Published by :
https://www.ijert.org/
An International Peer-Reviewed Journal

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 11 , November - 2026

Design and Development of A Smart Self-Balancing Single-Wheel Electric Board

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Abstract - **This paper describes the design approach for converting a conventional self-balancing hoverboard into a single-wheel electric vehicle by reusing its existing propulsion and electronic subsystems. The proposed configuration retains two brushless direct-current (BLDC) hub motors, the donor battery system, Hall-effect motor feedback, and two HP-IBC-V12.7 controller boards, while introducing a mechanically adapted common-wheel assembly and supporting frame. The work focuses on mechanical conversion, electrical integration, and the assessment plan for the resulting prototype rather than on developing new controller firmware. The reported donor-system specifications are a 36 V, 5 Ah battery, a stated 350 W motor rating, a reported maximum speed of 3-4 km/h, and an intended load range of 30–45 kg.**

The nominal battery energy calculated from the stated voltage and capacity is 180 Wh. These values are reported specifications or calculations; they are not presented as independently measured prototype results. The manuscript outlines the system architecture, conceptual balance-control sequence, implementation considerations, and testing required to assess motor response, sensing, stability, runtime, and safety. The conversion illustrates a potential hardware-reuse pathway for experimental electric-mobility systems. Experimental validation is still required before claims about balancing performance, safe load capacity, efficiency, or practical operating range can be established.

Keywords - single-wheel electric vehicle, hoverboard conversion, BLDC hub motor, embedded controller, inertial sensing, hardware reuse, electric mobility.

I. INTRODUCTION

Compact electric mobility devices have attracted interest for short-distance transportation and engineering experimentation. Unlike conventional multi-wheel vehicles, a single-wheel vehicle relies on dynamic interaction among the rider, wheel, sensing system, and motor controller. Its behaviour therefore depends on mechanical geometry, mass distribution, sensing feedback, motor response, and safe integration of the propulsion system.

Developing a new propulsion and control system from individual components can increase prototype cost and development effort. A discarded hoverboard may contain reusable BLDC hub motors, a battery pack, motor-position feedback, and integrated controller electronics. This work investigates a conversion approach that reuses these subsystems while adapting the mechanical arrangement to a single-wheel configuration.

The contribution claimed in this manuscript is the proposed integration and reuse approach. The paper does not claim a newly developed balance-control algorithm, reverse-engineered firmware, or validated vehicle performance beyond the information and measurements actually available.

II. RELATED WORK

Research on electric monowheels has examined dynamic stability, feedback control, sensing, propulsion, and mechanical design. Sengupta et al. studied dynamic stability using an LQG-based adaptive-control approach, illustrating the importance of state estimation and feedback for monowheel dynamics [1]. Prototype studies of self-balancing electric uni-wheelers have also explored hub-motor propulsion and sensor-based control [2]. Mechanical studies of one-wheel electric vehicles address chassis design, rider positioning, and wheel integration [3].

These research directions provide context for the present project. The approach described here differs in emphasis: it

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International Journal of Engineering Research & Technology (IJERT)
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seeks to reuse a donor hoverboard's existing powertrain and controller architecture rather than claim a new control method. The exact novelty should be evaluated against a verified literature review and the final, documented prototype.

III. PROBLEM STATEMENT

Single-wheel electric vehicles offer a compact form factor but introduce challenges involving dynamic balance, rider control, mechanical stability, and safe motor response. Designing all propulsion and control electronics independently may increase development effort. The project therefore aims to adapt a conventional hoverboard into a single-wheel electric vehicle by reusing its existing BLDC motors, battery, sensing components, and controller electronics, subject to compatibility and safety verification. The primary objective is to design and integrate the mechanical structure and existing electrical subsystems, then evaluate the prototype through controlled tests. The work does not assume that the donor firmware will automatically remain stable after the mechanical conversion.

IV. PROPOSED METHODOLOGY

The proposed methodology consists of five major stages:

A. Donor System Analysis

The original hoverboard is examined to identify reusable electrical, electronic and mechanical components. The controller architecture, motor connections, battery system, Hall feedback and sensing components are retained wherever compatible with the proposed configuration.

