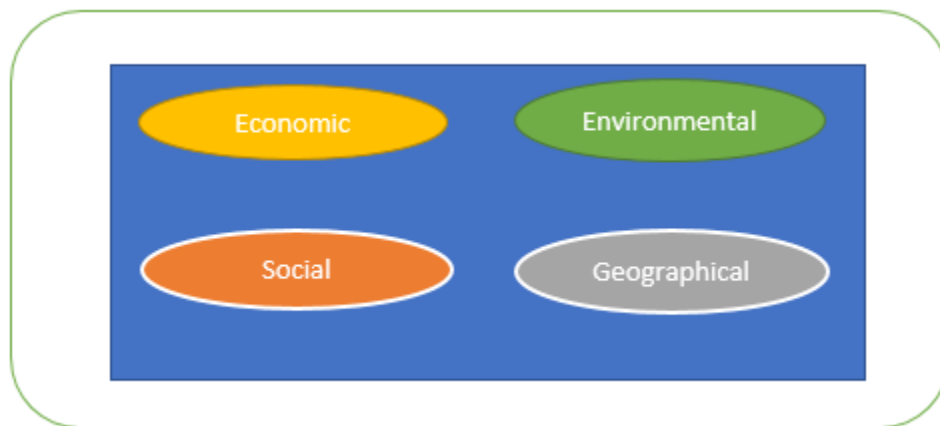
Figure 3.1: Collected data categories

Each group in the figure 3.1 above has relevant data for the mobility indicators. Economy related data will have wealth and revenues related information. Social data will contain the number of people, number of deaths, accidents happened and available vehicles. The environmental data is containing the information about effective gases in terms of value. The last one is geographical data which will contain the information related to land cover area and streets for example the condition of street, potholes, and electric pillars. The data related to each category can be seen figure 3.2.
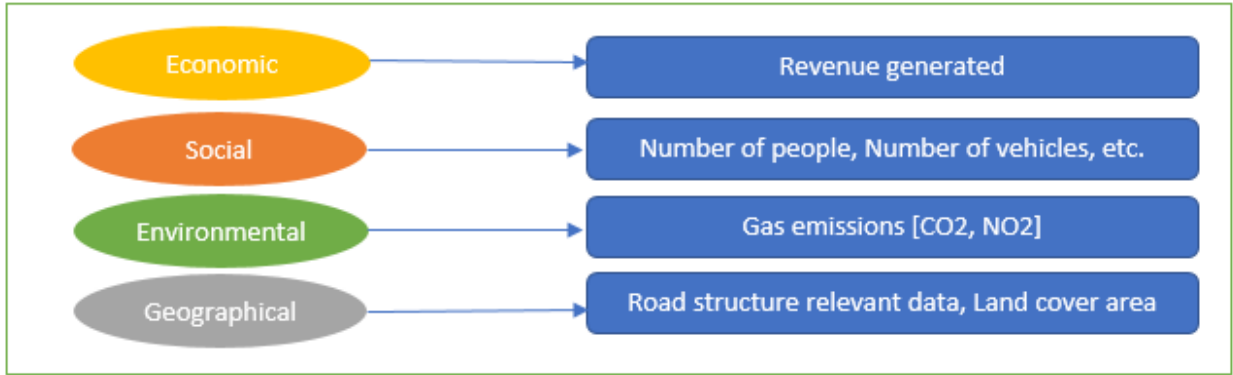
Figure 3.2: Data corresponding to each data dimension

3.2 Users roles

As the GUI is interactive and user collaborative platform where one user will be uploading the data and store them. The second user will be able to reach that data and process the available data. The data processing means data structuring which includes the data organization and storing in data base so that queries can be used to extract the data from data base. So, the users have been divided into two categories based on their roles. In figure 3.3 you can see the user type and their responsibilities on the platform.
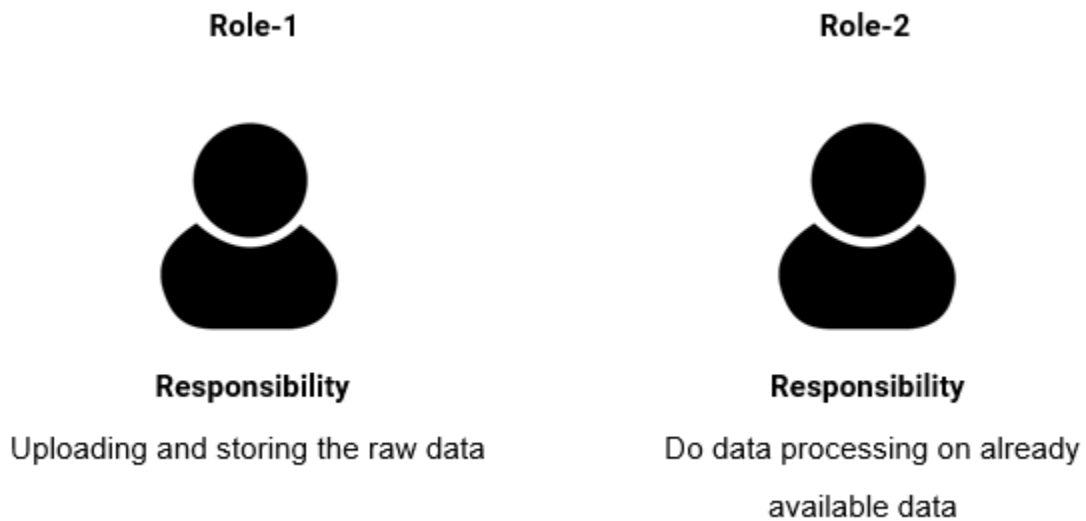
Figure 3.3: The roles of user on platform

3.3 Participants

The participants who will be participating in the application will include the universities globally (as mentioned in last chapter about the hurdles and the most feasible participants to collect the data are research institutes). From each university there will be categories of researchers including the professors and research students. They will be able to upload and share the data for data processing and visualization activities.
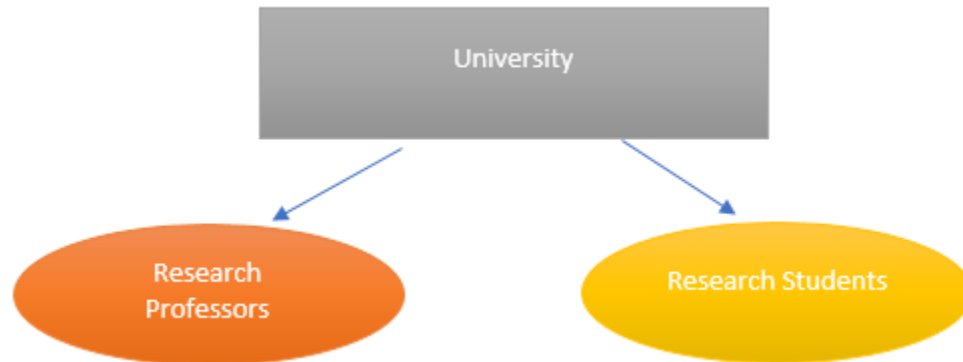
Figure 3.4: Major participants

As shown in figure 3.4 we have participants in form of university where two types of participants are available from a university including research professor and research student. According to aCar Mobility ASTU (Adama Scienxe and Technology University), INPHB and TUM (Technical University Munich) will be the university who will be dealing with the application.

3.4 File formats

For users to upload the data in the platform a specific format has been selected after thorough research (explained in chapter 2). PDF format for the document files and PNG & JPEG file formats for the Images are the most feasible formats of data for this platform based on data protection and platform performance. The document files will be uploaded in a PDF file which will have the data related to facts & figures and percentage values for mobility indicators. User will be asked to give the population data, number of vehicles, number of deaths, gas emission data having the coordinates of the specific location in PDF file. On other hand, image file will give image information about the road condition, number of potholes on that street and number of electric poles determined by the sight of the place in image file. The location of the place will be pertained by its metadata.

There are some sample images of the files as shown in the figure 3.5 and figure 3.6.

Technical University Munich

Village: Harar

Coordinates: 9.314116, 42.116604

Social

- **Population:**
  4500
- **Vehicles Available:**
  250
- **Accidents:**
  154
- **Deaths:**
  12
- **Vehicles types:**
  Car: 150, Carts: 200, motorcycle: 300
- **Women/Men:**
  Women: 2800, Men: 1700
- **Vulnerabilities**
  Flood: 12%

Geographical:

- **Land use:**
  Green: 30% Buildings: 60%

Environmental:

- **Gas Emission:**
  CO2: 12%, NO2: 13%

Economic:

- **Budget for development:**
  1.2 Millions

Figure 3.5: PDF raw data file

The above image is showing the raw data for specific village with specified coordinates in the document file. As you can see above the village name is Harar and the coordinates are also given.

Figure 3.6: Image raw data file

The Image above is showing the condition of the road which is only for the road visualization. Where we can see the pothole and the available electric poles as well. The road condition is divided into the three classes good, moderate and bad.

Figure 3.7: default parameters of the road condition

3.5 Data processing

After getting the data from the users, the next step is to structure the data. For that the HTML form will be used in the platform because it will give the user the ability to collaborate and flexibility in structuring the partial data as well. The second user will be able to access the available data and then structure the raw data while having a look into the available files. That form is transferring all the indicators to the database. Those indicators will be retrieved from the database for the visualization. In the given figure 3.8 below, the idea of the HTML form which has been used in the website has been shown.

Figure 3.8: Concept of HTML sample form

In the above form, the main latitude and longitude section for giving the location of the village is shown. There are two other sections i.e. population data and vehicles data. The information is stored in different corresponding tables in the database. The column fields are same as the fields in the html form.

3.6 Mobility impact factors

After the literature review and based on the data taken from user in HTML form these are the mobility indicators that will be shown on the web map.

Overall indicators for the whole village:

- Population: Showing the number of people in the village.
- Vehicles Available: Showing the available vehicles in that location.
- Accidents: Number of accidents that happened in that area.
- Deaths: Number of deaths that happened in that area.
- Vehicles types: Number of vehicles with their types.
- Women/Men: Number of men and women.
- Vulnerabilities: Flood value.
- Land use: Percentage of built-in area and vegetation.
- Gas Emission: Percentage of gas emitted.
- Budget for development: Available budget for development and food.

- Access: Access to transportation.

Street view indicators:

- Roads: Roads condition will be shown on the map.
- Electric poles: Number of electric poles on that road.
- Potholes: Number of potholes on that road.
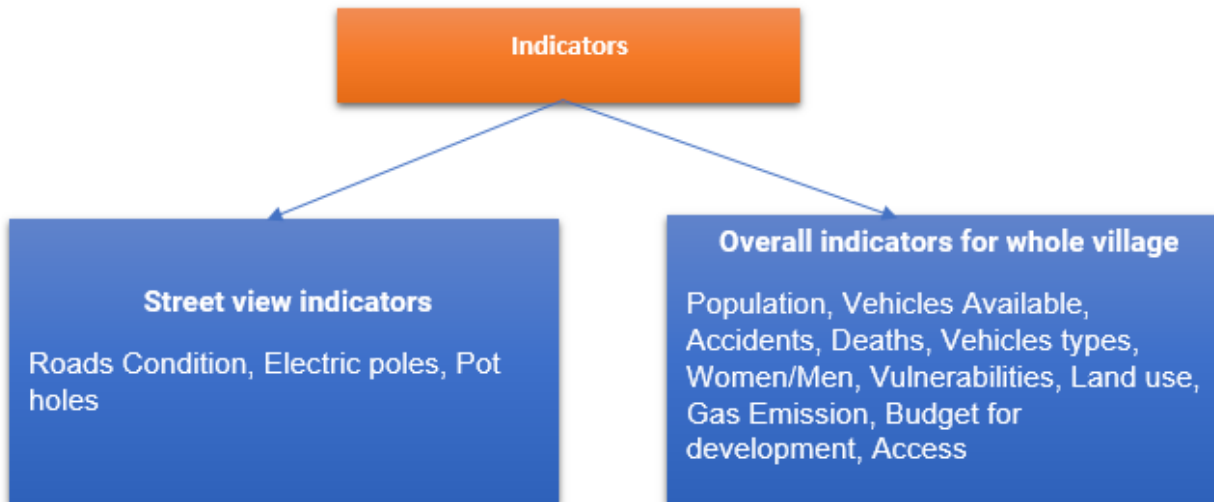
Figure 3.9: Used mobility indicators.

