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Prototype Model Development and Design Analysis of A Solar Tricycle for Physically Challenged People in India

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Abstract

Society is greatly concerned about the mobility of individuals with physical disabilities. The scarcity of energy resources and the issue of pollution are currently the primary concerns. These issues can be resolved by employing alternative energy sources such as solar power. This paper presents an overview of the existing solar tricycles designed for those with disabilities. It also improves a handicapped-friendly solar-powered tricycle. The goal is to reduce handicapped people's physical exertion, making it suitable for India. This research explores the utilization of solar power using solar panels or photovoltaic cells to operate a brushless DC motor, battery, controller, throttle, and other components with minimal human effort. The design specifications were determined by analyzing the issues faced by disabled individuals, conducting a general survey on disabled people who use tricycles, and considering the input of experts working with disabled individuals. These factors helped determine the solar tricycle's design needs. New solar tricycles are smarter and more efficient. This solar three-wheeler, designed for physically disabled people in our country, has many features to improve maneuverability, solar energy utilization, biomechanics and comfort, suspension, all-terrain traffic, and ease of use. The countershaft, sprocket, chain, bearing, and other components are being designed in this study. Solar tricycles require careful selection of a solar panel, DC motor, battery, and power requirements for drives and battery charging. The solar panel's rated power must also be established. All these elements were considered to create a new, improved, and efficient solar tricycle. Its steel structure supports a solar panel, battery, charging pack, drive system, and braking system. Electricity powers this solar system, so it doesn't emit harmful compounds. This tricycle uses a mechanical drive mechanism to remove manual effort for disabled people. It is cheaper than a traditional engine vehicle. The paper details Solar Tricycle construction and operation. We created the Solar Tricycle blueprint using data from various journals. This study tested numerous Solar Tricycle components' functions. The computations and expected results are discussed. The findings suggest it can exceed 15 km/h. After a full charge, the device can run for 4 hours. Additionally, it can hold 120 kilograms. Thus, the solar-powered tricycle allows disabled people to use it anywhere, even without electricity.

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INTRODUCTION

In the present era, our rapidly advancing world faces various challenges such as fuel scarcity,

pollution reduction, and the growing dependence on fuels like petrol, diesel, and coal. Consequently, individuals are experiencing economic difficulties. In order to address these issues, a decision has been made to harness the maximum amount of solar energy and develop a solar tricycle. This is because solar energy plays a crucial part in our daily lives [1].

The Solar Tricycle (ST) combines the benefits of cars and bicycles for economic and personal transportation [2]. The document begins by comparing comparable mobility options to the ST car and assessing their pros and cons. The car is planned to be utilized largely in developing countries like India and China, where disabled people are prevalent. Therefore, these projects benefit such people greatly. Solar tricycles are quiet and eco-friendly [3]. Tricycles are popular in India, especially for disabled people. Hand-powered or manual tricycles have three wheels. Daily laborers that commute long distances use tricycles most [4]. Traditional trike riders cannot ride owing to injuries, exertion, and misery. Three types of tricycles exist: pedal, motorised, and electric. People avoid tricycles due to their frailty. A paddle tricycle takes a lot of energy to start. The tricycle will tyre the user. Next, automate a fuel-powered tricycle. Tricycle fuel is pricey. Motorized tricycles also pollute, which is bad for the environment, especially in these times of global warming. A battery-powered electric tricycle lasts around an hour. The user must find a power source to recharge the battery or peddle the tricycle, which consumes more energy due to its weight. Solar-powered automobiles use photovoltaic cells to generate electricity. A battery-powered tricycle can run for an hour. The user must recharge the battery after discharging [5, 6].

This idea uses India's underutilized solar energy to power a tricycle. Solar energy will power the tricycle using rechargeable batteries. In the absence of the Sun, a portable charger will charge the Battery. This study examines how solar energy can power tricycles, relieving disabled people's physical burden. Solar panels on top of the tricycle provide electricity and cover. A battery power pack platform under the driver seat, braking, and steering are also included. We offer PV panels to convert solar power into electricity. Battery power is used to power the tricycle via an electrical prime mover and chain gearbox drive. This includes tricycle design, assembly, and performance evaluation. This solar tricycle is lighter and can use conventional electricity to supplement the solar photovoltaic (PV) cell roof's power. This approach powers a bike without fossil fuels while remaining complete and cost-effective. Because it uses few mechanical parts, the solar-powered electric tricycle is safe, efficient, and easy to maintain. It benefits experienced riders, non-athletes, the elderly, and those with health difficulties.

