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Design and Fabrication of an Indigenous Electronic Driven Wheelchair

Olawale O.E. AJIBOLA[1], Olumide ADEBAYO[2] and Davidson O. OSUNDE[3]

[1,2]*Department of Systems Engineering, University of Lagos, Akoka, Yaba, Lagos, Nigeria*
[1]oajibola@unilag.edu.ng; [2]olumide_adebayo@yahoo.com

[3]*Department of Electrical and Electronic Engineering, University of Lagos, Akoka, Yaba, Lagos, Nigeria*
[3]dosunde@unilag.edu.ng

Corresponding Author: oajibola@unilag.edu.ng

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Abstract: *The essence of mobility in humans cannot be over-emphasized, thus the difficulty that persons living with motor impairment suffer with impeding effect on their physical development and social interactions. Electronic driven wheelchair (EDW) can mitigate against the effects of the aforementioned suffering. However, the cost of acquiring an EDW is beyond the reach of an average Nigerian. In this paper, the design and fabrication of a locally produced low cost EDW was reported. The device was designed for outdoor use with two rear motor driven wheels, two 12V DC deep cycle batteries, angle bar, galvanized metal pipes, solar panel, rattan (cane) and bamboo. Control for the EDW is achieved through the use of a joystick. The batteries can be charged either by using 220V AC mains or a solar module. The framework of the wheelchair is made up of about 50% metal, 35% rattan, and 15% bamboo. Available anthropometric data for Nigerian adult was used in designing an applicable prototype. The product of the study is a functional EDW. The essence of the innovation is to afford average income earners the opportunity to acquire and use an electric wheelchair.*

Keywords: *Electronic wheelchair, indigenous, geared motors, deep cycle battery, relay.*

1. INTRODUCTION

Wheelchairs help people with motor impairment to move from one place to another. It is estimated that about Eight million (8,000,000) in a population of around One hundred and seventy million people in Nigeria live with one form of disability or the other [1]. It is also estimated that about 40% of the total disabled population are motor impaired [2]. Disability is not limited to incapability to function adequately, it also concerns development, because of its symbiotic link to poverty: disability raises the propensity of poverty, and vice-versa [3].

EDWs are prescribed for people who have difficulty in propelling a manual wheelchair: patients from the maternity wards, patients from surgery, or those who have a medical condition that may not enable them to cope with the excessive energy exertion. Progress made in the area of development of EDWs have engendered modalities with adjustable seat height, leg rest, tilt and backrest recline [4]. The steady reduction in the price of microcontrollers and ease of acquisition has been a major drive that spur wheelchair designers to constantly develop devices to suit different needs of their users. EDWs now range from a bi-directional wheelchair to automated multidirectional controlled wheelchairs giving the user a variety of options. The base classification of EDWs are rear-wheel, mid-wheel, front-wheel and all-wheel drive with trade-offs between terrain capabilities, closed area manoeuvring, stair- climbing, assisted driving and battery life. [5, 6]. With the plethora of options available, clinicians and end users consider safety and performance related characteristics of EDWs that suits the medical conditions of the users. Also to avoid unnecessary cost, the prescribed wheelchair should have only those optional features that are necessary to achieve optimal functioning of both the user and the device, fitting the body profile of the user properly so as to annihilate discomfort, or at least reduce it to the barest minimum [7]. Comfort is of absolute essential in the design of consumer products, especially products that come in physical contact with the user, e.g. seats or headsets. Discomfort, whilst not the exact opposite of comfort should be avoided or greatly reduced in order to garner satisfactory response from the user. Products should be designed to enhance the productivity of the user by mitigating against the discomfiting limitations, rather than having users adapt to the design [8, 9]. Achieving this is heavily dependent on understanding and tailoring a design for the variables represented in the target population, encompassing attributes such as age, size, strength, financial capability, prior experience, cultural expectations, etc. [10, 11].

