Low Cost Robotic Wheel Chair for Disabled People in Developing Countries

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Abstract: There is a need of a mean of locomotion for people with walking disabilities. While many problems can be answered by crutches but there are some cases where crutches might not be able to resolve the problem completely. The answer is the wheel chair. In today's time, with the advancement in technology, the design and motion of the wheel chairs has significantly improved. Today these can be operated using microcontrollers which eliminates the need of human effort. But the cost factor is important as using such technologies may lead to a significant increase in the cost of the equipment. Financial aspects play a crucial role in hampering the spread and widespread usage of such costly equipment especially in developing countries like India. This research paper aims at developing a low cost wheel chair model controlled using a microcontroller.

Keywords: Robotic Wheel Chair, Low Cost, Design, Developing Countries

Introduction:

The robotic wheel chair is the greatest invention for the physically disabled patients as a solution of easy locomotion. However, this was not the scenario around 10 years back. Even today in developing countries like India, Pakistan, Bangladesh etc. many people are still using the hand driven or assisted wheel chairs. This is due to the fact that the commercial cost of the robotic wheel chair is very high when taken in account the spending capability of a handicapped individual.

According to the Census 2001, there are 2.19 crore people with disabilities in India who constitute 2.13 per cent of the total population. This includes persons with visual, hearing, speech, locomotive and mental disabilities. [1]

Seventy five per cent of persons with disabilities live in rural areas, 49 per cent of disabled population is literate and only 34 per cent are employed. The earlier emphasis on medical rehabilitation has now been replaced by an emphasis on social rehabilitation.

Type of Disability	
(a) In seeing	49%
(b) In speech	7%
(c) In hearing	6%
(d) In movement	28%
(e) Mental	10%

Table 1. Census India Yr. 2000-2001

	Population	(%)
Total population	1,028,610,328	100.0
Total disabled population	21,906,769	2.1
Type of Disability		
(a) In seeing	10,634,881	1.0
(b) In speech	1,640,868	0.2
(c) In hearing	1,261,722	0.1
(d) In movement	6,105,477	0.6
(e) Mental	2,263,821	0.2

Table 2. Census of India 2010-11

From various researches it is observed that the market for wheelchairs in India is estimated to be 120,000 units worth US $ 15 million, growing at rate of 10 per cent over last three years. Organised market is $6 million, growing at a rate of 10 per cent annually. Also the cost of robotic wheelchairs is beyond the reach of major part of disabled population. Although various NGOs and government organizations are providing the necessary support to the disabled population but somewhere cost bounds the extent of the help extended to the patients.

Aim of the Research

We are trying to develop a new robotic wheel chair by modification in the design and changing the fabrication materials. The overall cost of the design can be reduced by using the aluminium profiles in the skeletal structure. Instead of using integrated specially designed PCB, simple ATMEGA 8 is used for controlling the direction and speed of the wheel chair. Using such modifications leads to a significant drop in the price of the model of the wheel chair while maintaining its usability and ease of use. Though the aesthetics are not much of a pleasure to eye, it serves the purpose of being a low cost model while serving the usage purpose.

Mechanical Design of the Model

The model of the wheel chair was prepared and simulated in SolidWorks v2012 software. SolidWorks software allows us to design, draft and simulate the working of the model with proper load application over it. The average weight of the person using the wheel chair is assumed to be 80 kg. The net gravitational force exerted on the frame in almost 1 kN (1000 N). The aluminium profile used for designing the frame is 40mm X 40mm.

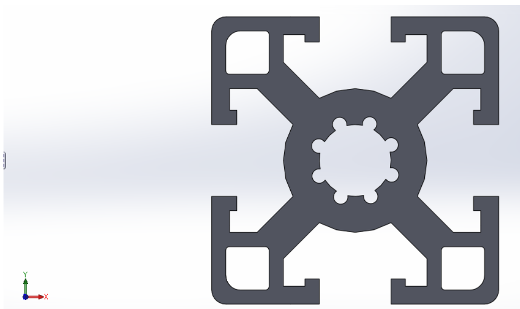

Fig 1. Cross-Section of profile (Front View)

The same profile is used for making the entire frame of the wheel chair.

The profile is made of Aluminium Alloy 6063 T5. The physical properties of this alloy are:

Property	Value	Units
Elastic Modulus	69000	N/mm^2
Poissons Ratio	0.33	N/A
Shear Modulus	25800	N/mm^2
Density	2700	kg/m^3
Tensile Strength	185	N/mm^2
Compressive Strength in X		N/mm^2
Yield Strength	145	N/mm^2
Thermal Expansion Coefficient	2.34e-005	/K
Thermal Conductivity	209	W/(m·K)

Table 3. Properties of Aluminium Alloy 6063 T5

The design of frame is as shown in the following figures.