MOTIVATION FOR THE STUDY

Some of the Research Gaps that We Have Found During the Literature Survey that Motivated us to Initiate This Project

- In order to enhance the user-friendliness of this Tricycle, it is imperative to ensure that the design of the vehicle is kept as straightforward and uncomplicated as possible.
- Further investigation is required to explore the design considerations in this context. When creating a transportation system for individuals with physical disabilities, it is crucial to prioritise factors such as safety, stability, reliability, control, and comfort.

Personal and Mentors Motivation Towards Initiation of the Present Project as a Contribution for the Societal Application of Disabled People

- The project was driven by our motivation, which was fueled by our mentor's ongoing support and the potential future impact of hybrid solar tricycles on impaired individuals.

OBJECTIVES OF THE PROJECT

The following objectives are considered for achieving our desired aim:

- Develop affordable, environmentally pleasant solar tricycles using renewable energy.
- Selection of suitable PV solar panel, D.C. motor and Battery which can run solar tricycle with 15 km/hrs.

- To study and develop a newer type of Eco-friendly Tricycle for the disabled people, operated by renewable source of energy (solar energy).
- Design of counter shaft, bearing, sprocket, chain
- To develop a Tricycle that is easy to operate.
- To make a design that is feasible.
- To enhance the comfort and safety criteria of the Tricycle.
- To improve the strength and stability of the Tricycle.
- To improve the overall operational performance.
- To minimize the cost of design and fabrication.

SOLAR POWER SYSTEM

The solar three-wheeler has a 100W solar panel, MPPT solar charge controller, and 12 V–80 Ahr lead-acid battery. The tricycle's solar power system includes:

1. A solar array may convert solar energy into electricity.
2. Power trackers provide battery storage voltage.
3. Power-generating batteries.
4. Motor controller that controls motor power.
5. An electric motor for vehicle propulsion

The typical solar power setup is shown in Figure 1.

COMPONENTS

The chassis/frame, wheels, body, seat, solar panel mounting frame, solar panel, charge controller, battery, motor, chain, steering system, speed controller, brake system, and lighting make up the solar three-wheeler.

Specifications

1. *Solar panel:* 12V, 75W, 2Nos.
2. 24-volt brushless dc motor maximum load current. Power is 250 W, 300 rpm.
3. *Battery:* 12V, 2 Nos.
4. Charges in 6 hours
5. *Maximum speed:* 33 km/hr
6. *Frame:* Steel for high-strength sections.
7. *Wheel dimensions:* 20×1.75 front, 23×2.00 rear. Tyres: 23×2.50 front, 20×2.00 rear, 2.25 moped strength.
8. *Length:* 2.3 M, *width:* 1.2 M.
9. *Chassis:* 98 kg.
10. *Load capacity:* 90 kg
11. Maxims design handlebars.

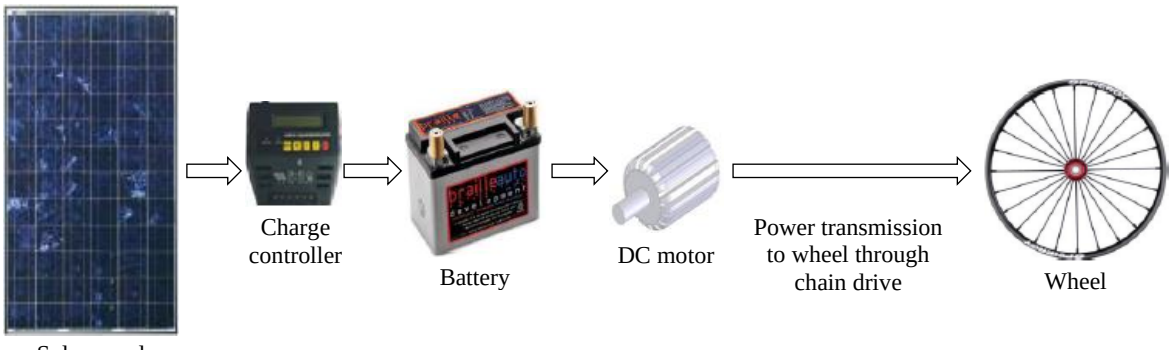

Figure 1. System diagram of solar power [7].

Solar Panel

A photovoltaic array, often referred to as a photovoltaic panel, is a collection of interconnected photovoltaic cells, which are commonly known as solar photovoltaic cells. This technology is commonly used in the construction of bigger solar systems that provide electricity for commercial and residential purposes (Figure 2).

Solar Charge Controller

A 12V, 6 amp Solar Photovoltaic (S.P.V.) Charge Controller has been utilised to regulate the solar power. Series solar charge controllers are utilised in compact off-grid solar photovoltaic (PV) systems. The device utilises Pulse Width Modulation (PWM) charging technology, which results in a steady reduction in charging current as the battery approaches full charge (Figure 3).