EDWs are generally safer than the manual wheelchairs because of the stability the system has due to its increased weight, which makes it more difficult to topple when on a steep terrain. The added weight comes from the batteries, electric motors and other peripheral devices. EDWs generally have two 12V batteries, two geared motors connected to the drive wheels, a controller for direction of movement, and some have speed control included in the design for the user to vary movement speed at will. Many variations of the base design include: A manual stair-climbing wheelchair where the user controls the propulsion rail via a geared mechanism that mimics the pedalling of a bicycle [12]. In improving the capability of the manual stair climbing wheelchair, an EDW that can climb stairs was developed [13]. This added functionality removes the limitation of wheelchair accessing stairs. Development of a hybrid wheelchair that uses both batteries and combustion engine was showcased in [14]. Combustion engine from a scooter can be started by the push of a button, and the design also embodies an alternator to charge the batteries while the engine is on. User can switch from the engine to batteries at will. However, fumes produced can be hazardous to the end user over time. When a wheelchair user is suffering from extreme motor impairment and can't propel themselves, a wheelchair integrated with GSM and GPS module for easy location, gives the caregiver access to always locate the position of the wheelchair at any point in time [4]. In [15], a beach solar–powered wheelchair with special tyres that have good traction was developed to travel on sand. During summer, there is plenty of sunlight and visits to the beach peaks during that season, hence the wheelchair was designed to access sunlight, and the solar module also shield user from the sun. The only drawback to this design is that it is limited to that terrain.

More recent researches in this field are geared towards user controls that are not limb-dependent. A head tilt control for quadriplegics where the chair is incorporated with wireless modules, tilt sensors and a diode logic circuit for resolution and generating appropriate signal for movement in the direction desired by user was designed in [16]. An improvement on that work is the introduction and implementation of drive assistance with the head motion controller. This took the study to the realm of artificial intelligence (AI) helps the user avoid obstacles [17]. A further work in the use of AI in wheelchairs is the use of object recognition with the movement of the eyes to control the direction of the wheelchair. A camera is placed in front of one of the user's eye, to get the movement of the pupil, which is then translated to the desired direction of motion This design incorporates obstacle detection as well [18]. According to United Nations Development Project in 2002 [19], about 1% of wheelchairs used in Africa is produced in Africa. In Nigeria, an NGO in Jos, Plateau state produces manual wheelchairs in the form of recombined parts of a bicycle with two big wheels mounted side by side and a seat placed in between, a pedal is connected via a chain to a third wheel in the front, the user propels by controlling the pedal with the hands [20]. Although there is a plan by the Plateau state government to start production of EDWs, that has not come into fruition [21]. Also, there have been anthropometric work by Nigerian researchers with the aim of addressing ergonomic anomalies in the current furniture being used in the country, wheelchairs' inclusive [10, 22]. To put all of the aforementioned designs in the perspective of the Nigerian situation where most people experience incessant power outage, there is the need for a low cost and an energy efficient design and fabrication of motorized wheel that provides the basic functionalities of an EDW, vis, the problem of mobility for the disabled person, the appropriate anthropometric measure for furniture design couple with the issue of energy generation, conservation and efficiency so that user is not heavily dependent on the power supply from the grid to keep the wheelchair functional.

2. MATERIALS AND METHODS

The materials deployed in this study include: 2 units of 18AH, 12 V battery of 0.9 retention capacity, 2 units of 180W motor, 1 unit of solar module with operating factor of 0.85.

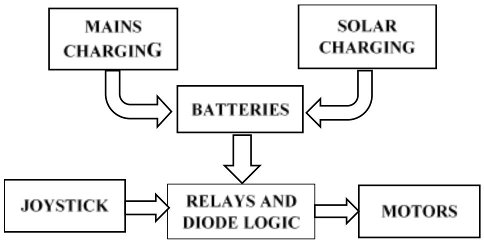

Figure 1: Block diagram of Indigenous EDW

The design of the structure of the EDW was executed using Autodesk Fusion 360 software. Figure 3 side view of the design while the rear view is as shown in Figure 4.

