EEG Operated Wheelchair

B. Tech Project Stage-I

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In partial fulfillment of the requirement for the award of the degree of
Bachelor of Technology
in
Electronics and Computer Engineering
by

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This is to certify that the Project Stage- I report entitled **"EEG Operated Wheelchair"** has been submitted by **Mr. Mir Mujtahid Mohtashim Ali, Mr. Gaus Mohiuddin Shafiyoddin Sayyad** and **Mr. Karankumar Pandharinath Nevage** with PRN **No. 202101104010, 202101104015** and **202101104018** in partial fulfillment for the award of the degree of Bachelor of Technology in **Electronics and Computer Engineering** from Jawaharlal Nehru Engineering College, MGM University, Chh. Sambhajinagar.

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ABSTRACT

Mobility limitations pose a significant challenge in India, particularly in rural areas where conventional wheelchairs often prove inadequate. This study investigates the prevalence of and challenges faced by individuals with limited mobility, emphasizing the need for specialized mobility aids. These aids must be designed to navigate varied terrains, such as paved roads, dirt paths, and uneven surfaces, ensuring compatibility and ease of use.

The proposed wheelchair design prioritizes the end-user, addressing the specific needs of individuals in rural India. By focusing on accessibility, customizability, and cost-effectiveness, this initiative aims to enhance the quality of life for approximately 1.5 million individuals with severe mobility limitations. The inclusion of new technologies, such as electric wheelchairs and assistive robots, reflects a growing trend towards innovative solutions in mobility aids. Additionally, the development process emphasizes contactless and hygienic features to reduce infection risks.

Highlighting the lack of wheelchair-friendly public and private spaces, this research underscores the importance of creating mobility aids that promote independence and dignity. By targeting the 60-70% of the affected population who are illiterate and impoverished, these specialized wheelchairs aim to empower marginalized communities, ensuring they can navigate their environments with ease. This approach not only enhances mobility but also fosters inclusivity and autonomy, making a substantial impact on the lives of individuals with limited mobility in India.

By ensuring the wheelchair is priced affordably, it aims to be accessible to a broad range of users, particularly benefiting the estimated 1.5 million individuals with severe mobility limitations in India, many of whom live in rural and impoverished areas. This design fosters independence, reducing the need for a helper and enabling users to navigate their environments with ease and dignity. The incorporation of innovative technologies addresses the specific needs of this population, significantly enhancing their quality of life.

NOMENCLATURE

Lbs – Pounds
INR-Indian National Rupees
Rs-Rupees
k-Thousand
NGO- Non-Government Organization
BCE- Before Common Era
FNN- Feed-Forward Neural Network
BCI-Brain-Computer Interfaces

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1. INTRODUCTION

1.1 Need Statement

“In India, a significant population of approximately 1.5 million individuals, primarily illiterate and impoverished villagers, grapple with severe mobility limitations. Conventional wheelchairs are often inaccessible to them due to various barriers. Therefore, there is an urgent need to develop and provide specialized wheelchairs designed to cater to their unique mobility challenges. These targeted solutions will not only enhance their quality of life but also promote inclusivity and autonomy, empowering them to navigate their environments with dignity and ease.”

In India, approximately 1.5 million individuals live with very limited mobility, with an additional 20,000 new cases emerging each year. This statistic highlights a pressing need for specialised mobility aids. A significant portion of this population, particularly the 60-70% who are illiterate and impoverished villagers, encounters substantial barriers in accessing conventional wheelchairs.

To address this gap, it is essential to develop wheelchairs specifically designed for their unique mobility challenges. Providing these targeted solutions not only promotes inclusivity and autonomy but also empowers marginalized communities to navigate their environments with dignity and ease, thereby significantly enhancing their quality of life despite their physical limitations.

Designing wheelchairs tailored to their specific needs can bridge this gap, fostering inclusivity and autonomy. By providing targeted solutions, we can empower marginalized communities to navigate their environments with dignity and ease, significantly enhancing their quality of life despite their physical limitations

1.2 Stakeholders

The success of the wheelchair project hinges on the collaboration of various stakeholders. The primary stakeholders are the end users, the individuals with limited mobility, whose needs and feedback are central to the design and development of the wheelchairs. Healthcare professionals, including doctors and physical therapists, provide critical insights into the specific requirements and challenges faced by these individuals.

Government agencies offer potential regulatory guidance, funding, and support, while non-governmental organisations (NGOs) working with disabled individuals or rural communities are invaluable partners in reaching and assisting those in need. Manufacturers and suppliers ensure the production of high-quality, affordable wheelchairs.

Lastly, funding bodies, from government grants to private sector contributions, are crucial in financing these projects, enabling the development and distribution of these essential mobility aids. Through a concerted effort involving all these stakeholders, we can significantly improve the lives of those with limited mobility in India. These stakeholders play a crucial role in the successful development and distribution of the specialized wheelchairs, ultimately improving the lives of those with limited mobility in India.

2. Literature Survey

2.1 History and Evolution

The history and evolution of the wheelchair is a testament to humanity's enduring commitment to enhancing mobility for individuals with disabilities. The earliest known depiction of a wheelchair can be traced back to ancient China around the 6th century BCE [1][2]. These initial wheelchairs were basic in design, comprising wooden platforms with wheels attached, and were primarily used to transport individuals of high social status [1][2].

Figure 2.1

Earliest Wheelchair from China

By the Middle Ages, the design of wheelchairs had evolved to include larger wheels and handles for pushing, thereby increasing their functionality for caregivers1. Despite these advancements, wheelchairs remained a rarity and were often custom-made for specific individuals [1].

Figure 2.1.2

European Evolution of Wheelchair

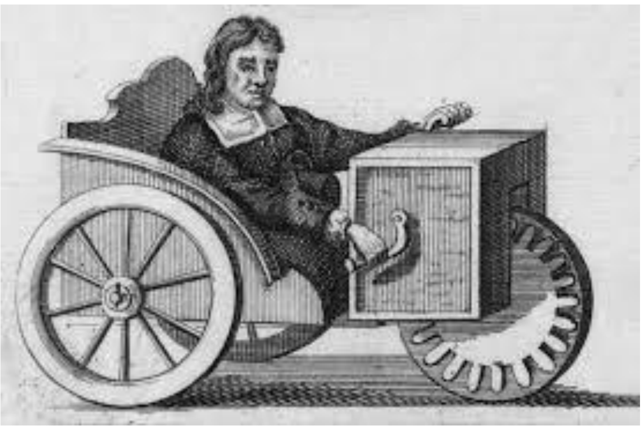
 

The 19th century marked a significant turning point in wheelchair design, spurred by the Industrial Revolution1. The advent of metalworking techniques facilitated the mass production of wheelchairs, thereby increasing their accessibility1. The late 19th century saw the introduction of the folding wheelchair, a development that greatly enhanced portability and storage options [1].

The catastrophic impact of World Wars I and II necessitated further advancements in wheelchair technology to cater to the needs of injured veterans [1]. This period saw the introduction of lightweight materials such as aluminium, which made wheelchairs more manoeuvrable and easier to transport [1].