3.7 Visualization of indicators

For the visualization of the indicators on the map, there are many types of visualization techniques as mentioned in the previous chapter. However, in this case point-based visualization is used frequently because of discrete data. For all the indicators, the icons have been designed for the GUI. Mobility indicators which are on the whole village level are visualized by self-made icons. In the case of streets level, streets are shown with color and pin markers showing the located indicators on each specific street. The icons used for the mobility indicators are explained below in figure 3.10.
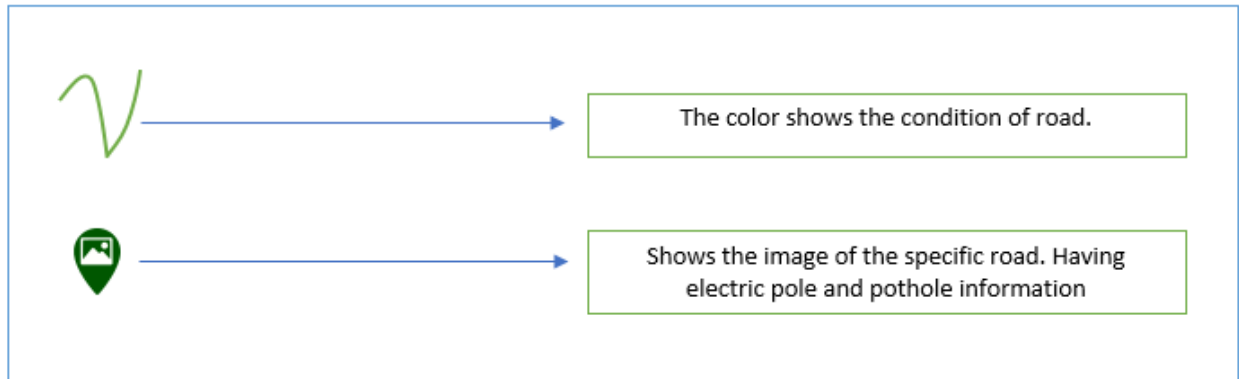
Figure 3.10: Street level Indicators

In the figure above, four types of visualizaition icons are shown, which show the specific information on street level. On-street level the GUI will show the condition of the streets whether it is good or bad. The whole street will be colored with the assigned color to the condition i.e. green color representing the good condition of the road. The next icon with an electricity sign inside the pin is showing the available electric poles on the roads the number of those poles is shown on the top of the icon. The next icon is for the image view of the street if the user will click on that pin he will get an image in the popup where he can see the real-world view of the street. The last icon is used for giving the information regarding the number of potholes on the road which could be dangerous for the electric vehicles and can cause trouble for the movement.
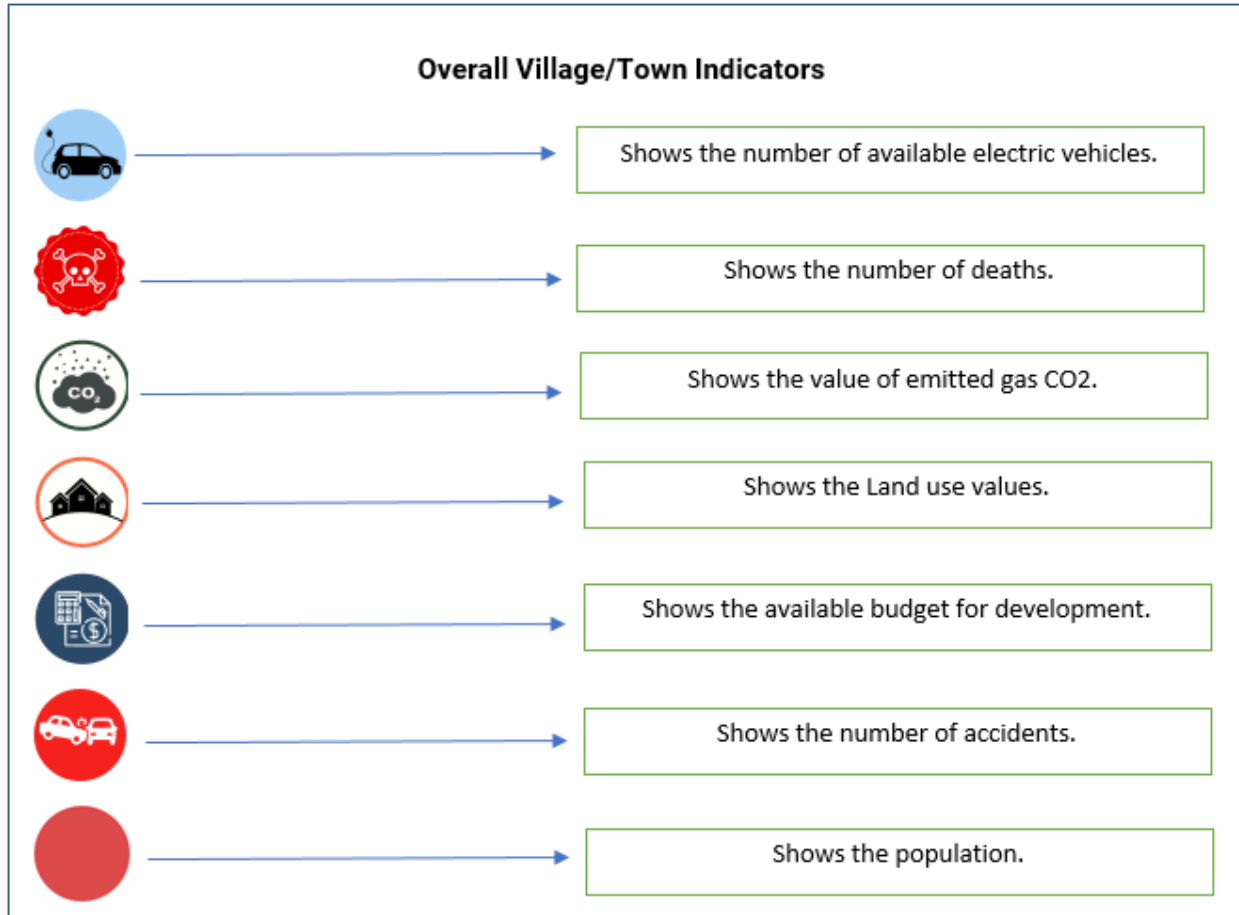
Figure 3.11: Village/Town level indicators

In figure 3.11 above, the global indicators which are giving the information on the entire the village or town level are shown. Where we are showing the number of vehicles in the village, the number of men and women, flood damage that happened in the village, number of deaths, emitted gas CO_2 value, land covered by buildings & pastures, available budget for the development and number of accidents. In the last simple leaflet circle the value of the population in town is shown inside the circle and the size of the circle varies in proportion to the population.

3.8 Prototype Development

The final step is the development of the user interactive GUI/platform after gathering all the relevant information through research data files, users, mobility indicators and icon used for the map. For the development some of major languages, frameworks, data base, SDK and open source libraries are used. The concept of the prototype is divided into some important parts including the data storage, frontend, backend and database.

In the given architecture in figure 3.12 below the basic concept of the prototype is shown. In this concept, the uploaded files by user are stored as raw data in cloud storage and shown in GUI as available files. The structured data is stored in the data base by the form available in the GUI. From this structured data the derived indicators are visualized in GUI.
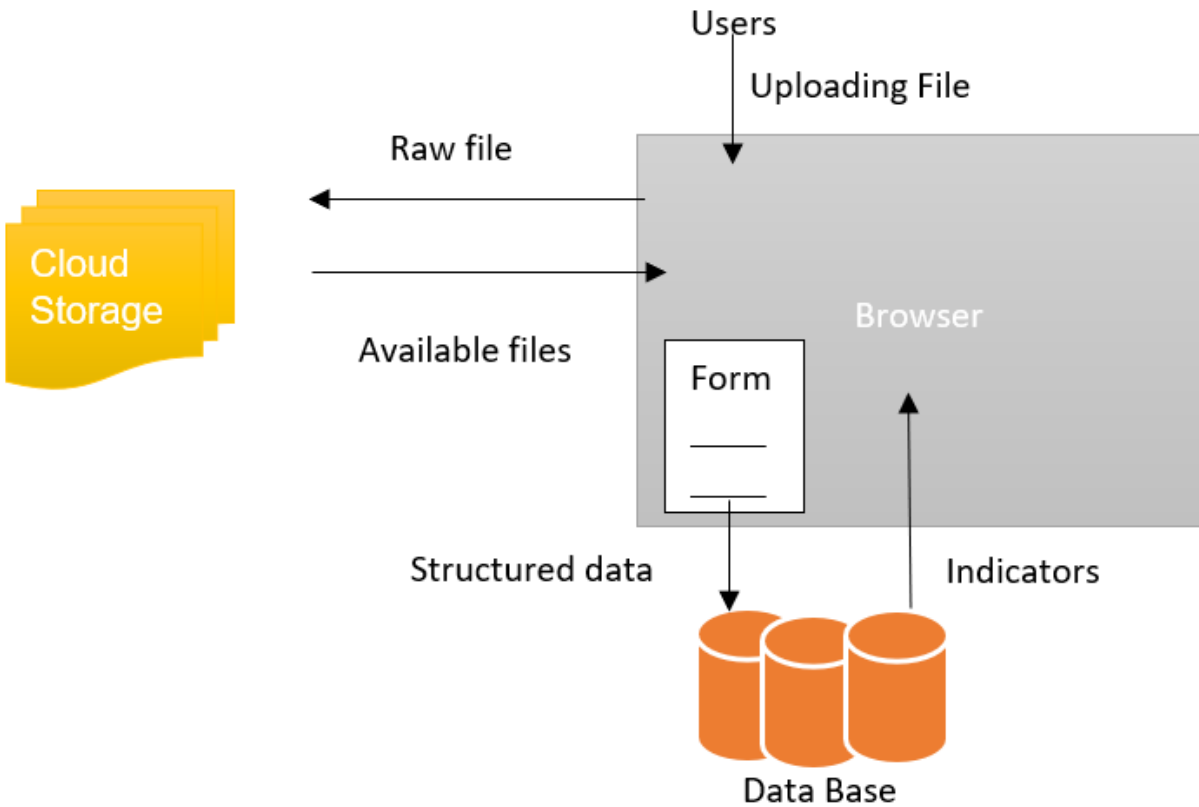
Figure 3.12: Basic concept of prototype

Based on the above concept the most suitable languages, framework, SDK, platform and open source libraries were selected. Development part is divided into these major subparts:

Front End: For the frontend HTML, CSS, JavaScript languages are used to display all the contents on the website.

Backend: Node.js an open source platform is used for backend. This platform is used for storing and retrieving the data from database.

Data file Storage: Firebase SDK is used for the data storage. This SDK is used to store all files in the firebase storage and save their meta data in the FireStore data store.

Structured data storage: For the storage of data, the postgres database management system is used for the storage of mobility indicators.

Visualization of indicators: For the visualization of the indicators leaflet JavaScript library is used.

The detailed working of prototype is explained figure 3.13. In the figure the role of framework, platform, languages, library and SDKs for developing the prototype can be seen.
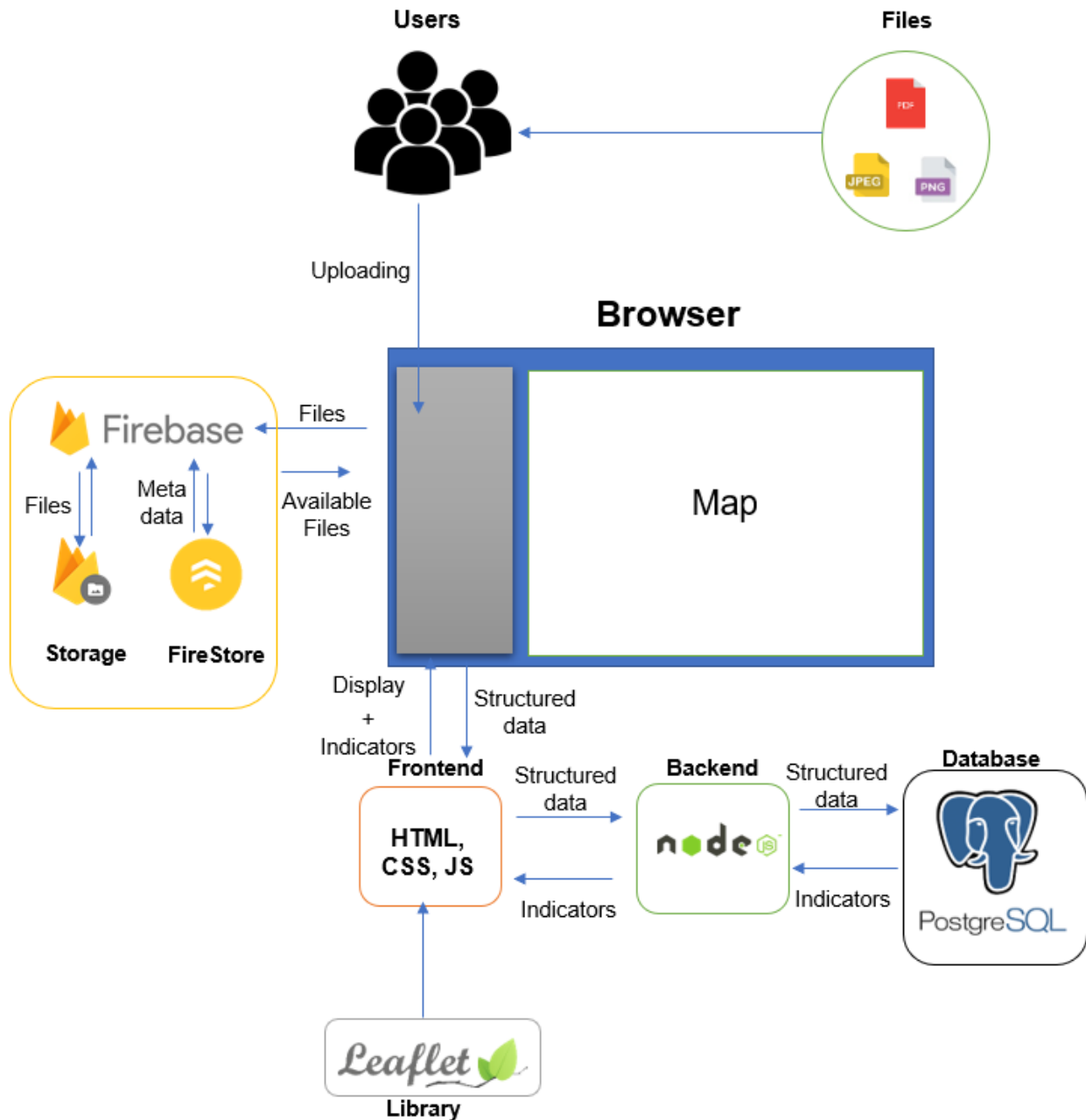
Figure 3.13: Prototype architecture and used tools

In this section we will talk about the architecture of prototype in detail. Moreover, the role and working of all the tools which have been used in the prototype development will be explained.

