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Design and Fabrication of Solar Photovoltaic Powered Low Cost Tricycle for Disabled Person

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Abstract: *Solar photovoltaic powered tricycle for disabled person (SPVPT-DP) was designed and fabricated to facilitate the movement of handicaps without polluting an environment and reduce the expenses of importing such item. Disabled persons are unable to attend school, work, or participate in the community activities due to an immobilizing disability. The designed SPVPT-DP has resulted into effortless to operate, and provide independence and confidence to ride on different road surfaces such as gravel, tarmac, paved and earth without assistance. It is expected that the SPVPT-DP will help people with disabilities to move from one place to another doing economic activities and interacting socially with others. This could help to reduce poverty among disabled persons, and hence contribute to the economic development of their nation.*
Keyword*: design, disabled persons, fabrication, solar photovoltaic, tricycle*

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I. Introduction

The three wheeled cycle especially for disabled people (DP) have long history. The first innovated tricycle, DP were helped by another person to push them. Early version, the disabled people had to use hands for pedaling, thus more effort needed to move the tricycle. Later, tricycle modified for the disabled people to use hands as well as small petrol engine (40cc) which later had challenges of fumes, sound pollution and escalated expenses. Other tricycle version was designed to be electrically operated by battery being charged whenever current drops. The newly innovated low cost tricycle for disabled people is powered by solar electricity as well as domestic electricity by using special charger when there are clouds or during night time. The empirical study was aimed at designing and fabricating solar photovoltaic powered tricycle for disabled persons as a new version which simplifies, reduces or cuts a lot of expenses as well as inconveniences which disabled people experienced before. The design and fabrication of solar photovoltaic powered tricycle for disabled persons is in line with various national policies governing technology development in Tanzania.

II. National Policies Governing Technology Development in Tanzania

In recognition of the importance of technology development, the government of Tanzanian has developed a number of policies. The main objective is to favor technology development and finally improving the technological capabilities and innovations in the country. Currently, the notable policies include:

National Science and Technology Policy: the main objective of this policy is to guide the country on building technological capabilities aimed at enhancing sustainable socio-economic development. The policy document asserts that science and technology should be applied in improving and to enable promotion of technological development in the country in order to reduce reliance on imported technologies [1].

National Research and Development Policy: the policy emphasizes that research undertaking in Tanzania should be directed towards addressing problems affecting our society, gaining knowledge, and building skills which will be of lasting benefits to the country. Also, this policy put importance on innovation and commercialization of research results which are the key in bringing about economic growth and at the same time solving societal problems [2].

Tanzania's Development Vision (TDV) 2025: aspires to have Tanzania transformed into a middle income and semi industrialized nation by 2025, which emphasize by the year 2025: (i) high quality and sustainable livelihoods; (ii) peace, stability and unity; (iii) good governance and the rule of law; (iv) an educated and learning society; and (v) a strong and competitive economy. The five-year development plan mentions persons with disabilities in relation to social protection [3] (MoFP, 2016).

National Five-Year Development Plan 2016/2017–2020/2021: nurturing industrialization for economic transformation and human development" which focuses on growth, economic transformation, poverty reduction, and improved livelihoods [4].

National Policy on Disability (2004): set out the significant challenges faced by people with disabilities in Tanzania and the intended measures to be taken to mitigate them [5].

III. Technology Development

Bennett [6] defines technology as a system of knowledge, techniques, skills, expertise, and organization used to produce, commercialize and exploit goods and services that satisfy economic and social demands. Thus, the use of our understanding of nature to develop a technical method for achieving a practical purpose and product is the application of technology in a particular physical form designed to carry out a specific set of functions. Technology development in the context of this paper is the process of creating technological solutions to problems or needs that currently do not have satisfactory solutions. The technical aspects must be developed to a point such that the technology is simple, friendly to the environment and rugged enough to be used in real world applications [7]. The available modes of transportation for disabled persons include various wheel chairs, tricycle etc. But their travelling range is limited due to sophistication of the machinery. So, this work focuses on a design of a unique tricycle that allows a physically disabled person to travel along with assisted solar powered tricycle in easy way operation and long traveling range [8, 9].