Figure 2.1.3

Evolution of Wheelchair during World war

In conclusion, the evolution of the wheelchair over thousands of years underscores the ongoing efforts to improve the quality of life for individuals with disabilities. Each advancement, from the rudimentary wooden platforms of ancient times to the lightweight, manoeuvrable designs of today, reflects a continuous commitment to fostering mobility, independence, and dignity for all [1].

2.2 Breakthroughs

The history of wheeled furniture, a precursor to the modern wheelchair, can be traced back to ancient civilizations. Archaeological evidence, such as an inscription on a stone slate in China and a depiction of a wheeled child's bed on a Greek vase, suggests the use of wheeled devices between the 6th and 5th centuries BCE [1] [3]. In China, early wheelbarrows served dual purposes, not only for transporting heavy objects but also for moving people [1] [3]. This fundamental concept of attaching wheels to a platform laid the foundation for future innovations in mobility aids, demonstrating the ingenuity of ancient civilizations in addressing the practical needs of their societies [1] [3].

The introduction of wheeled chairs in Europe around the 12th century, possibly alongside the wheelbarrow, marked a significant shift in societal approaches to disability and mobility [1]. The first recorded use of self-propelled chairs by disabled individuals in Europe dates back to the 17th century, a period characterized by increasing mechanical innovation[1].

German mechanic Johann Hautsch crafted rolling chairs in Nürnberg in the early 17th century, showcasing the specialized craftsmanship of the era[1]. Around 1655, Stephan Farfler, a disabled German watchmaker, designed a three-wheeled chair that he could propel using a rotary handle on the front wheel[1]. Farfler's design, a precursor to modern wheelchairs, integrated mechanical advantage to enhance user independence[1].

The 18th century witnessed wheelchairs appearing in surgical and medical instrument catalogs, indicating a shift towards the medicalization and formal recognition of mobility aids[1]. The bath chair, introduced around 1750, was designed for use by ladies and invalids and gained popularity in Victorian Britain[1]. This development underscores the intersection of mobility aids with the social norms and medical practices of the time[1].

By the 19th century, wheelchairs, featuring wooden frames with cane seats and backs, were widely used by veterans of the Civil War in the United States[1]. This period saw a convergence of practicality and necessity, as the demand for wheelchairs increased with the rise in war-related injuries[1]. Technological advancements, such as the introduction of wire-spoke wheels and rubber tires, reflected a growing understanding of user needs[1]. These innovations laid the groundwork for the modern wheelchair, combining functionality with comfort to enhance the quality of life for users[1].

the evolution of the wheelchair is a remarkable journey that spans centuries and civilizations. From rudimentary wheeled platforms in ancient China to the sophisticated, user-friendly designs of today, each advancement reflects humanity’s enduring commitment to enhancing mobility for individuals with disabilities. The wheelchair’s history is not just a chronicle of technological innovation, but also a testament to societal shifts in understanding and addressing disability. Today, as we continue to innovate and improve wheelchair design, we carry forward this legacy of empathy, inclusivity, and respect for human dignity. Each new development brings us one step closer to a world where everyone, regardless of physical ability, can navigate their environment with ease and independence. The history of the wheelchair reminds us that in the quest to improve mobility, we are not just engineering better devices - we are, in fact, creating a more inclusive and accessible world.

Table1.1
List of Research on Wheelchair

TITLE	YEAR PUBLISHED	PUBLISHED AT	DESCRIPTION
Tongue Drive Wheelchair	2013	News Center Features | Georgia Institute of Technology (gatech.edu)	Individuals with paralysis were able to use a tongue-controlled technology to access computers and execute commands for their wheelchairs at speeds that were significantly faster than those recorded in sip-and-puff wheelchairs, but with equal accuracy.
A hybrid brain computer interface system based on the neurophysiological protocol and brain-actuated switch for wheelchair control	2014	Journal of Neuroscience Methods - News Center Features | Georgia Institute of Technology (gatech.edu)	A simulated wheelchair training task by 3 control methods was implemented firstly and a real wheelchair control experiment was performed for assessing our hybrid BCI system.
EEG Classification for Hybrid Brain-Computer Interface Using a Tensor Based Multiclass Multimodal Analysis Scheme	2015	Article in Gerontechnology · April 2010 DOI: 10.4017/gt.2010.09.02.263.00	(EEG-) based brain-computer interface (BCI) systems usually utilize
Classification of Electroencephalogram Signal for Developing Brain-Computer Interface Using Bioinspired Machine Learning Approach	2022	Computational Intelligence and NeuroscienceVolume 2022, Article ID 4487254, 17 pages https://doi.org/10.1155/2022/4487254	analyze the best performances between two age groups 20–28 and 29–40 using the AR Yule-Walker features with crow search optimization based FFNN classifier.

2.3 Modern Evolution

Today's wheelchairs, available in both motorized and manual versions, represent a significant evolution from the rudimentary wheeled furniture of ancient times. Motorized wheelchairs leverage batteries and electric motors for propulsion, while manual wheelchairs depend on the power exerted by the user or an attendant.

Over recent decades, the design of wheelchairs has been revolutionized by advancements in materials, electronics, and ergonomics. Modern wheelchairs often feature lightweight carbon fiber frames, customizable seating options, and advanced propulsion systems. The integration of smart technologies has further enhanced wheelchair functionalities, introducing features such as automated navigation and remote monitoring.

Figure 2.3.1
Modern Wheelchair

The latest innovations in wheelchair design aim to improve accessibility, comfort, and functionality for users. These include adjustable seating configurations and advanced suspension systems, making modern wheelchairs adaptable and comfortable for a wide range of needs.

In addition to the historical evolution of wheelchairs, recent research has explored innovative technologies to improve accessibility and control for individuals with limited mobility. The Tongue Drive Wheelchair, introduced in 2013 by the Georgia Institute of Technology, is a significant advancement in assistive technology. This system allows individuals with paralysis to control computers and wheelchairs using tongue-controlled technology. Research conducted in 2013 demonstrated that users could execute commands for their wheelchairs at speeds significantly faster than those recorded in sip-and-puff wheelchairs, with equal accuracy.

Furthermore, a hybrid brain-computer interface (BCI) system developed in 2014 enabled wheelchair control through neurophysiological protocols and brain-actuated switches. This system was assessed through simulated training tasks and real wheelchair control experiments, indicating its potential for enhancing mobility for individuals with paralysis.

Recent years have seen further advancements in BCI technology. A study published in 2015 proposed an EEG classification scheme for a hybrid BCI using a tensor-based multiclass multimodal analysis. This approach aimed to improve the accuracy and efficiency of BCI systems by integrating multiple modalities of brain signal analysis. Additionally, research conducted in 2022 analyzed the performance of EEG-based BCI systems utilizing AR Yule-Walker features with crow search optimization-based FFNN classifiers. The study compared performance between age groups of 20–28 and 29–40, highlighting the potential impact of age on BCI effectiveness.

Moreover, the integration of fuzzy neural networks (FNN) in BCI design has shown promise in enhancing wheelchair control. A paper published in 2016 presented a BCI system based on FNN for wheelchair control, evaluating the emotional and muscular states of the user for control purposes. This approach demonstrates the potential for incorporating user-specific physiological and emotional cues into wheelchair control systems, thereby improving user experience and efficiency.

