

AN ANALYSIS OF SHARED ELECTRIC BICYCLE INFRASTRUCTURE REQUIREMENTS FOR SOUTH AFRICA

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ABSTRACT

The possibilities and challenges associated with implementing a shared electric bicycle (e-bike) infrastructure in South Africa are examined in this conference paper. The goal of the study is to pinpoint the specific conditions and factors that must be taken into account for shared e-bike systems to be successfully incorporated into urban transportation systems. The analysis revealed that South Africa's existing bicycle infrastructure is inadequate and requires significant improvements to accommodate shared electric bicycle systems. Key findings include the need for dedicated bicycle lanes, secure parking facilities, charging stations, and integration with existing public transportation networks. Additionally, the study identified the importance of public awareness campaigns and user-friendly mobile applications to promote the adoption and usage of shared electric bicycles. Future work may aim to conduct more comprehensive analyses of the social and cultural determinants that impact the adoption and usage patterns of e-bikes, encompassing views on safety, convenience, and cycling-related social norms. Furthermore, to determine their efficacy, pinpoint areas for development, and guarantee that they satisfy the changing requirements of users and urban environments, continuous monitoring and assessment of installed e-bike systems will be necessary.

1. INTRODUCTION

Globally, shared electric bicycle systems have become increasingly popular as an eco-friendly and effective form of last-mile and short-distance transportation (Salmeron-Manzano & Manzano-Agugliaro, 2018). Users of these programs, sometimes referred to as "bike-sharing" or "e-bike-sharing," can rent bicycles for a brief period of time, usually for travel or leisure. Infrastructure for shared electric bicycles may help ease traffic jams, lower carbon emissions, and encourage healthy living (Otero, Nieuwenhuijsen & Rojas-Rueda, 2018). Nevertheless, a number of aspects, such as user demand, policy frameworks, and infrastructure needs, must be carefully taken into account for such systems to be implemented successfully. A shared e-bike program will provide an additional transportation option to users of mass public transport systems such as trains, buses and taxis as these systems do not drop a commuter at their final destination and commuters need to walk the remaining kilometres.

The aim of this research is to examine the infrastructural needs for shared electric bicycles in South Africa. With its varied metropolitan environments and growing urban population, South Africa offers a special setting for the use of shared electric bike networks. There are several transportation-related issues that the nation must deal with, such as heavy traffic,

few public mass transportation options, and excessive air pollution. Thus, it becomes imperative to investigate shared electric bicycles as a viable sustainable transportation option (Bieliński, Kwapisz & Ważna, 2021).

The analysis's main goal is to pinpoint the essential infrastructure needs required for shared electric bike systems to be implemented successfully in South Africa. This entails determining the necessity of dedicated bike lanes, e-bike battery charging stations, e-bike rental stations, efficient e-bike safety and security systems, and the integration of these systems with the current mass transportation infrastructure. The study will also consider how shared electric bicycles might affect public space usage, urban planning, and the general urban environment.

To achieve these objectives in this paper, a thorough analysis of the body of research, case studies, and international best practices will be carried out. This analysis will give important insights into the various methods and tactics used to put shared electric bike systems into place. The analysis's conclusions will add to the corpus of information already available on shared electric bicycle systems and how South Africa is implementing them. They will provide information to transportation authorities, urban planners, and legislators about what must be done to build a successful and long-lasting infrastructure for shared electric bicycles across the nation. The study will also be used as a guide for upcoming investigations into shared electric bicycle systems in other developing nations with comparable transportation issues (Fishman, 2016; Kamargianni, Li, Matyas & Schäfer, A., 2016).

This investigation will offer important insights into the prerequisites and factors for the effective deployment of shared electric bicycle networks across the nation by looking over the current literature, and prototype development. It is crucial to remember that the analysis in this work has its limits. The study is predicated on case studies and existing literature, and could have biases and limitations of their own. Furthermore, because South Africa's urban environments differ greatly, the conclusions and suggestions made might not be appropriate for all areas of the nation especially where there are long distances to be covered more than the average cycling range. As a result, care should be used while interpreting and using the findings of this work.

In addition, it is important to note that e-bikes offer a valuable means of transportation for distances less than 15 km. The use of an electric motor means that the distance from 5 to 15 km that would not be practically feasible for walking or cycling becomes achievable in the context of electrically driven motors to assist cyclists.