Leishman et al. [10] described the implementation of assistance to the driving of a smart wheelchair through a deictic approach. Initially, a state of the art of mobility assistance, interfaces and types of commands for smart wheelchairs is presented. The deictic concept and more particularly, the approach used for the design of interface are examined. Then the two functionalities carried out to implement this type of interface, as well as methodology used to control wheelchair are illustrated.

IV. Technological Capabilities

Kim [11] defines technological capability as the ability to make effective use of technological knowledge in efforts to embrace, use, familiarize and change existing technologies. For the purpose of this paper, technological capabilities are defined as the effective use of the technical skills, knowledge and experience, not only in the procedures to acquire and develop new technology, but also to generate new skills and knowledge to improve the existing technologies, in response to the local environment.

V. Material and Methods

The study was aimed to design and fabricate a solar photovoltaic (PV) powered tricycle for disabled person (SPVPT-DP). Both primary and secondary data were used in this study. Literature review was carried to contextualize the study. Field survey was conducted in Arusha to seek views from disabled persons with regard to the design of SPVPT. From the survey, the following opinions were gathered from physical disabled persons that helped to conceptualize the design consideration of the SPVPT-DP: (i) tricycle should be easy to operate; (ii) tricycle should be stable apart forward or backward movement also during cornering; (iii) tricycle to travel long distance without recharging of batteries; (iv) easy to climb elevated planes; (v) give proper width so that DP can enter inside the room and; (vi) incorporate provision of roof to shed rain and sun. Subsequently design calculations, selection of materials, fabrication and assembly of tricycle and performance evaluation were carried out whereby the final product of SPVPT-DP was realized as illustrated in Figure 3.

VI. Design Considerations

Design of frame and platform include space considerations for tricycle chair positioning and the battery. Thus, parameters such as length from wheel base of tricycle chair to shoulder support, length from wheel base of tricycle chair to hand rest, width of tricycle chair, total length of wheel chair were ascertained. Likewise, reach-ability data of a disabled person sitting on the tricycle chair was required for selecting the above parameters. According to ADA standards [12], the size of a tricycle has been taken as 2000mm Long x 700mm Wide x 1600mm High. The design consideration predicts the data related to vertical and horizontal reaching zones for a tricycle chair user. Data obtained and ergonomics are used to design frame and handle. Therefore, the following reach-ability data is needed to finalize the positions of functional control such as brakes and accelerator as illustrated in Figure 1 and Figure 2 respectively:

- Length of platform = 1000mm
- Width of the platform = 800mm
- Position of functional controls = 700mm above the platform

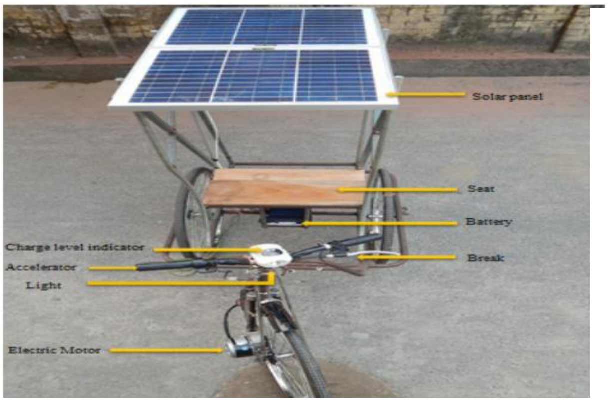

Figure1. Main Parts of SPVPT-DP, Masud et al. [13]

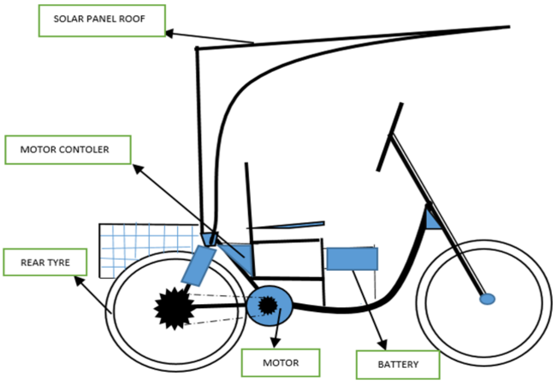

Figure 2. Schematic Diagram of SPVPT-DP

VII. Material Selection and Design

The selection of materials for fabrication was based on materials that are reliable and can provide high strength to the tricycle. In order to reduce materials cost and overall weight of tricycle, consideration should be taken into the desirable properties of materials needed for fabrication of the model [14]. These required material properties include the following:

- Material must have high tensile strength
- Material should withstand torsional and shear stresses
- Material should be highly resistant to changing weather conditions
- Material should be light in weight
- Material should be cost-effective and cheap
- Solar panel should be quality and sizing to the tricycle roof.