Battery

A battery is an electrical storage device designed to store the energy generated by solar power. Batteries are a cost-effective and viable component. It is crucial for the storage system to be optimised based on the available energy and the design of the local demand. A battery should have the following qualities: low cost, longer life, high consistency, high efficiency, low discharge, low maintenance, amp-hour and watt-hour efficiency. We used two 12V AMCO ATZ9 L 9Ah Battery for our Tricycle which is shown in Figure 4.

DC Motor

Electric motors convert electricity into mechanical power. A magnetic field exerts a magnetic pull on an electrically charged conductor. The orientation is established by Fleming's Left hand rule. The motor produces torque, as indicated in Figure 5(a). Current creates a supporting magnetic field above the conductor, which opposes the primary magnetic field below it. A force on the conductor pushes it downward. Direct current at the field poles generates flux. The conductors are brushed to the DC power supply. The schematic in Figure 5(b) shows six fundamental motor components.

Figure 2. Solar panel [8].

Figure 3. Solar charge controller [9].

Figure 4. AMCO ATZ9 L9Ah battery [10].

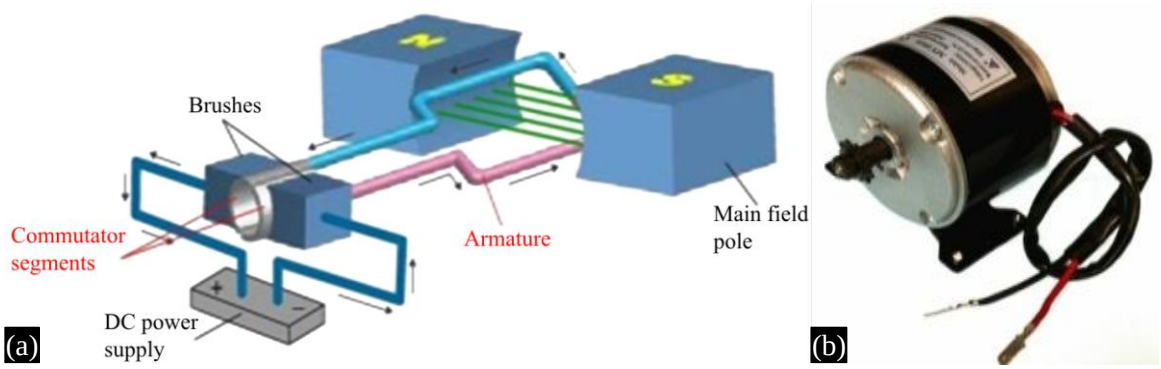

Figure 5. (a) DC motor construction [11], (b) DC motor used for the tricycle [11].

Electric motors use magnets and magnetism. Motion is generated by magnets. Poles of the same kind repel, while opposing types attract. The south end of one magnet attracts the north end of the other if their ends are marked north and south. Southern ends of magnets resist southern ends of other magnets, and northern ends repel northern ends. Repulsive and attracting forces alternate to cause rotation.

Electronic Circuit

An electronic circuit governs the entire linkage between the motor and throttle device, while also regulating the operation of the light and horn. Additionally, it aids in the regulation of battery charge (Figure 6).

Steering System

The steering system used in bicycles is also employed in tricycles. The steering is operated manually. Both hands are necessary to control the tricycle.

Braking Mechanism

The steering system of the Bicycle is utilised for the Tricycle. The steering is performed manually. Both hands are necessary to control the tricycle.

Power Charger

The steering system of Bicycle is adopted for the Tricycle. The steering is done manually. Both the hands are required to steer the Tricycle (Figure 7).

Figure 6. Electronic circuit [12].

Figure 7. Power charger [13].

LITERATURE REVIEW

A complete literature review of journals, books, articles, and other relevant sources was undertaken for this research. All relevant prior research is covered in this section. We must conduct a literature analysis before commencing a project to incorporate relevant material into execution. Thus, a detailed literature study was done to learn about previous and current studies on this topic. Numerous periodicals and articles from organizations and institutes were thoroughly evaluated. Several significant literary works have undergone thorough analysis (Table 1).

Conclusion of the Literature Survey

From the literature survey it has been observed that:

- There is a significant potential for the development of a Tricycle that utilises renewable energy and is environmentally sustainable.
- Additionally, we aim to develop a lightweight electric tricycle that has the capability to recharge its battery when not in use.
- Exploring the feasibility of constructing a low-speed tricycle capable of covering longer distances while minimising the physical exertion required to operate it.
- Offers enhanced mobility and comfort compared to existing manual tricycles, effectively addressing the limitations and vulnerabilities faced by individuals with physical disabilities.
- The user's text consists of a bullet point symbol. The Tricycle should require a lower amount of energy to operate. The overall efficiency is greater.
- Further investigation can be conducted on the process of harnessing solar energy to power a tricycle.