2. LITERATURE REVIEW

Shared electric bicycle infrastructure has gained significant attention in recent years as a sustainable and efficient mode of transportation in many countries. This literature review aims to analyse the requirements of shared electric bicycle infrastructure in the context of South Africa. The review will examine existing studies, research articles, and reports to gain insights into the potential benefits, challenges, and necessary considerations for implementing such infrastructure in the country.

The concept of shared electric bicycles has emerged as a viable solution to address the challenges of urban mobility, congestion, and environmental pollution. This mode of transportation offers a convenient and sustainable alternative to private vehicles, particularly for short-distance trips. It has been observed that shared electric bicycles can reduce traffic congestion, improve air quality, and promote physical activity among users.

In a study conducted by Zhang et al. (2018) in China, it was found that shared electric bicycles significantly reduced carbon emissions compared to traditional modes of transportation. The study also highlighted the positive impact of shared electric bicycles on public health, as they encouraged physical activity and reduced sedentary behaviour. An e-bike can save an average 249g of CO₂ for every 1km travelled which will significantly air pollution in South African cities (2024 Scottish Power Ltd., 2020). These findings suggest that implementing shared electric bicycle infrastructure in South Africa could contribute to achieving sustainability goals and improving public health outcomes.

However, several factors need to be considered when designing shared electric bicycle infrastructure in South Africa. One crucial aspect is the availability and accessibility of charging stations. Electric bicycles require regular charging to ensure uninterrupted service. Therefore, establishing a network of charging stations strategically located throughout urban areas is essential. A study by Shaheen et al. (2014) emphasized the importance of integrating charging infrastructure with existing transportation networks to ensure seamless operations.

Another critical consideration is the design and layout of bicycle lanes and paths. Shared electric bicycles require dedicated infrastructure to ensure the safety of riders and minimize conflicts with other road users. Research conducted by Fishman et al. (2014) in Australia highlighted the importance of well-designed bicycle infrastructure in promoting cycling as a mode of transportation. This finding suggests that South Africa should invest in developing safe and convenient bicycle lanes and paths to encourage the adoption of shared electric bicycles.

Moreover, understanding user preferences and behaviour is crucial for the successful implementation of shared electric bicycle infrastructure. A study by Wang et al. (2019) in the United States revealed that user satisfaction and acceptance of shared electric bicycles were influenced by factors such as pricing, availability, and ease of use. These findings suggest that South Africa should conduct user surveys and pilot projects to gain insights into user preferences and tailor the infrastructure accordingly.

The economic feasibility of shared electric bicycle infrastructure is another aspect that requires careful consideration. While shared electric bicycles have the potential to generate revenue through user fees, sponsorship, and advertising, the initial investment and operational costs should be evaluated. A study by Nello-Deakin et al. (2018) in the United Kingdom highlighted the importance of a sustainable business model and public-private partnerships to ensure the long-term viability of shared electric bicycle schemes.

It is important to note that the implementation of shared electric bicycle infrastructure in South Africa may face certain challenges such as load shedding, country's diverse geography, varying urban densities, and socio-economic disparities. South Africa is also facing an electricity crisis due to supply constraints and increasing demand. The shared bicycle infrastructure will be grid-independent as charging stations will be solar powered. It generally takes between 4-5 hours to charge a 48v 15ah battery (PEDAL Electric, 2023). As most commuters require transportation from 6:30 to 9:00 am and 15:30 to 19:00, there is a peak charging time between 9:00 am to 15:00 pm (6 hours) where there is limited demand for e-bikes. Therefore, a comprehensive analysis of the local context, including demographic and geographic factors, is necessary before designing and implementing shared electric bicycle schemes.

3. METHODOLOGY

The research methodology reviewed current research literature on the state of bicycle and bicycle sharing infrastructure in South Africa. In addition, in the Department of Electrical and Electronic Engineering Science (DEEES) at the University of Johannesburg, several fourth year engineering students completed a final year project in a field related to electric bicycles. These projects included the development of a generic e-bike sharing rental platform, a battery charging system and an electronic lock.

