# Towards transportation of people with disabilities: urban two-seater experimental platform

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**Abstract**

Electric vehicles (EVs) represent a crucial alternative in efforts to decrease the emissions of pollutants. Moreover, their integration with autonomous driving technologies is a critical aspect that research in this field must continue to increase. In addition, they are closely related to autonomous driving, and it is essential to maintain that relationship when conducting research in the area. This paper describes the assembly of an experimental platform similar to a two-seater electric vehicle. It specifies the main characteristics of its mechanical and electrical system and findings from an analysis of motor performance. The results show that the experimental platform is a close approximation of an electric vehicle (EV) in terms of dimensions, speed, and autonomy. In conclusion, the constructed platform offers a realistic simulation of an EV within a controlled urban setting, facilitating near-real experiments on the Campus in domains like transport and mobility solutions for individuals with disabilities or assisted navigation.

**Keywords:** Electromobility, disabled people, two-seater platform, motor performance.

## 1 Introduction

The main objective of technological advancement is to develop products or tools that facilitate and enhance the efficiency of people's activities. Technological innovations must encompass environmental and social responsibility. In this context, electric vehicles (EVs) exemplify the progress in green technology towards a more sustainable future, showing an advantage over internal combustion motors in maintenance and $CO_2$ emissions reduction [1]. The advantages of EVs align with eco-friendly initiatives to mitigate climate change, reduce air pollution, and conserve natural resources by providing equitable transportation solutions.

EVs are classified into five types according to their engine technology: battery-powered, plug-in hybrid, hybrid, fuel cell, and extended-range. Battery electric vehicles (BVEs) stand out because they are 100% electrical powered without an internal combustion process and the need for liquid fuel [2]. Energy consumption is simplified to a single source (electricity), eliminating emissions from the vehicle itself and marking a significant step forward in automotive technology. BVE's main components are the electric motor, the battery, and the controller.
Electric vehicles operate through the power of electric motors, which translate electrical energy into

mechanical movement, moving the car forward without the conventional use of a combustion engine [3]. However, the choice of motor in electric vehicles is influenced by the type of transmission they employ, for instance, one-speed and two-speed gearboxes showing their efficiency in handling the electric motor's power output and torque characteristics. Also, two types of motors are the most commonly used: the permanent magnet synchronous motor (PMSM) and the induction motor (IM). The choice of motor depends on the type of control required to supply power to the drive shaft. For example, the PMSM requires an electronic controller, while the IM requires a more general controller and a power inverter module [3]. Energy storage systems for electric vehicles have evolved to utilize various power sources. These include but are not limited to advanced battery technologies like lead-acid, nickel-metal hydride, and the increasingly popular lithium-ion batteries, each contributing to the versatility and efficiency of electric transportation. Thus, lithium-ion batteries are the most commonly used in the electric vehicle market due to their advantages, such as higher energy storage capacity, more excellent power supply, longer charging and discharging cycles, lower cost, higher operational efficiency, and thermal stability [4]. The fundamental components required to set an electric vehicle in motion include the charger, batteries, controller, electric motor, and drive shaft. All components must be selected based on the purpose of the vehicle; for instance, urban vehicle requirements differ from vehicles designed for transporting raw materials [4].
In [5], an internal combustion vehicle was converted into an electric vehicle by removing all combustion system components and integrating the primary required components. Another prototype in [6] deals with developing a three-wheeled electric vehicle using a direct current motor and the general components necessary to drive an electric vehicle. Additionally, it includes solar panels for recharging the power supply. BEVs are increasingly being used due to the relative ease of acquiring the components to build them. Their use ranges from private mobility to public transportation, so they must be affordable, economically, and accessible for passengers [7]. An important sector affected in this area is people with disabilities. A study by Anne Goralzik et al. [8] showed that in Europe, ridesharing services are not designed to ensure equal access for people with disabilities, concluding that some of them have the potential to improve in this field. On the other hand, Karin Julissa Ponce-Rojas [9] mentions that in Latin America and the Caribbean, transportation services for people with disabilities are still inaccessible. Furthermore, although measures have been taken, at least in Peru, people who use inclusive public transportation consider the service deficient.