As the application includes various forces and moments on the fabricated model, the material selected must be either metal rods or tubes for safety and efficient working. Mild steel provides high tensile and torsional strength required for the application. In that case, MS was selected for the fabrications.

VIII. Selection of Pipes

The size of MS tubes were selected based on the factor of reaction forces calculations and safety consideration. A function of frame is to make the tricycle robust and strong enough to withstand all the forces acting on it. Stresses developed in the pipe depend upon the cross section area of pipe. Larger the area, smaller the stress in the pipe. By considering weight and size of a pipe, maximum stresses developed in the critical component and factor of safety is calculated and the size which gives maximum factor of safety is selected. Table 1 shows various factor of safety obtained for different dimensions of MS pipe. Thus, it is observed that MS tubes provide high strength and are reliable for the application. Also, the MS tube with 27.94 mm outer diameter and 1.75mm thickness is well sufficient against the impact and tensile forces acting on the tricycle.

Table 1: Factor of Safety for Different Tubes

Pipe material	Do (mm)	Di (mm)	Thickness(mm)	Max. BM (Mpa)	FoS
Mild steel	38.10	34.10	2.00	239.92	1.66
Mild steel	38.10	34.60	1.75	268.78	1.48
Mild steel	27.94	24.44	1.75	468.82	0.85
Mild steel	25.40	21.40	2.00	584.83	0.68

IX. Calculations for Frame

When the vehicle hits an obstruction, impact forces are transmitted to chassis through suspension spring. So, the component on which suspension spring is mounted is the critical component. In that case, the following parameters to be used in the calculations were ascertained and defined as follows:

F = Force that is transmitted through suspension system
θ = Angle made by the spring to vertical axis
Do = Outer diameter of the pipe
Di = Inner diameter of the pipe
Syt = Yield strength of the MS pipe

y = Position of neutral axis
I = Area moment of inertia.

Assuming total impact force acting on the rear wheels of the tricycle in upward direction is 2g times the weight of the tricycle.
Here, $\theta = 30°$
Total force =2 x 9.81 x 150 (since weight of tricycle is assumed to be 150 kg) = 2943N
As two suspensions are given, force acting on each suspension is (F) = (Total force/2) =1471.50N
Vertical force acting on the pipe (Fv) = FCos (θ) = FCos (30) = 1274.39N
Horizontal force acting on the pipe (Fh) = FSin (θ) = FSin (30) = 735.75N
Length of the critical component of chassis is 380mm, and it acts as a cantilever beam fixed at one point and load is applied at the 190mm away from fixed point.
Maximum bending moment due to vertical force:
BMmax v = 1274.39 x 0.19 = 242.13Nm
Maximum bending moment due to horizontal force:
BMmax h = 735.75 x 0.19 = 139.79Nm
Resultant bending moment:
BMres = √ (242.134 + 139.793) = 19.54 Nm
Maximum bending stresses:
FBmax. = BMresy I = 19.54 x (0.02794/2) π /64 (0.028- 0.024) = 468.82N/mm2
Available factor of safety = (Syt / Maximum bending stress) = (400/468.817) = 0.85.

X. Design of Shaft

Materials selected for the design of shaft:
SAE 1045 (Carbon steel) oil quenched and drawn 700 °C
Sut = 579 MPa and Syt = 306 Mpa (From T.N. II-7 of data book)
For the solid shaft
Ʈ ≤ 0.3 Syt or Ʈ ≤ 0.18 Sut
Ʈ = 0.3×306 = 91.80MPa or Ʈ = 0.18×579 = 104.22MPa
Consider minimum value of 'Ʈ'
Therefore, Ʈ = 91.8MPa (without keyway)
According to torsional strength of shaft,
T ×Kl = π/ (16) ×τ×D^3
128 × (10) ^3 ×1 = π/16×91.8×D^3
Therefore, D =19.22 mm ≈ 20mm
Therefore, the standard diameter for the shaft D = 20 mm.