3.1 The E-Bike Rental Platform

To encourage small-scale entrepreneurs to invest in e-bike sharing schemes it is vital that an easily customisable and integrated mobile bike sharing platform is made available to them. In the Department of Electrical and Electronic Engineering Science at the University of Johannesburg, we have developed a prototype cloud-based bike rental system to assess the viability of implementing a shared e-bike infrastructure in South Africa. This platform allows multiple owners/entrepreneurs to customise their individual mobile applications with logos, etc whilst utilising the same backend platform to manage the rental of e-bikes. The basic functionality provided includes the following:

- Software to track each bicycle.
- Customizable mobile application for electric bicycle rental stations.
- Communication and integration system to connect a rented electric bicycle to its administrators at a rental station.
- Accurately determine the distance travelled and the usage time to determine the cost of the rental for the consumer.
- A payment system for renting a bike to allow the bike rental station owner to receive payment when a bike is rented by a subscribing commuter.
- Customers, rental locations, electric bicycles, and the administration all communicate with each other through mobile and web applications.

The Agile methodology for software development was used in the development of the software project. This is an appropriate strategy since it enabled us to review the requirements and make incremental adjustments as the platform was developed. The software components consist of a mobile application, a web application, a cloud-based database and integration application programming interfaces to communicate between the various sub-systems.

The rental system enables a new user to register on the system via the mobile application. Once registered, the user can log in and perform administrative updates to their profile, book an e-bike or cancel an e-bike booking. Once the user is at the rental station, they can use the mobile app to unlock an e-bike and use it. The administrator and owner can track each e-bike as it is fitted with a GPS location tracking device to ensure the security of the e-bike. The GPS location is also used to determine the charge allocated to the user based on distance and time travelled.

3.2 Anti-Theft Architectural Design

As e-bikes become more popular, they also become attractive targets for thieves due to their higher cost and valuable components. An anti-theft e-bike refers to an electric bicycle equipped with features and technologies designed to deter theft and enhance security. To address this concern, we have implemented various anti-theft measures. The system

features involve enhancing the security of an e-bike by providing real-time alerts to the owner when someone comes in contact with the bike. The owner receives a message with various options to manage the situation effectively. When the contact detection system is triggered, indicating that someone is interacting with the e-bike, the communication module sends an immediate notification to the owner's smartphone. This notification is in the form of a text message, using GSM technology.

Figure 1 shows the Anti-theft architectural design as one of the developments for the University of Johannesburg e-bike implementation. Anti-theft systems in e-bikes work by combining various technologies and components to create a secure and reliable system. The system includes electronic switches and sensors that are placed strategically on the e-bike. These switches and sensors are responsible for detecting any unauthorized access to or tampering of the e-bike. Once the switches or sensors detect any suspicious activity, such as someone attempting to unlock or move the e-bike without authorization, the system triggers an alarm and sends notifications to the owner. The notifications can be sent through various methods, such as short messages to the owner's phone or alerts through a mobile application. In addition to the alarm and notification features, anti-theft systems in e-bikes utilizes IoT connectivity. This allows for remote monitoring and real-time alerts, enabling the owner to receive notifications and updates about their e-bike's status from anywhere in the world. Furthermore, GPS technology is integrated into anti-theft system in e-bikes. This allows the owner to track the location of their e-bike in real-time, making it easier to recover the bike in case of theft. Overall, the logical operation of this anti-theft e-bike system involves the continuous monitoring and detection of unauthorized access or tampering through electronic switches and sensors.