3.8.1 Front End Development

As mentioned above, for the frontend development basic languages HTML, CSS, JavaScript are used. The frontend plays an important role in the display of the website. On the main page of GUI, the title bar, side drawer (with three options Uploading, Available data, Processing of data) are shown. In the main window, the map is added. The map is provided by the leaflet library. All the markers and popup actions on markers are done by using the leaflet library. In the uploading option the data is loaded on the page. In the available field all the available data from storage is displayed. The final option is the processing of data integrated with HTML form option. The form is asking users to fill it out to store the data. The visualization is on the leaflet map. In figure 3.14 below the components of the front end in detail can be seen.
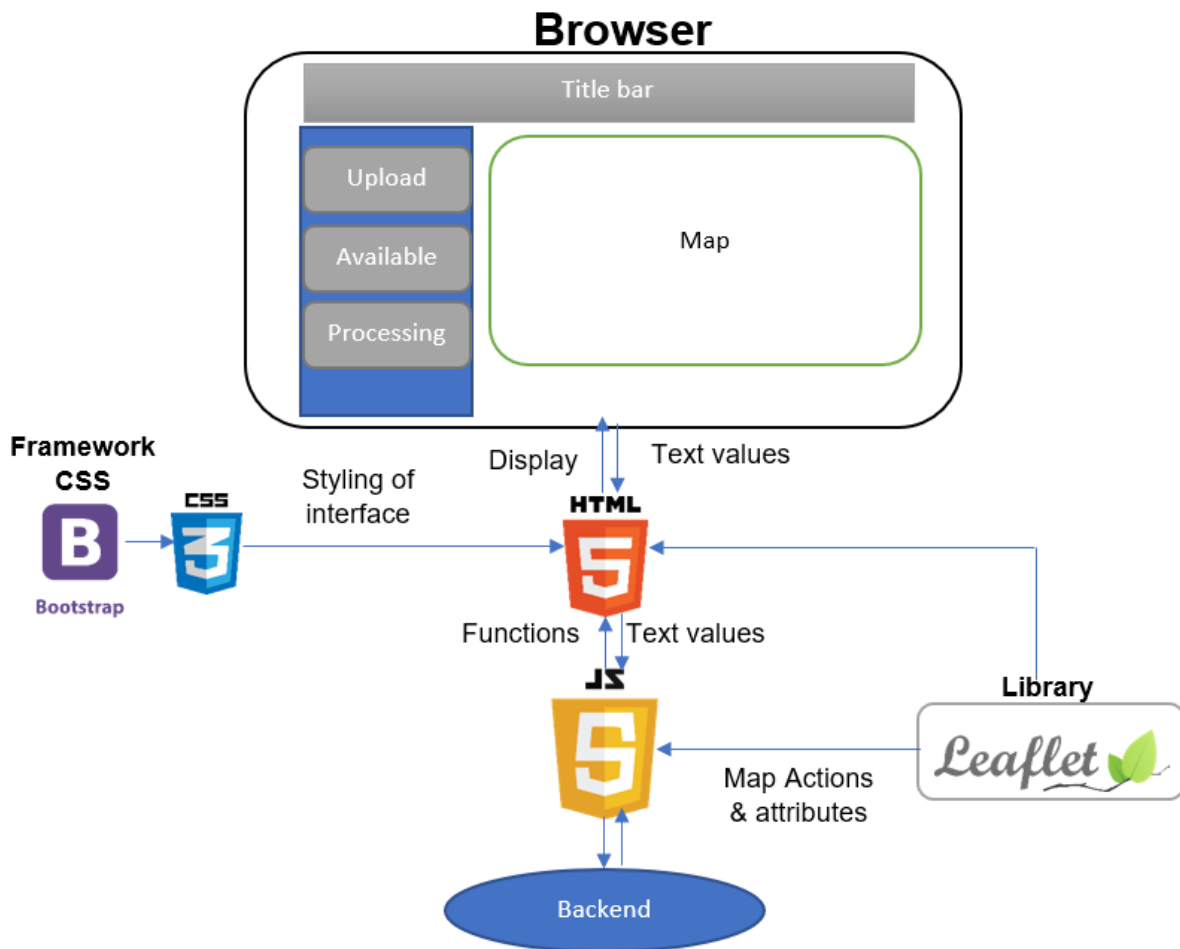
Figure 3.14: Frontend development architecture

In figure 3.14 above the logic behind the frontend part is shown. GUI components are depending on HTML, CSS, JavaScript and Leaflet.js. Every file is connected with a HTML file. For styling of the website components, Bootstrap framework is used. The JavaScript has all the functions which are getting and sending the values to html documents. In JavaScript, functions are called, and the map attributes are shown on the map.

3.8.1.1 Uploading and retrieving the files

For uploading and storing the files in the Cloud Firestore and retrieving them back on the graphical user interface the concept is shown in figure 3.15 below:
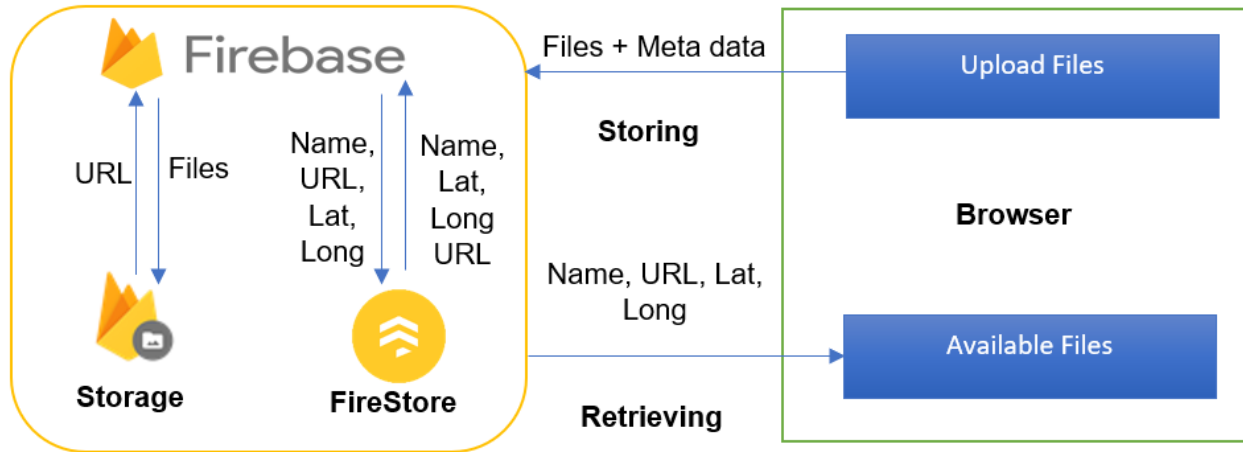
Figure 3.15: Data handling architecture

3.8.1.2 Storing data files

The user has been provided with a button in GUI to upload the files. The meta data of data file will be entered by user in the given fields. For the storage of data files and their corresponding mete data Firebase SDK has been used. In Firebase SDK there are two types of tools used. First one is cloud storage and the second is FireStore data base.

3.8.1.3 Cloud Storage

Cloud storage is provided by firebase which can store any object easily. Two folders named as "Images" folder and "PDF" are added in firebase. In Image folder both types of images including JPEG and PNG will be stored. In the PDF folder, only PDF files will be kept figure 3.16.
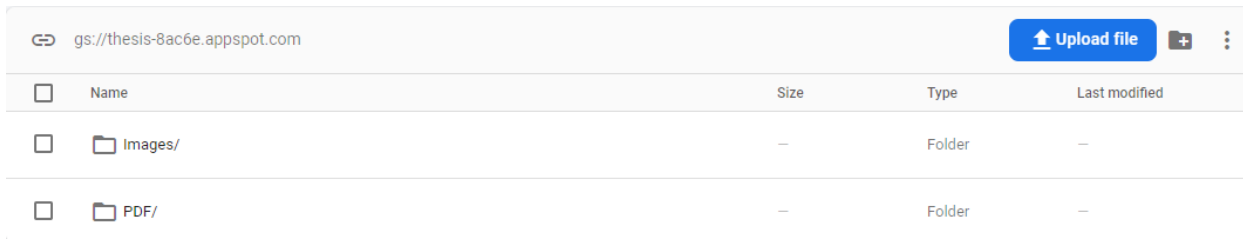
Figure 3.16: folders in cloud storage

In each folder the file is being stored with information including the type of file, modified date, URL and the size of the file. In the given figure 3.17 the information of the stored files is shown.

	Name	Size	Type	Last modified
☐	PDF .pdf	6.85 MB	application/pdf	May 17, 2021
☐	PDF PDF1.pdf	567.92 KB	application/pdf	May 18, 2021
☐	PDF PDF3.pdf	4.54 MB	application/pdf	May 18, 2021
☐	PDF PDF_FILE.pdf	4.54 MB	application/pdf	May 17, 2021

Figure 3.17: Information stored in storage

3.8.1.4 FireStore database

FireStore database is used to store the meta information of all files. In FireStore, the data stores in the form of collection so two collections corresponding to file folders named PDF and Images are created. In these collections, there are documents representing the single file. In each document the meta information is stored as nodes. The information from user entered fields and uploaded files is taken. The file name and URL of the file is taken from the Firebase cloud storage. The meta information is different for each file type. For images, latitude, longitude of image, name of image, user type, and URL generated after the image upload are stored. The latitude and longitude of the image file is calculated via click on the map by user. But for the PDF, the name of the file, URL of file and the user type are stored.

The metadata coming from user entered fields looks like the figure 3.18 given below:
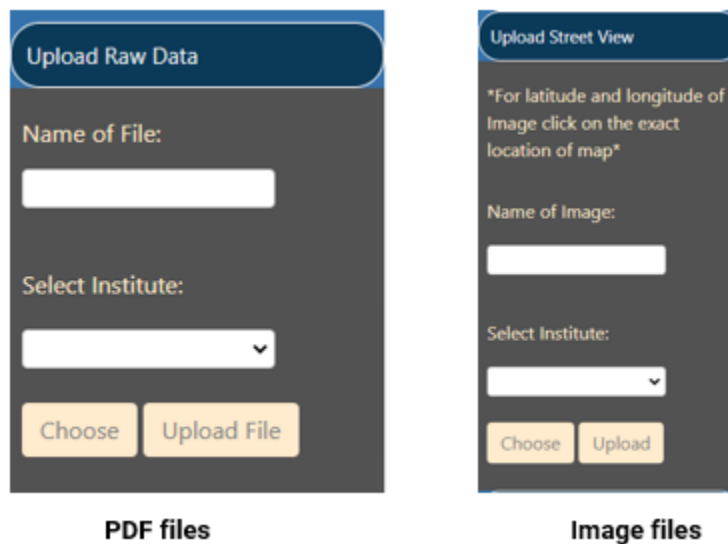
Figure 3.18: Raw data file uploading

Figure 3.19 shows how the data stored in the Firestore database looks like.

Figure 3.19: Firestore data collection

3.8.1.5 Retrieving Available files

After the storage of files, all the previous added files in the storage are retrieved. In this case, all the stored metadata of files as mentioned above are retrieved.

In the figure 3.20 all the retrieved files in the available dropdown option and on map in the GUI are shown. Where we have two sections of PDF and Images. In PDF there are two more sections related to user type. In each user type section, there are corresponding files. And in Image section, the same sections of student and the researcher are shown and in each user type section available images with their meta information retrieved from the FireStore database are shown. It has name, latitude and longitude and the open option where second user will be able to open the file on blank browser.

Figure 3.20.1: Retrieval of data files on side navbar
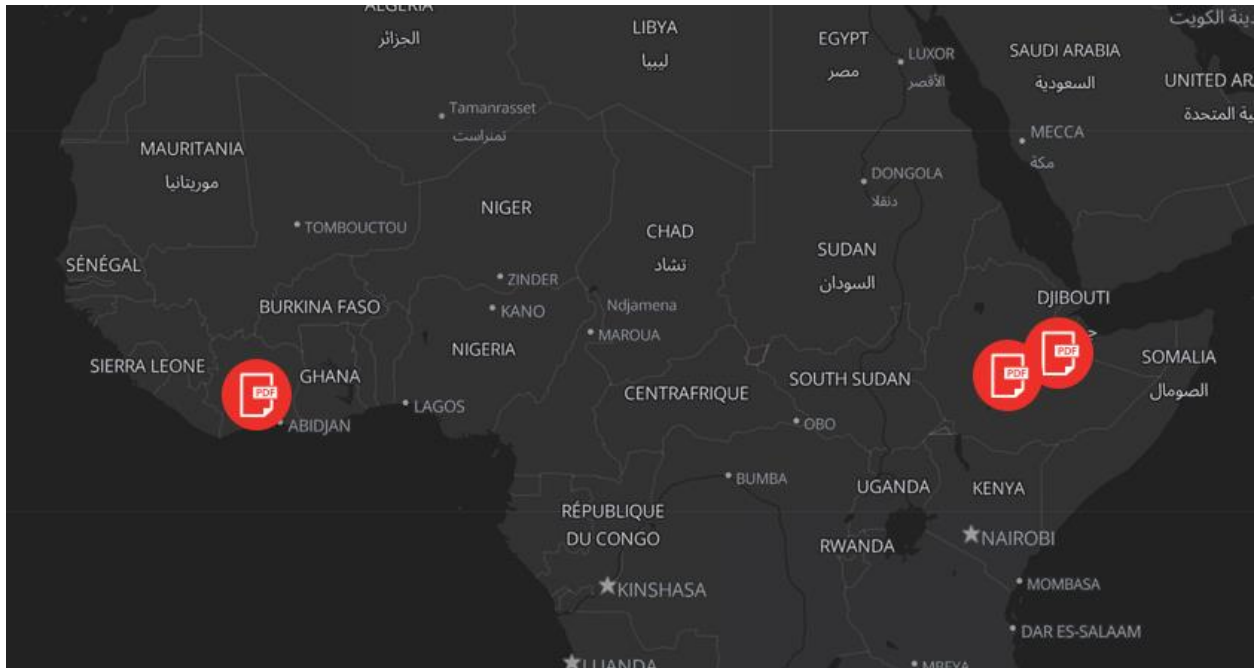
Figure 3.20.2: Retrieval of PDF data files on map

Figure 3.20.3: Retrieval of Image data files on side map

3.8.1.6 Data processing of raw data

The third option in the GUI is processing of data. Where user will enter the data in the input fields. This is done by adding the html form in that option. The user will click on the form then user will see the form in the drawer. The logic behind the form is shown in the figure 3.21.
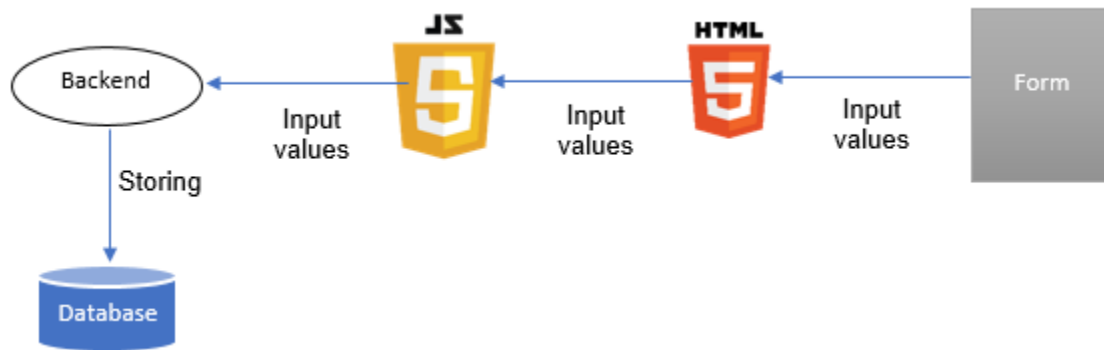
Figure 3.21: Data processing architecture

The input values are entered in the form and then those values are transferred to html document. From where the values are called in the JavaScript functions. By calling JavaScript functions those values are stored in database via Rest API. The image of html form is shown in figure 3.22.

