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# DESIGN OF GEOSPATIAL-DATA SYSTEM FOR PEOPLE WITH MOBILITY IMPAIRMENT IN MBEYA CITY

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Community Engagement, Crowdsourcing, Data Processing, Geospatial-data, Mbeya city, Mobility challenges, Sidewalk accessibility, Tanzania.

## ABSTRACT

The solution described in the study uses a customized geospatial data model to improve urban accessibility. The study was carried out in Tanzania's Mbeya Region, one of the country's 31 administrative regions. Tanzania's Mbeya City is a small, undeveloped city with few parks and walking sides. Tunduma Road is the sole major route that leads into and out of the city. Specifically designed to meet the needs of those people with mobility challenges, the system incorporates comprehensive accessibility information for both pedestrian and building settings. Through the use of a dynamic database, the system enables users to submit up-to-date information regarding barriers and accessibility elements found in walking sides. The study contributes to easier navigation in urban areas for people with mobility challenges and encourages city planners to make physical improvements in areas that lack friendly accessibility of a path.

## INTRODUCTION

In several disciplines, including urban planning, health, and transportation, the accessibility of a path is highly relevant. The accessibility of a path is regarded as one of the most important components in building a sustainable city because it enhances community ties [4,5], promotes public health [1-3], alleviates traffic congestion, lowers carbon emissions when combined with green transportation [8,9], and fosters community development [6, 7]. Many cities worldwide are advocating an eco-friendly and people-centered walking environment as the top priority in urban design, as knowledge grows about the significant impact that walkability has on our daily lives [10–13]. Additionally, the Ministry of Constitutional and Legal Affairs created a relevant Action Plan for National Human Rights to support the walking environment in 2013–2017 [14]. The pedestrian rights campaign in the United Republic of Tanzania started in October 2008. Local governments around the nation create a baseline plan and conduct surveys to improve pedestrian safety and convenience every five years.

The research was conducted in Mbeya Region, one of the 31 administrative regions of Tanzania. The study area was selected purposively. This area was chosen because this topic has not been studied in this area. Especially Mbeya City is an underdeveloped city in Tanzania with limited parks and walking sides; and there is only one main road in and out, i.e., Tunduma Road.

The World Disability Report, prepared jointly by the World Health Organization (WHO) and the World Bank (WB), shows that more than one billion people live with a disability in the world today. This means that about 15% of the world's population lives with some form of disability, and when it comes to travelling through cities, this is one of the main concerns for pedestrians with mobility challenges [15]. In the context of Tanzania's mainland, according to the 2022 census conducted highlights on the disability status. There are 5.1 million persons (about 11.2%) of the total population aged 7 years and above living with some form of disability. People with mobility challenges or walking correspond to 1.9% and this is the most common type of disability in the country. The prevalence of disability has increased from 9.3 percent in 2012 to 11.2 percent in 2022. Therefore, for many people with mobility challenges, access to appropriate assistive technology (AT) such as the Web or, more recently, via smartphones/tablet applications has been identified as a facility for the full enjoyment of human rights [16- 18]. The use of assistive technology (AT) among Persons with disabilities (PWDs) is very low.

The rest of the paper is organized as follows: Describes the data collection procedures and the analysis approaches for both the paper review and the interviews in section II. Presents results from studies of GIS and of the interviews in section III. Discusses the results, linking the insights emerging from the two analyses and identifying possible bridges and barriers for engagement in section IV. Concluding remarks are given in section V.



## MATERIALS AND METHODS

To answer the above question, we adopted two different but complementary methods. The first part includes a qualitative analysis of the accessibility of a path-related paper published, representing the recent trends in the walking environment or accessibility of paths in recent research. The information is divided into different categories such as the author's discipline, place of publication, subject, author's background, field of research, and respect to accessibility of a path.

This method only establishes a relationship based on a description of the current situation, which needs to be completed in scope and limited in depth. These may be sufficient to find a hypothesis that can explain the data (inductive reasoning [19]), but may not be enough to prove a cause (e.g., decision or inductive reasoning).In addition to the article review; we conducted in-depth interviews with people with mobility challenges in Mbeya who participated in the study. We used the Maps of Easy Path (MEP) app as an exploratory study to identify potential designs. The questions focused on favorite routes, everyday travel habits, and path accessibility. We opted to conduct four focus group interviews with different users to gather important information on the designers' interpretations of user scenarios and design ideas. We conducted seven interviews in Kiswahili with members of the group in various positions. Central content analysis and the information about the accessibility of sidewalks, participation in society, quality of life, skills, and allowed us to identify possible causes of barriers to the sidewalk identified through the analysis of publications.