2.4 Existing Solutions

In recent decades, advancements in materials, electronics, and ergonomics have revolutionized wheelchair design. Carbon fiber frames, customizable seating options, and advanced propulsion systems are now standard features. Integration of smart technologies enables automated navigation and remote monitoring, enhancing functionality. Several contemporary wheelchair models exemplify these innovations. The Whill Model Ci boasts front omni-wheels for enhanced maneuverability and app-controlled features. The Permobil M3 Corpus prioritizes advanced seating and positioning options for optimal comfort. The Invacare TDX SP2 offers versatility and stability, catering to a wide range of users. Conversely, the Drive Medical Silver Sport 2 provides durability and affordability with its manual design.

Table 2.4

Comparison on Existing Wheelchairs

Name	Specification	Price
Whill Model Ci	Drive Range: 11.00 miles Top Speed: 5.00 mph Heaviest Piece: 42 lbs Turning Radius: 29.90" Weight capacity: 300 lbs Total Weight: 120 lbs Seat Width: 18" (optional 16") Seat Depth: 18" (optional 16") Can be remotely controlled using the Whill CI iPhone app Battery fully charges in just 5 hours Seat is height, depth, and angle adjustable	$4000
Permobil M3 Corpus	Maximum User Weight: 149.69 kg Driving Range: 25 km Alternate Driving Range: 32 km Base Width: 60.96 cm Minimum Turning Radius: 52.07 cm Ground Clearance: 7.62 cm	$10,000
Invacare TDX SP2 Power Wheelchair	Base Length: 35.6" L Base Width: 24"W narrow, 25.5"W wide Battery: Group 24, 22NF Battery Range: Up to 20 miles* Dimensions: 16"-23"D x 16"-20"W or 19"-22"W Drive Wheel Options: 14" Ground Clearance: > 2.5" Incline Capability: 9 degrees Product Weight Capacity: 300 lbs Seat To Floor Height: 17.25", 18.25", 19.25" Speed: 5.8 mph* Motor: 4-Pole Sealed Housing Turning Radius: 20"	$7000

Average cost of Wheelchairs for the people with Limited Disability $7,000 which is equal to **6 Lakh Rupees**. Overall Average Cost of a wheelchair with advanced special control mechanisms **6 Lakh Rupees.**

2.5 Literature Observations

In India, particularly in rural regions, there is a notable prevalence of individuals with mobility limitations. This underscores the urgent need for specialized mobility aids that are tailored to their unique needs. Conventional wheelchairs often pose significant challenges for these individuals in terms of accessibility and usability. This leads to discomfort and difficulties in usage, especially for those with specific needs. Moreover, the lack of wheelchair-friendly infrastructure in both public and private spaces further restrict the mobility and independence of wheelchair users, exacerbating their challenges.

Recognizing these issues, there has been a growing trend of innovation in the field of mobility aids. This includes the development of new technologies such as electric wheelchairs and assistive robots. These innovative solutions hold promise in addressing the unique needs of individuals with mobility limitations, potentially significantly improving their quality of life. However, it is crucial for these advancements to prioritize customization and accessibility. This ensures their effectiveness in meeting the diverse needs of users, particularly in the context of India's varied socio-economic landscape. Furthermore, it is essential to consider the affordability of these solutions, as cost can be a significant barrier to access for many individuals.

In addition to technological innovation, there is a need for societal and infrastructural changes to create a more inclusive and accessible environment for individuals with mobility limitations. This includes improving the accessibility of public and private spaces, raising awareness about the needs and rights of individuals with disabilities, and promoting policies that support their inclusion and participation in all aspects of society. Addressing the mobility needs of individuals with disabilities in India requires a multi-faceted approach. This includes not only the development of innovative and customized mobility aids but also broader societal and infrastructural changes to promote inclusivity and accessibility. Through these concerted efforts, we can significantly improve the quality of life for individuals with mobility limitations and foster a more inclusive society.

2.6 Realized Design Requirements

The design of the wheelchair should be meticulously crafted to ensure adaptability to a variety of terrains. This includes not just paved roads, but also dirt paths and uneven surfaces commonly found in rural areas of India. This adaptability is crucial in ensuring that the wheelchair is accessible and usable for individuals with diverse mobility limitations, particularly those residing in rural areas where infrastructure may be lacking.

Table 2.6
Observations and Realization of Requirements

Observation from Literature survey	**Requirements**
Prevalence of mobility limitations in India, particularly in rural areas. Challenges faced by these individuals in Accessing & Using conventional wheelchairs.	The design should be compatible with the varied terrains (paved roads, dirt paths, uneven surfaces) where it will be used.
The need for specialised mobility aids tailored to the needs of these individuals.	The wheelchair should be designed keeping the end-user in mind. It should cater to the specific needs of individuals with limited mobility in India, particularly those residing in rural areas.
The impact of these mobility aids on the quality of life of these individuals.	Accessible to individuals with disabilities of all kinds.
There is a growing trend of innovation in the field of mobility aids. New technologies like electric wheelchairs and assistive robots are being developed.	Contactless and hygiene are prioritised during development to mitigate the risk of infections.
Most conventional wheelchairs are not designed with customization in mind. This can lead to discomfort and difficulties in usage for individuals with specific needs.	Minimum intraoral Trauma
Many public and private spaces are not designed to be wheelchair-friendly. This can limit the mobility and independence of wheelchair users.	Cost-effective and affordable for common man

Comfort should be a top priority in the design process. The wheelchair should be ergonomically designed to cater to the specific needs of the user, providing adequate support and minimizing discomfort during prolonged use. This could include features such as adjustable seating, cushioning, and customizable support for different parts of the body.

In light of the ongoing global health concerns, the wheelchair design should also incorporate contactless and hygiene features to mitigate infection risks. This could involve the use of antimicrobial materials, easy-to-clean surfaces, and possibly even touch-free control options. Cost-effectiveness is a key factor in ensuring the wheelchair’s affordability and widespread accessibility. The design and manufacturing process should strive for efficiency and sustainability, using durable yet affordable materials and minimizing waste. This will help to ensure that the wheelchair remains within a price range that is accessible to as many individuals as possible.

The design of the wheelchair should be a careful balance of adaptability, comfort, hygiene, safety, and cost-effectiveness. By keeping these factors at the forefront of the design process, we can create a wheelchair that truly meets the needs of individuals with mobility limitations in India, particularly those in rural areas. This will not only enhance their mobility but also significantly improve their quality of life.

3. Problem Statement

3.1 Users and Clients

In conducting a study on mobility aids, several key questions can guide the inquiry. Firstly, understanding the nature of the individual's mobility-limiting condition provides a foundational understanding of their specific needs and challenges. Secondly, exploring how they currently navigate their surroundings offers insight into existing methods and potential limitations. Thirdly, identifying the most important features desired in a mobility aid helps guide the development process towards user-cantered design. Additionally, understanding preferences for wheelchair control and the level of adjustability and customization desired informs design considerations.