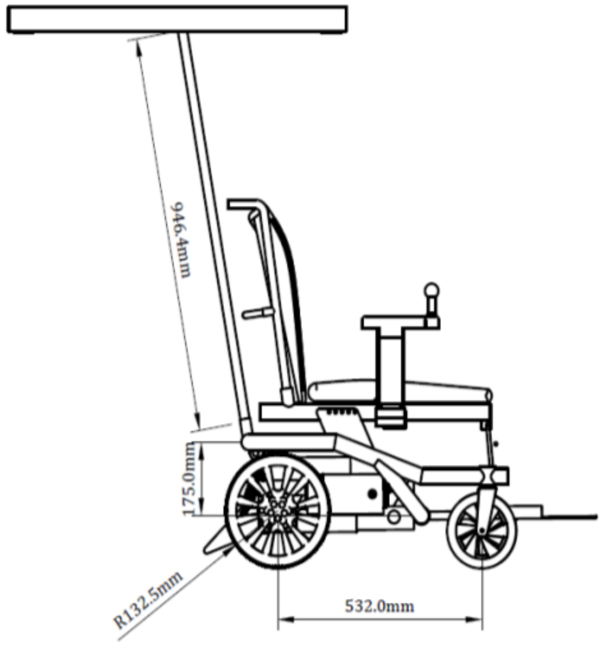

Figure 3: Side view of the design

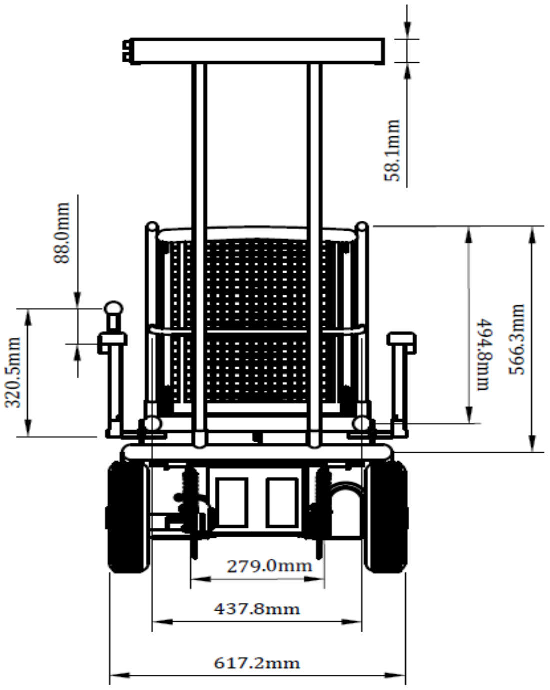

Figure 4: Block diagram for control and monitoring subsystem

The EDW makes use of two (2) pneumatic tires connected to the motors, the motors are connected to the frame of the wheelchair via dampers and an adjoining rod for balance. Bamboo was used for the framework in place of the conventional metal while the seat was made of woven rattan popularly called “cane”. The choice of materials is informed partially by the Federal Government policy on local content and partially by heat dissipation property of the chosen materials and their ability to engender considerable comfort to the user.

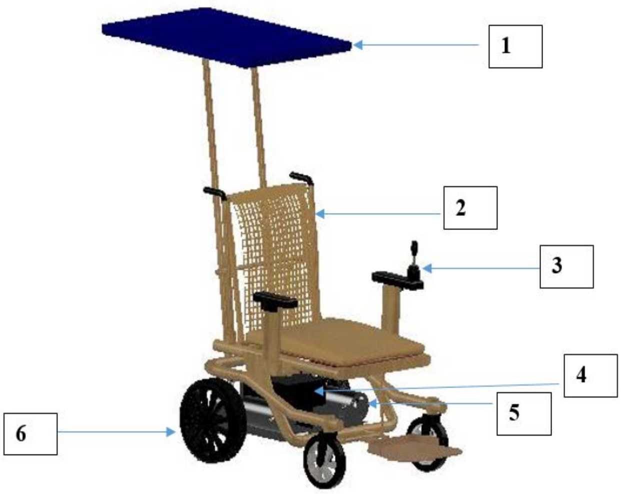

Figure 4: Conceptual design of the proposed indigenous wheelchair 1. Solar panel (single crystal, 30 W) 2. Rattan seat 3. Joystick controller 4. Batteries 5. Motor (180 W × 2) 6. Drive wheel

The majority of the human weight in sitting position is transmitted to the earth via the buttocks, hence the mechanical advantage that rear wheel drives have over other forms of wheelchair drives. The parameters considered in the course of fabrication of the EDW are summarised below:

The evaluated parameter include:

Required force F = ma = 66N

Frictional force = 66 x 0.1 = 6.6N

Total required force = (66 + 6.6) N = 72.6N

Torque per wheel = Force x distance

= 3.63Nm

At 60% efficiency, torque required = 6.05Nm

RPS = velocity/circumference

= 1.1/0.628 = 1.75

Required RPM = 1.75 x 60 = 105 RPM

Output of solar panel = peak power rating x operation factor

Current supplied by solar panel = $25.5W / 12V = 2.125A$

Charging time = $18AH / 2.125 = 8.47H$

Charging current at 25% of battery capacity = 4.5A

Charger voltage 14.5V

Charging time = $18AH / 4.5A \approx 4H$

Figure 5: The framework during construction

2.1 Fabrication Process

During fabrication, anthropometric data for adults in Table 1 was implemented in the design of the wheelchair. Although people living with disabilities usually have distorted frames, this works considers average adult structure in order to accommodate various forms of deformation, and create room for future improvements in body frames as their health conditions improve. Figure 5 is a display of the frame of the base of the EDW.

Table 2: Cost analysis of the fabrication of the EDW

MATERIALS	COST (₦)
DC motor x2	30, 000
Caster Wheel X2	2, 000
Pneumatic Tyres x2	3, 000
Battery x2	15, 000
Metal	9, 000
Bamboo and Cane	12, 000
Electrical Components	10, 000
Dampers x2	5, 000
Miscellaneous	7, 000
TOTAL	**103, 000**

Table 1: Anthropometric data for adult paraplegics in Nigeria

S/N	Anthropometric dimensions measured	5th percentile (cm)	50th percentile (cm)	75th percentile (cm)	95th percentile (cm)	Mean
1	Age	25.2	43	47.5	55.6	42.83
2	weight	45	68	81	93.6	71.90
3	Sitting height	68.1	79.0	84.5	90	80.40
4	Waist depth	18.1	25	28	30.9	25.50
5	Popliteal height	33.1	39	42.5	46.9	40.38
6	Knee height (sitting)	39.1	49	51	57.9	49.25
7	Buttock to knee length	41.1	51	56	59	51.78
8	Eye height (sitting)	51.2	64	70.5	77.9	65.90
9	Forward reach (maximum)	60.2	71	75.5	89.9	74.15
10	Mid – shoulder height	42.1	52	59	65.9	53.53
11	Body width	38	51	56	61	51.50
12	Hand length	17	19	21	22	19.75
13	Hip breadth	26.1	37	40	43.9	36.75
14	Shoulder breadth	30.2	41	45	48	41.05
15	Head height	19	24	27	29.2	24.4

The structure supports the weight of the user despite it being a combination of bamboo and galvanized metal pipes. Table 2 is summary of the cost analysis covering the acquisition of components, design and fabrication of the EDW.

3. RESULTS AND DISCUSSION

Table 2 shows the total cost involved in the fabrication of the indigenous EDW to be over a hundred thousand naira, this is in sharp contrast to the cost of imported ones priced at about six hundred thousand naira [23, 24]. With the cost of a single unit being a sixth of the imported ones, the price can still be further driven down if many units were produced and overhead cost split over the units. Figures 7 and 8 show the front and side view respectively of the EDW consisting of casing for the electronic circuitry, plastic material has been used to conceal and prevent moisture from affecting the circuit system for the modality. LCD is fixed on the plastic to display the voltage of the battery in real time and for charging notification as both solar and mains charge replenishes the power bank. The outlet for the mains charging is also hooked on the plastic casing. To improve the charging time with mains, a higher rated charger was used, this is a trade-off between charge time and battery energy dissipation time. Slower charge with less current would imply that energy was dissipated more slowly.

After fabrication and testing, the following data was observed and recorded. During testing, users of different masses used the vehicle. It supported up to a mass of 100Kg. The battery lasts for a mean time of about eighty minutes for an average load of 85Kg. Figure 9 shows the power dissipation characteristics of the EDW, the wheelchair can work for over an hour twenty minutes when used continuously, while Figures 10 and 11 show the graph of battery charging times with 220V AC mains and 30W DC solar panel. It takes about five hours to charge fully with the mains varying slightly from the expected time of four hours, and about twelve hours with the solar module varying widely from the expected time of 8.5 hours. The large variation in the solar time charge can be attributed to the varying angle of the sun in the course of the charge period and the solar panel not getting adequate light intensity for optimal function. Also, the time it took to charge exceeded a day, thus a certain amount of charge is expected to have been lost in the night while waiting for the next sunrise.

