1. PROBLEM STATEMENT

Everyday tasks are difficult for manual wheelchair users, and electric wheelchairs are expensive. Consequently, many manual wheelchair users are unable to afford electric wheelchairs, leaving them to endure frequent physical strain. There is a need for a low-cost product for manual wheelchair users that improves mobility and mitigates pain.

1.1. Need Statement

According to the U.S. Department of Transportation, "An estimated 5.5 million Americans use wheelchairs" [1]. Wheelchair users and, more broadly, people with disabilities face many obstacles with mobility. The U.S. Bureau of Labor Statistics states that only 24.2 percent of disabled people are employed [2]. One healthcare clinic asserts that electric wheelchair prices start in the range of $1000-$3000, while manual wheelchair prices start in the range of $100-$500 [3]. Though manual wheelchairs are less expensive, they can cause strain on upper extremities. This physical strain can lead to fatigue, stress injuries, and even long-term health problems, such as joint and back pain. Studies show that the risk of developing musculoskeletal disorders increases significantly with prolonged manual wheelchair use [4]. A research article exploring treatments for shoulder pain details that 71 percent of manual wheelchair users have shoulder pain [5]. The low employment rate among the disabled and the high starting cost for basic electric wheelchairs are barriers to a pain-free, independent lifestyle. A product is needed to increase mobility and decrease pain for manual wheelchair users at a low cost.

1.2. Objective Statement

The objective of this project is to provide a conversion kit that allows the user to integrate electronic capabilities into a manual wheelchair. This would help increase mobility and reduce the stress in their arms that comes from propelling the wheelchair. The user is able to change the wheelchair from acting as a manual wheelchair to an electric wheelchair at the push of a button. The electric mode deploys electronic wheels, and the user is able to propel the wheelchair in different directions using a joystick-like controller. The device also communicates information related to the battery status to the user through an LED screen.

1.3. Background and Related Work

Free Wheelie aims to widen the user's degree of freedom with the integration of a hybrid wheelchair conversion kit. There are currently other conversion kits on the market, but they are missing some core functions that are present in Free Wheelie. One of these kits is Permobil's SmartDrive, which is a single motorized wheel attached to the back of the wheelchair and controlled by their speed control dial, which allows the user to control the speed of the SmartDrive [6]. The speed control dial has a limiting factor for users who have limited hand motion and may have trouble operating the dial. Free Wheelie surpasses other control platforms because of its ergonomic design. It allows users to change the mode of their wheelchair, giving an increased degree of freedom in their everyday lives.

2. DESIGN REQUIREMENT SPECIFICATIONS

The following section outlines the requirements, constraints, and standards that are taken into consideration for the design, testing, and implementation of Free Wheelie.

2.1. Requirements

Free Wheelie's design complies with requirements on two different levels: marketing and engineering. The marketing requirements detail the desired functions of Free Wheelie that appeal to the customer base, and the engineering requirements detail the high-level application of those functions. Both sets of requirements are further expanded upon in the following subsections.

2.1.1. Marketing Requirements

The marketing requirements for Free Wheelie are outlined as such:

1. Free Wheelie is easy to install and requires no special tools.
2. Free Wheelie is compact and does not hinder manual wheelchair operation.
3. Free Wheelie is powered by a rechargeable, long-lasting battery.
4. Free Wheelie supports a wide range of user weights.
5. Free Wheelie is user-friendly with interchangeable modes and ergonomic controls.

Figure 2-1 shows the objective tree that lays out Free Wheelie's goals.

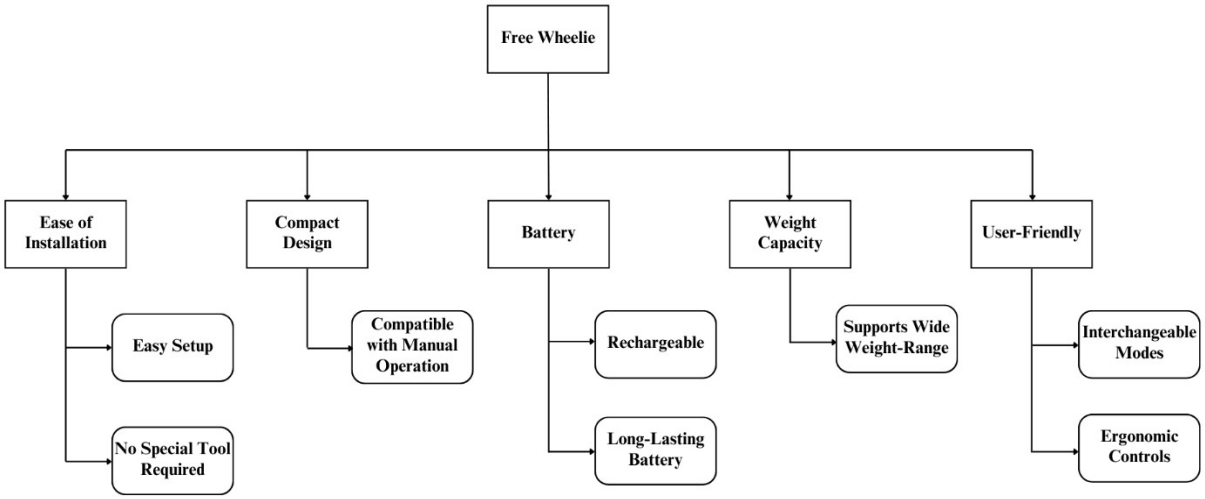

Figure 2-1: Objective Tree for Free Wheelie

The objective tree expands the marketing requirements into different categories and sub-categories. The engineering design requirements further discuss the technical design plan to achieve the marketing requirements.