Moreover, determining factors such as the optimal charging cycle for the battery and suggestions for improvements to current mobility aids provide valuable insights for innovation. Furthermore, assessing budget limitations ensures that proposed solutions remain feasible and accessible. Additionally, gathering information about the terrain or environment where the wheelchair will be most frequently used informs design considerations for durability and adaptability. Moreover, discussing the basic features intended for inclusion in the wheelchair ensures clarity on user expectations. Finally, inquiring about any additional needs beyond mobility ensures a comprehensive understanding of user requirements and preferences.

Table 3.1

Questions for Users and Clients

Questions
1. What is the nature of your mobility-limiting condition?
2. How do you currently navigate your surroundings?
3. What are the most important features you would like to have in a mobility aid?
4. How would you like to control the wheelchair?
5. What level of adjustability and customization would you prefer in your wheelchair?
6. What should be the charging cycle for the battery?
7. What improvements would you suggest for your current mobility aid?
8. Do you have any limitations on your budget?
9. Can you describe the terrain or environment where you would most frequently use the wheelchair?
10. Can you briefly talk about the basic features you intend to have in the wheelchair?
11. Do you need anything else apart from mobility in your wheelchair?

3.2 Feedback Analysis

Feedback from clients and users reveals specific requirements for their mobility aids. One user, affected by a mobility-limiting condition except for certain facial muscles and the tongue, seeks independence with a wheelchair controlled hygienically through movable body parts. They prioritize adjustable seat features for comfort during transportation and desire a battery lasting 8-10 hours with improvements in seat comfort and slope climbing. Affordability is capped at ₹70,000, considering the middle-class income in India. Residing in a semi-urban area with varied terrains, they need a wheelchair enabling easy movement, adjustable speed, and user-friendly operation, with openness to additional features enhancing functionality and convenience.

Table 3.2

Responses from the Users

Responses from clients and Users	Objective	Constraint	Function
The nature of my mobility-limiting condition primarily affects my whole body except ability to use my **tongue and certain facial muscles. (Objective -operated through working muscles and brain signals)**	*		
I currently use a manual wheelchair. I rely on family members for assistance when going outdoors or **navigating difficult terrains.**			*
I would like a wheelchair that enables me to **move independently** without the need for constant accompaniment by another person.	*		
I want to control the wheelchair with my currently moveable body parts **hygienically**	*		
I prefer a wheelchair with **adjustable seat height and backrest angle** to accommodate my comfort needs as I often need to **transport** my wheelchair in a vehicle. (function- Adjusting seats)			*
Ideally, the battery should last for a full day of use (around **8-10 hours**) and be able to fully recharge overnight		*	
A more **comfortable seat, better back support,** and an easier way to climb slopes would be great improvements. I prefer a **lightweight** wheelchair for ease of handling but need it to be sturdy enough for daily use.	*		
Considering the average income of a middle-class family in India, the maximum affordable price would be around **₹70,000**.		*	
I live in a semi-urban area. The terrain includes paved roads, dirt paths, and sometimes, uneven surfaces with potholes. (Function -**Detection of uneven surface**)			*
The wheelchair should allow for easy forward and backward movement, turning, and stopping. **Adjustable speed** would be a plus. It should also be **easily operable**, even for a layman.	*		*
A small storage space for personal items would be helpful. **(Portability and carrying space)**	*		
No, **independent mobility** is my primary concern, but I'm open to additional features if they enhance the overall functionality and convenience of the wheelchair such as **safety systems like sos and emergency call.**	*		*

3.3 Identified Objectives

The identified objectives are realized from the responses, emphasizing that the ideal wheelchair should be controllable using the user's tongue and certain facial muscles, with a hygienic control mechanism. It must feature an adjustable seat height and backrest angle for comfort and be portable for easy transportation. The seat should be comfortable with good back support, and the wheelchair must handle various terrains, including paved roads, dirt paths, and uneven surfaces with potholes. User-friendliness is crucial, ensuring it is easily operable even by a layman. It should facilitate smooth forward and backward movement, turning, and stopping, with adjustable speed as an added benefit. A small storage space for personal items is essential. Safety must be guaranteed, providing reliable mobility on flat surfaces. The wheelchair should be affordable, ideally priced around ₹70,000 to suit the average income of a middle-class family in India. A battery life of 8-10 hours with overnight recharge capability is ideal. It should be lightweight yet durable for daily use, and enable the user to move independently without constant assistance from others.

Table 3.3.1

List of Objectives

Objective	Description
Precise Control	The wheelchair should be controllable using the user’s tongue and certain facial muscles, with a hygienic control mechanism.
Adjustability	The wheelchair should have an adjustable seat height and backrest angle to accommodate the user’s comfort needs.
Portability	The wheelchair should be portable for easy transportation in a vehicle.
Comfort	The wheelchair should have a comfortable seat and provide good back support.
Terrain Compatibility	The wheelchair should be capable of handling different terrains, including paved roads, dirt paths, and uneven surfaces with potholes.
User-friendly	The wheelchair should be user-friendly and easily operable, even for a layman.
Maneuverability	The wheelchair should allow for easy forward and backward movement, turning, and stopping. Adjustable speed would be a plus.
Storage	The wheelchair should have a small storage space for personal items.
Safety	The wheelchair should provide safe and reliable mobility on flat surfaces.
Affordability	The maximum affordable price should be around ₹70,000, considering the average income of a middle-class family in India.
Battery Life	The battery should last for a full day of use (around 8-10 hours) and be able to fully recharge overnight.
Weight and Durability	The wheelchair should be lightweight for ease of handling but sturdy enough for daily use.
Independence	The wheelchair should enable the user to move independently without the need for constant accompaniment by another person.