### *A. Studies on the SideWalking Environment*

A variety of studies have assessed the accessibility of a path in the environment and recognized the importance of walkability. [20] revealed that the better the physical design features of sidewalks, such as residential density, land use mix, and street network connectivity, the more pedestrian activity there is. [21] found that the frequency of walking activities was high both when the land-use mix was high and nearby living facilities such as walking, exercise, and shopping were good. In most studies analyzing the physical characteristics of the walking environment, key factors that affected walking, such as pedestrian comfort, safety, street diversity, street connectivity, and public transport accessibility, were extracted through surveys or site visits [22 – 27].

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Unlike the existing studies based on a survey or site visits, new approaches, which assess the physical sidewalk environment by applying the semantic segmentation technique to the street view image, have evolved recently [28]. They created four visual walkability indexes: psychological greenery, visual crowdedness, outdoor enclosure, and visual pavement. In addition, they calculated the Integrated Visual Walkability (IVW) score and found that the IVW was uneven in space. [29] developed Walkability on Urban Street (WoUS), composed of seven indicators and focused on the area around Osaka University in Japan. The seven indicators were walk score, pedestrian flow density, noise, light, greenery, enclosure, and relative walking width. Among them, greenery, enclosure, and relative walking width were calculated by segmenting street view images. By comprehensively analyzing seven scores, they visualized WoUS by street and compared physical WoUS with perceived WoUS obtained by an expert questionnaire. [30] analyzed SVIs in Shenzhen using semantic segmentation techniques and confirmed that the importance of objects varied according to spatial scale. On the other hand, [31] developed the sky view factor (SVF) and green view index (GVI) by analyzing the physical characteristics of the street view image. Applying SVF and GVI confirmed that the correlation between street landscape characteristics and pedestrian activity was different for each type of land use.

The recent development of SVIs and semantic segmentation technology is expanding the possibility of including not only GIS data but also various objects obtained from SVIs in the assessment of the physical sidewalk environment. However, there is a limitation in that the accuracy and problems of the semantic segmentation result of the SVIs have not been analyzed in detail.

### *B. Study Location*

The research was conducted in Mbeya Region, one of the 31 administrative regions of Tanzania. The study area was selected purposively. This area was chosen because this topic has not been studied in this area. Especially Mbeya City is an underdeveloped city in Tanzania with limited parks and walking sides; and there is only one main road in and out, i.e., Tunduma Road. The city is home to over 385,000 people and covers an area of about 59 square kilometers. It is noted for its varied topography, which includes fertile plains, hills, and valleys [32]. Roughly 3% of people in Mbeya City live with a mobility challenges, according to recent data. Individuals in this demographic require customized solutions to improve accessibility and quality of life. They include people who use wheelchairs, walking aids, and people who are visually impaired.

Mbeya City faces issues common to fast urbanizing regions, such as unequal infrastructure distribution and a lack of integration of technology-driven solutions to assist those with mobility challenges. The significance of creating a geospatial data system that meets particular accessibility requirements and promotes inclusive urban development is highlighted by these factors.