B. Component Recovery

The major reusable components include:

- Two BLDC hub motors
- Two HP-IBC-V12.7 controller boards
- Hoverboard battery pack
- Hall-effect motor sensors
- Power switch
- Charging interface
- Original power and motor wiring
- Auxiliary electronic boards

C. Mechanical Conversion

The original two-wheel configuration is replaced by a common single-wheel mechanical arrangement. The two BLDC motor assemblies are integrated into the wheel structure and mounted within a newly fabricated frame.

D. Electrical Integration

The salvaged battery, controller boards, motors and sensor connections are integrated into the new mechanical structure. The controller boards remain responsible for motor-drive operation.

E. Functional Testing

The completed prototype is tested progressively, beginning with individual electrical subsystems and continuing toward integrated balance and mobility testing.

V. SYSTEM ARCHITECTURE

The proposed system consists of four major subsystems:

A. Power Subsystem

The original hoverboard battery provides the electrical energy required by the controller and motor system.

B. Sensing Subsystem

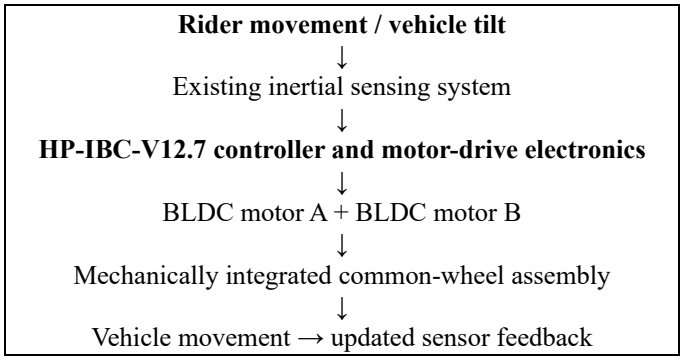
The existing inertial sensing system provides information related to vehicle orientation and movement. Hall-effect feedback from the BLDC motors provides rotor-position information required for motor operation.

C. Control Subsystem

The HP-IBC-V12.7 boards act as the main embedded control and motor-drive units. Their processing circuitry receives sensor information and generates the required motor-control response.

D. Mechanical Propulsion Subsystem

Two BLDC hub motors are mechanically integrated into a common wheel arrangement. The resulting wheel assembly provides propulsion and participates directly in the balance response.



Conceptual system architecture. Actual sensor paths and motor coordination must be confirmed on the assembled hardware.

A). Block diagram

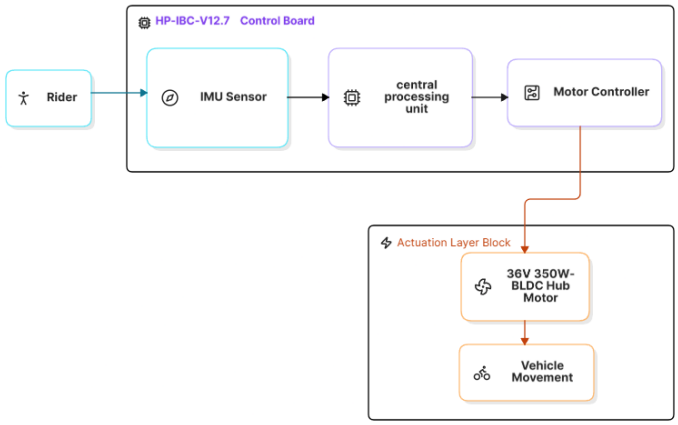


Fig.1. Block Diagram of Implementation of Board

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International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 11 , November - 2026