In Mexico, in 2019, Nissan launched the Nissan Versa GO, a vehicle adapted for the mobility of people with disabilities. This vehicle uses only the hands and has seats that rotate $90^o$ for easy access. However, there is currently no information on whether it is still available. Other options to provide mobility for people with disabilities in Mexico include adopting a regular vehicle or importing one from another country. The first option can be complicated because the original design has a purpose, and adapting a new system requires modifications and other components. The second option implies some procedures to obtain authorization but with some exceptions. To avoid extra resources, a vehicle can be designed according to the requirements of people with disabilities, with an appropriate space to facilitate their accessibility and ensure their comfort and security. If the person uses a wheelchair, it must have a system in the seat that allows a companion to transfer the person from the wheelchair to the vehicle seat with minimal effort. In addition, the vehicle must have a wheelchair storage compartment.

This paper describes the assembly of an experimental platform that resembles a two-seater electric vehicle. This experimental platform is designed to conduct tests and assessments tailored to Electric Vehicles (EVs) needs. It includes the proposed analysis of a mechanism specifically adapted to assist individuals with disabilities in entering and exiting vehicles. Additionally, the platform can accommodate multiple sensors such as cameras, LiDAR, GPS, and inertial measurement units. These tools are crucial for evaluating new methodologies that validate autonomous navigation assistance modules. The primary contribution of this work lies in detailing the mechanical and electrical structures that are adapted to various sensor-based strategies, aiming to enhance the quality and performance of electric vehicles equipped with autonomous driving aids for disabled individuals.

## 2 Material and methods

The case study proposed in this work starts with an experimental platform ensembled from scratch, following a basic structure similar to any vehicle. The global diagram in Figure 1 shows the essential parts of propulsion system of our prototype divided into electrical and mechanical features. The electrical components were studied, such as the battery type, the acceleration controller, the braking power, the inverter module, and the most suitable electric motor. Thus, the overall description of the assembled prototype will include the chassis, the accelerator, and brake pedals, which are essentials for controlling speed and motion. The electrical measurements were performed under no-load conditions to set a controlled environment. The following subsections describe the mechanical components of our experimental platform, followed by the evaluation tests to measure current and voltage in the induction motor to show the car's performance.

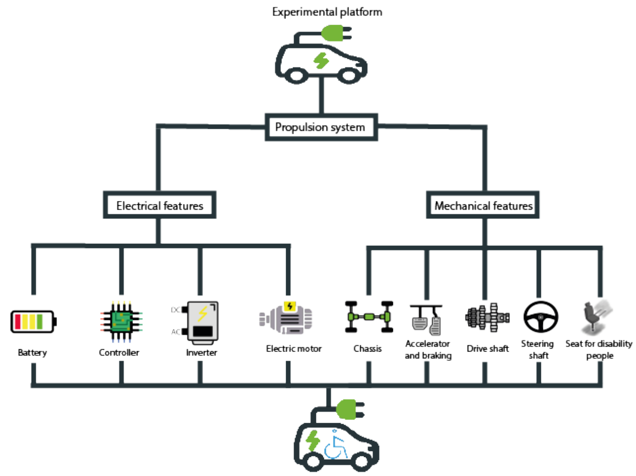



Fig. 1: General diagram of an experimental platform for mobility of people with disabilities

### 2.1 Electrical features

The electrical system is shown in Figure 2. The three-phase electric motor is the main component that operates at 60V with a power rating of 2500W; the most relevant features of the motor are shown in Table 3. This motor is controlled by a switch that can open or close electric current. In addition, the system includes a voltage inverter that converts the direct current from 48VDC to 60VAC in three phases, allowing the electric motor to be properly powered. The system controller is powered at 48V and can support up to 150A. The controller performs essential functions in the electrical system of the proposed experimental platform. On the one hand, it regulates the vehicle's acceleration based on the voltage supplied by the accelerator pedal. As the pedal voltage increases or decreases, the controller adjusts the current supplied to the motor to control the revolutions per minute (RPM). In addition, the controller also receives an input signal to change the direction of the motor, allowing the vehicle to move forward or backward as needed. Finally, the system is backed by a 48$V$ lithium battery with a capacity of 150A per hour, which provides the energy needed to power all the electrical components of the system.