Table 3,3.2

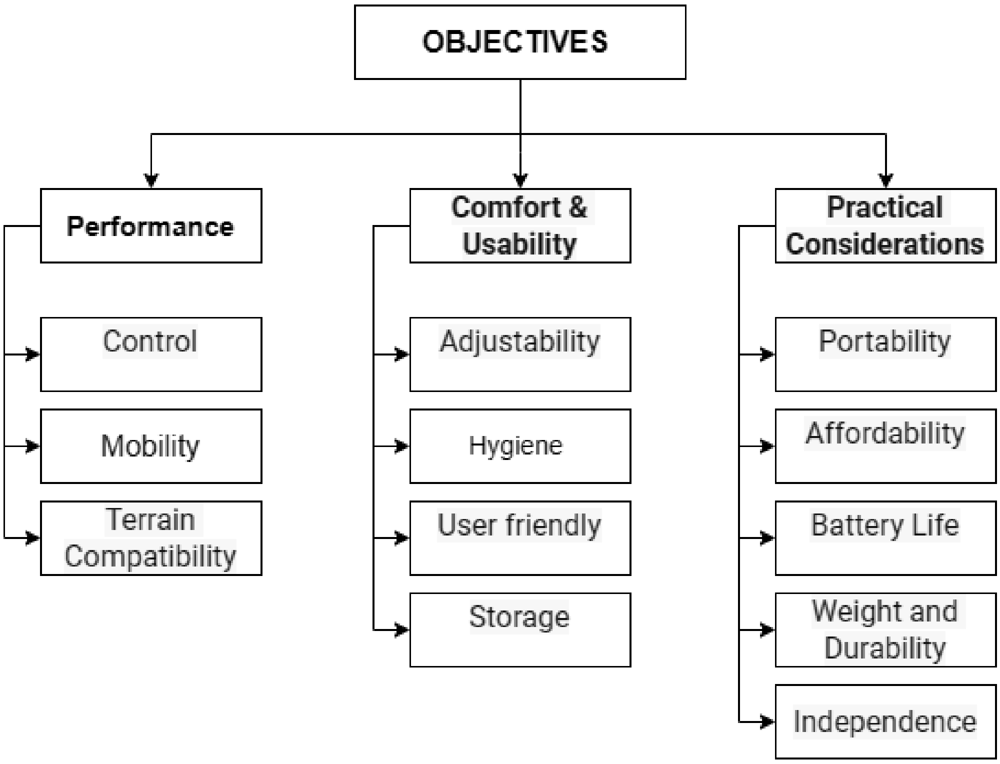
PCC Chart

Objectives	Precise Control	Maneuverability	Terrain Compatibility	Adjustability	Portability	Affordability	Battery Life	Weight and Durability	Independence	Comfort	User friendly	Storage	Score
Precise Control	*	1	1	1	1	1	1	1	0	1	1	1	10
Maneuverability	0	*	0	1	1	1	1	1	0	1	1	1	9
Terrain Compatibility	0	0	*	1	1	0	0	0	0	0	0	1	3
Adjustability	0	0	0	*	1	0	0	0	0	0	0	1	2
Portability	0	0	0	0	*	0	0	0	0	0	0	1	1
Affordability	0	0	1	1	1	*	1	1	0	1	1	1	8
Battery Life	0	0	1	1	1	0	*	1	0	1	1	1	7
Weight and Durability	0	0	1	1	1	0	0	*	0	1	1	1	6

Independence	1	1	1	1	1	1	1	1	*	1	1	1	11
Comfort	0	0	1	1	0	0	0	0	0	*	1	1	4
User friendly	0	0	1	1	1	0	0	0	0	1	*	1	5
Storage	0	0	0	0	0	0	0	0	0	0	0	*	0

Problem Statement v1.1: To design and develop an autonomous wheelchair which can be controllable using working body parts having good battery life along with high durability and terrain compatibility. Comfortable and adjustable seat. It is affordable to lower class and having some storing capacity.

Figure 3.3
Objective Tree



3.4 Identified Constraints

The constraints identified for the wheelchair design include affordability, independence, and battery life. With a target price below ₹70,000, the wheelchair aims to remain accessible while empowering users to move independently without constant assistance. Ensuring a battery life of at least 8 to 10 hours enables uninterrupted mobility throughout the day, enhancing user autonomy and reducing reliance on frequent recharges. By addressing these constraints through innovative design and technology, the wheelchair seeks to provide a practical and empowering solution for users with mobility impairments.

Table 3.4
List of Constraints

Constraint	Description
Price	Less than 70k
Independent	Does not require a helper for operation
Battery Life	At least 8 to 10 hours of battery life

Problem Statement v1.2: To design and develop an autonomous wheelchair which can be controllable using working body parts, with good battery life, high durability, and terrain compatibility. It should feature a comfortable and adjustable seat, be affordable to lower-income individuals, have storage capacity, and be capable of handling different terrains. Additionally, it should provide safe mobility, have storage space, a long battery life, and be lightweight yet durable. The wheelchair should be priced under 70k, have a battery life of at least 8 to 10 hours, and be designed to promote user independence without requiring a helper for operation

3.5 Identified Functions

Table 3.5
List of Functions

Function	Description
Movement Control	Allows the wheelchair to move forward, backward, and turn based on EEG signals.
Adjustability	Enables adjustments in seat height and backrest angle for user comfort.
Terrain Navigation	Facilitates navigation across different types of terrains for mobility.
Sensing	Detects and senses various environmental quantities for situational awareness.
Decision Making	Employs autonomous decision-making algorithms for self-navigation and control.

Problem Statement v1.3: To design and develop an autonomous wheelchair that is user-friendly, affordable, and promotes independence. The wheelchair should be controllable using the user’s tongue and facial muscles, allowing it to move forward, backward, and turn in response to the user's commands. It should be adjustable for comfort, with options for adjustments in seat height and backrest angle. The wheelchair should be portable, capable of navigating different types of terrains, and have an easy-to-use, clean, and understandable user interface. It should also provide safe mobility for that sensing and terrain navigation and decision-making capabilities, have storage space, a long battery life, and be lightweight yet durable. Additionally, the wheelchair should be priced less than 70k, have a battery life of at least 8 to 10 hours, and be designed in such a way that it doesn't require a helper for operation, thereby promoting user independence.

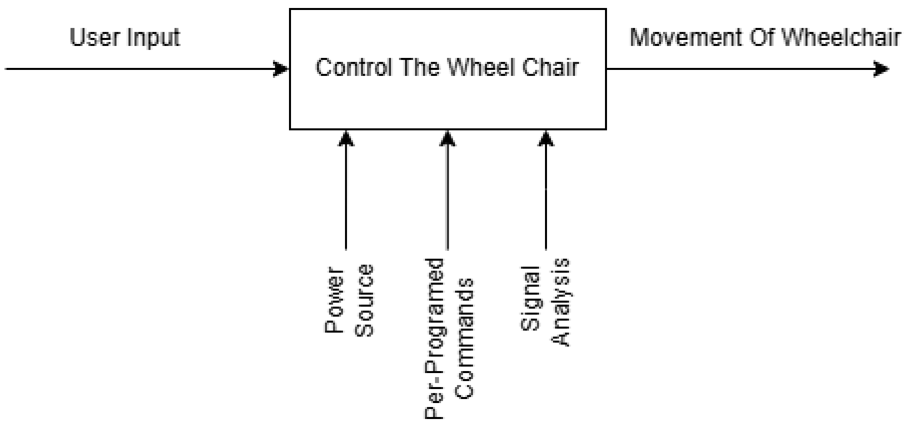
4. Conceptual Design

4.1 Blackbox

At the core of the wheelchair lies the black box, a compact yet essential hub of functionality. Within its confines, power input, user commands, and pre-programmed instructions converge in a symphony of control. Electrical currents pulse with energy, ready to be harnessed at the user's touch or directed by the silent guidance of pre-set commands. Algorithms within process these inputs with precision, orchestrating seamless movement and navigation. In this way, the black box serves as the central conduit, transforming intention into motion, and empowering the user with autonomy and control.