Figure 3.22: Web forms for the data processing

3.8.1.7 Map visualization

For the visualization of all the indicators, leaflet library has been used which is an open source JavaScript library. Indicators and base map styling are done with leaflet. There are two major components of the map. First one is the base map and second one is visualization of the elements on base map. User has the options to select the base map of his own choice. First one is simple street view base map which is suitable for general visualization. The dark mode

base map is also given which is more in contrast with the streets data visualization. The grey base map; used for the darker visualization of the data values on the map.

The icons of different signs are used for the visualization of the indicators on map. And user is given the option of selecting any indicator to visualize on the map. On the top right corner, there is a dialog box where user can select for different visualization. The logic of the map is explained in the figure 3.23.

Figure 3.23: Map visualization architecture.

Base map used in map are shown below figure 3.24.
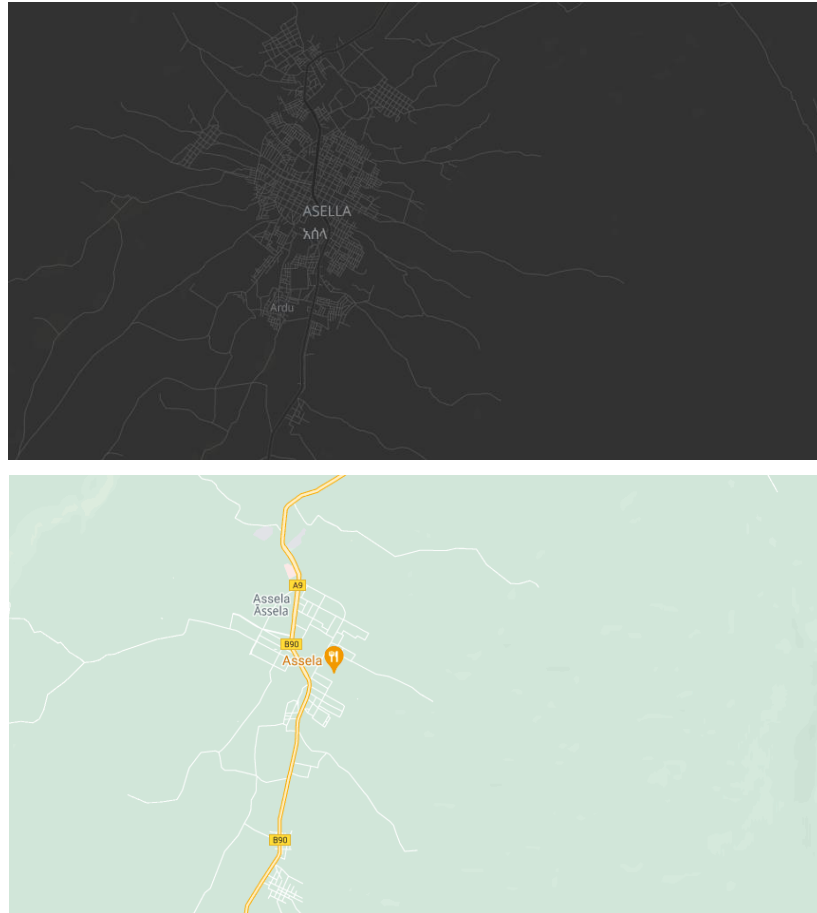
Figure 3.24: Available base maps

The visualization of indicators is done like the image shown below. Where you can see the marker of green color with the image icon inside the maker. When user will click on that the image of that street and the information related to that street will be popped up.
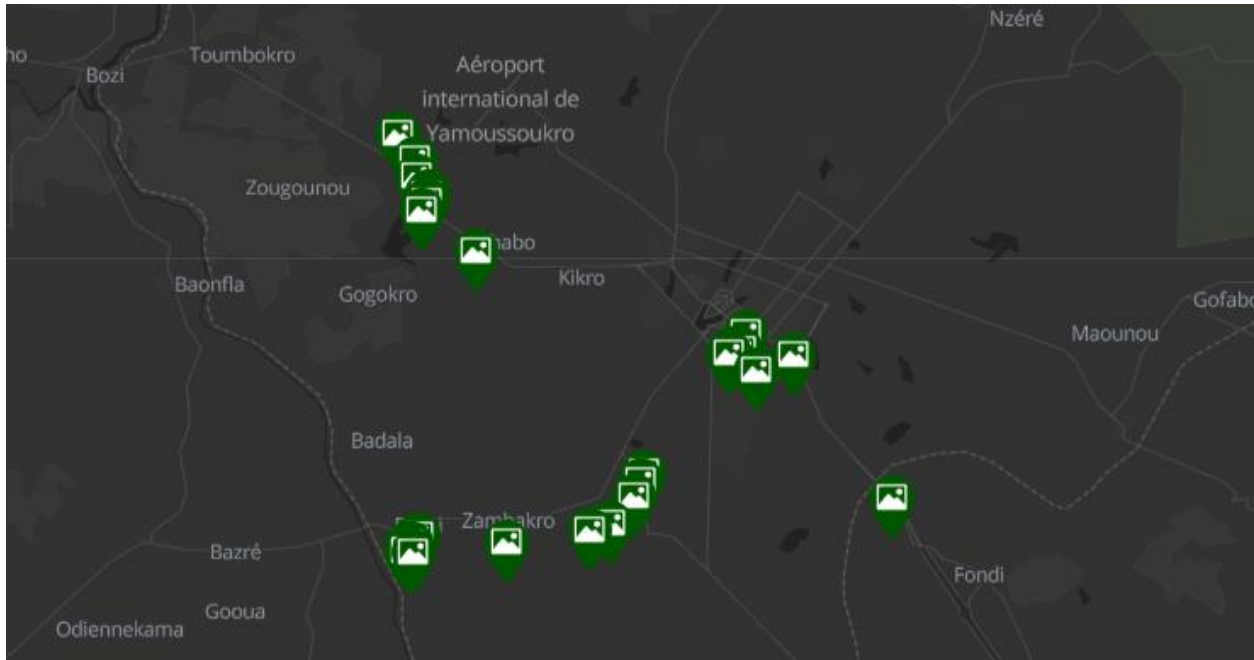
Figure 3.25: streets markers visualization.

Figure 3.26: Population indicator visualization.
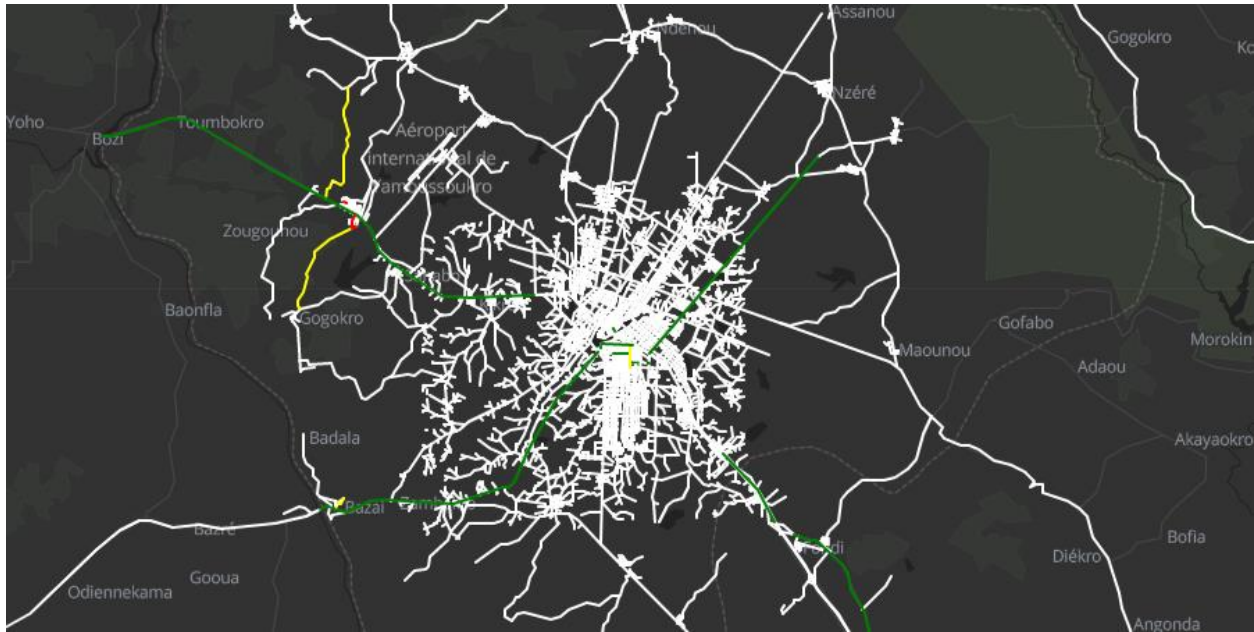
Figure 3.27: Roads condition visualization.

The check box is given to select the base map and indicators. Users can select any base map for the making visualization interactive. And they can select the indicator whatever they want to see on the map.

Figure 3.28: Interactive elements box

For user understanding, the legend on map has also been added. Where all indicators with their icon and the label has been shown figure 3.29.
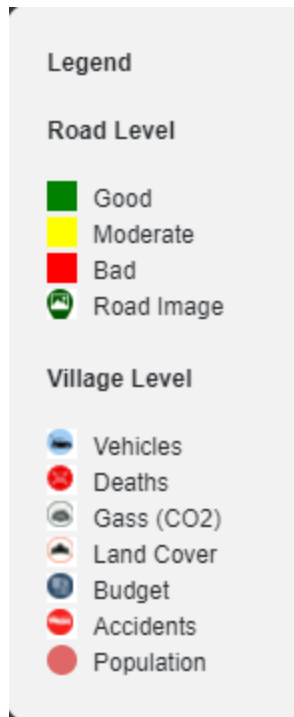
Figure 3.29: Interactive element (Legend)

3.8.2 Backend Development

Node.js platform is used for backend development where Rest APIs are created. In APIs, update, extract and insert data queries are used. GET and POST http requests are used for inserting/updating the data and extracting the data from database. The request is coming from the front end and using in the http request where the APIs use the coming parameters to give a response in the form of JSON. That JSON contains the extracted indicators from the database. The API has the SQL queries. These queries are run on the data in the database.
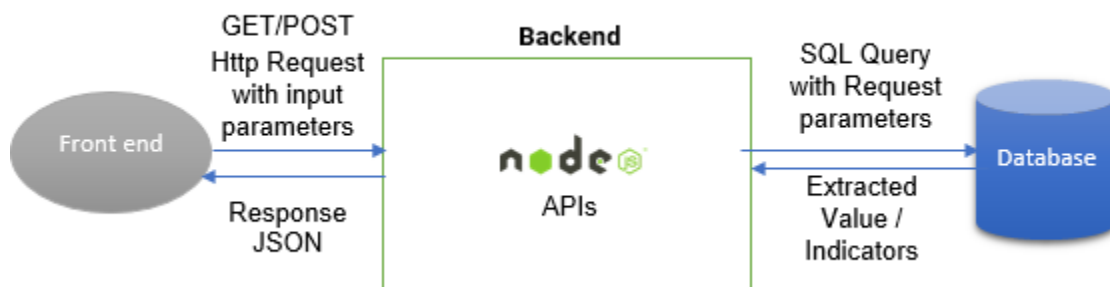
Figure 3.30: backend development architecture

3.8.3 Database

For the data base, postgreSQL database and for managing the data pgadmin4 has been used. The data in backend is taken from the frontend via form. And it is stored in database in

specific table fields. The indicators are retrieved back to the backend from database tables and sent to frontend to show them on the map. In the database, two tables have been created. One table is containing the road vector lines and their corresponding condition field. The second table is containing the overall indicators of whole village. In which we have the fields of village name, village latitude, longitude, and all corresponding indicators.