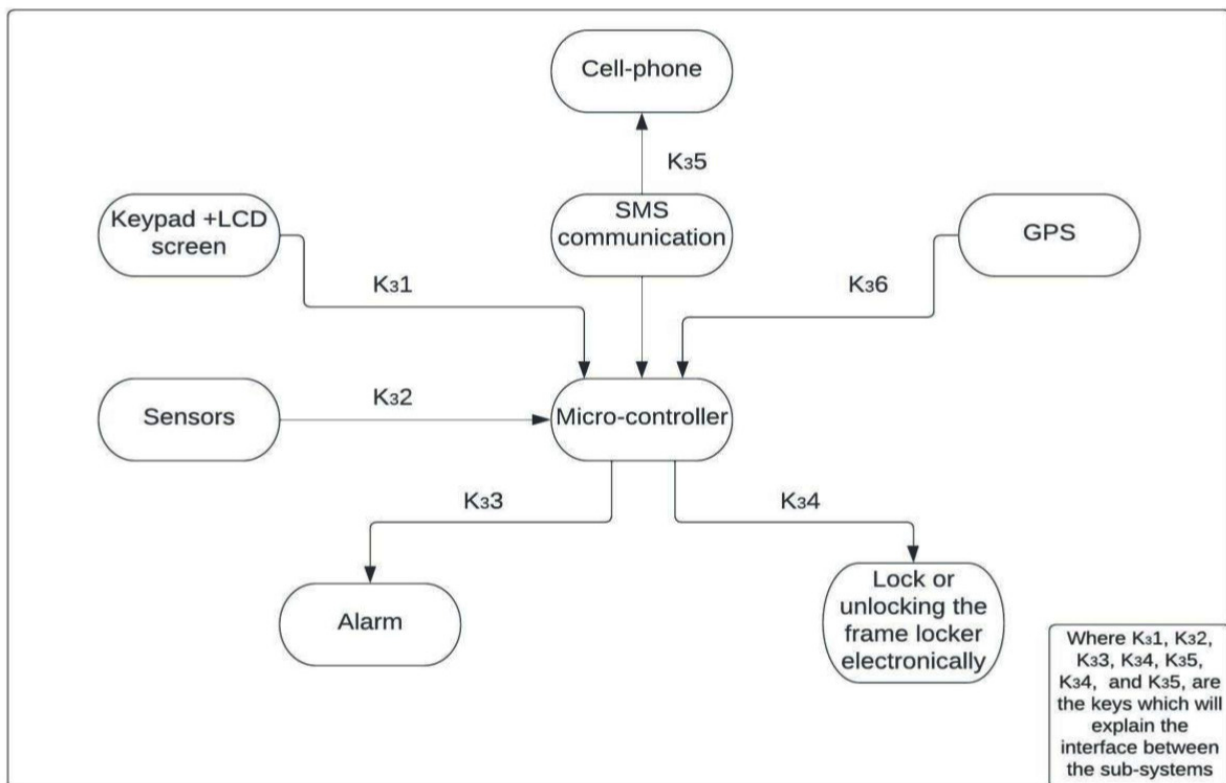


Figure 1: Anti-theft architectural design

Table 1 shows some of the implemented features in for the anti-theft measures.

Table 1: Naming conventions of components on the architectural design

Key	Explanation
K31	Input the password for the frame locker using the keypad, and the password shall be displayed on the LCD. The user shall use the keypad to switch between the system's various modes, and the results shall be shown on the LCD screen.
K32	The sensor shall send signals to the microcontrollers whenever they are activated, and the microcontroller's embedded programming shall determine how the sensors respond
K33	Depending on the embedded code in the microcontroller, the alarm shall ring in a specific pattern and volume whenever the sensors are activated, when the password is incorrect or when the location of the bike changes
K34	The electronically controlled frame locker shall be constructed. It shall be locked or unlocked by entering the password on the keypad.
K35	SMSs shall be used to maintain the connection between the user and the system affixed to the bike. The user shall receive a message any time the sensors are activated, or the password entered is incorrect or when the location of the bike changes; at that point, they can choose to turn off or on the alarm or find out where the bike is.
K36	In the event that the bike's location needs to be retrieved, the microcontroller must be able to obtain the GPS module's latitude and longitude coordinates.

3.3 EV Charging Platform

The principal algorithm to be deployed is the First-Come-First Served (FCFS). FCFS is a type of scheduling algorithm used by operating systems and networks to execute queued tasks, processes, and requests efficiently and automatically by the order of their arrival. An FCFS scheduling algorithm may also be referred to as a first-in, first-out algorithm or a first-come, first-choice algorithm. The charging station shall comprise of 12 charging ports tailored to accommodate four distinct types of electric vehicles: bicycles, tricycles, and motorbikes. Each electric vehicle type exhibits specific power consumption requirements, resulting in varying power needs.

The station maintains continuous monitoring of power requirements for charging vehicles and the overall power capacity of the station. This constant monitoring is essential to ensure that power demands stay within the station's capacity.