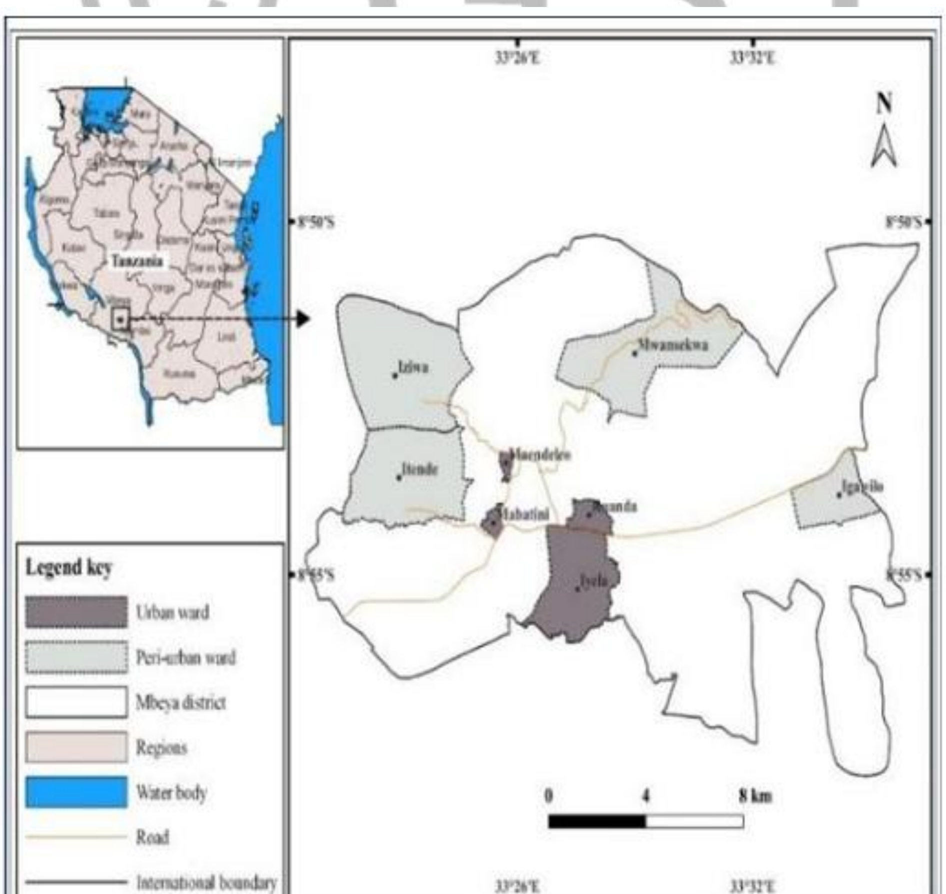




**Figure 1 Study location**

The figure 1 shows that, Mbeya City is situated on a rugged terrain surrounded by two mountain ranges (Mbeya Peak and Loleza Mountain Ranges in the North West and Uporoto Mountains in the South East), at an altitude rising from 1600 to 2400 meters above sea level. The Mbeya City is within Mbeya District. It is located between latitudes 80 50' and 80 57' South of the equator and between longitudes 330 30' and 350 35' east of the Greenwich meridian. It has a total land area of 214 sq km and borders Mbeya District Council on all sides. Mbeya City is the headquarters of the Mbeya Region. Administratively the City has two divisions, 36 wards, and 181 streets. The road network of Mbeya City is as follows Tarmac road - 24 km, Gravel roads - 61.72 km, Earth roads - 305.91 km, and Total - 391.63 km . About 80 percent of roads are not passable throughout the year to people with mobility challenges. Because of the topographical situation of Mbeya City and heavy rains, as well as absence of storm water drainage to most of the roads poses a major problem in the road.

### *C. Participants*

The participant sample consisted of 116 people with mobility challenges (n=116). This study specifically includes the elderly, the crippled, paralytic, walking aids, and other wheelchair users, as well as those who are "healthy-fit" population, depending on their availability. Members with limited mobility challenges must meet the normal demands of daily movement, not as a normal and natural life activity but as a challenge. [33] also pointed out various methods that can be used in selecting the sample size. These may include sampling the entire small population, using similar samples for similar studies, using published tables, and calculating the target population. In this way, the simple Yamane calculation method will obtain the sample size. The formula is as follows:

$$n = \frac{N}{1 + N(e)^2}$$

Where n is the sample size, N is the population size, and e is the precision level, for example, e = 0.05. This sample size is expected to provide substantial information for the study. The table below shows the summary of key indicators for elderly people.

**Table 1. Showing the summary of key indicators for elderly people**

| Indicator | Tanzania Mainland | | Rural | | Urban | |
|---|---|---|---|---|---|---|
| | Number | % | Number | % | Number | % |
| **Population Size** | | | | | | |
| **Total Population** | | | | | | |
| **Elderly Population (60+years)** | **3,406,465** | **5.7** | **2,461,986** | **6.3** | **944,479** | **4.6** |
| **Male** | **1,546,222** | **5.3** | **1,114,757** | **5.8** | **431,465** | **4.4** |
| **Female** | **1,860,243** | **6.1** | **1,347,229** | **6.7** | **513,014** | **4.8** |
| **Elderly Population (65+years)** | **2,286,314** | **3.8** | **1,679,892** | **4.3** | **606,422** | **2.9** |
| **Male** | **1,006,619** | **3.5** | **738,741** | **3.8** | **267,878** | **2.7** |
| **Female** | **1,279,695** | **4.2** | **941,151** | **4.7** | **338,544** | **3.2** |

Table 1 show the population size of Elderly Population (60+years) for both for male and female which also are beneficial of the designed.

**Table 2. People with mobility challenges aged 7 years and above in Mbeya region**

| Region | Prevalence | Total Number | People with mobility challenges/Walking | | |
|---|---|---|---|---|---|
| | | | Both Sexes | Male | Female |
| **Mbeya** | **11.2** | **204,994** | **1.9** | **1.8** | **2.0** |

### *D. Instrumentation for Survey and Data Collection*

To obtain reliable and valid data, the researcher uses both primary and secondary data. The researcher collected primary data through a prepared questionnaire, interviews, and focus group discussions. Information on the Handheld GPS coordinates and device sensors during user navigation, such as the accelerometer, magnetometer, and gyroscope, formed part of the implicit data. This data has been aggregated and merged with other data collected from other users for processing to provide an optimal and personalized service based on the private profile of the service user. Secondary data was collected from published and unpublished land satellite images of the study area, shape files of the study area, documents, reports, books, magazines, newspapers, and other electronic media (internet). Table 3 show the methods used to collect the data and the personal information such as the type of mobility device used.