2.1.2. Engineering Requirements

Free Wheelie is an electronic conversion kit that aims to meet the needs of manual wheelchair users while minimizing cost and mitigating injury from daily operation. Table 2-1 shows engineering requirements met by the design.

Table 2-1: Engineering Design Requirements

Marketing Requirements	Engineering Requirements	Description
1	The conversion kit includes a 3-part assembly for easy integration.	This is the minimum number of parts required to provide inexperienced users the ability to install without additional support.
2	The conversion kit, when installed, does not infringe on the manual wheelchair frame.	The versatile design allows the kit to combine with any manual wheelchair while maintaining normal operation.
3	The battery stores up to 8 kW of power while supplying 24 VDC.	This power supply supports multiple components that, in total, absorb roughly 4 kWh.
4	The material and design support different payloads not exceeding 350 lbs. [7].	The components operate effectively when at the rated weight for most wheelchairs.
5	The controls are ergonomic to serve a wide range of users.	This design helps the user navigate while having an intuitive control scheme.
Marketing Requirements: 1. The kit is easy to install with clear instructions and requires no specialized tools or expertise. 2. The kit is compact and lightweight, ensuring it does not add bulk or hinder wheelchair maneuverability. 3. The kit is powered by a long-lasting battery that ensures reliable performance with minimal recharging needs. 4. The kit supports a wide range of user weights. 5. The kit has user-friendly controls that are easy to operate, even for individuals with limited hand movement.		

Free Wheelie integrates with a wide range of manual wheelchairs without requiring additional modifications. The design ensures users can install the system with minimal technical experience with no special tools required, making it accessible to a broader audience.

Free Wheelie has motorized components and manages these components efficiently. The rechargeable battery supports extended use of up to 8 kilowatt hours. The system has high and low power modes to optimize performance.

Free Wheelie serves all manual wheelchair users, including those with low aptitude for electronic controls or limited hand movement. To address this, Free Wheelie has ergonomic controls that do not require strenuous hand motions or much technical knowledge.

2.2. Constraints

Table 2-2 lists constraints imposed on the design of Free Wheelie. These constraints relate to economic, manufacturability, reliability, health and safety, and operational factors.

Table 2-2: Constraints

Type	Name	Description
Economic	Budget	The total budget of the project is $1000.
Economic	Time	The system is designed and developed from January 2025 to November 2025.
Manufacturability	Size	The physical dimensions of the product are compatible with standard manual wheelchairs.
Reliability	Durability	The product maintains system integrity despite the stress from daily operation.
Health and Safety	Safety	The product includes guards for pinch points, rotating elements, and electrical wires.
Operation	Controls	The controls for the product are intuitive.

The Department of Electrical and Computer Engineering allots a budget of $1000 over a two-semester period in which to complete the design.

The product is applicable to a standard, full-sized manual wheelchair. Such wheelchairs are 42” long, 36” tall, and 25” wide, with a seat height of 19.5” [8]. The individual components and overall assembly of the product are strong enough to withstand frequent use by operators of various weights.

The control system and power supply are hardwired to other elements of the assembly. These wires require proper covers for the safety of the user. The product also has various rotating elements and pinch points, which have guards as well. The user controls are constructed and configured in such a way that provides the most straightforward means of control to operators with limited hand movement.

2.3. Standards

Table 2-3 details four standards that Free Wheelie follows to ensure that it complies with safety, ease of use, and medical standards.

Table 2-3: Engineering Standards

Specific Standard	Standard Document	Specification / Application
ISO 7176-6	International Organization for Standardization (ISO). *Part 6: Determination of maximum speed of electrically powered wheelchairs* [9].	The Free Wheelie does not exceed a nominal speed of 15km/h (~9m/h).
ISO 14971	International Organization for Standardization (ISO) *ISO 14971: Medical devices –*	The system’s potential risks have been identified and have fail-safes to help counter-act them.

	Application of risk management to medical devices [10].	
ISO 13485	International Organization for Standardization (ISO) *ISO 13485: Medical devices – Quality management systems – Requirements for regulatory purposes* [11].	The devices meet both customer and regulatory demands for safety and efficacy.
K0801	Healthcare Common Procedure Coding System (HCPCS). *Power operated vehicle, group 1 heavy, patient weight capacity 301 to 450 pounds* [7].	The device meets the requirements for use for individuals that do not exceed a weight of 350 lbs.

These standards ensure that Free Wheelie continues to meet safety, accessibility, and medical standards required for wheelchairs. They include meeting guidelines set for managing the top speeds of the chair, requirements for the needs of an individual weighing up to 350 lbs. and meeting the safety requirements that come with medical and transportation equipment.

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