XI. Selection of Battery Power

Lead acid batteries are the most suitable in existing technology for electric vehicle because they can deliver high output because of having capability to store high power per unit of battery mass.
Calculations for selecting battery power:
Tricycle Weight = 60 Kg
Individual's Weight = 90 Kg (Approx.)
Add up to Weight = 60+90= 150 Kg (previously assumed weight of tricycle)
Ordinary response on each wheel = Weight of tricycle/number of wheels = 60/3 = 20 Kg
Power Requirement = 500 W
Battery voltage = 48 V (12 Volts - 4 Nos.)
Power = V x I
I = P/V = 500/48 = 10.42 Ah   Minimum Ah for each battery to drive the tricycle.

XII. Selection of Motor

Brushless DC motors use a rotating permanent magnet or soft magnetic core in the rotor, and stationary electrical magnets on the motor housing. A motor controller converts DC to AC. This design is simpler than that of brushed motors because it eliminates the complication of transferring power from outside the motor to the spinning rotor. Advantages of brushless motors include long life span, little or no maintenance, and high efficiency. Disadvantages include high initial cost and it needs motor speed controllers. Some such brushless motors are sometimes referred to as "synchronous motors" although they have no external power supply to be synchronized with, as would be the case with normal AC synchronous motors.
Weight: Chassis 60 Kg.

Load Capacity: 90 kg
Diameter of the back wheel = 20 inches
Diameter of the front wheel = 20 inches
RPM of brushless dc motor = 300rpm.

Calculations for selecting motor:
V = W x R
ɖ = 2 π n/60 =2 x π x 300/60 =31.41rad/sec.
Finished solar tricycle
V = 31.41 x 0.292 =9.17 m/s.
V = 9.17 x 3600/1000= 33.012 km/hr
V ≈ 33 km/hr

XIII. Brakes Selection

A brake is a mechanical device which inhibits motion, slowing or stopping a moving object or preventing its motion. In this tricycle there are two types of brake used together, one is for cutting electric current to motor and the most commonly used brakes, friction between two surfaces pressed together to convert the kinetic energy of the moving object into heat. Drum brakes are used in the tricycle because it moves with a slow speed V ≈ 33 km/hr. Three engineering activities have been taken into account, those were designing, production and development of new technique. At the designing stage the economic aspect has been considered. The important selection of process parameters has been implemented. Further in the other activity applied, is development of new manufacturing process and modification of the existing technology/standard components.

XIV. Results and Discussion

Each part of the tricycle was always checked and tested just to make it certain that it is in a good condition according to its specification [15]. The carefully design and selection based on the defined specifications have resulted into various components needed to assemble the tricycle as shown in Figure 3. The components with their specifications include four solar panel 12 volt and18W; one brushless DC motor with 48 volt, 500W power rating and 300rpm; battery of 12V-4Nos., 48v, 500w with Charging time of 8 hr; frame composed of steel hollow pipes in parts with high strength; one front tyre 20 x 1.75 and two rear tyres 20 x 1.75; volume (size) of the tricycle 200cm long x 70cm wide x 160cm high with 60Kg chassis. The carrying capacity of the tricycle is estimated to be 90Kg with maximum speed of 33km/hr.

Figure 6: Final Prototype of the Designed and Fabricated SPVPT-DP

XV. Conclusion

Solar photovoltaic powered tricycle for disabled person (SPVPT-DP) was designed and fabricated to facilitate the movement of handicaps without polluting an environment and reduce the expenses of importing such item. From the design, various components of the tricycle were designed and assembled to create SPVPT-DP with maximum speed of 33km/hr. As earlier mentioned, the tricycle works on solar source and employs one brushless DC motor with 48 volts to drive the tricycle. The maximum speed was obtained as 33Kmph and 300rpm respectively. Due to limited solar energy during unfavorable conditions of sun availability provision is made to charge the battery using external electric power source. The battery of 12V with charging time of 8 hours was adopted. Consequently, the designed and fabricated SPVPT-DP serves as a solution for the movability of the impaired individuals of the Society.

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