**Table 3. Some of the responses from data collected in the questionnaire for Mobility device used**

| | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|
| Valid | 5 | 5.1 | 5.1 | 5.1 |
| crutches | 3 | 3.0 | 3.0 | 8.1 |
| Elderly | 24 | 24.2 | 24.2 | 32.3 |
| Electrical wheelchair | 4 | 4.0 | 4.0 | 36.4 |
| Manual wheelchair | 33 | 33.3 | 33.3 | 69.7 |
| Walking stick | 30 | 30.3 | 30.3 | 100.0 |
| Total | 99 | 100.0 | 100.0 | |

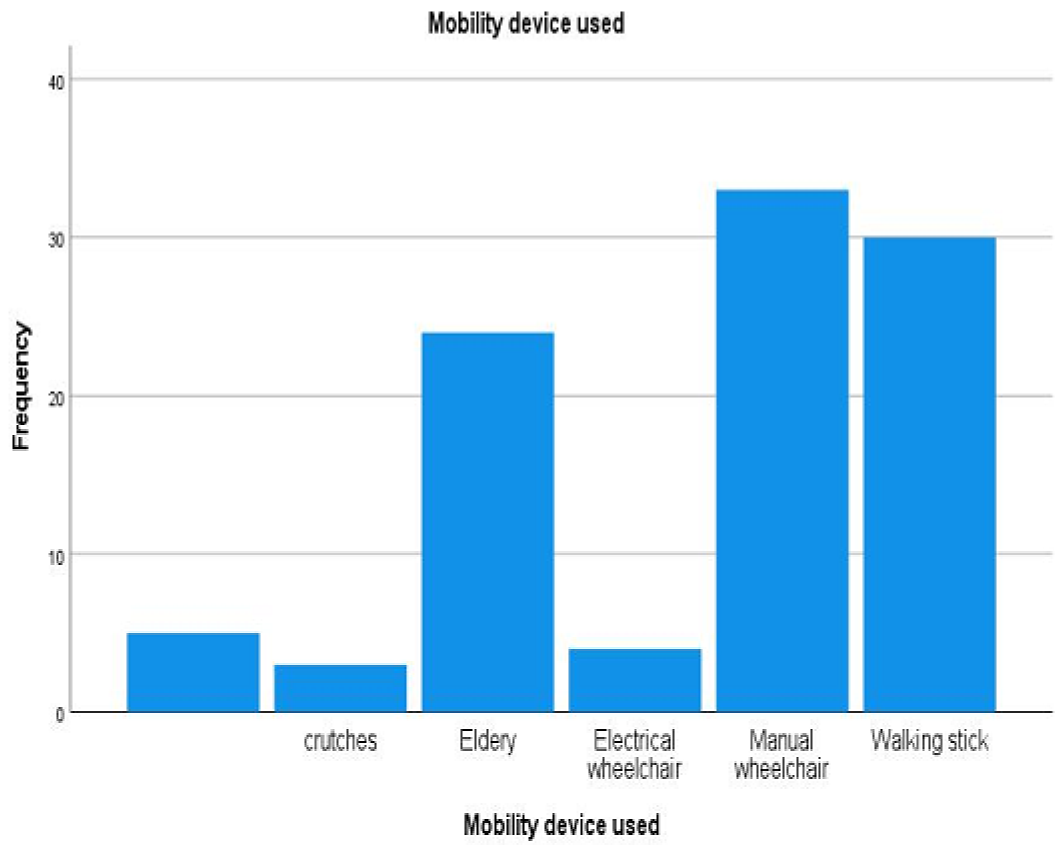


**Figure 2. Distribution of mobility devices used by most people with mobility challenges individuals in Mbeya City.**

Fig 2 illustrates the distribution of different types of mobility devices reported to be used by respondents. The majority of respondents identified as using manual wheelchairs (33.3%), followed by those using walking sticks (30.6%), and a good number of elderly with respondents (24.2%) who may use crutches or walking sticks.