Figure 7: Front and Side view of the finished EDW

Figure 8: Front and Side view of the finished EDW

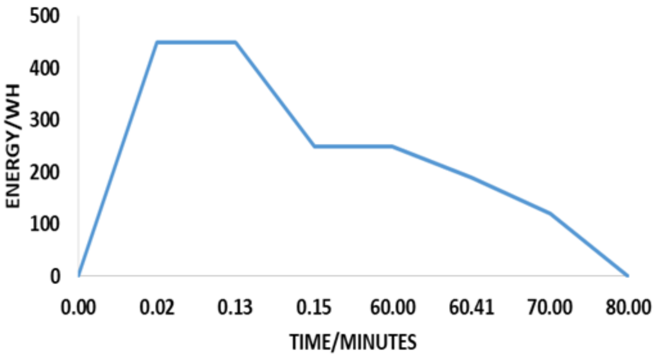

Figure 9: Energy dissipation under normal load condition.

The result is based on a battery capacity of 18 Ah, batteries and 180W DC motors. These were the readily available parts in the market. The aim of the prototype was to ensure that a workable model is achievable. However, the average runtime can be greatly improved upon by using higher rated solar panel and the use of commercial wheelchair-grade batteries which is 36Ah, and the use of low power dissipation motors of 13.2W as used in [5] that runs for twelve hours. The wheelchair is deployable all day round, day or night, the solar panel is capable of converting light beams from both the sun and artificial sources to electricity. However, charging from artificial sources like: incandescent bulbs, LEDs and fluorescent lights, may be less effective compared to sunlight.

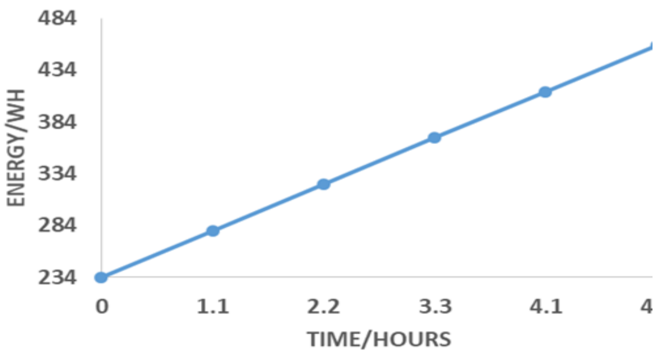

Figure 10: Battery charging time with mains 220V AC.

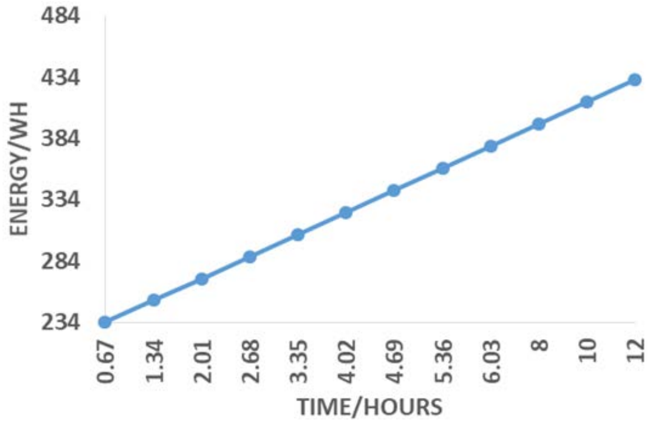

Figure 11: Graph of battery charging time with solar module

Statistics show that the number of people dependent on wheelchair is on the increase due to aging of the industrial workforce, as well as increased road accidents in Nigeria.

4. CONCLUSIONS

In this work, we have considered all the biometric variables necessary for analysis, design and fabrication of cost effective, and ergonomic EDW which runs on 12V DC power supply which can be charged by a solar panel in situations where there is electric power outage. Our goal is for this work to improve welfare for the disabled populace, and help them contribute their quota to the society through improved social participation.

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