Figure 4.1

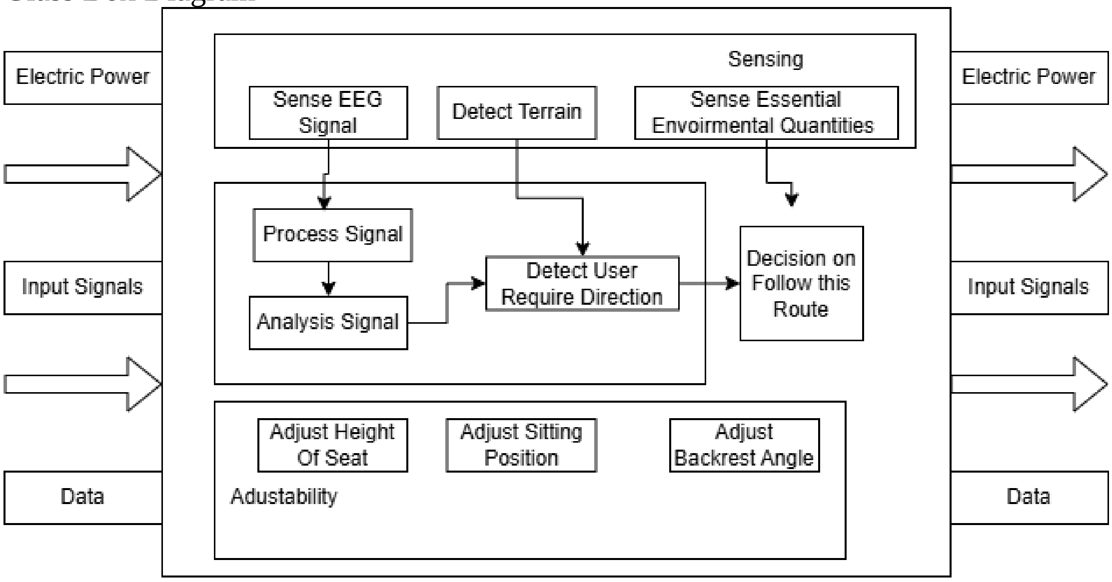
Blackbox Diagram



4.2 Glass Box

The core functionality of the wheelchair is encapsulated within a sophisticated system, symbolized by a glass box. Within this framework, user inputs serve as the initial trigger, setting off a sequence of operations. These inputs undergo meticulous scrutiny, beginning with the analysis of the power supply signal to ensure optimal energy availability. Subsequent command verification steps validate the accuracy of user instructions, ensuring safety and efficiency.

Figure 4.2
Glass Box Diagram



4.3 Expanded Glass box

A pivotal element lies in the intricate analysis of EEG signals from the user. Leveraging advanced technology, the wheelchair deciphers these brain signals, discerning the user's cognitive intentions. This comprehensive process transforms the wheelchair from a mere mobility aid into a responsive extension of the user, facilitating seamless interaction between human and machine.

Figure 4.3
Expanded Glassbox Diagram

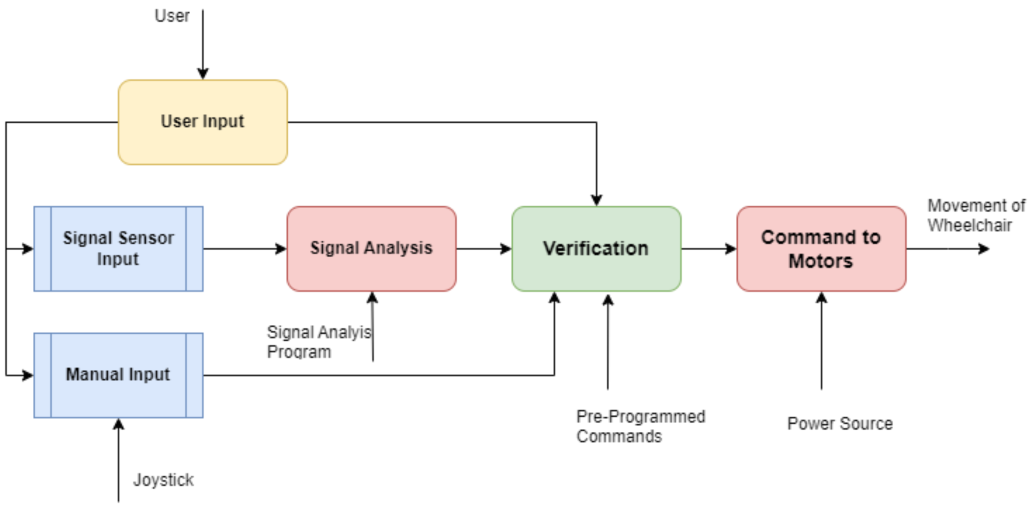
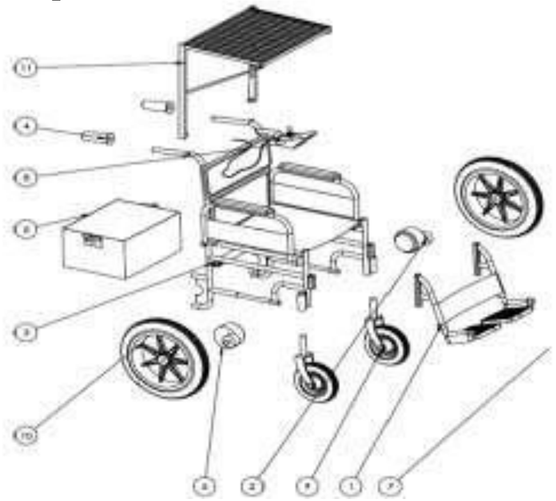


Table 4.3
Functional Strucutre

	Mean 1	Mean 2	Mean 3
Function 1: Control	Manual; Joystick, EEG Sensor	Autonomous; Pre-programmed Destination Points	Hybrid; Includes both
Function 2: Connectivity	Wired Connection	Internet Of Things	Radio Frequency Signal
Function 3: Sensing	Tongue, EEG Signals	Environment Sensing	Includes Both

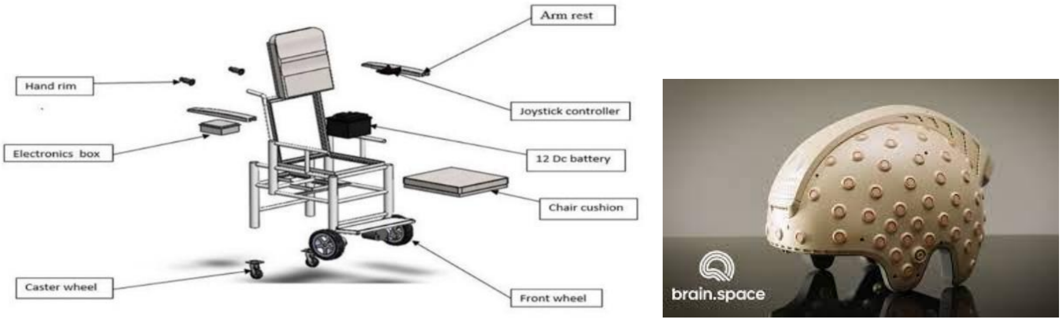
4.4 Realized Concepts
In Concept 1, the BCI interface is ingeniously incorporated into a sleek headband structure, strategically positioned over the ears and the central region of the head, akin to the anatomical location of the cerebellum. This design not only facilitates ease of use but also presents a visually appealing and ergonomic solution for EEG signal detection.

Figure 4.4.1
Concept 1



Contrastingly, Concept 2 takes a more encompassing approach by encasing the entire head within a helmet-like apparatus. This design ensures complete coverage and robust EEG signal detection, offering a sense of security and protection to the user. However, it may potentially sacrifice some comfort and flexibility due to its comprehensive coverage.