B). Flowchart

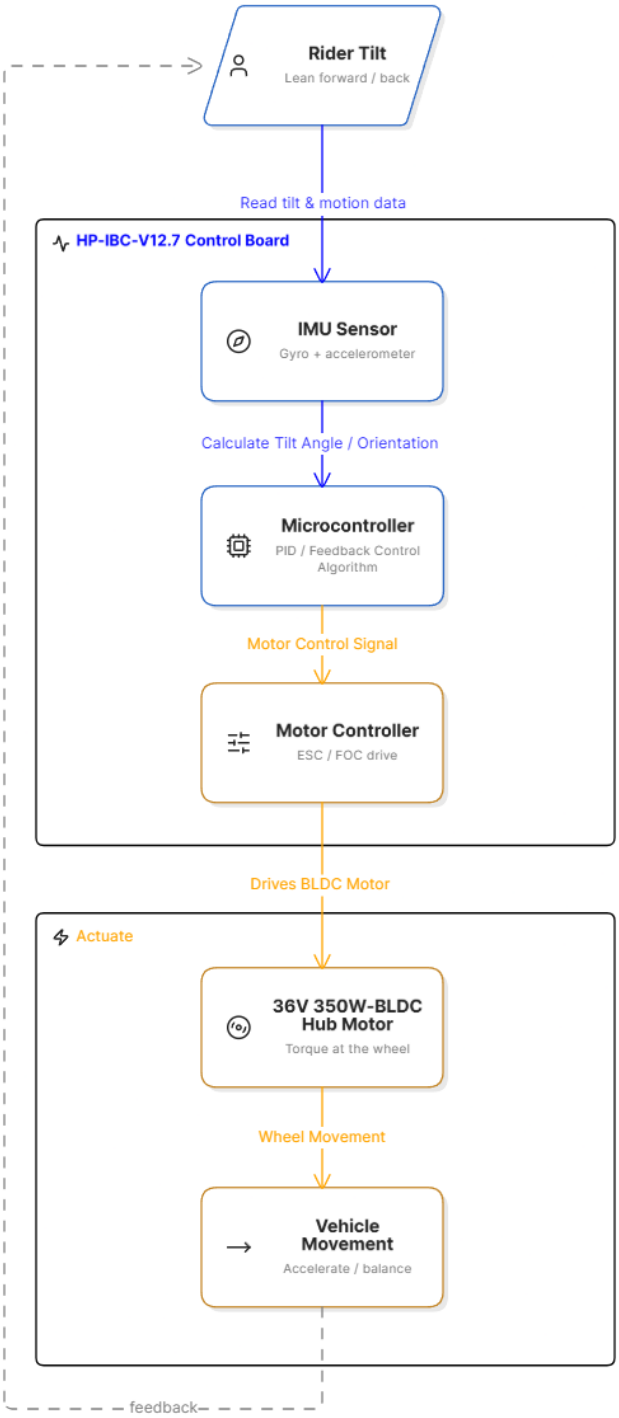


Fig.2. Flowchart of Implementation of Board

VI. HARDWARE IMPLEMENTATION

A. BLDC Hub Motors

The donor hoverboard provides two BLDC hub motors. These motors are retained as the primary propulsion elements of the proposed vehicle. Their integrated Hall sensors provide rotor-position feedback to the controller.

B. HP-IBC-V12.7 Controller Boards

Two HP-IBC-V12.7 controller boards are retained from the donor system. They provide the embedded processing and motor-drive functions required for operating the BLDC motors.

The exact internal firmware implementation is not modified as part of the basic prototype. Therefore, the project focuses on utilizing the existing controller architecture rather than replacing it with an external microcontroller.

C. Battery System

The original rechargeable battery system is reused as the primary energy source. The battery supplies power to the controller and motor-drive system through the existing electrical architecture.

D. Inertial Sensing

The existing hoverboard sensing system provides orientation-related feedback to the embedded controller. This information is essential for detecting changes in vehicle inclination during balancing operation.

E. Mechanical Frame

A new supporting structure is fabricated to accommodate the common wheel assembly, rider foot platforms, controller boards and battery.

VII. BALANCE AND MOTION CONTROL

The vehicle operates using a closed-loop electromechanical feedback mechanism.

The rider changes the vehicle inclination by shifting body weight forward or backward. This produces a change in the measured orientation of the vehicle.

The control sequence can be represented as:

Rider Movement → Inertial Sensing → Tilt Estimation → Embedded Control → Motor Response → Wheel Movement → Feedback

When the rider leans forward, the sensing system detects the corresponding change in inclination. The embedded controller generates an appropriate motor response, producing forward wheel movement.

Similarly, backward inclination results in a corrective response in the opposite direction, producing deceleration or reverse motor action.

This enables the rider to control acceleration without requiring a conventional mechanical throttle.