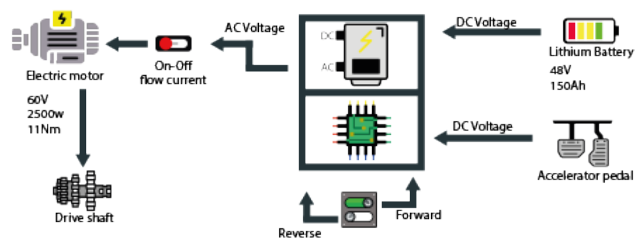



Fig. 2: Schematic electric diagram

In our case, we used a controller equipped with a current inverter. Within the controller with the inverter, consideration must be given to the input from the battery and the output that will drive the motor for proper operation. The controller adjusts the output current to the motor based on the position of the throttle, which functions like a potentiometer. This throttle varies

Tab. 1: Electric motor features

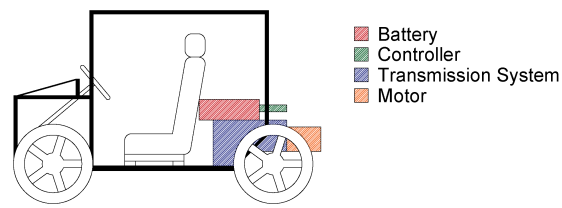
| | |
|---|---|
| Rated power (w) | 2500 |
| Rated voltage (v) | 60 |
| Rated speed (RPM) | 3420 |
| No-load speed(RPM) | 3800 |
| Rated current (A) | $\leq 67.5$ |
| No-load current (A) | $\leq 7.5$ |
| Rated torque (Nm) | 11 |
| Maximum efficiency | $\geq 85$ |

the voltage to increase revolutions per minute. The voltage range it provides is from 0.832V to 3.56V. Table 2 shows the vehicle speed relative to the voltage supplied by the throttle. Additionally, the controller features a direction change to steer the vehicle forward or backward.

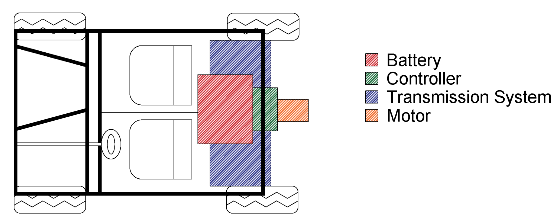
The choice of the battery was based on a comparative analysis proposed in [10], considering the characteristics of the battery, the motor, and the controller. The rechargeable battery utilizes lithium-ion technology with iron and lithium phosphate ($LiFePO_4$). The battery is 48V with a current capacity of 150Ah, sufficient to support the controller. Additionally, the battery can withstand 3000 charge and discharge cycles. These specifications meet the performance requirements.

## 2.2 Mechanical features

The experimental platform was assembled using parts from a Volkswagen sedan, including the frame, rear suspension, front suspension, transmission, and steering. The chassis was cut to separate the suspensions, which were then welded to a metal base that supports the vehicle's floor. The mechanical steering was kept in place and supported by the bodywork cage. A schematic diagram of the proposed platform is shown in Figure 3a. A coupling was adapted at the input of the transmission system to allow its connection to the electric motor, as depicted in Figure 3b. The supports in the schematic diagram provide stability to the steering wheel and similar structural elements. The real experimental platform measures 1.65 meters in width and 3.28 meters in length and uses tires with




(a) Side view




(b) Top view

Fig. 3: Two views of the schematic diagram of the prototype.

a radius of 0.27 meters with only two seats installed inside. Three metal bases were fixed in the rear part to support the battery, controller, and motor.

Considering the navigation conditions and the urban environment around the campus in the University, a three-phase motor with the characteristics from table 3 fulfills the desired conditions. The aerodynamic resistance ($F_{air}$) of the vehicle is calculated using equation 1. The estimated values considered in equation 1 are: air density ($\rho_{air}$) is $1.05\frac{kg}{m^3}$, the vehicle's area is $5.41m^2$, the aerodynamic coefficient ($C_d$) is 0.5, and a maximum analysis speed of $15\frac{km}{h}$, resulting in a force

Tab. 2: Vehicle speed concerning accelerator pedal voltage

| Speed (Km/h) | Voltage range (DC) |
|---|---|
| 5 | 1.8 - 2.0 |
| 10 | 2.1 - 2.2 |
| 15 | 2.3 - 2.6 |
| 20 | 2.7 - 2.9 |

of $1010.96N$.

$$F_{air} = 0.5 \cdot \rho_{air} \cdot A \cdot C_d \cdot V^2 \quad (1)$$

Rolling resistance ($F_{rl}$) is determined using equation 2, where the asphalt rolling coefficient ($\mu_{rl}$) is 0.03, the vehicle's mass is $325kg$, and gravity is $9.81\frac{m}{s^2}$, yielding a force of $95.64N$.

$$F_{rl} = \mu_{rl} \cdot m \cdot g \quad (2)$$

Equation 3 provides the force required to move the vehicle, resulting in $1206.6N$.