## Experiment and Result

*A.* ***PostGIS*** *Analysis*

Spatial data was analyzed using GIS technology and the experimental activity was carried out in the city of Mbeya and consisted of two days of acquisition, with the tool designed with MEP-Traces installed on different Android smartphones and tablets. The equipment device used to collect the data is the Samsung SM-T335, Galaxy Tab4 8.0 LTE, which has larger screens and can hold information more easily. The entire hand-held GPS sample coordinates collected from the study area are used to verify the land use and land cover type of the study area, graphically represented in figure 3, the experiment primarily serves four purposes:

i. Data collection targeted at further processing, which ends with the construction of the user path and analysis
ii. Emulation of realistic scenarios of designed tools,
iii. Accuracy, precision, and resolution , which are key properties to assess the quantity of a measurement process
iv. Verification and validation of Algorithm

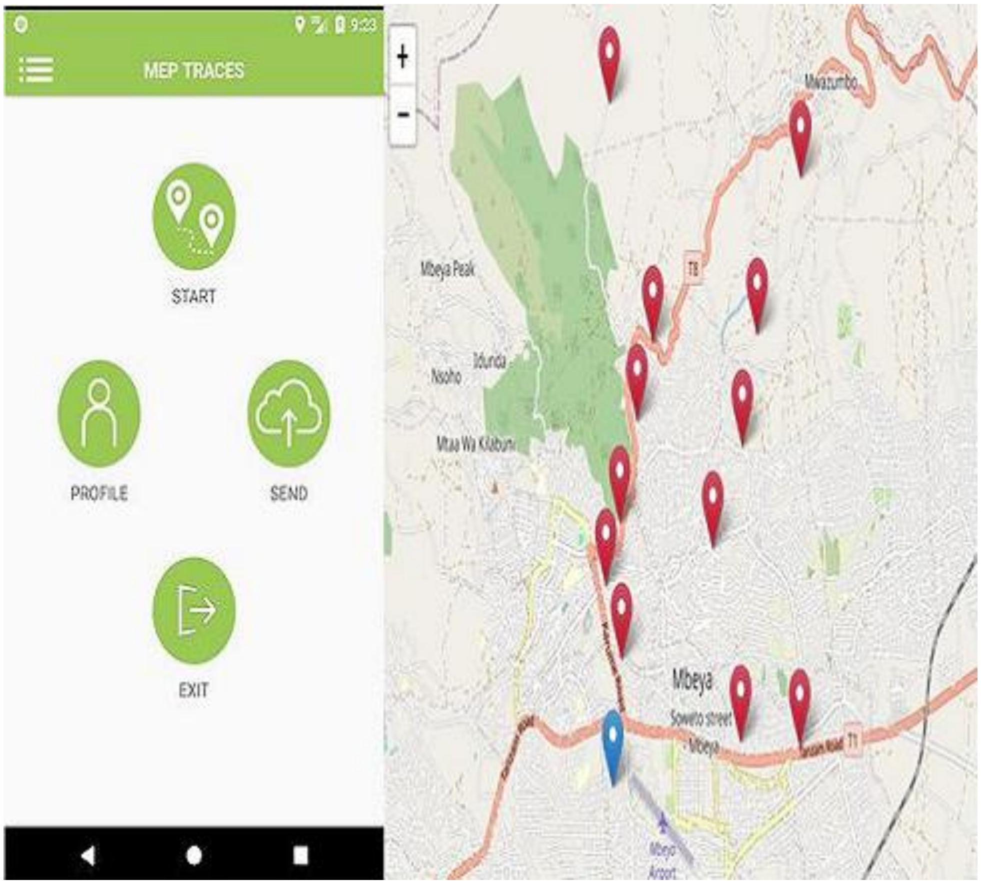


**Figure 3. Visualization of perceived walkability by street**

The spatial analysis techniques included buffer analysis, network analysis, and overlay analysis to identify areas lacking in accessibility of a path. In Fig 4 and 5 of how marks are shown on the map with all Mbeya city features including terrains such as roads, buildings, and green spaces are likely shown, the dropped obstacle marks by the user are indicated by the red mark which may indicate physical barriers, hazards or other impediments and the blue mark indicates the GPS location of the user showing the user's current position