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International Journal of Engineering Research & Technology (IJERT)
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Representative Control Algorithm

The following algorithm represents the functional balance-control logic of the system. It should **not be interpreted as the proprietary source code of the HP-IBC-V12.7 controller**.

```
Initialize IMU;
Initialize HallSensors;
Initialize MotorControllers;

desiredAngle = 0;

while (vehicle_is_active)
{
   acceleration = ReadAccelerometer();
   angularRate  = ReadGyroscope();

   tiltAngle = EstimateTilt(acceleration, angularRate);

   tiltError = desiredAngle - tiltAngle;

   motorResponse = BalanceController(
                     tiltError,
                     angularRate
                   );

   if (abs(tiltAngle) > SafetyLimit)
   {
      StopMotor();
   }
   else
   {
      ApplyMotorCommand(motorResponse);
   }

   UpdateHallFeedback();
}
```

*The implementation demonstrates the **functional principle** of closed-loop balancing without claiming a particular proprietary control algorithm such as PID, LQR or FOC unless verified from the controller firmware.*

VIII. WORKING PRINCIPLE

When the system is powered, the controller initializes the required sensing and motor-control functions. The rider stands on the two foot platforms positioned on either side of the wheel.

During forward movement, the rider shifts their center of mass forward. The resulting inclination is detected by the inertial sensing system. The controller interprets the change and commands an appropriate motor response.

As the wheel moves forward, the vehicle orientation changes again. The new orientation is detected by the sensing system, creating a continuous feedback loop.

The same principle operates during deceleration when the rider shifts their weight backward.

Therefore:

Acceleration

Forward Lean → Tilt Detection → Motor Response → Forward Wheel Movement

Deceleration

Backward Lean → Tilt Detection → Motor Response → Reduced/Reverse Wheel Movement

Balancing

Tilt → Sensor Feedback → Corrective Motor Action → Reduced Tilt

IX. SOFTWARE AND EMBEDDED CONTROL

The proposed system does not require an additional external microcontroller for the basic balancing and propulsion functions.

The embedded controller architecture is retained from the donor hoverboard. Its functional responsibilities include:

- Processing sensing information
- Determining vehicle operating condition
- Controlling the motor-drive circuitry
- Processing motor feedback
- Providing appropriate motor response
- Implementing protection and fault-related functions

The exact firmware source code and proprietary control parameters of the HP-IBC-V12.7 boards are not available in the current implementation. Consequently, this work describes the controller at a **functional system level** rather than claiming access to or reproduction of the original firmware.

X. EXPERIMENTAL IMPLEMENTATION AND RESULTS

The proposed single-wheel electric board was physically fabricated and assembled using components recovered from a conventional hoverboard. The completed prototype incorporates two BLDC hub motors, the original battery system, two HP-IBC-V12.7 controller boards, sensing components, and a newly fabricated supporting mechanical structure.

The implementation demonstrates the physical integration of the propulsion, electronic, and mechanical subsystems into a single-wheel configuration.

A. Prototype Implementation

The mechanical structure was developed to accommodate the common-wheel arrangement, rider foot platforms, motor assemblies, battery, and controller electronics. The existing hoverboard electrical and electronic subsystems were retained for the proposed configuration.

B. Theoretical Battery Energy Calculation

The nominal battery energy is calculated using the specified battery voltage and capacity:

$E = V \times Ah$
$E = 36 \times 5$
$E = 180\ Wh$

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ISSN: 2278-0181
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Therefore, the nominal energy capacity of the donor battery is approximately 180 Wh.
This represents the theoretical nominal energy and does not indicate the actual usable battery energy.

C. Preliminary Performance Observations

During preliminary operation of the completed prototype, an approximate maximum speed of 3–4 km/h and an operating duration of approximately 20–30 minutes were observed. The prototype accommodated an approximate rider mass of 30–40 kg during initial operation.

The battery charging process required approximately 1.5 hours from a near-empty condition to full charge under the observed charging conditions.
These values represent preliminary observations rather than results obtained using calibrated experimental instruments. Consequently, they should not be interpreted as validated performance limits.