The architecture of data base is given in the figure 3.31
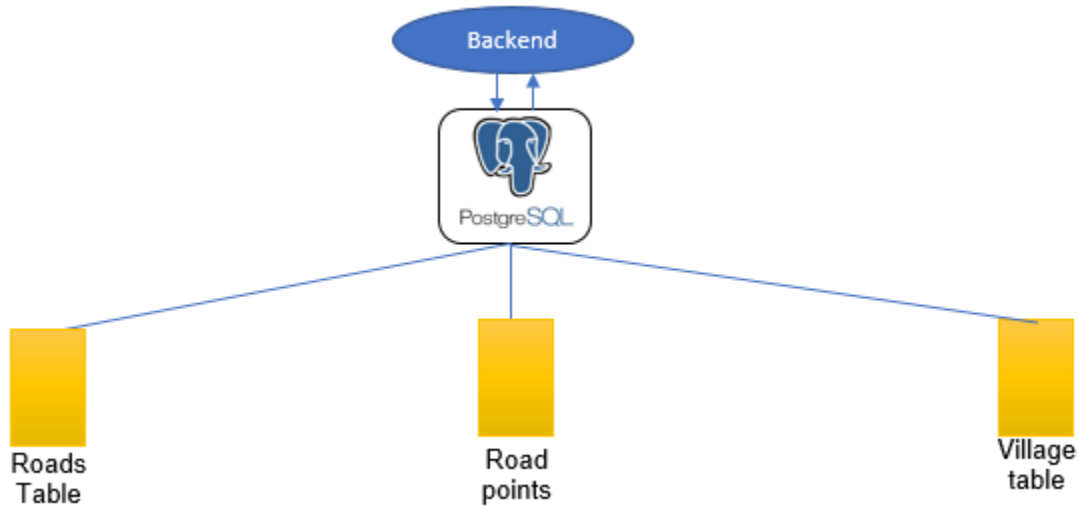
Figure 3.31: Database architecture

3.8.3.1 Village table

In the village table, the whole village indicators with their name of the village, latitude, longitude, population, number of men, number of women, number of vehicles, number of deaths, access of poor people and budget for development are stored figure 3.32.

	lat character varying (255)	lon character varying (255)	village_name character varying (255)	vehicles character varying (255)	population character varying (255)	men character varying (255)	women character varying (255)	deaths character varying (255)
1	7.957978	39.132678	Asella		67269	33826	33443	
2	9.312594	42.119865	Harar	8000	98829	49448	49380	42
3	6.809920	-5.275987	Yamoussoukro		213156	107380	105775	10

Figure 3.32: Village/town values table

3.8.3.2 Roads table

The values from streets section of form are kept in roads table. When user inserts the data, the user is asked to give the latitude and longitude of the nearest point and then closest road is calculated by the SQL query. And then the calculated street condition, number of electric poles and number of potholes are filled in the table. During the retrieval of this table the streets captured are classified by their condition.

name character varying (100)	ref character varying (20)	oneway character varying (1)	maxspeed smallint	layer double precision	bridge character varying (1)	tunnel character varying (1)	geom geometry	street_cond character varying (255)
[null]	[null]	B	0	0	F	F	0105000020E6100...	[null]
[null]	[null]	B	0	0	F	F	0105000020E6100...	[null]
Rue de Sopim	[null]	B	0	0	F	F	0105000020E6100...	[null]
[null]	[null]	B	0	0	F	F	0105000020E6100...	[null]
Rue de l'Hotel Président	[null]	B	0	0	F	F	0105000020E6100...	[null]
[null]	[null]	B	0	0	F	F	0105000020E6100...	[null]
[null]	[null]	B	0	0	F	F	0105000020E6100...	[null]
[null]	[null]	B	0	0	F	F	0105000020E6100...	[null]
[null]	[null]	B	0	0	F	F	0105000020E6100...	[null]
Route de Daloa	[null]	B	0	0	F	F	0105000020E6100...	[null]
[null]	[null]	B	0	0	F	F	0105000020E6100...	[null]

Figure 3.33: Roads condition table.

3.8.3.3 Road points table

In this table, the points (based on which the nearest roads are calculated) are stored. These points are the points of image where they were taken. So, in this table, the latitude, longitude, image URL coming from file store, number of potholes and number of electric poles on the corresponding road are stored.

	lat character varying (255)	lon character varying (255)	image character varying (255)	epoles integer	pothole integer
1	6.732411111111111	-5.4121166666666667	https://firebasestorage.googl...	1	0
2	6.730761111111112	-5.409141666666667	https://firebasestorage.googl...	0	0
3	6.763030555555556	-5.3159	https://firebasestorage.googl...	1	0
4	6.737830555555556	-5.4075722222222223	https://firebasestorage.googl...	0	0
5	6.739705555555555	-5.3382472222222222	https://firebasestorage.googl...	1	0
6	6.810552777777778	-5.281797222222222	https://firebasestorage.googl...	1	0
7	6.752883333333333	-5.2158527777777778	https://firebasestorage.googl...	12	0
8	6.810552777777778	-5.281797222222222	https://firebasestorage.googl...	1	3
9	6.812083333333333	-5.2770166666666665	https://firebasestorage.googl...	2	0
10	6.732411111111111	-5.4121166666666667	https://firebasestorage.googl...	5	0
11	6.898232999999999	-5.415471	https://firebasestorage.googl...	0	0

Figure 3.34: Road points table.

Chapter 4: Results & Evaluation

In this chapter, the end results of developed GUI are discussed. This chapter focuses on the processing of mobility data and the visualization on the map. The processing of the mobility data could be performed on two levels including road level and the village level. To explain the complete functionality of GUI, the sample data is used. The data for Yamoussoukro (Cote d'Ivoire) was provided by doing survey. However, the data for Ethiopian region including Harar and Assela was not provided due to Covid situation.

4.1 Road level

On road level the Image of the specific road is uploaded and the meta information including the latitude and longitude of the Image are filled by the user1. The role of user1 has been explained in previous chapter. Two of all the images of road uploaded in GUI is shown in figure 4.1.

Figure 4.1: Road image data

This image contains all the relevant data i.e. the location of the image and the visual indicators including the road condition, number of potholes, and the electric poles.

The second user access this image from the storage of the data set. And then processes the road data. Where he got the roads visualization of the map after processing showing the location, number of the potholes and the number of electric poles on that location. Below you can see the outcome of the processed roads data. In the figure 4.2 you can see the roads conditions on map with the color assigned. White color is showing no data on that place. Green color is depicting good condition of the roads and the red color is showing the bad condition.
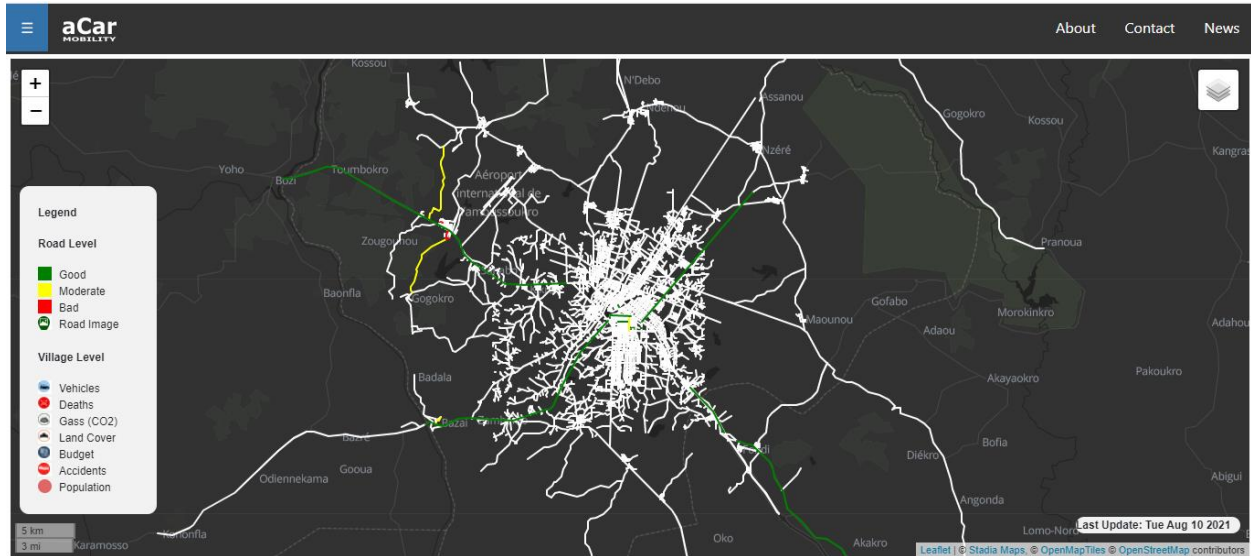
Figure 4.2: Road conditions.

In figure 4.3 you can see the markers on the roads. Which show the location of picture taken, the number of poles and the number of electric poles on that location. The information is also shown on the bottom right dialogue box.
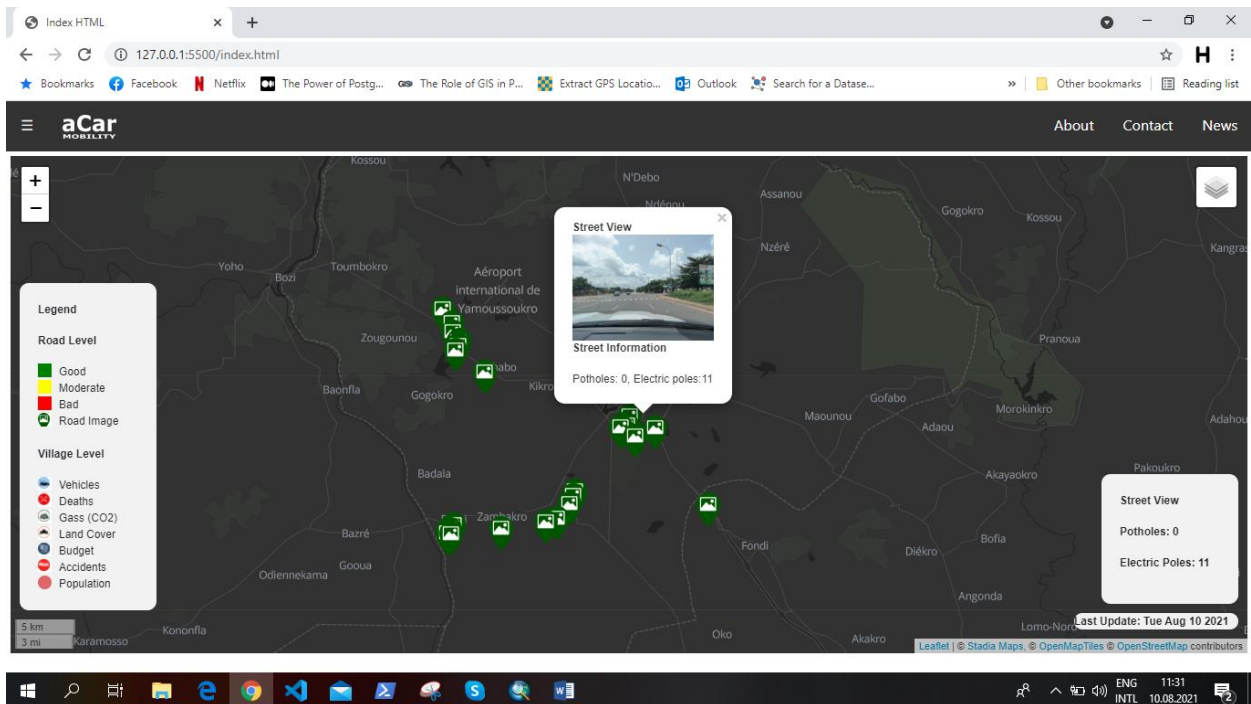
Figure 4.3: Markers showing an image

4.2 Village/Town level

On the village level the PDF file is uploaded by a user on the GUI and later the data is processed by the second user to visualize all the indicators on the map. Those indicators are working on a wide level. In which we can compare the indicators of different villages and towns. In figure 4.4 the PDF report for Harar village is shown.

Indicators

Survey

Lat = 9.312594, Long= 42.119865

Village Name= Harar

Overall indicators for whole Town/City:

1. Total Vehicles = 8000
2. No. of cars = Not available
3. No. of bus = Not available
4. No. of motorbikes = Not available
5. No. of electric cars = Not available
6. No. of rickshaw = Not available
7. Population = 98829
8. No. of men = 49448
9. No. of women = 49380
10. No. of deaths = 42 per 1000 live births
11. CO_2 gas emission value = 0.02
12. Percentage of fields/ pastures covered = 25.08
13. Percentage of built-up covered = 60.68
14. Budget = Not available
15. Accidents = 382

Figure 4.4: PDF data file uploaded

After the processing of the data the indicators were visualized on the map. Which include the environmental, economic, social and geographical indicators on the map. These values are gathered from opensource websites. In figure 4.5 the population indicators on the map which contain the number of men and number of women are shown.