An Internet of Things (IoT) platform called ThingSpeak enables users to gather, examine, and display data from a variety of sensors and devices. ThingSpeak, created by MathWorks, is a platform that makes it simple for people, companies, and organizations to develop Internet of Things projects and applications. Utilizing ThingSpeak, ensures real-time monitoring of the station's charging capacity, enabling the operator to make informed decisions in the backend calculations. This functionality is instrumental in optimizing the allocation of power resources and ensuring the grid sustainability objectives of the project are met.

4. RESULTS

4.1 The E-bike Rental Platform

The development of the rental platform included a customisable mobile application that allows a user to register, log in and book a bicycle as shown in Figure 2 – Figure 7.

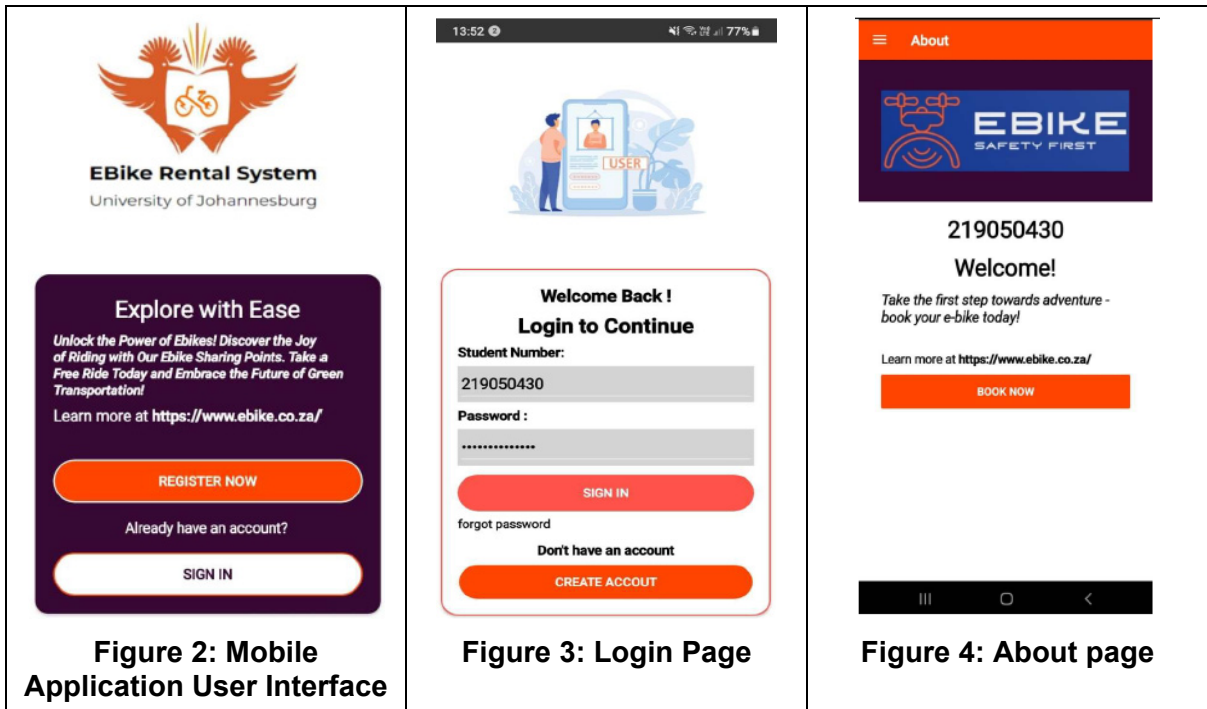


Figure 2: Mobile Application User Interface

Figure 3: Login Page

Figure 4: About page

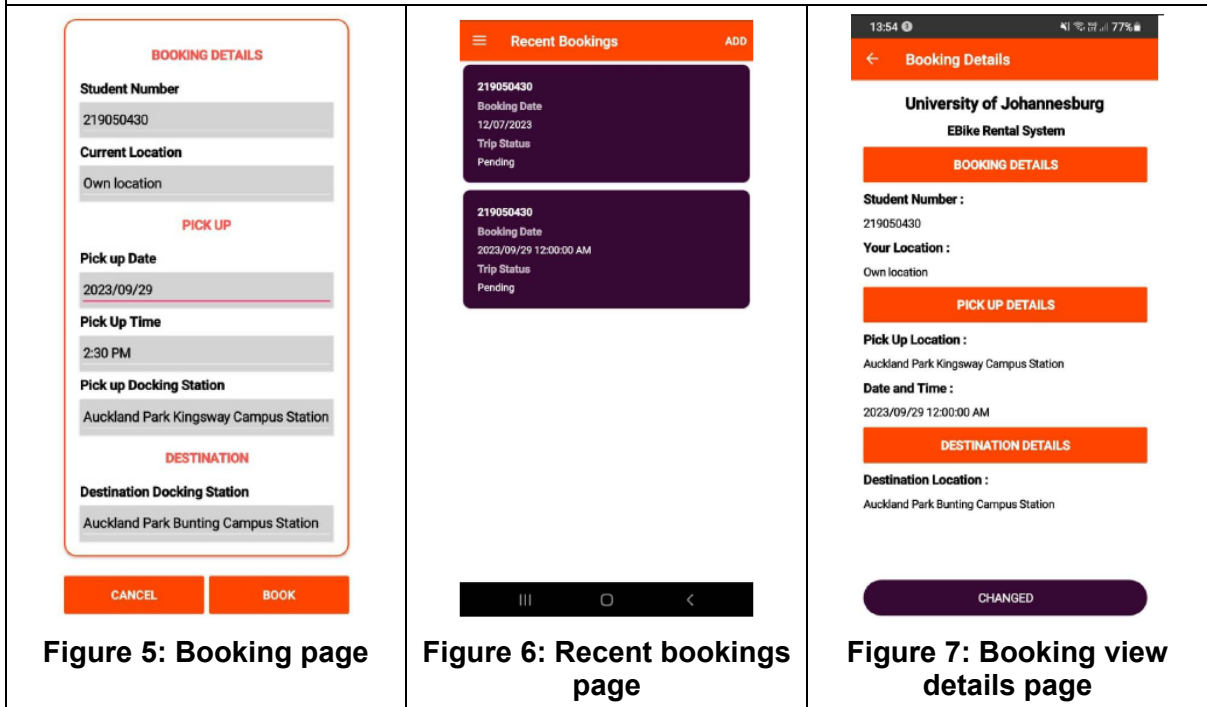


Figure 5: Booking page

Figure 6: Recent bookings page

Figure 7: Booking view details page

4.2 Anti-Theft Architectural Design

Figure 8 and 9 below show the extracted latitudes and longitudes that were used to plot a line graph that was used to determine the minimum range that could be worked with for coding the threshold of location that will trigger the alarm sub-system:

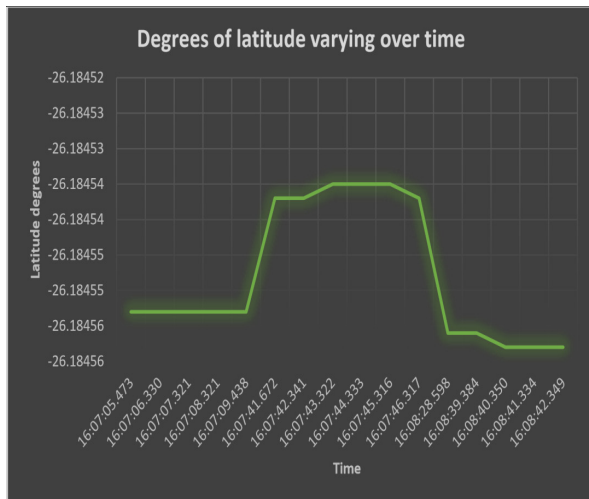


Figure 8: Degrees of latitude varying over time

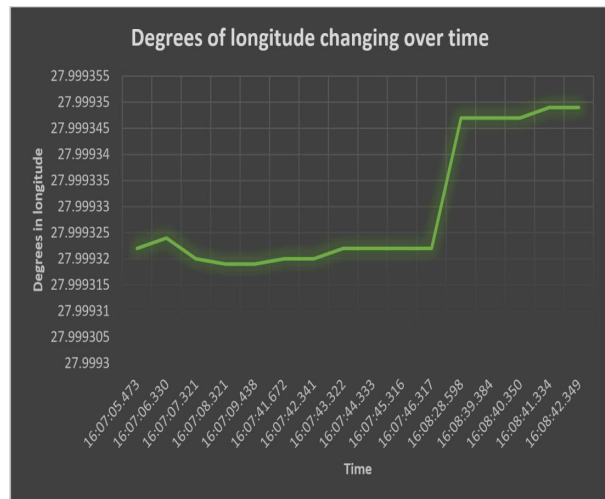


Figure 9: Degrees of longitude varying over time

4.3 EV Charging Platform

Figure 10 shows the user registration form that new users must fill out so they can have booking rights. Figure 11 shows the voltage readings as seen on ThinkSpeak respectively. These values on ThinkSpeak represent the electric vehicle charging station charging capacity which is used to either accept or decline charging requests depending on how power is being requested and the type of charging port vehicle the user wants to charge. The e-bikes may be kept charged and ready for use without needing extra infrastructure or downtime for manual charging by incorporating charging capabilities into docking stations. By guaranteeing that there are always enough charged bikes available for users, this strategy can improve the effectiveness and usability of shared e-bike networks.

USER REGISTRATION

Fields marked * are required.

Email *

Password *

Retype Password *

First Name *

Last Name *

Phone number *

Address

Town

Age *

Type Electric Fleet *

Vehicle Capacity *

Figure 10: User registration form on the EV charging station platform

Channel Stats

Created: 1 minute ago
 Last entry: less than a minute ago
 Entries: 119

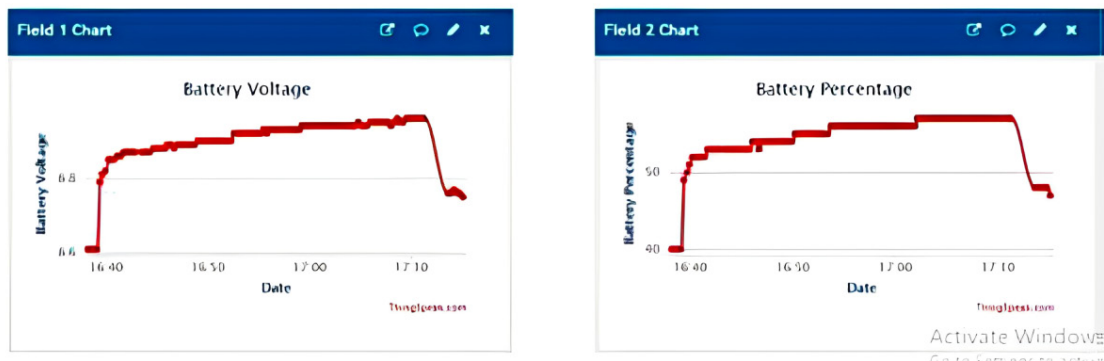


Figure 11: Live battery voltage monitoring on ThingSpeak

5. SOCIO-ECONOMIC AND GEOGRAPHICAL CONSIDERATIONS

The socioeconomic and topographical characteristics specific to South Africa that affect the feasibility of shared e-bike systems will be examined in this section. We will specifically take into account factors like income levels, rates of urbanization, and the geographic dispersion of population centres. We may better grasp the opportunities and difficulties associated with deploying shared e-bike systems in South Africa by comprehending these variables. Table 2 shows the socio-economic and geographical considerations with recommendations to be adapted to the South African infrastructure.

6. INFRASTRUCTURE REQUIREMENTS

In many nations, shared e-bike systems have become more popular as an eco-friendly and effective form of transportation. Numerous advantages are provided by these systems, including decreased carbon emissions, increased physical activity, and less traffic congestion. However, careful consideration of particular infrastructure requirements that are customized to the local context is necessary for the successful deployment of shared e-bike systems. This section covers the exact infrastructure needed to develop shared e-bike systems in South Africa. It includes information on where to put bike docking stations, charging stations, safety precautions, and integration with the country's current public transportation systems. Table 3 shows the infrastructure requirements that can be adapted to the South African infrastructure.

Furthermore, first- and last-mile connectivity problems can be mitigated by combining shared e-bike systems with current public transportation networks. Due to distance or insufficient feeder services, many commuters have difficulty getting to public transportation from their residences or places of business. By offering a flexible and effective means of transportation for short distances, shared e-bike systems can close this gap and make it easier for users to utilize public transportation options.