Figure 4.4.2
Concept 2



Concept 3 represents a thoughtful refinement, addressing several key concerns encountered in the previous concepts. By situating the BCI interface predominantly on the forehead and extending over the head, this design optimizes hygiene maintenance, minimizes infection risks, and enhances user comfort. Moreover, by prioritizing these aspects, Concept 3 aims to improve the accuracy and reliability of EEG signal capture, thereby advancing the overall functionality of the interface.

Figure 4.4.3
Concept 3

Table 4.4.1
Objective weight distribution

Objective	Weightage Rating (out of 10)	Reasoning
Independence	9	Promotes user autonomy and self-reliance.
Precise Control	10	Essential for ensuring precise navigation and operation.
Maneuverability	10	Core function of a wheelchair, facilitating movement in various environments.

Affordability	8	Ensures accessibility to a wider range of users.
Battery Life	7	Enhances convenience and reduces downtime for recharging.
Weight and Durability	6	Balances manoeuvrability with durability for long-lasting performance.
User-Friendly	9	Ensures ease of use for users of all abilities.
Comfort	6	Crucial for user satisfaction and prolonged use.
Terrain Compatibility	7	Enables navigation across different surfaces and environments.
Adjustability	4	Accommodates individual user preferences and needs.
Portability	5	Facilitates ease of transportation and storage.
Storage	3	Enhances convenience by providing space for personal items.

Table 4.4.2

PUGH Chart

Objectives	Weight	Concept 1	Concept 2	Concept 3
Independence	9	Datum	+	++
Precise Control	10	Datum	+	+
Maneuverability	10	Datum	+	+++
Affordability	8	Datum	-	+
Battery Life	7	Datum	--	+
Weight/Durability	6	Datum	+	+
User-Friendly	9	Datum	-	+
Comfort	6	Datum	--	++
Terrain Compatibility	7	Datum	+	-
Adjustability	4	Datum	-	+

Portability	5	Datum	--	-
Storage	3	Datum	+	-
Total +ve score		0	+45	+104
Total -ve score		0	-57	-15
Overall score		0	-12	89

4.5 Realized Conceptual Design

Concept 3 represents a thoughtful refinement, addressing several key concerns encountered in the previous concepts.

Figure 4.5.1

Realized Concept Mechanical Diagram and 3D Model

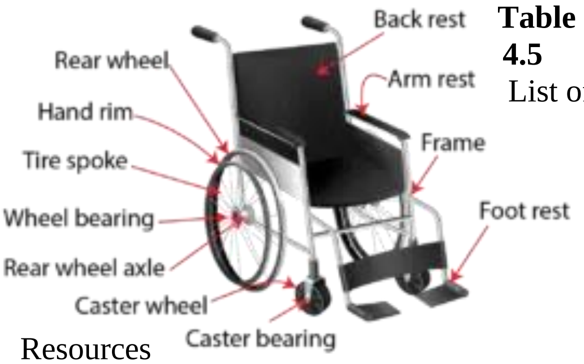
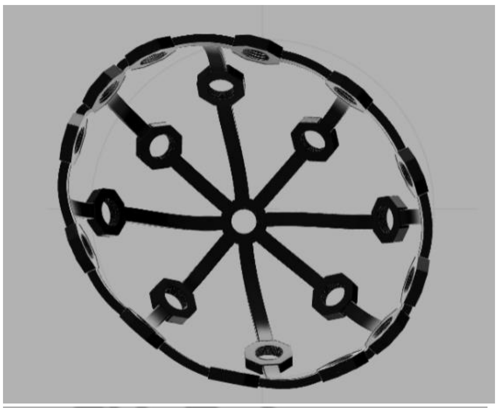
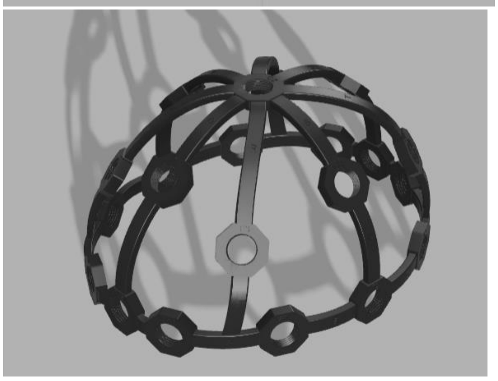
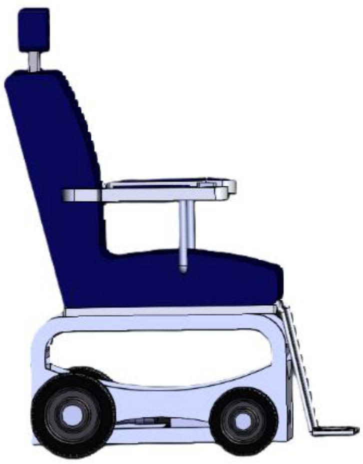