When the user clicks on each circle, he will get the number of men and number of women inside the popup.
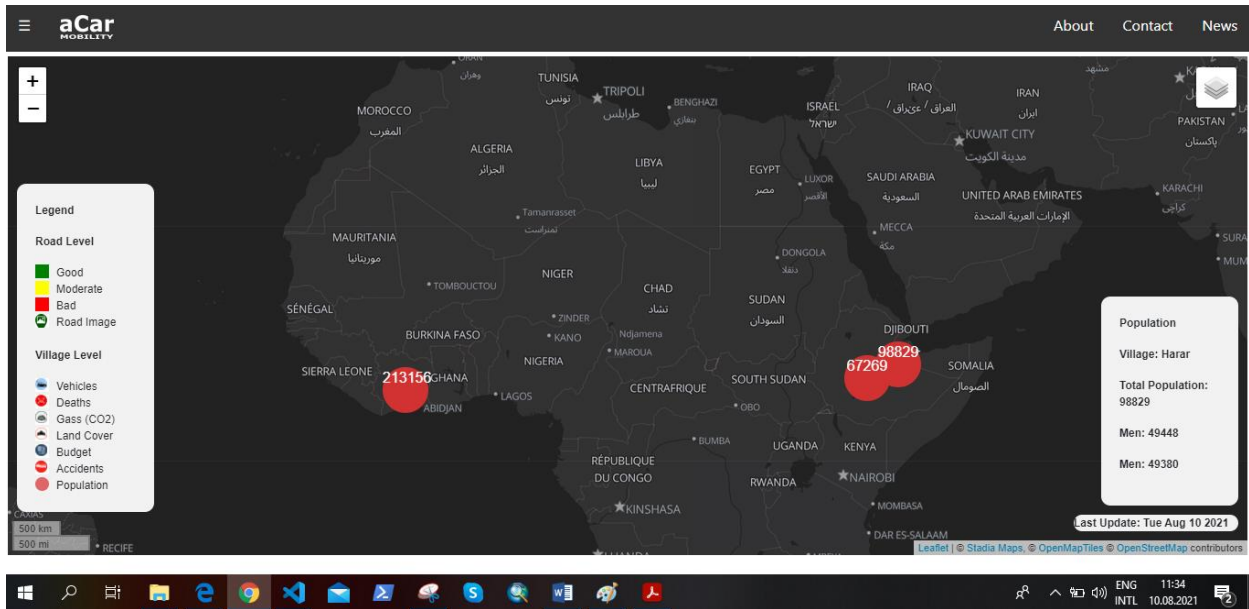
Figure 4.5: Population indicators

In figure 4.6 the vehicle indicators are shown with total number of vehicles available in each village or town. The types of vehicles with their amount can be seen in the popup window after clicking on the icon.
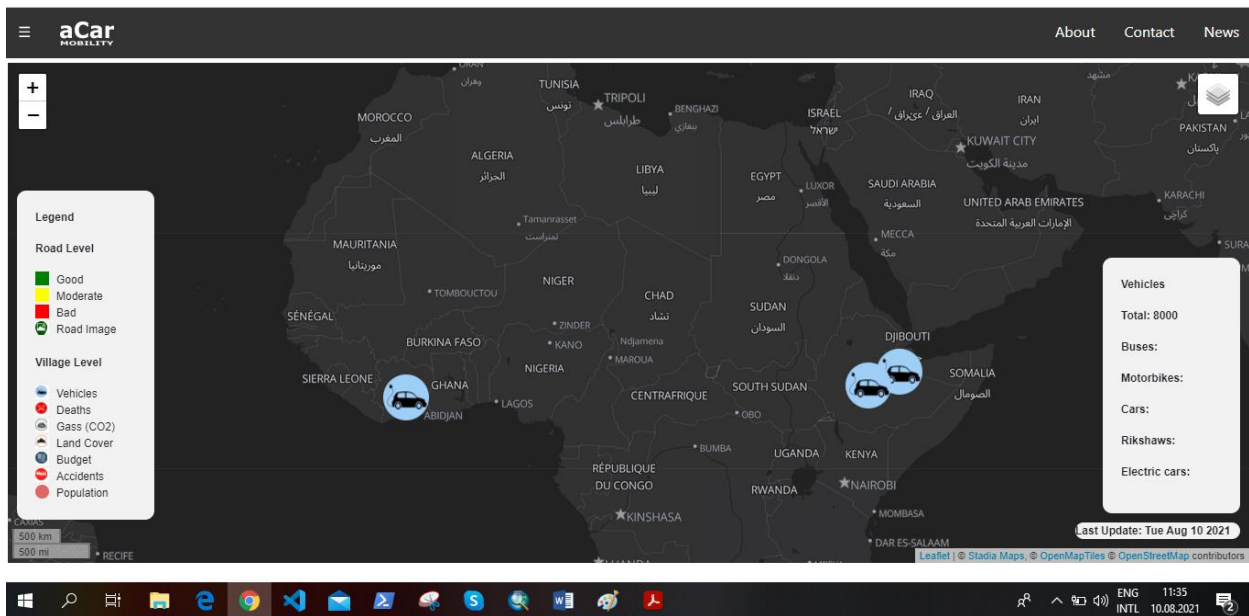
Figure 4.6: Vehicle indicators

In figure 4.7 the deaths happened in each village can be seen. The numbers are on the top of the icon.
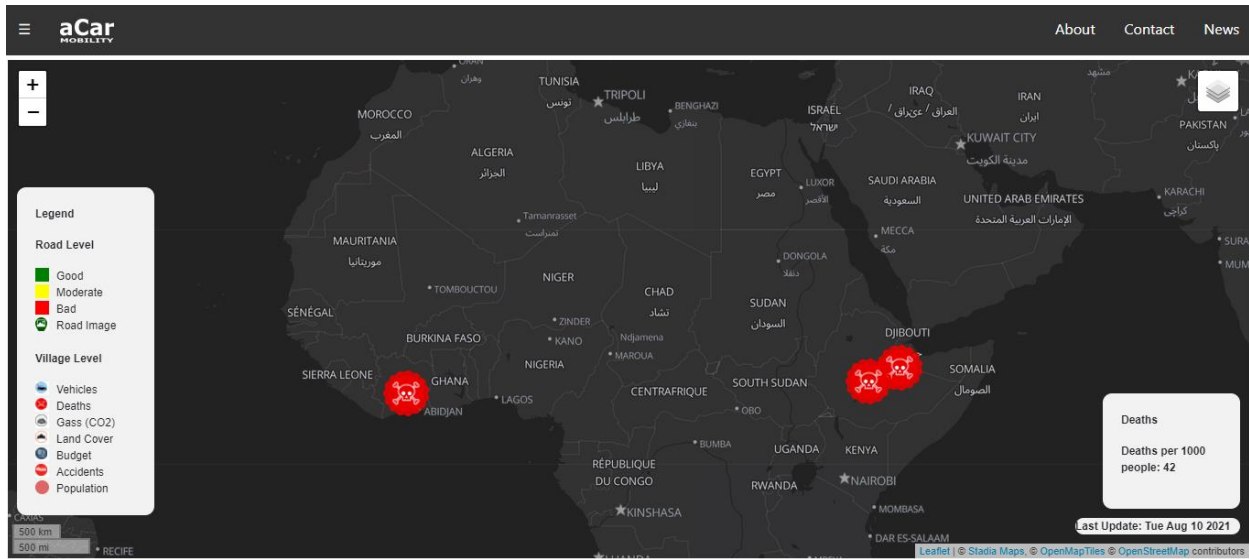
Figure 4.7: Deaths indicators

In figure 4.8 below you can see the emitted gas value in each village. The numbers are displayed on the top of the icon.
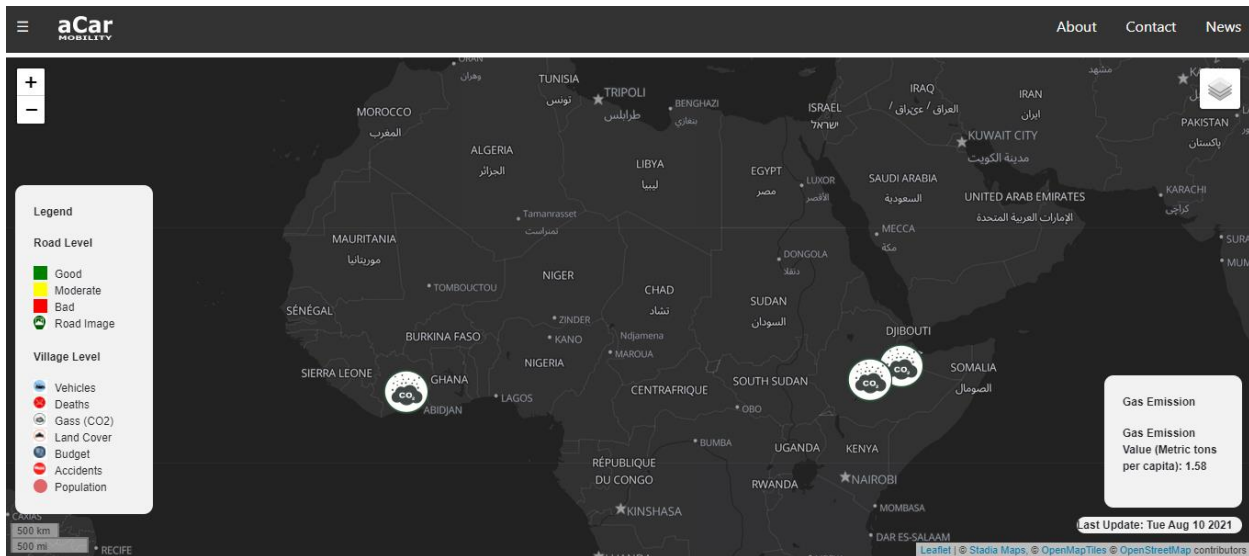
Figure 4.8: Gas indicators visualization

In figure 4.9 below you can see the land covered indicators showing the percentage of the buildup and the areas covered by fields or pastures.
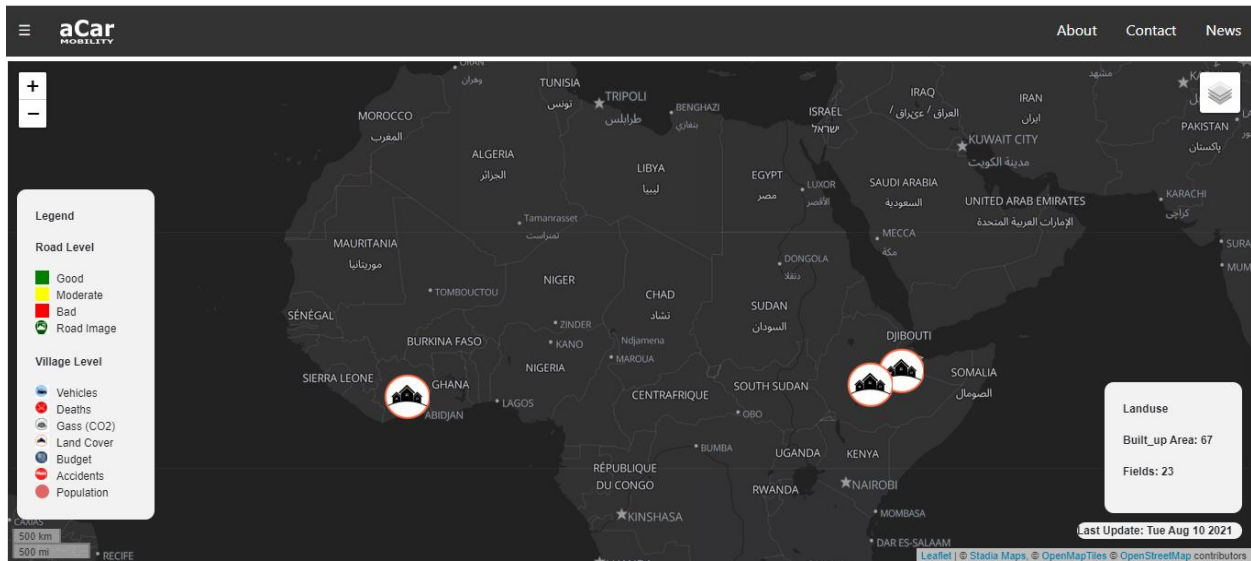
Figure 4.9: Land use indicators visualization

Figure 4.10 shows the available budget for the development of each village provided by government.
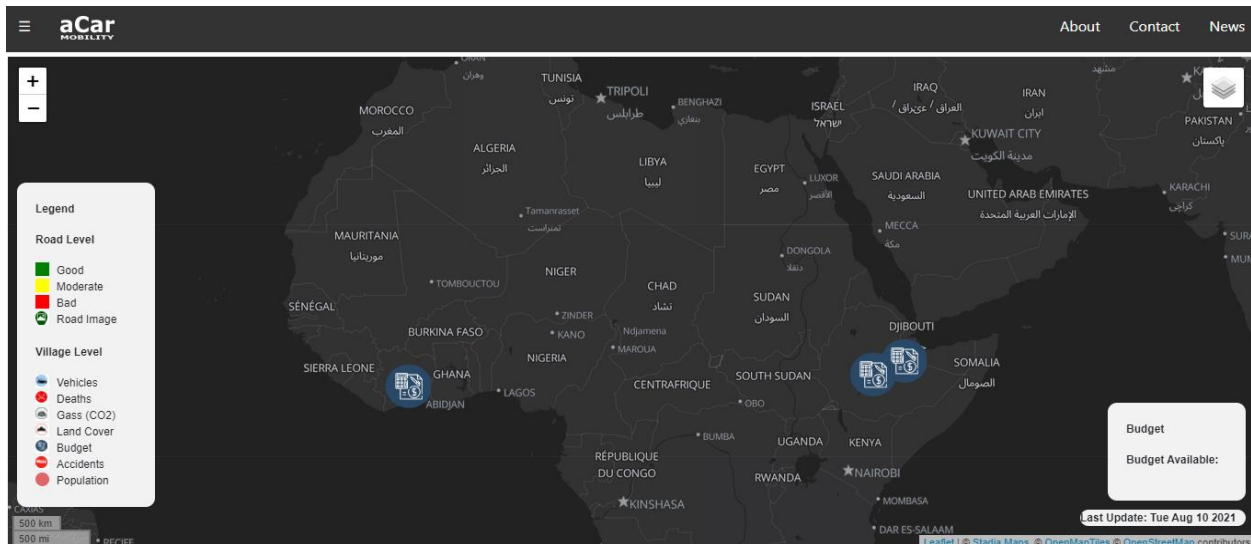
Figure 4.10: Development budget indicators visualization

In figure 4.11 below, the indicator for the accidents happened in each village or town are shown. The numbers of accidents happened in each village on the top of indicator icon.
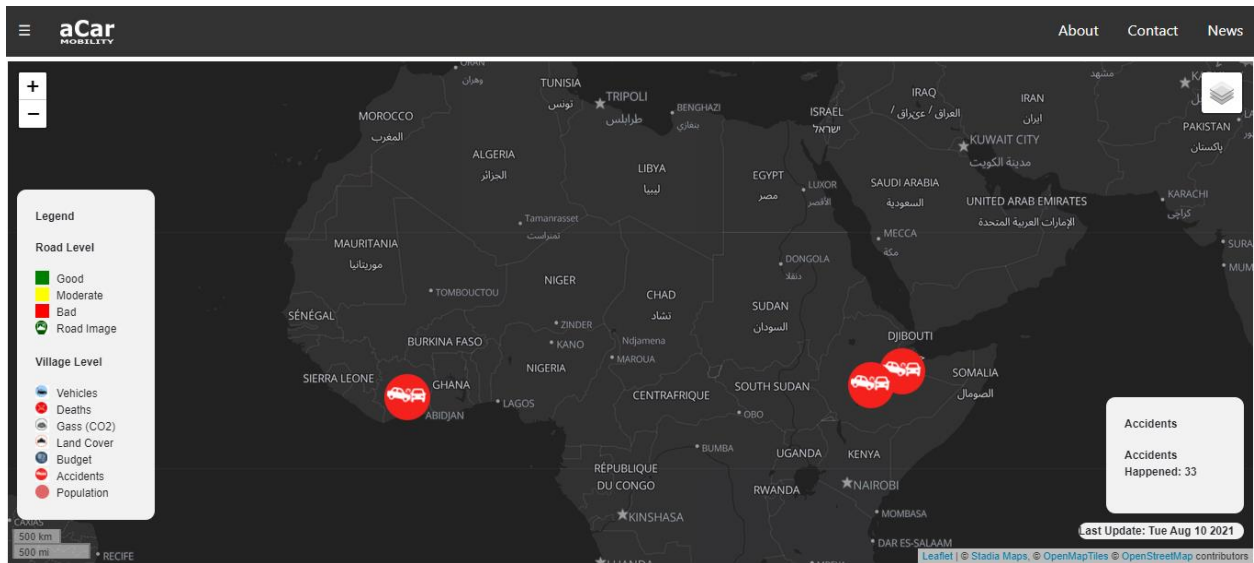
Figure 4.11: Accidents happened indicators visualization.