PROPOSED METHODOLOGIES TO BE ADOPTED

- Modeling.
- Design and calculations.
- Analysis.
- Prototyping.
- Costing and evaluation.

Table 1. Several significant literary works.

S.N.	Author	Topic name	Major findings
1.	Prof. P.R. Jawale, *et al.* [10]	An Evaluation of Contemporary Hybrid Tricycles Designed for Individuals with Disabilities	The objective is to create a tricycle that exhibits optimal efficiency and enhanced flexibility. .
2.	Fiyanshu Karla, *et al.* [11]	Solar Assisted Hybrid Tricycle: Design and Development	A "solar assisted hybrid tricycle" was created to facilitate cost-effective automation.
3.	Ripalkumar Patel, *et al.* [12]	Solar Tricycle Design and Development for Individuals with Disabilities	The tricycle has reached a maximum speed of 15 km per hour while carrying a load.
4.	Prof. Palak Desai, *et al.* [13]	Design And Fabrication of Solar Tri Cycle	The mean and maximum velocity were recorded at 12.8 km/h and 20 km/h respectively.
6.	Ravikumar Kandasamy, *et al.* [9]	Design of Solar Tricycle for Handicapped Person	Efficient in facilitating mobility for individuals with disabilities. .
7.	Sandesh G. Ughade, *et al.* [4]	Fabrication of Solar Powered Tricycle for Handicapped Person	It is very cheap as compared to the other motorized vehicles in the market.
8.	Sandesh G. Ughade, *et al.* [5]	Literature Review on Solar Powered Tricycle for Handicapped Person	The recharging capacity of the panels is satisfactory.
9.	Madhura Raul, *et al.* [6]	Smart Hybrid Tricycle for Disabled Person	To advance the tricycle that can charge even when travelling by addition of foldable solar panel.
10.	S. Devaneyan, *et al.* [7]	Solar Powered Electric Tricycle for Physically Challenged Person	Designing an appropriate technology considering longevity, reliability, and efficiency.

Modeling

Several adjustments were needed to integrate the electrical system with the tricycle frame for the driver's convenience. CATIA V5 is initially used to make the required modifications to the tricycle frame, as shown in Figure 8.

In addition, we utilised various Computer Aided Design (CAD) software programmes, including Solidworks and Autodesk Fusion 360, to create the model of our Tricycle (Figures 9 and 10).

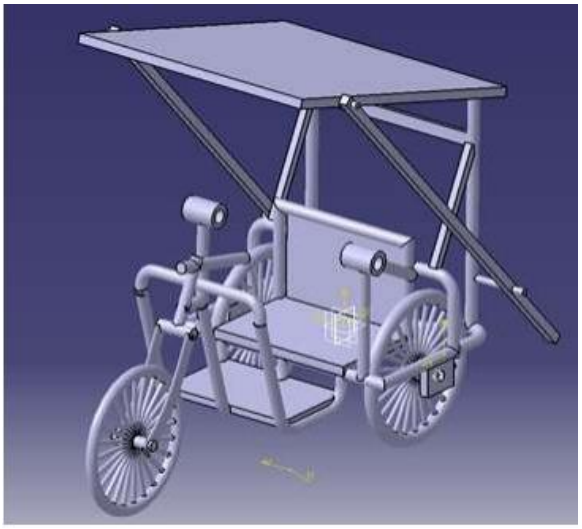

Figure 8. CAD model of tricycle.