D. Theoretical Operating Duration

The ideal operating duration can be estimated using the nominal battery energy and the combined motor power rating:

t = E / P
t = 180 / 350
t = 0.5143 hours

Therefore, the ideal theoretical operating duration at continuous 350 W power consumption is approximately 30.86 minutes.
The actual operating duration may differ because of battery discharge characteristics, electrical losses, motor loading, rider mass, and operating conditions.

E. Further Performance Evaluation

Further controlled testing is required to establish accurate values for maximum speed, operating duration, rider load capacity, balance response, battery discharge characteristics, and overall efficiency.
The theoretical calculations and preliminary observations are presented separately to distinguish calculated specifications from prototype operating observations.

Prototype specification table:

Parameter	Unit	Experimental Value
Total vehicle mass	kg	**30kg**
Battery voltage	V	**36 V**
Battery capacity	Ah	**5Ah**
Motor rating	W	**350W**
Maximum speed	km/h	**3-4km/h**
Operating duration	min	**0.51 hr**
Charging time	h	**1.5hr**
Rider/load capacity	kg	**30-45kg**
Balance response	—	**Positive**

Calculations:

Nominal battery energy
180 Wh
36 V × 5 Ah

Combined motor rating
350 W
Both motors combined

Ideal runtime
30.86 min
At continuous 350 W

Measured charging time
1.5 hr
Near-empty to full, observed

Calculation 1 – Battery energy

$$E = V \times Ah = 36 \times 5 = 180Wh$$

Calculation 2 – Ideal operating duration

$$t = \frac{E}{P} = \frac{180}{350}$$

$$t = 0.5143h = 30.86 \text{ minutes}$$

Calculation 3 – Theoretical DC current equivalent

Assuming 350 W represents electrical input power:

$$I = \frac{P}{V} = \frac{350}{36} = 9.72A$$

XI. DISCUSSION

The proposed conversion demonstrates an alternative approach to the development of a single-wheel electric vehicle. Rather than designing the motor-control electronics independently, the project utilizes an existing integrated hoverboard platform.

This provides several advantages during prototyping. The BLDC motors, motor feedback, battery system and controller electronics are already designed to operate as a coordinated electric mobility system. Consequently, development effort can be concentrated on mechanical adaptation and system integration.

However, the conversion also introduces challenges. The original hoverboard controller was designed for a two-wheel configuration, whereas the proposed vehicle uses a common wheel arrangement. Therefore, the mechanical arrangement, controller orientation, sensor placement and motor coordination require careful verification.

Mechanical balance is particularly important because uneven mass distribution can produce vibration and affect the sensing response. Electrical connections must also be verified carefully before operation because the controller boards and battery operate at potentially hazardous electrical power levels.

XII. APPLICATIONS

The proposed platform can potentially be adapted for:

A. Personal Mobility

Compact short-distance electric transportation.

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ISSN: 2278-0181
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B. Educational Demonstration

Demonstration of BLDC motors, inertial sensing and embedded control.

C. Engineering Research

Experimental platform for self-balancing vehicle research.

D. Industrial Mobility

Potential short-distance mobility within controlled industrial environments.

E. Hardware-Reuse Research

Demonstration of repurposing discarded electric mobility systems.

XIII. FUTURE SCOPE

Several improvements can be investigated in future versions.

1. Advanced Control Algorithms

The controller architecture could be replaced or augmented with a programmable control platform to experimentally compare PID, state-space, LQR and other balancing strategies.

2. Improved Sensor Fusion

Multiple inertial sensors could be combined to improve orientation estimation and reduce measurement noise.

3. Real-Time Data Logging

Vehicle tilt, motor speed, current, battery voltage and acceleration could be recorded for detailed performance analysis.

4. Improved Safety

Future versions could include:

- Emergency shutdown
- Independent braking
- Overspeed protection
- Battery protection
- Redundant sensing
- Rider presence detection

5. Lightweight Frame

The mechanical structure can be optimized using lightweight materials and structural analysis.

6. Mobile Monitoring

Bluetooth or Wi-Fi connectivity could provide real-time information about battery level, speed, faults and operating conditions.

7. Energy Optimization

Future work can investigate regenerative braking and improved battery utilization.