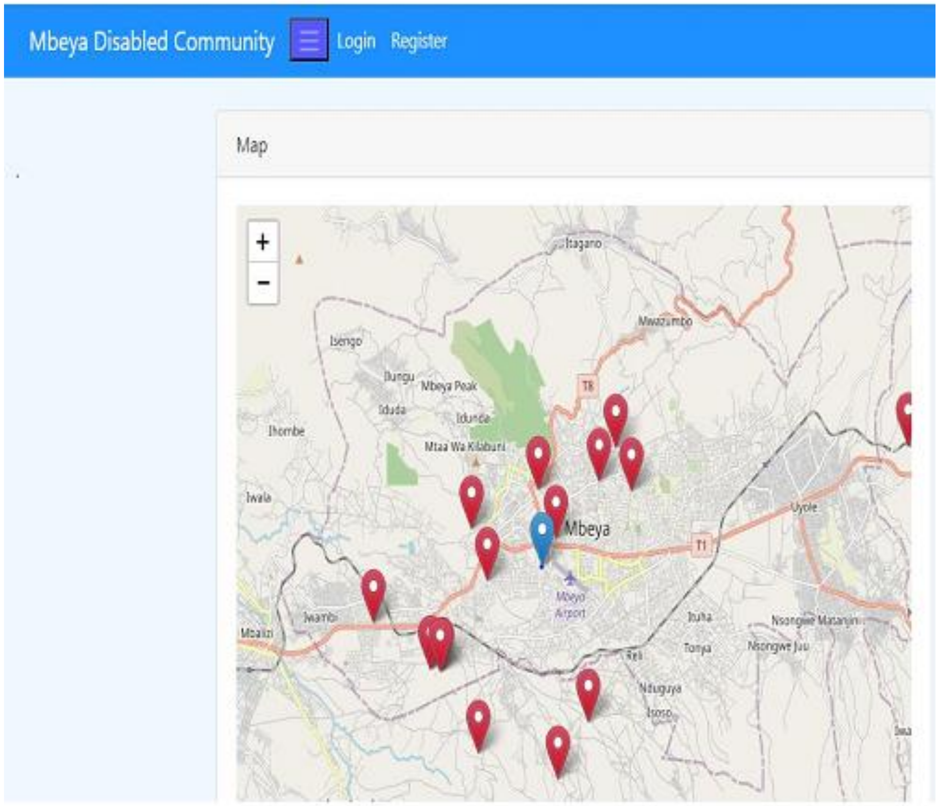


**Figure 4. Markers indicating obstacles and positions**

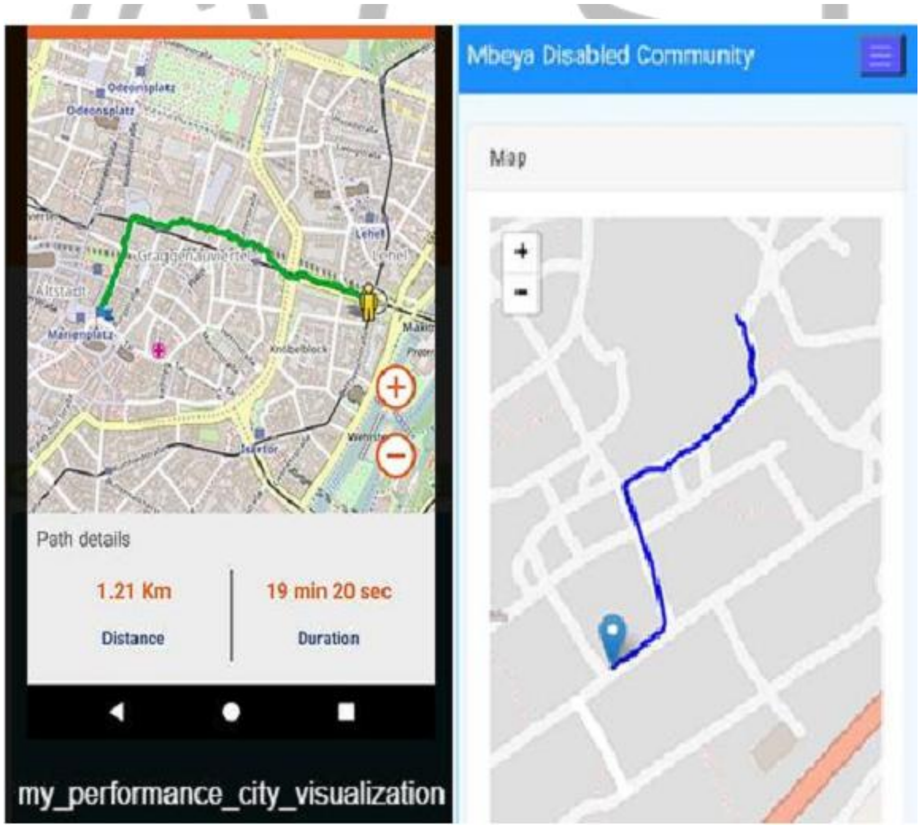


**Figure 5. Construction of the path and details**

***B. Questionnaire analysis***

A questionnaire was administered to individuals with mobility impairments to understand their specific accessibility needs and challenges. The analysis of questionnaire responses provided valuable insights.