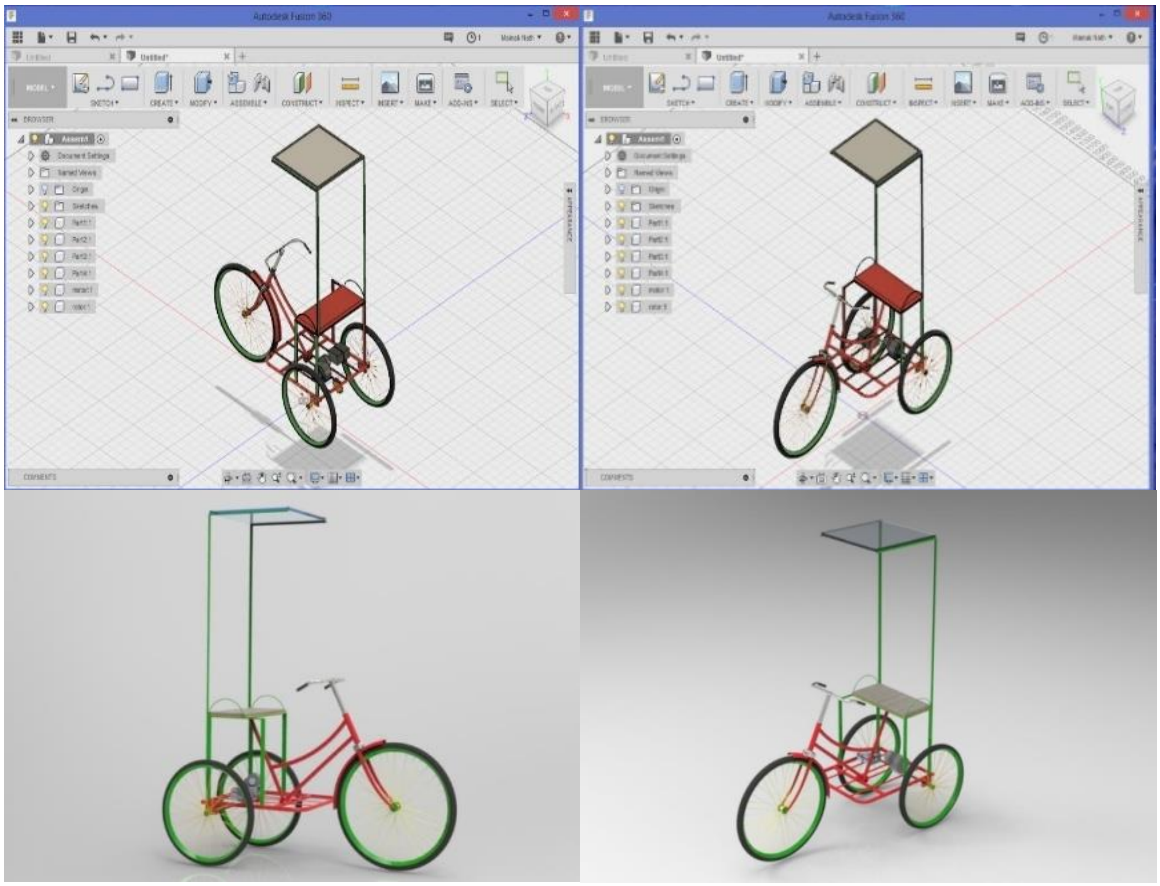

Figure 9. Solid works modeling.

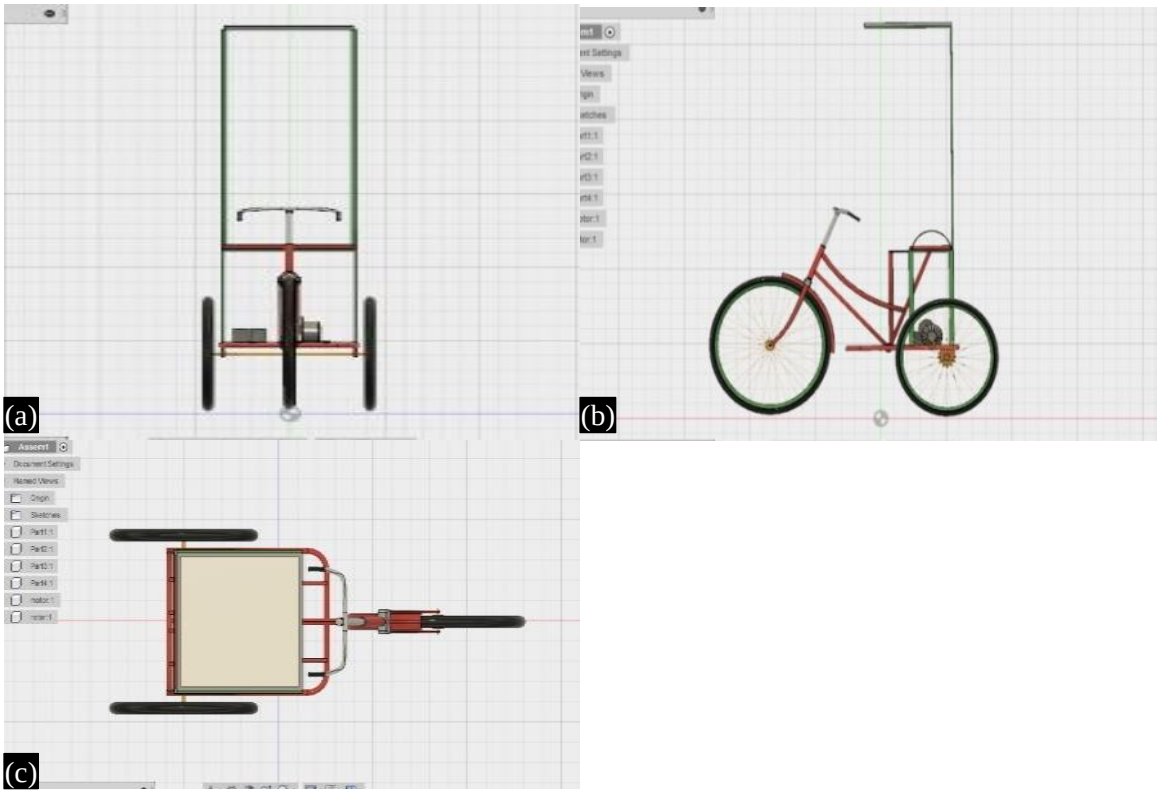

Figure 10. Autodesk F360 modeling. (a) front view, (b) top view, (c) side view.