$$F_{rq} = F_{air} + F_{rl} \quad (3)$$

The torque required at the wheel is calculated using equation 4, considering a wheel radius of $0.27m$, resulting in $325.78Nm$ to move the vehicle.

$$T_{wmax} = F_{rq} \cdot r_w \quad (4)$$

According to the Volkswagen manual on the transmission [11], the sprocket efficiency ($\eta_S$) was 90%, the transmission efficiency ($\eta_F$) was 95%, the transmission ratio ($R_S$) was 3.78, and the differential gear ratio ($R_F$) was 4.12. The optimal torque to be provided by the motor to the differential should be 140 to 180 Nm. However, theoretically, the torque applied by the motor to the platform is obtained with equation 5, resulting in $138.76Nm$, matching the torque required by the differential.

$$T_{wmax} = T_{motor} \cdot R_s \cdot R_f \cdot \eta_S \cdot \eta_F \quad (5)$$

## 3 Results and discussion

Tests were conducted by varying the throttle pedal's input voltage to control the three phases of the motor, as shown in Figure 4. The voltage measurement at the motor terminals was 38V with the pedal fully pressed (3.56V). The voltage required by the motor when the pedal is positioned at an intermediate level is measured at 25V. This specific voltage level is crucial because it indicates the motor's operational demand at partial throttle, a joint state during vehicle cruising or moderate acceleration. Operating at this voltage allows the motor to deliver the necessary power for intermediate speeds without reaching its maximum capacity, ensuring efficient energy use and prolonging its lifespan. Additionally, the analysis of the current in the three phases of the motor revealed a peak amperage of 80A. This peak amperage is significant as it represents the maximum current draw under high-load conditions, such as during rapid acceleration or climbing steep inclines. Understanding this peak amperage is vital for designing and selecting the motor controller and power electronics to ensure they can handle these maximum current levels without overheating or failing.

Figure 5 illustrates various current measurements, demonstrating a proportional variation with incremental changes in voltage decimals. It has been established that specific current ranges can be identified with each 5 km/h increase in speed, allowing for the parameterization of power consumption by the motor on flat surfaces.

The analysis revealed that these components exhibit a superior power density, indicating their capability to deliver greater power despite their reduced size and decreased weight. This attribute is especially advantageous for electric vehicles, as it directly contributes to

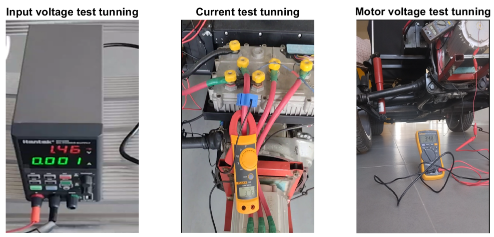



Fig. 4: Instrumentation for voltage and current measurements in the three-phase motor.

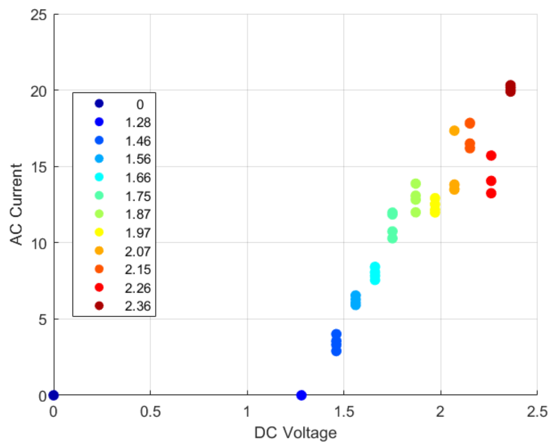



Fig. 5: Experimental tests of the accelerator concerning current.

enhanced performance metrics. By integrating smaller and lighter elements that can output significant power, electric cars can achieve higher speeds and better acceleration without negatively impacting their efficiency or range.

The distinct versatility of three-phase motors stands out as a critical characteristic, emphasizing their capability to handle a broad spectrum of speeds and torques. This flexibility facilitates dynamic adjustments to diverse driving conditions, ensuring a smooth and efficient driving experience. This was demonstrated in the experimental tests conducted, where the adaptability and performance of these motors were analyzed. Moreover, the inherent structural simplicity of AC motors enhances their reliability and durability. The reduction in moving parts and the ease of maintenance lead to improved operational efficiency and a longer lifespan. This contributes to substantial savings over the vehicle's life cycle in terms of reduced maintenance and repair costs.