Chapter 5: Summary & Outlook

5.1 Summary

In this work, the main object was the implementation of user interactive platform/GUI for geovisualization of mobility indicators for processing of raw data gathered. The work started with the detailed research. The implementation of GUI started after finalizing the data source, methods for data collection & processing and technologies for frontend & backend development. Then the web application/GUI was developed successfully and tested. It was tested first with mock data. Then it was tested with open source data gathered from internet. After getting the good results GUI was tested with real-time data provided by the participants in aCar Mobility project who surveyed in the target region.

The data was collected in two formats image and PDF files and uploaded on browser. Some of the data was not open source and some of the indicators were not collected due to Covid19. The uploaded data is stored in the backend database which is fetched in frontend by REST APIs. After uploading the files, those files can be seen in the side navigation bar of the GUI. The locations can be seen on the map in the form of the pinpoints. The image and PDF files can also be opened after the click event on the image and PDF markers on map.

The impact factors including road level indicators that consists of road condition, number of electric poles and number of potholes were visualized on browser. Similarly, global indicators which consists of number of populations, number of deaths, number of accidents, number vehicles, available budget for development, built-up covered area and vegetation covered area were visualized on the web browser.

Roads conditions were visualized using line visualization techniques while the other numeric indicators were visualized using the point-based visualization. User can hover over the indicator to see the information on the dialogue box showed at bottom-right of the map. There is also an option of click event on the points showing the same information. After the click event on streets level points, the image of that street is popped up with information right below the picture. The date of the data uploading on the map is also shown on the right-bottom of the browser. The indicator can be visualized separately. Otherwise if we turn on all layers the points will overlap each other. There is a table of legend for the recognition of the indicators sign.

At the end the visualization of mobility indicators on the map gave the insight about comparison among the target places. The major goal of uploading the data on field is fulfilled by this application. All involved institutes have access to the data uploaded by the surveyors and have the capability to structure the raw data. The visualization of indicators enabled the researchers to see the impact factors so that they can use them for the mobility pattern analysis.

5.2 Outlook

The basic functionality of GUI (e.g. features) was working fine. The results achieved after testing with data were satisfying. The functionality of the application depends on the data provided. The more accurate data, the more precisely the information can be displayed as mobility indicators on the platform. The GUI can handle the large amount of data and can be used by multiple users at a same time. This GUI is tested on different devices such as laptops, mobile phones & tablets and compatible with these devices.

5.2.1 Improvements

This web application developed can be improved in many ways. But that would depend on the future project demand. For instance:

1. More data should be collected via surveys.
2. The platform can be extended by introducing more mobility indicators.
3. A query tool can be embedded to help the new user to get the relevant information.
4. The HTML form to organize and structure the data can be filled automatically upon uploading the raw data in a pdf file.
5. More features can be added such as the automatic report generation in the end of geovisualization.
6. Machine learning techniques can be used to calculate some of the indicators by browser itself.
7. Overall statistics of particular region can be displayed.

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List of Tables:

List of Figures:

Appendix I: Source files

Link of Source Code:

https://github.com/muhammadhamza454/Masters_thesis.git

Appendix II: HTML Code

```html
<!DOCTYPE html>
<html lang="en">
  <head>

  <meta name="description" content="Leaflet Template">
  <meta name="viewport" content="initial-scale=1.0">
  <meta charset="utf-8">
  <link rel="stylesheet" href="https://unpkg.com/leaflet@1.3.1/dist/leaflet.css" integrity="sha512-Rksm5RenBEKSKFjg
  I3a41vrjkw4EVPlJ3+OiI65vTjIdo9brlAacEuKOiQ5OFh7cOI1bkDwLqdLw3Zg0cRJAAQ==" crossorigin="" />
  <script src="https://unpkg.com/leaflet@1.3.1/dist/leaflet.js" integrity="sha512-/Nsx9X4HebavoBvEBuyp3I7od5tA0UzAxs+j83Kg
  C8PU0kgB4XiK4Lfe4y4cgBtaRJQEIFCW+oC506aPT2L1zw==" crossorigin=""></script>
<!-- Bootstrap -->
<link href="https://cdn.jsdelivr.net/npm/bootstrap@5.0.0/dist/css/bootstrap.min.css" rel="stylesheet" integrity="sha384
-wEmeIV1mKuiNpC+IOBjI7aAzPcEZeedi5yW5f2yOq55WWLwNGmvvx4Um1vskeMj0" crossorigin="anonymous">
<script src="https://cdn.jsdelivr.net/npm/bootstrap@5.0.0/dist/js/bootstrap.bundle.min.js" integrity="sha384-p34f1UUtsS3
wqzfto5wAAmdvj+osOnFyQFpp4Ua3gs/ZVWx6oOypYoCJhGGScy+8" crossorigin="anonymous"></script>

    <meta name="viewport" content="width=device-width, initial-scale=1.0">
    <meta charset="UTF-8" />
    <meta http-equiv="X-UA-Compatible" content="IE=edge" />
    <meta name="viewport" content="width=device-width, initial-scale=1.0" />
    <title>Index HTML</title>
    <script src="https://unpkg.com/axios/dist/axios.min.js"></script>
    <link
      rel="stylesheet"
      href="https://unpkg.com/leaflet@1.7.1/dist/leaflet.css"
      integrity="sha512-xodZBNTC5n17Xt2atTPuE1HxjVMSvLVW9ocqUKLsCC5CXdbqCmblAshOMAS6/keqq/sMZMZ19scR4PsZChSR7A=="
      crossorigin=""
    />
    <script
      src="https://unpkg.com/leaflet@1.7.1/dist/leaflet.js"
      integrity="sha512-XQoYMqMTK8LvdxXYG3nZ448hOEQiglfqkJs1NOQV44cWnUrBc8PkAOcXy20w0vlaXaVUearIOBhiXZ5V3ynxwA=="
      crossorigin=""
    ></script>
    <script type="text/javascript" src="https://cdnjs.cloudflare.com/ajax/libs/exif-js/2.3.0/exif.min.js"></script>


    <script src="css.css"></script>
    <script src="logo.png"></script>


    <style>
    #mapid {
  height: 87vh;
}

/* Style the sidenav links and the dropdown button */
.sidenav a, .dropdown-btn {
```

Appendix III: Frontend JavaScript

```javascript
var GPSImagelatitude;
var GPSImageLongitude;
var clickedlat,clickedlon;
// Only for testing of group layer

var streets = L.layerGroup();
var Point = L.layerGroup();

// var Population2=L.layerGroup();

var Population=L.layerGroup();
var Vehicles=L.layerGroup();
var Deaths=L.layerGroup();
var Gas=L.layerGroup();
var Landcover=L.layerGroup();
var Budget=L.layerGroup();
var Accidents=L.layerGroup();

// Available files
var availpdf=L.layerGroup();
var availimg=L.layerGroup();




// Map
var mymap = L.map("mapid").setView(
  [
    6.811804, -5.270520
  ],
  13
);
var base1=L.tileLayer("http://{s}.google.com/vt/lyrs=m&x={x}&y={y}&z={z}", {
  maxZoom: 20,
  subdomains: ["mt0", "mt1", "mt2", "mt3"],
});

var base2= L.tileLayer('https://tiles.stadiamaps.com/tiles/alidade_smooth_dark/{z}/{x}/{y}{r}.png', {
  maxZoom: 20,
  attribution: '&copy; <a href="https://stadiamaps.com/">Stadia Maps</a>, &copy; <a href="https://openmaptiles.org/">OpenMapTiles</a> &copy
}).addTo(mymap);

var base3=L.tileLayer('https://tiles.stadiamaps.com/tiles/alidade_smooth/{z}/{x}/{y}{r}.png', {
  maxZoom: 20,
  attribution: '&copy; <a href="https://stadiamaps.com/">Stadia Maps</a>, &copy; <a href="https://openmaptiles.org/">OpenMapTiles</a> &copy
});




// ICONS*****
var streetIcon = L.icon({
  iconUrl: 'imgpin.png',
});
```

```
visualize();



// Layer contol

var basemap={'Street View':base1,'Grey Mode':base3,'Dark Mode': base2};
var overlayMaps={'PDF':availpdf,'Images':availimg,'Streets View':Point,'Roads':streets,'Population': Population,'Vehicles':Vehicles,'Deaths':
L.control.layers(basemap,overlayMaps).addTo(mymap);




//scale******
L.control.scale().addTo(mymap);


// Legends

var legend = L.control({ position: "bottomleft" });

legend.onAdd = function(mymap) {
  var div = L.DomUtil.create("div", "legend");
  div.innerHTML += "<p><b>Legend</b></p>";
  div.innerHTML += "<p><b>Road Level</b></p>";
  div.innerHTML += '<i style="background: Green"></i><span>Good</span><br>';
  div.innerHTML += '<i style="background: Yellow"></i><span>Moderate</span><br>';
  div.innerHTML += '<i style="background: Red"></i><span>Bad</span><br>';
  div.innerHTML += '<i class="icon" style="background-image: url(pins/imgpin.png);background-repeat: no-repeat;"></i><span>Road Image</span><
  div.innerHTML += "<br>";
  div.innerHTML += "<p><b>Village Level</b></p>";
  div.innerHTML += '<i class="icon" style="background-image: url(pins/Vehicles.png);background-repeat: no-repeat;"></i><span>Vehicles</span><
  div.innerHTML += '<i class="icon" style="background-image: url(pins/deaths.png);background-repeat: no-repeat;"></i><span>Deaths</span><br>'
  div.innerHTML += '<i class="icon" style="background-image: url(pins/CO2.png);background-repeat: no-repeat;"></i><span>Gass (CO2)</span><br>
  div.innerHTML += '<i class="icon" style="background-image: url(pins/Builtup.png);background-repeat: no-repeat;"></i><span>Land Cover</span>
  div.innerHTML += '<i class="icon" style="background-image: url(pins/Budget.png);background-repeat: no-repeat;"></i><span>Budget</span><br>'
  div.innerHTML += '<i class="icon" style="background-image: url(pins/accidents.png);background-repeat: no-repeat;"></i><span>Accidents</span
  div.innerHTML += '<i><span class="dot"></span></i><span>Population</span>';
  return div;
};
legend.addTo(mymap);



  // Date for updates
  var d = new Date();
  var Date2;


// CLick on map and getting lat long

mymap.on('click',
        function(e){
          var coord = e.latlng.toString().split(',');
          clickedlat = coord[0].split('(');
          clickedlon = coord[1].split(')');
          console.log("You clicked the map at latitude: " + clickedlat[1] + " and longitude:" + clickedlon[0]);
        });
```

```javascript
// Visualize when page opens

async function visualize(){

    const road = await axios.get(`http://localhost:5200/show/`);




var legend = L.control({ position: "bottomright" });

road.data.getdate.rows.forEach(row => {

legend.onAdd = function(mymap) {
    var div = L.DomUtil.create("div", "legend2");
    div.innerHTML += "<p><b> Last Update:  "+row.updatedate1+"</b></p>";
    return div;
};
legend.addTo(mymap);

});

    road.data.dbroads.rows.forEach(row => {

        var s;

        var type;
        if (row.street_cond == 'Good') {
            type = "Green";
        }
        else if (row.street_cond == 'Moderate') {
            type = "Yellow";
        }
        else if (row.street_cond == 'Bad') {
            type = "Red";
        }
        else
            type = "white";


            s = L.geoJSON(JSON.parse(row.st_asgeojson), {

                style: {
                    "color":type,
                    "weight": 2,
                    "opacity": 1
                }
            });

        streets.addLayer(s);

    });

// Points

road.data.dbresponse.rows.forEach(row => {
    var p;
    var legend
    p=L.marker([Number(row.lat), Number(row.lon)],{icon: streetIcon}).bindPopup(`<h10><b>Street View</b></h10>
    <img src="${row.image}" height="100%" width="100%" class="markerPopupImage"resizable=1/>
    <br>
```

```
  var legend
  p=L.marker([Number(row.lat), Number(row.lon)],{icon: streetIcon}).bindPopup(`<h10><b>Street View</b></h10>
  <img src="${row.image}" height="100%" width="100%" class="markerPopupImage"resizable=1/>
  <br>
  <h10><b>Street Information</b></h10>
  <p>Potholes: ${row.pothole}, Electric poles:${row.epoles}</p>`).on('mouseover',function(e){

  legend= L.control({ position: "bottomright" });

  legend.onAdd = function(mymap) {
    var div = L.DomUtil.create("div", "legend");
    div.innerHTML += "<p><b>Street View</b></p>";
    div.innerHTML += "<p><b>Potholes: "+row.pothole+"</b></p>";
    div.innerHTML += "<p><b>Electric Poles: "+row.epoles+"</b></p>";
    return div;
  };
  legend.addTo(mymap);

  }).on('mouseout',function(e){

  legend.remove();

  });
  // Adding all points in one layer group
  Point.addLayer(p);

  });


  //Population points

  road.data.dbresponse2.rows.forEach(row => {
   var h, popu2;
   h=L.marker([Number(row.lat), Number(row.lon)], {
     icon: L.divIcon({
         className: 'my-custom-icon',
         html: row.population,
         iconAnchor:   [25, 25],
         iconSize: [50,50],

     })
   }).bindPopup(`<h10><b>Population</b></h10>
   <p>Vaillage: ${row.village_name} <br> Men: ${row.men} <br> Women:${row.women}</p>`).on('mouseover',function(e){

     legend= L.control({ position: "bottomright" });

     legend.onAdd = function(mymap) {
       var div = L.DomUtil.create("div", "legend");
       div.innerHTML += "<p><b>Population</b></p>";
       div.innerHTML += "<p><b>Village: "+row.village_name+"</b></p>";
       div.innerHTML += "<p><b>Total Population: "+row.population+"</b></p>";
       div.innerHTML += "<p><b>Men: "+row.men+"</b></p>";
       div.innerHTML += "<p><b>Men: "+row.women+"</b></p>";
       return div;
     };
     legend.addTo(mymap);

   }).on('mouseout',function(e){

     legend.remove();
```