Design and Calculations

The solar tricycle has two main parts. First, mechanical and biomechanical principles will be used to design the tricycle and its parts. To automate the modified manual tricycle, a solar power system will be included. When designing improvements to the manual tricycle, the restrictions and needs of impaired users are carefully considered. The solar tricycle's solar power system balances and optimizes limited solar energy, considering solar module space, energy storage, and power needs.

Wheelchair and manual tricycle users were surveyed extensively. To determine their needs, the people were asked tailored questions. Their concerns and opinions were voiced. Physically challenged people who use manual wheelchairs or three-wheelers have certain needs. Disability specialists' opinions are also considered.

Design Considerations

Design considerations are qualities that affect component or system design. Strength, size, and geometry of each element must be considered while building a mechanical system. Safety, stability, reliability, control, and comfort are essential when designing a transportation system for people with physical limitations. Simplicity, durability, stability, safety, corrosion and wear resistance, weight, size, flexibility, ease of control, modularity, efficient solar energy use, effective energy storage, and all-terrain tyres are important when designing the solar three-wheeler. We assumed the tricycle and user weigh 150 kg.

- Battery
- DC Motor

The trike gets its electricity from the sun, hence the name "solar panel." Using a solar cell, the batteries can be charged from the sun. Solar cells convert sunlight into electricity by using the photovoltaic effect. Electric potential is created via the photovoltaic effect when electromagnetic radiation is absorbed.

Sunlight is linked to both the photoelectric and photovoltaic effects, although their underlying mechanisms are distinct. When a material is subjected to high-energy radiation, it emits electrons from its surface, an effect known as the photoelectric effect. The photovoltaic effect, on the other hand, involves the creation of electrons and their subsequent transition from the valence band to the conduction band. This causes voltage to build up between the electrodes.

A 4-by-15.7-centimeter solar cell produces power at a rate of between 0.52 and 0.63 volts with a current of 3 amps. In this module, 36 cells are connected in series to ensure that the PV module constantly provides a voltage considerably above 12 volts, which is necessary for charging a 12 V battery under all working scenarios. We have used a total of four solar panels to generate enough energy for the solar tricycle to function.

The DC electric motor, which has been damaged, generates torque straight from the DC electricity supplied to it. An electric motor is a mechanical device that converts electrical energy. A magnetic force is exerted on any electrically charged conductor that is located within a magnetic field. Fleming's Left hand rule specifies the direction of travel. Torque is produced by the motor when it is operating. The magnetic field produced by the current in the conductor acts to both strengthen the primary field above the conductor and weaken it below the conductor. It has been found that any force applied to a conductor would try to pull it to the ground. A higher force is exerted on the conductor when the current is reversed because the magnetic field lines are stronger and more centrally placed beneath the conductor. Direct current applied to the field poles results in flux creation. The brushes connect the conductors to the DC power supply.

Calculations

Motor Drive Power Requirement

Wattage (W) = Mass (kg) × Acceleration (g) × Velocity (km/h) × Inclines (%)

Here, we estimate a 3% gradient and a maximum speed of 25 kilometres per hour (6.95 metres per second) for a total vehicle weight of 120 kilogrammes, including the driver.

Wattage (Power) = 245.44

Therefore, a tricycle can be powered by a 250 Watt direct current engine.

Battery

Its load current is 10.42 A at 24 V and 250 W.

If you ride your tricycle for 2 hours each day, every day, the load current will be 2×10.42×1.2, or 25 Ah.

Assuming a total loss of 20%, the battery capacity would be 25 × 1.2 = 30 Ah/day.

The daily energy consumption of a 250-watt motor is equal to 30Ah multiplied by 24V.

Therefore, the system needs 24 Volts and 25 Ah per day of power. Two 12-volt, 25-ampere-hour batteries will do the trick.

Time Required for Charging

Duration of solar power recharge: 10 W × 12 V / 0.83 A = Current from a Solar Charger.

10.84 hours of sunlight are needed, hence Time = 9 Ah / 0.83 A.

Power-charger Recharge Time

Power supply voltage is 24 V.