XIV. GRAPHS

1. Battery Energy vs Capacity

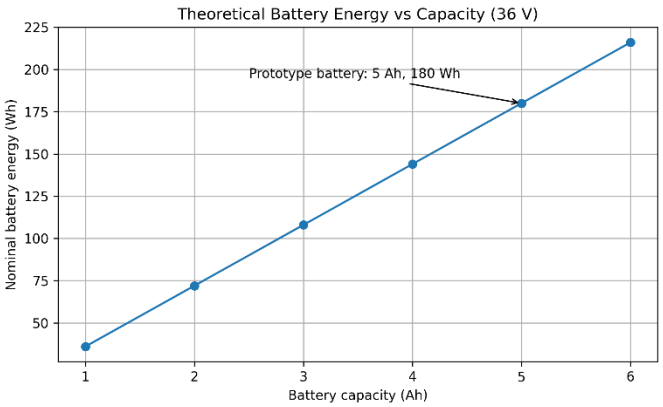


Fig.3. Variation of nominal battery energy with battery capacity at a constant voltage of 36 V.

2. Runtime vs Power Consumption

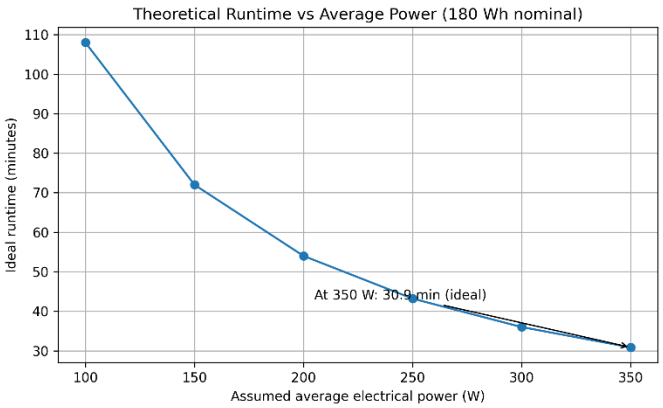


Fig.4. Battery operating duration at different assumed average power consumption levels.

3. Battery Energy vs Voltage

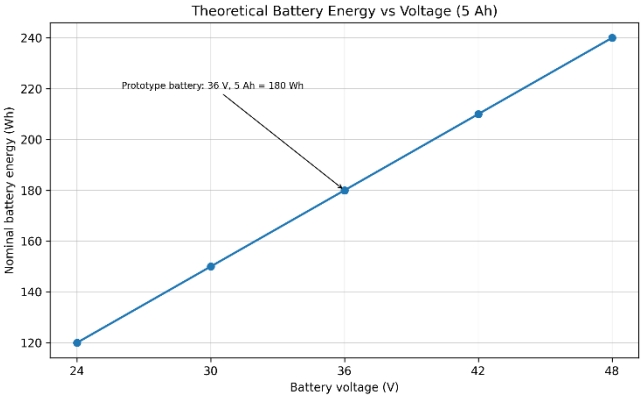


Fig.5. Variation of nominal battery energy with battery voltage at a constant capacity of 5 Ah.

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International Journal of Engineering Research & Technology (IJERT)
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XV. CONCLUSION

This paper presented the design and physical development of a single-wheel electric board by repurposing the major electrical and electronic components of a conventional hoverboard. The prototype retains two BLDC hub motors, the donor battery system, Hall-effect motor feedback, and HP-IBC-V12.7 controller boards, together with a newly fabricated mechanical supporting structure.

The work demonstrates the physical integration of reused propulsion and electronic subsystems into a single-wheel configuration. The donor battery has a nominal energy capacity of 180 Wh, calculated from its 36 V and 5 Ah specifications. Preliminary prototype observations indicated an approximate operating speed of 3–4 km/h, an operating duration of 20–30 minutes, and accommodation of a rider mass of approximately 30–40 kg. The observed battery charging time was approximately 1.5 hours.

Although the prototype has been physically assembled and operated, comprehensive calibrated testing has not yet been completed. Further investigation is required to establish its dynamic stability, validated load capacity, energy efficiency, braking performance, and long-term operational reliability.

The project demonstrates the potential of hardware reuse as a practical approach to developing compact electric mobility prototypes while reducing the need to develop an entirely new propulsion and electronic control system.

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