**Table 4. Which kind of road accessibility obstacles do you encounter during your routine movements?**

| | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|
| Valid | 5 | 5.1 | 5.1 | 5.1 |
| Canyons, cars, holes | 6 | 6.1 | 6.1 | 11.1 |
| Gravel paths, cobblestones, high steps | 17 | 17.2 | 17.2 | 28.3 |
| Many cars in road, holes, level | 27 | 27.3 | 27.3 | 55.6 |
| Road drainage, ueven road surfaces | 25 | 25.3 | 25.3 | 80.8 |
| Slippery surfaces, gravels path, high steps | 1 | 1.0 | 1.0 | 81.8 |
| Steep slopes, uneven surfaces, cobbles | 18 | 18.2 | 18.2 | 100.0 |
| Total | 99 | 100.0 | 100.0 | |

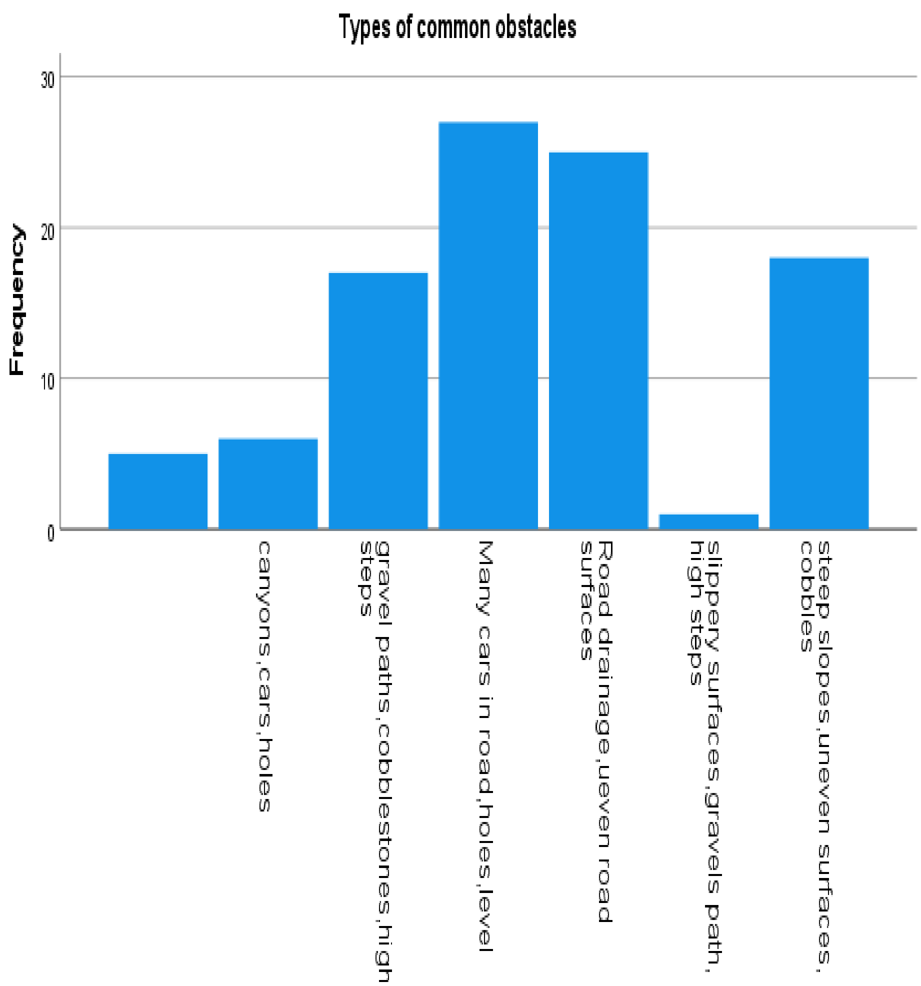


**Figure 6. Types of road accessibility obstacles**

Figure 6 illustrates the distribution of features that are more critical for people with mobility challenges reported by respondents. The majority of respondents identified rugged paths and avoiding obstacles, followed by those who identified avoiding steep slopes, uneven surfaces, and accessible entrances.