Power supply output current is 2 A.

In this case, 4.5 hours is the appropriate amount of time for charging.

Analysis

Various forms of analysis have been conducted to optimise power, load, and torque. We utilised Computer Aided Design software such as SolidWorks for this purpose.

Analysis for Equivalent Stress, Total Deformation and maximum shear stress (Figure 11).

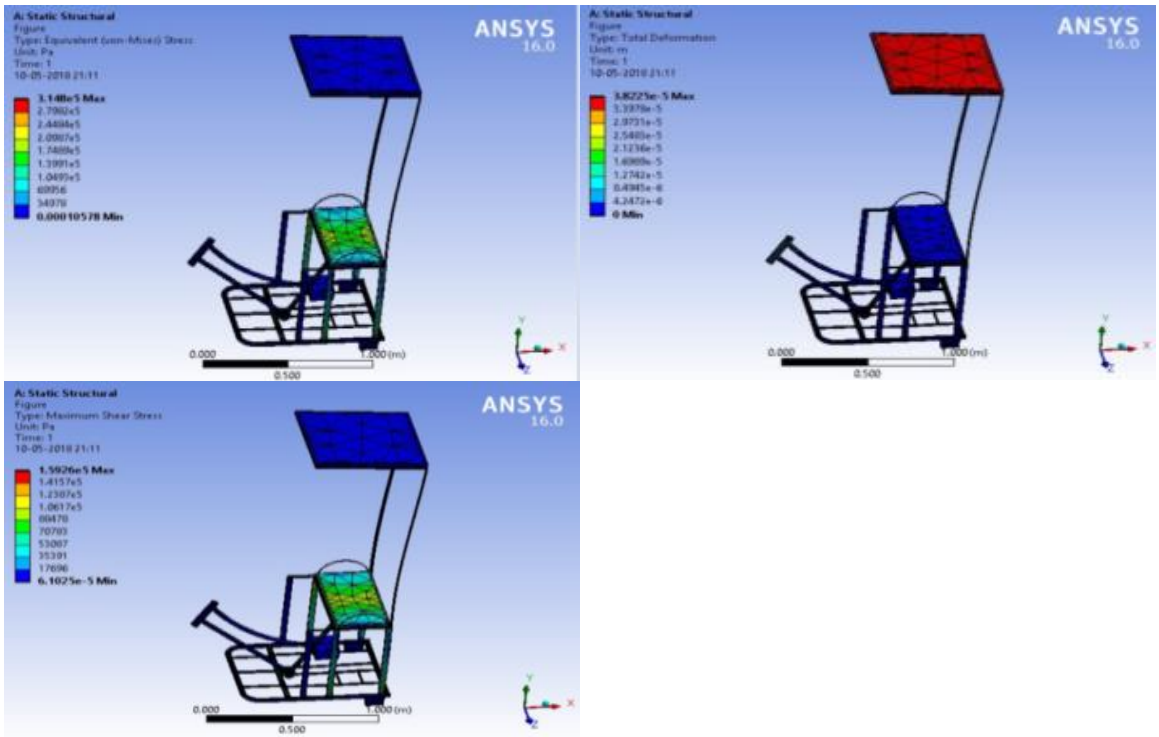

Figure 11. Analysis for equivalent stress.

Prototyping

We successfully developed the prototype of our functional model within a span of 14 days. Initially, we constructed the underlying framework. Subsequently, we affixed the axle by utilising bearings. Subsequently, we affixed the wheels to the axle. Subsequently, we joined the front section of the bicycle with the posterior section (Tables 2 and 3). Next, we install the motor assembly, which includes the batteries. Subsequently, we proceeded to construct the roof section and affixed the solar panel to its apex. Ultimately, we established all the necessary electrical connections (Figure 12).

Table 2. Major specifications of a proposed solar tricycle.

General specifications	
Size: 132×86×137 cm	*Steering/drive system:* Handle bar
Height: 137 cm	*Speed control:* continuous (voltage regulation)
Weight with battery: 85 kg	*Seat:* Cushioned and water proof.
Speed: 6 km per hour	*Breaking system:* friction type
Distance per charge: 39 km	*Shock absorber:* leaf spring at rear
Maximum load/weight capacity: 70 kg	*Tool kit:* standard
Tire size: (40×5) cm	*Career:* attached at the back
Power specifications	
Solar panel: 100 watts (16.2 V, 6 amps)	*Batteries:* lead acid battery, 12 V-80 A-hr
Motor: 200 W (DC)	*Charge controller:* Solar based (MPPT type)

Table 3. Cost analysis.