It is proposed to incorporate an innovative seat design to significantly enhance the mobility experience for individuals with disabilities, especially for get in and get out the car. In light of the vital importance of accessibility and mobility for those with disabilities, we have designed a schematic seat, as illustrated in Figure 6. The seat operates on a horizontal axis, facilitated by two secured rails equipped with locking mechanisms. These locks ensure the seat remains firmly in place during regular use. The armrest serves a dual function, featuring a wheel at its end to aid movement. It can rotate up to $-90°$ from its original position. When the seat is moved outward, the locks are disengaged, allowing the seat to slide along the rails. Simultaneously, the armrest can be manually rotated to assist in the seat's displacement and provide additional support, preventing deflection in the rails during the transition. In this position, the seat is ready for the individual with a disability to be seated. The same procedure is followed in reverse to return the seat to its original position. As the seat is moved inward, the armrest/support rotates to its original position once it reaches the chassis limit. The seat slides along the rails until it reaches the end, securely locked back into place.

Furthermore, this proposed platform can be improved with passive or active sensors installed to acquire videos or position measurements during navigation. A real-time stereo camera mounted on the front of the vehicle is shown in Figure 7. Color and depth image sequences in different situations are acquired to develop new strategies for driving assistance to facilitate the driving and moving of the experimental platform to an autonomous vehicle.

Moreover, the proposed platform could be enhanced by incorporating passive or active sensors for capturing video or positional data throughout the navigation process [12]. Figure 7 illustrates a real-time stereo camera mounted at the front of the vehicle. This setup enables

Tab. 3: AC Motor Performance Evaluation

| |
|---|
| Max Power = 2.5 kW |
| Voltage DC = 34 V |
| Current = 16 A |
| Max speed = 15 km/h |
| Battery voltage = 48 V |
| Max efficiency = 0.85 |
| Operating temperature limit = 50°C |

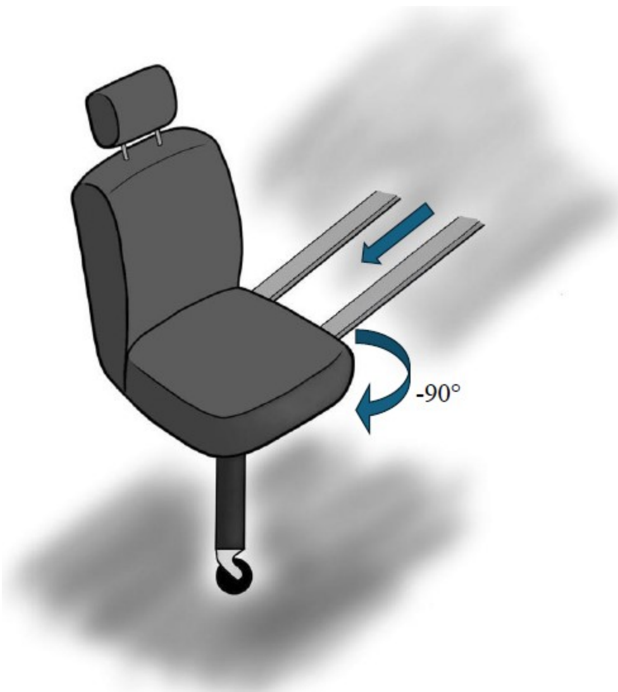



Fig. 6: Schematic diagram of the adapted seat

the acquisition of color and depth image sequences across various scenarios, which are instrumental in devising innovative driving assistance strategies. These advancements aim to ease the operation of the experimental platform, steering it towards becoming an autonomous vehicle.

Fig. 7: Visual sensor for navigation assistance.

## 4 Conclusion

In conclusion, this article highlights the significance of electric vehicles as a pivotal alternative for reducing pollutant emissions. It further emphasizes integrating these technologies with advancements in other research domains. Our study details the construction of an experimental platform, including a two-seater electric vehicle, elaborating on its mechanical and electrical specifications and the insights gained regarding engine performance. The findings demonstrate that the experimental platform mirrors an electric vehicle's dimensions, speed, and performance.

Future works in this experiment involve utilizing the acquired results to design and evaluate adaptive devices to enhance transfer and mobility for individuals with disabilities. Additionally, the experiment includes vision sensors to conduct assisted navigation trials in controlled urban settings around the campus.

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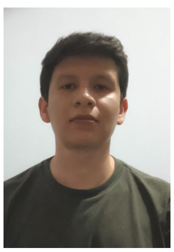

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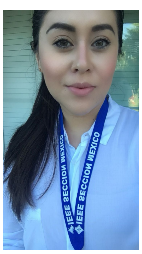

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