**Table 5. What features would you like the app to include?**

| | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|
| Valid | 5 | 5.1 | 5.1 | 5.1 |
| Notify an obstacles | 49 | 49.5 | 49.5 | 54.5 |
| Notify the accessibility alerts | 45 | 45.5 | 45.5 | 100.0 |
| Total | 99 | 100.0 | 100.0 | |

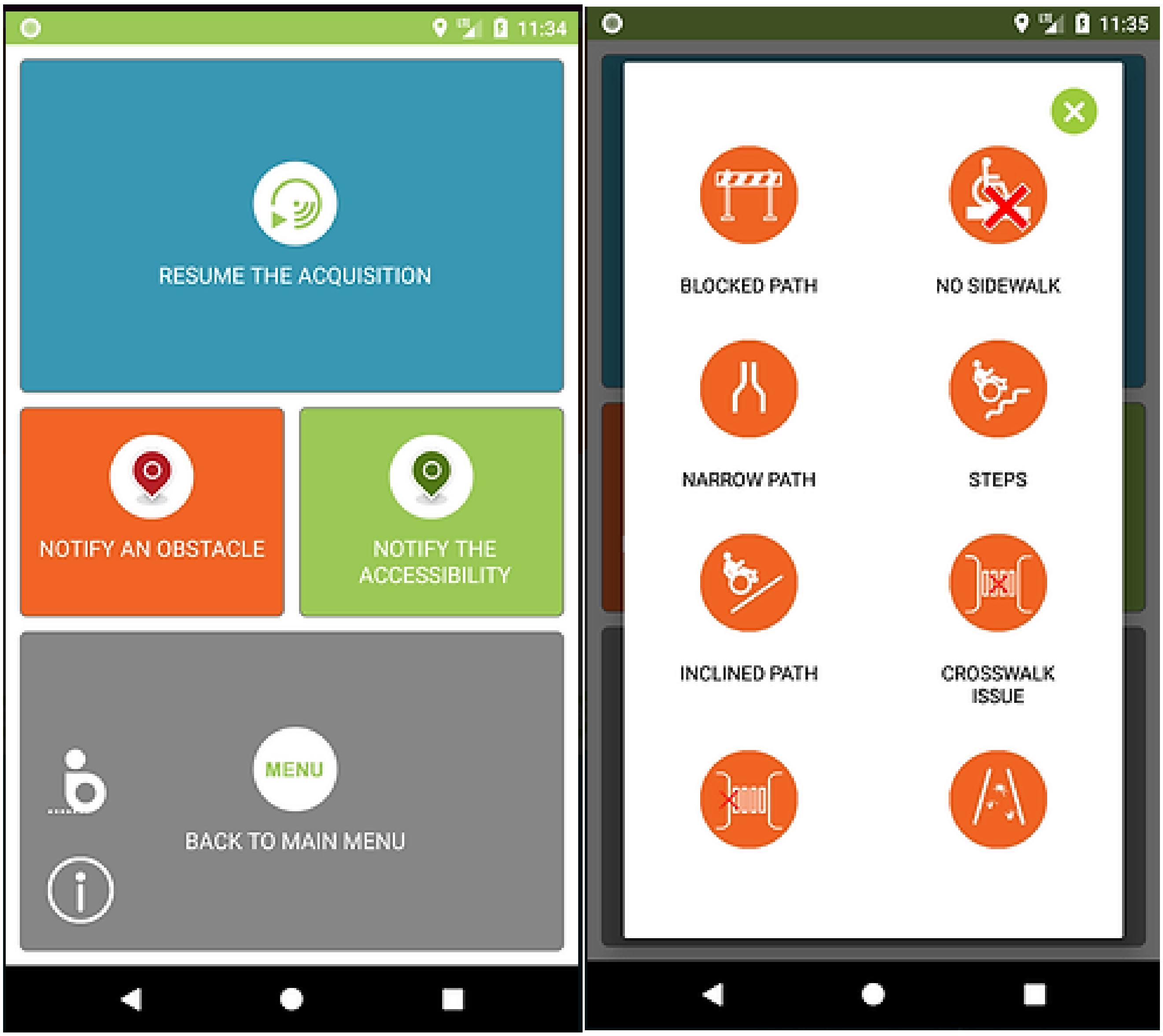


**Figure 7. Features the app should include**

The diagram in Table 5 and Figure 7 illustrates results from respondents on the preferable features would like the app to include. Therefore results showed that respondents prefer to be notified of an obstacle (49.5%), followed by those who like to receive the notification on the accessibility alerts (45.5%). Figure 14 illustrates the features of the app.

## Conclusion

This study aimed to design an effective geospatial data system tailored to enhance the mobility and accessibility of people with mobility challenges in Mbeya City. The proposed system integrates essential accessibility features, mapping pedestrian pathways, public spaces, and transportation networks suited to individuals with mobility challenges. Using user-centered design principles, the system responds to real-world barriers and provides detailed layers of accessibility data. Implementing this geospatial system has the potential to significantly improve the daily mobility experiences of people with mobility challenges, making Mbeya City more inclusive and accessible. Furthermore, this design can serve as a model for other cities in Tanzania and beyond that aim to address mobility challenges for people with mobility challenges. Although this study presents a solid framework, further data quality and system maintenance research is needed.

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## Disclosure statement

The authors have no conflicts of interest.

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