Part	Unit cost (Rs.)	Number	Total cost (Rs.)
DC motor	4000	1	4000
Battery	2000	2	4000
Solar panels	1500	2	3000
Bicycle	1000	1	1000
Assembly	1000	1	1000
Electrical wiring	500	1	500
S.P.V. charger and power charger	500	1	500
Sub total			14000

Figure 12. Working model of our solar tricycle.

RESULTS AND DISCUSSIONS

We were able to determine how fast the solar-powered tricycle was going by using an android app. Maximum, minimum, and average velocities are all calculated using this programme. We have conducted two trial tests at different places. Table 4 displays the findings.

Table 4. Results of the trail run.

S.N.	Trip	Distance	Time Taken	Average speed	Maximum speed
1.	CGPIT to Tarsadi	1.6 km	3.31 min	12.81 kmph	20 kmph
2.	CGPIT to Mahuva	6.7 km	35.41 min	11.35 kmph	20 kmph

We have analyzed our solar tricycle against other available cars in India. Table 5 displays the results of this comparison.

Table 5. Comparison of various vehicles.

Parameter	Solar tricycle	Moped [6]	Bicycle [7]
Max speed (kmph)	20	50	20
Pedaling requirement	No	No	Yes
Initial cost	24500	27343	4000
Operating cost	Nil	Re. 1/km	Nil
Weight – vehicle only (kg)	80	66	9
Max. travelling distance at a stretch in km	40–45	198	15–20
Fuel used per 100 km	Nil	1.5 L	Nil
Charging time (hr)	3.5–4	NA	Na
Type of energy used	Solar	Petrol	Muscle power
Driving noise (dB)	Noiseless	65–70	Noiseless
Driver's license required	No	Yes	No
Helmet required	No	Yes	No
Age limit	No	Over 18	No
Engine size (cc)	NA	69.90	NA

EXPECTED RESULTS WITH FINDINGS

- Enhancement of the velocity of a tricycle with enhanced manoeuvrability.
- Enhancement of the operator's safety requirements.
- Enhancement of the tricycle's stress absorption capabilities.
- Significant decrease in battery charging time.
- Maximising the efficiency of tricycle travel distance under full load conditions per one charge.

The calculated distance covered without interruption is 10 km.

CONCLUSIONS

The solar tricycle was effectively developed according to the specifications for the impaired community. The tricycle operates using solar power and utilises a BLDC motor for propulsion. The mean and maximum velocity were recorded as 12.8 km/h and 20 km/h, respectively. A comparison was conducted among several vehicles in the same category available in India, considering numerous parameters. The analysis found that solar tricycles, which utilise solar energy, are particularly beneficial for the disabled community compared to vehicles that rely on other sources of energy. Multiple pieces of evidence were combined to arrive at this conclusion. The battery can be charged by an external electric power source to make up for the diminished solar energy available on cloudy or rainy days.

Based on the study and after thorough literature reveals the following up to conclusions are made carefully:

- The current issue arose from a desire to offer a more advanced Tricycle system to individuals with physical disabilities, in order to enhance their mobility and comfort.
- After extensive examination of several literary works, certain research gaps have been identified and an attempt has been made to examine the current need in the context of the study.
- Identified approaches have been determined and will be further utilised to complete the investigation.

Future Scope

The following are the primary future prospects of the study:

- Using solar cells, the sun's rays are transformed into electricity. In addition to human peddling, the tricycle is powered by a DC motor that converts electrical energy into mechanical energy.
- To find a replacement for traditional fuels.
- Both the ecological balance and the budget tricycle need to be maintained.

- There is a need for renewable energy.
- The potential for India to use solar power is enormous. The country has ideal conditions for the production of solar energy due to its position. More research might be done to learn more about the many applications of solar power.
- The solar panel makes use of the highly efficient ultra efficient solar cell. The Nickel-cadmium battery is what's being used. Nickel cadmium batteries can take a deep discharge without being damaged, and they are also more resistant to overloads. Nickel cadmium batteries offer reduced maintenance requirements and increased lifespan.
- Further inquiry can be undertaken on the design features of the Tricycle to enhance its stability and manoeuvrability.

Limitations of The Study

1. The initial cost is expensive.
2. Storage batteries will require replacement approximately every 3 to 5 years.
3. Tricycles are not designed to accommodate more than one passenger.
4. Slower velocity in comparison to alternative modes of transportation.
5. Solar energy, while being an inexhaustible source, is not consistently accessible as it relies on the presence of sunlight.
6. It is necessary to conduct thorough testing of all prototypes and modified tricycles prior to their use on public roads.
7. Like any other electric car, the battery pack may contain dangerous levels of energy, and hence it should be handled with caution and respect.

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Data Availability

The authors affirm that this research report contains the information necessary to understand the findings of the investigation.

Conflict of Interests

All of the authors contributed equally and have no conflict of interest in any way with this paper.

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