Table 4.5

List of Resources



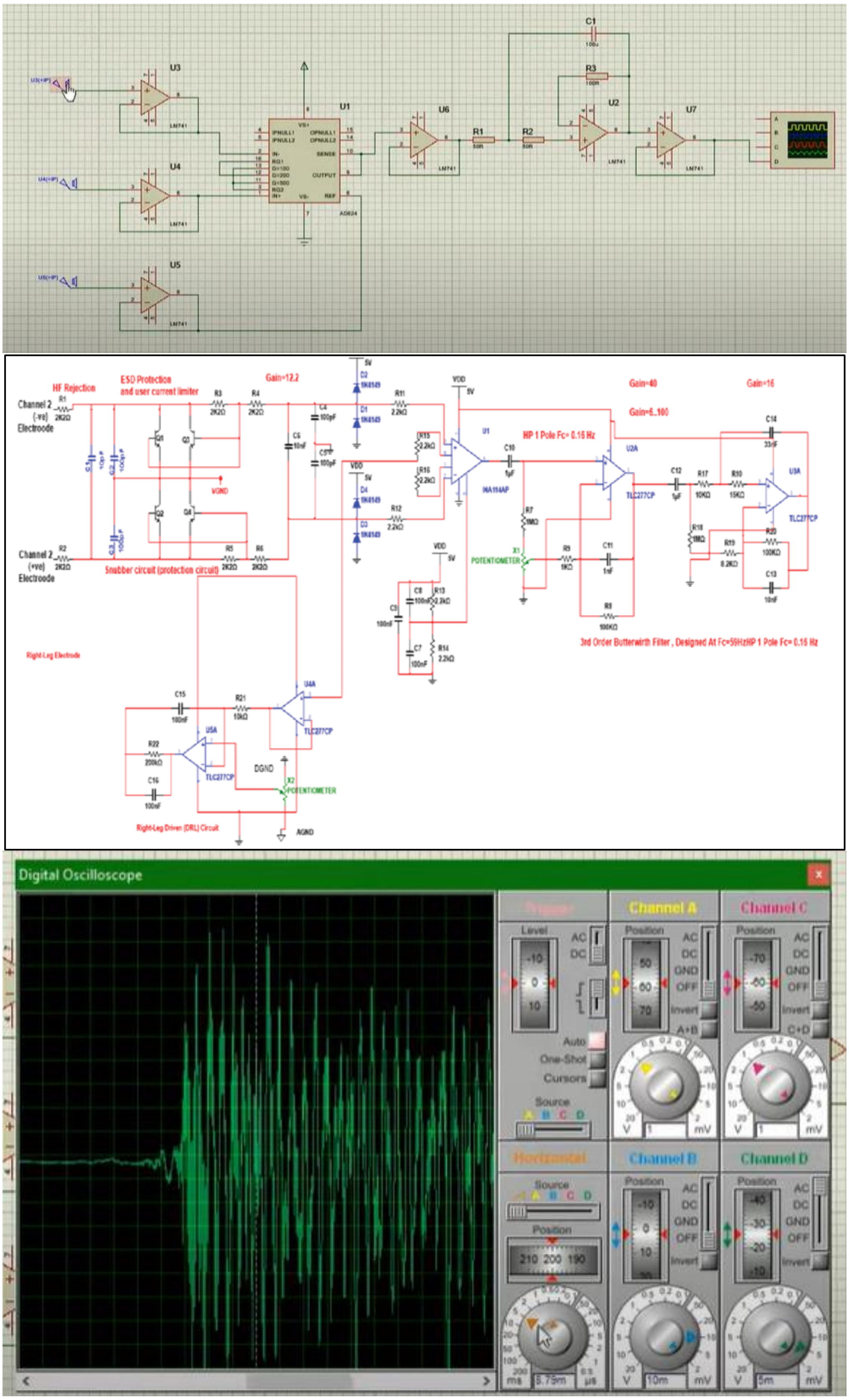




S. No.	Resource	Quantity	Specification
1	Wheelchair Chassis	1	Material: High-strength lightweight alloy (such as aluminum or titanium) for durability and ease of use Design: Foldable or rigid design depending on user needs. Foldable designs are more portable, while rigid designs offer better performance Weight Capacity: Should match or exceed the user's weight. Standard wheelchairs usually have a weight capacity of around 250 lbs (113 kg), but heavy-duty models can support much more Adjustability: Adjustable seat height, backrest angle, and footrest position for optimal comfort and posture Dimensions: Should fit the user's body dimensions and be able to navigate through the user's environment (doorways, hallways, etc.) Compatibility: Should be compatible with various wheelchair accessories such as cushions, armrests, and different types of wheels
2	Wheels	4	Diameter: Standard diameters range from 20 to 26 inches for rear wheels, and 6 to 8 inches for front casters Material: High-strength lightweight alloy (such as aluminum or titanium) or composite materials for durability and ease of use Tire Type: Pneumatic (air-filled) or solid. Pneumatic tires provide a smoother ride, while solid tires require less maintenance Tread Pattern: Depending on the usage, it could be smooth for indoor use or treaded for outdoor use
3	Brain Waves SENSOR	1	Sensor Type: Electroencephalography (EEG) Sensor Frequency range: 0.5 Hz - 100 Hz, covering Delta, Theta, Alpha, Beta, and Gamma brainwave bands Channels: At least 32 channels for comprehensive brain activity mapping Connectivity: Wireless connectivity (Bluetooth 5.0 or higher) for seamless data transmission Data Transfer Rate: High-speed data transfer rate (at least 1 kHz sampling rate) Power: Rechargeable battery with at least 8 hours of continuous use Compatibility: Compatible with multiple operating systems (Windows, macOS, Linux, Android, iOS)
5	Battery	2	Size- 119 mm x 60 mm x 129 mm Battery Cell Composition- Silver-Zinc Product Dimensions-11.9D x 6W x 12.9H Centimeters Number Of Cells- 6
6	Seat	1	Material: Durable and easy-to-clean material such as vinyl or nylon Design: Ergonomic design to support good posture and distribute weight evenly

Table 4.5
List of Resources

Figure 4.5.2
Proteus Simulation



5. Conclusion

We have successfully designed an autonomous wheelchair that meets the outlined needs. This wheelchair is envisioned to be user-friendly, affordable, and promote independence. It’s designed to be controlled using the user’s tongue and facial muscles, allowing for a range of movements. Comfort and portability are key features, with adjustable seat height and backrest angle, and the ability to navigate different terrains. The user interface is planned to be easy-to-use, clean, and understandable. Safety features, storage space, long battery life, and durability are also incorporated in the design. Priced under 70k with a battery life of at least 8 to 10 hours, this wheelchair is designed to promote user independence, eliminating the need for a helper for operation. We look forward to the development phase where we can bring this design to life and enhance mobility and independence for individuals with mobility challenges.

6. Future Scope

Commercializing the specialized wheelchair project presents a significant potential with a broad future scope. The design, adaptable to varied terrains such as paved roads and dirt paths, ensures accessibility for individuals with diverse mobility limitations, particularly in rural areas of India. The project prioritizes user comfort and caters to specific needs while incorporating contactless and hygiene features to mitigate infection risks. It also aims to minimize intraoral trauma and is cost-effective, ensuring affordability for widespread accessibility.

The potential for expansion to other geographies, particularly to regions with similar terrain and infrastructure challenges, is vast. The integration of smart technologies such as GPS for navigation, IoT for remote monitoring of the wheelchair’s condition, and AI for improving the user interface and control mechanisms could further enhance the wheelchair’s functionality.

Customization and personalization present another avenue for innovation, offering adjustable seating, customizable control mechanisms, and aesthetic personalization to cater to the specific needs and preferences of individual users. Partnerships with hospitals, rehabilitation centre, and other healthcare institutions could provide valuable insights into user needs, help in user testing, and could be potential channels for distribution.

7. Appendices

EEG -Short form of Electroencephalography, is a technique that records the brain’s electrical activity. It’s usually non-invasive, with electrodes placed on the scalp. The signals they pick up are in the range of 1 to 30 Hz, with amplitudes between 20 and 100 μV. These signals are mainly used to diagnose brain disorders like epilepsy. The signals come from neurons in the brain, and their strength on the EEG depends on their orientation and distance from the electrodes. Different frequency bands within the signals, like alpha, beta, delta, and theta, have different characteristics and uses.

Conventional wheelchairs-Conventional wheelchairs are standard, manual mobility devices, often made from durable materials like steel or aluminium. They are recognized for their stability, sturdiness, and features like removable armrests for easy transfers.

Marginalized communities-Marginalized communities are groups that face social, economic, and political disadvantages due to various factors. They often experience barriers to resources, opportunities, and fair treatment.

Signal Analysis- EEG signal analysis involves using mathematical methods and computer technology to extract information from EEG signals1. It typically involves stages like acquisition, denoising, feature engineering, and classification

Backrest angle- The backrest angle of a wheelchair, relative to the vertical, provides lumbar and mid-trunk support1. It's crucial for maintaining proper posture, comfort, and preventing potential health issues.

Mobility aids-Mobility aids are devices that help individuals who have trouble moving around. They enhance personal freedom and independence. Examples include canes, crutches, wheelchairs, scooters, and walkers. These aids are crucial in improving the quality of life for those with mobility issues. They provide an important means for people to maintain their independence and carry out their daily activities.

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