Appendix IV: Backend Node.js

```javascript
const express = require("express");
const cors = require('cors');
// const bodyParser = require('body-parser');


// express app
const app = express();
// app.use(bodyParser.urlencoded({extended: true}));
// configure the app to use bodyParser()
app.use(express.urlencoded());
app.use(express.json())


// listen for requests
app.listen(5200);

// register view engine
app.set("view engine", "ejs");
// app.set('views', 'myviews');


app.use(cors());
app.options('*', cors()); // request accept from all server

var pg = require('pg');
var connectionString = "postgres://postgres:Hafizhabib.123@localhost:5433/ethiopia";
var pgClient = new pg.Client(connectionString);
pgClient.connect().then(() => console.log("Connected Successfully"));




app.get("/", (req, res) => {
  const blogs = [
    {
      title: "Hamza finds eggs",
      snippet: "Lorem ipsum dolor sit amet consectetur",
    },
    {
      title: "Mario finds stars",
      snippet: "Lorem ipsum dolor sit amet consectetur",
    },
    {
      title: "How to defeat bowser",
      snippet: "Lorem ipsum dolor sit amet consectetur",
    },
  ];
  res.json({ blogs });
});


// finding the line

app.get("/roads/:a/:b", async (req, res) => {
  const dbroad = await pgClient.query(`SELECT osm_id,name,ST_asgeojson(geom),ST_Distance(ST_Buffer(r.geom,0.00000000000001),ST_SetSRID(ST_MakePo
  res.json({
    dbroad
```

```javascript
// Updating after getting that line


app.get("/updategid/:c/:e", async (req, res) => {
  await pgClient.query(`UPDATE export2 SET street_cond ='${req.params.e}' WHERE osm_id = '${req.params.c}'`);
});

// Updating Date


app.get("/updatedate/:d", async (req, res) => {
  await pgClient.query(`UPDATE updatedate
  SET updatedate1 = '${req.params.d}'
  WHERE updatedate1 IS NOT NULL;`);
});


// Testing CSV file data insert

// app.get("/csv/:d", async (req, res) => {
//   try {
//     const message = await pgClient.query(`insert into img (lat, lon, username) values('32', '54', '${req.params.d}');`);
//     res.json({
//       name: req.params.d,
//       message: message
//     })
//   } catch (error) {
//     console.log(req.params.d, error)
//     res.json({
//       message: error
//     })
//   }
// });


// adding the image link in the point data

app.post("/saveimage", async (req, res) => {
  console.log(req.body.ImageUrl)
  await pgClient.query(`INSERT INTO LATLON (lat, lon,image,epoles,pothole) VALUES ('${req.body.lat}', '${req.body.lon}' , '${req.body.ImageUrl}', '${req
  res.json(req.body)
});

// Adding the village data
app.post("/villagedata", async (req, res) => {
  await pgClient.query(`INSERT INTO village (lat, lon, village_name, vehicles, population, men, women, deaths, gas, fields, built_up, budget,
  accidents,bus,motorbike,car,electric_car,rikshaw)
  VALUES ('${req.body.lat}', '${req.body.lon}' , '${req.body.name}', '${req.body.vehicle}', '${req.body.pop}', '${req.body.men}',
  '${req.body.women}', '${req.body.death}', '${req.body.gas}', '${req.body.pastures}', '${req.body.builtup}', '${req.body.budget}',
  '${req.body.accident}','${req.body.bus}','${req.body.motorbike}','${req.body.car}','${req.body.ecar}','${req.body.rikshaw}')`);
  res.json(req.body)
});


// app.get("/hamza/:a/:b", async (req, res) => {

  // await pgClient.query(`INSERT INTO LATLON (lat, lon) VALUES(${req.params.a},${req.params.b})`);
```

```
app.get("/show", async (req, res) => {
  const dbresponse = await pgClient.query("SELECT lat, lon, image, epoles, pothole from LATLON");
  const dbresponse2 = await pgClient.query("SELECT lat, lon, village_name, vehicles, population, men, women, deaths, gas, fields, buil
  const dbroads = await pgClient.query("SELECT street_cond,ST_AsGeoJSON(geom) from export2");
  const getdate= await pgClient.query("SELECT updatedate1 from updatedate");
  res.json({
    dbroads,dbresponse,dbresponse2,getdate
  });

});


// 404 page
app.use((req, res) => {
  res.status(404).render("404", { title: "404" });
});
```

Appendix V: Raw data files

Indicators

Survey

Latitude = 6.809920, Longitude = -5.275987

Village Name= Yamoussoukro, cote d'ivoire

Overall indicators for whole Town/City:

1. Total Vehicles = Not available
2. No. of cars = Not available
3. No. of bus = Not available
4. No. of motorbikes = Not available
5. No. of electric cars = Not available
6. No. of rickshaw = Not available
7. Population = 213,156
8. No. of men = 107380
9. No. of women = 105775
10. No. of deaths = 10
11. CO2 gas emission value = 1.58
12. Percentage of fields/ pastures covered = 23
13. Percentage of built-up covered = 67
14. Budget = Not available
15. Accidents = 33

Indicators

Survey

Lat = 9.312594, Long= 42.119865

Village Name= Harar

Overall indicators for whole Town/City:

1. Total Vehicles = 8000
2. No. of cars = Not available
3. No. of bus = Not available
4. No. of motorbikes = Not available
5. No. of electric cars = Not available
6. No. of rickshaw = Not available
7. Population = 98829
8. No. of men = 49448
9. No. of women = 49380
10. No. of deaths = 42 per 1000 live births
11. CO_2 gas emission value = 0.02
12. Percentage of fields/ pastures covered = 25.08
13. Percentage of built-up covered = 60.68
14. Budget = Not available
15. Accidents = 382

Indicators

Survey

Latitude = 7.957978, Longitude = 39.132678

Village Name= Assela

Overall indicators for whole Town/City:

1. Total Vehicles = Not available
2. No. of cars = Not available
3. No. of bus = Not available
4. No. of motorbikes = Not available
5. No. of electric cars = Not available
6. No. of rickshaw = Not available
7. Population = 67,269
8. No. of men = 33,826
9. No. of women = 33,443
10. No. of deaths = Not Available
11. CO2 gas emission value = 0.015
12. Percentage of fields/ pastures covered = Not available
13. Percentage of built-up covered = Not available
14. Budget = Not available
15. Accidents = Not available

Appendix VI: Geovisualization techniques

Figure A: Point Visualization of census data by Chris Weaver (2006) [40]
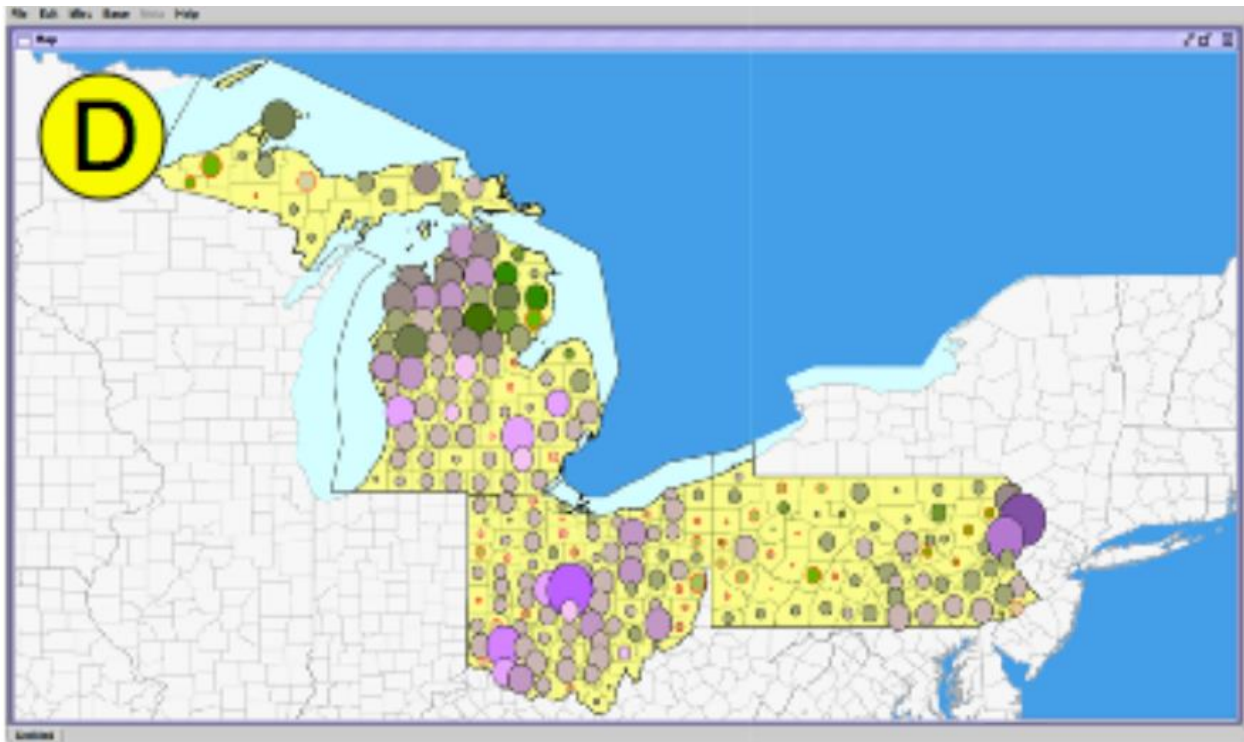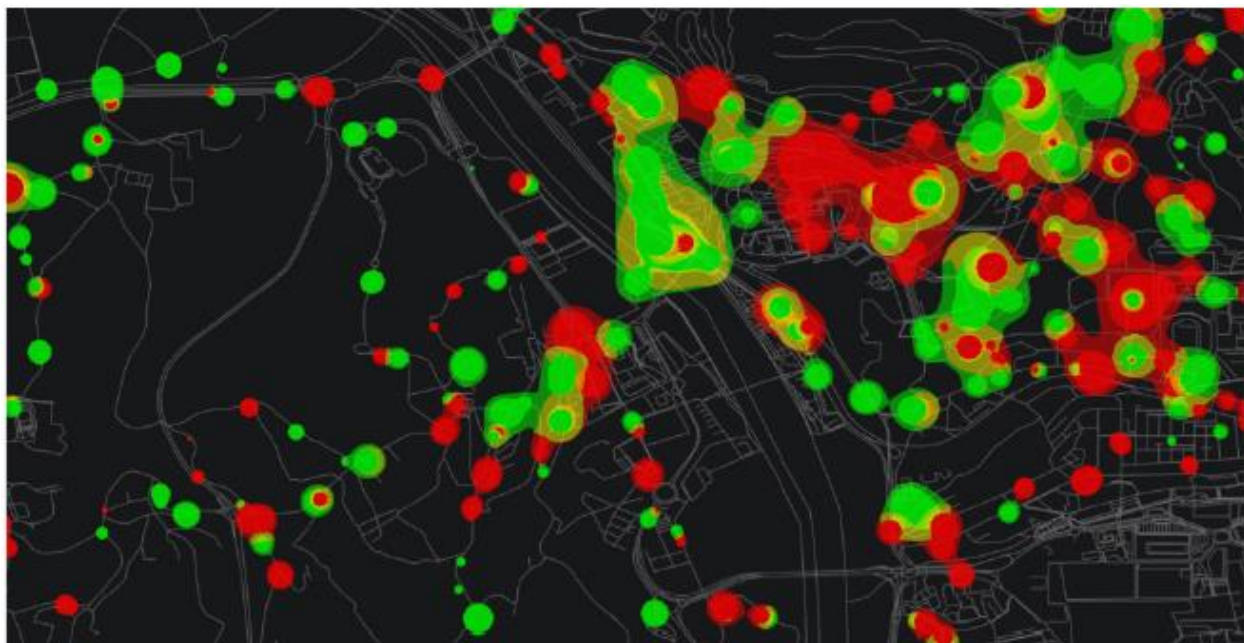

Figure B: Heat point visualization [41]

Figure C: Point visualization by Sobral, T. et al. (2019) [41]

Figure D: Second line-based visualization by Sobral et al. (2019) [41]