Table 2: Socio-Economic and Geographical Considerations

Factors	Description	Recommendation
Income levels (Arndt et al 2020)	Significant income inequality and a high percentage of the population living below the poverty line are features of South Africa. For people with lesser means, the initial cost of buying an e-bike may be too high, therefore shared e-bike systems are a more practical choice.	Pricing options need to be carefully considered to guarantee that shared e-bike systems are affordable for a broad spectrum of income levels.
Urbanization rates (Güneralp, Lwasa, Masundire, Parnell & Seto, 2017)	The nation has rapidly become more urbanized, with a large percentage of the people living in cities and other metropolitan areas. The density of the population in urban areas creates a favourable environment for shared e-bike networks to flourish.	Shared e-bike systems' should be encouraged in urban and metropolitan areas to contribute to their transportation services due to their dense population, traffic volume, and the accessibility of alternate modes of transportation.
Geographic distribution of population centers (Shackleton et al., 2018)	The topography of the nation is varied, encompassing vast townships, rural areas, and heavily populated urban centres. Townships and rural areas may need to be reached with extra infrastructure investments, such as building charging stations in outlying locations and growing bike networks.	It might be necessary to make extra infrastructure investments to reach townships and rural areas, like building charging stations in outlying locations and growing bike networks.
Cultural and behavioural factors (Bieliński, & Ważna, 2020)	Distinct communities and areas may have differing cultural norms, perspectives on e-bikes, and attitudes towards cycling. Designing successful marketing and awareness initiatives to encourage the usage of shared e-bike systems requires an understanding of these aspects.	In South Africa, shared e-bike systems can become more widely accepted and adopted if safety issues are addressed, e-bike usage education is given, and system design is inclusive.

Table 3: South African Infrastructure Requirements

Requirement	Description	Recommendation
Road Infrastructure (Rich et al., 2021)	For e-bikes to be available to users, they must be charged on a regular basis. Thus, it is imperative to have a network of charging stations positioned thoughtfully throughout cities at the same docking stations.	By integrating charging capabilities into docking stations, the e-bikes can be kept charged and ready for use without requiring additional infrastructure or downtime for manual charging.
E-bike docking locations (Fukushige, Fitch & Handy, 2021)	The strategic distribution of these docking spots throughout the city is necessary to ensure adequate coverage and accessibility.	Public parks, business districts, educational institutions, and transit hubs are a few possible places for docking.
Safety measures (Haustein & Møller, 2016)	There is a general public concern about crime and personal safety; in order to reassure potential users, these concerns must be addressed.	Safety concerns can be reduced by putting in place safety measures including emergency call buttons, surveillance cameras, and well-lit docking spots.
Integration with existing public transportation (Guidon et al., 2019)	Users may have easy and convenient transport options by integrating shared e-bike systems with these current networks.	This integration can be accomplished in a number of ways, like by creating bike lanes specifically for them and parking lots close to stops for public transportation.

Furthermore, first- and last-mile connectivity problems can be mitigated by combining shared e-bike systems with current public transportation networks. Due to distance or insufficient feeder services, many commuters have difficulty getting to public transportation

from their residences or places of business. By offering a flexible and effective means of transportation for short distances, shared e-bike systems can close this gap and make it easier for users to utilize public transportation options. The integration of the e-bike system with the current public transportation network has the potential to improve both its overall efficiency and appeal.

7. CONCLUSIONS

This study concludes by highlighting the critical need for swift and deliberate actions to rectify the shortcomings in South Africa's bicycle infrastructure and clear the path for the effective integration of shared electric bicycle (e-bike) systems into metropolitan transportation networks. According to the findings, complete infrastructure improvements are required, and essential requirements include dedicated bicycle lanes, secure parking facilities, and charging stations. The study also emphasizes the significance of user-friendly mobile applications and public awareness efforts in promoting the broad acceptance and use of shared e-bikes. Section 3 and 4 of this paper presents some of the applications developed that can be used by shared e-bikes. This includes e-bike rental platform, charging platform and anti-theft application. All these applications are fully functional as shown in Section 4 and can be integrated into shared e-bike infrastructure. We can unleash the full potential of shared e-bike infrastructure in South Africa and usher in a new era of equitable and sustainable urban mobility by making these factors a priority and encouraging cooperation between urban planners, policymakers, and transportation stakeholders.

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