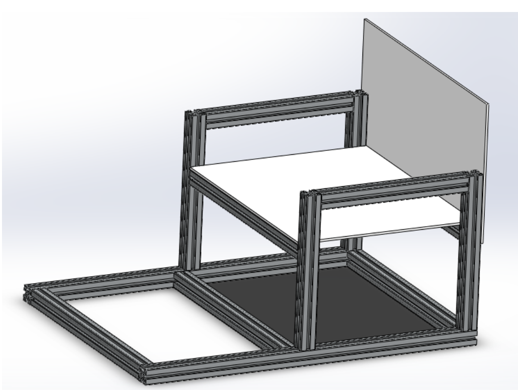

Fig 2. Frame of the chair (Isometric View)

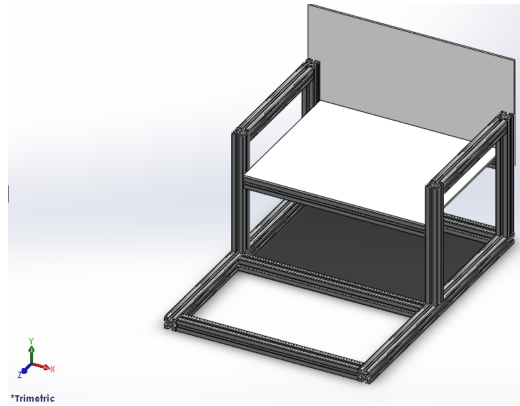

Fig 3. Frame of the chair (Trimetric View)

Design Analysis and Simulation:

Total weight of the model = 15.43 kg

Mesh type	Solid Mesh
Mesher Used	Standard mesh
Automatic Transition	Off
Include Mesh Auto Loops	Off
Jacobian points	29 Points
Element Size	21.1083 mm
Tolerance	1.05541 mm
Mesh Quality	High
Remesh failed parts with incompatible mesh	Off

Table 4. Mesh Information

Total Nodes	326920
Total Elements	181250
Maximum Aspect Ratio	167.87
% of elements with Aspect Ratio < 3	3.36
% of elements with Aspect Ratio > 10	33.3
% of distorted elements(Jacobian)	0.0138
Time to complete mesh(hh:mm:ss):	00:05:04
Computer name:	ANANT-PC

Table 5. Mesh Information - Details

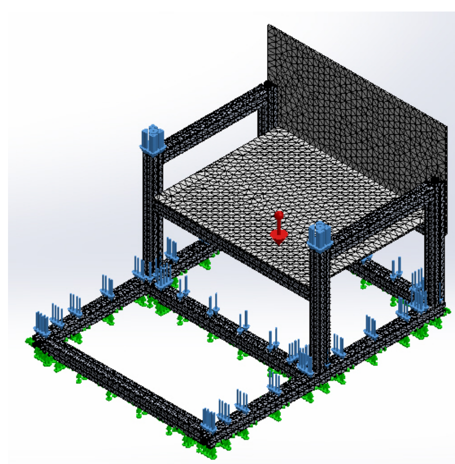

Fig 4. Mesh Diagram

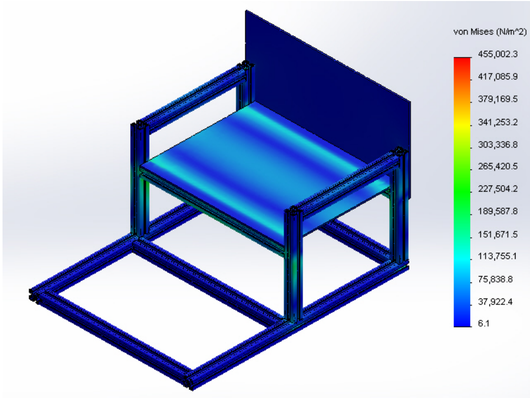

Fig 5. von Mises Stress

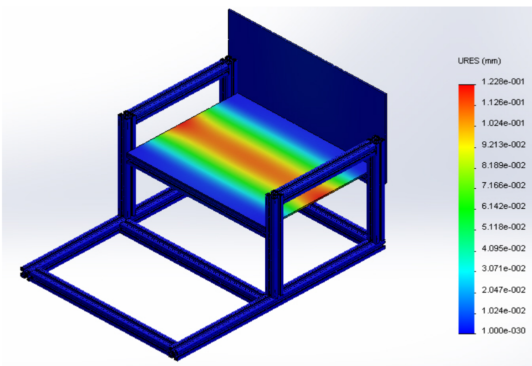

Fig 6. URES: Resultant Displacement

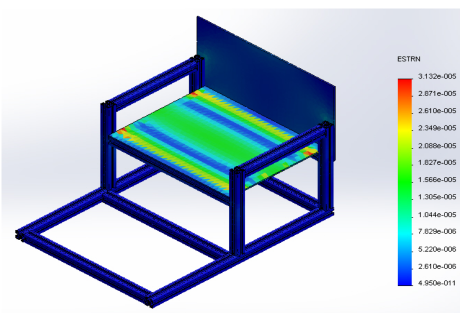

Fig 7. ESTRN: Equivalent Strain

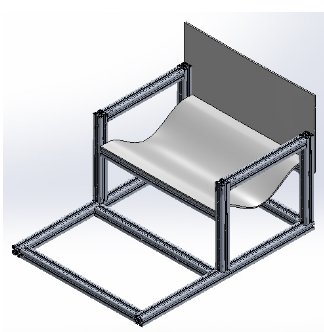

Fig 8. Ultimate Deformation (Scaled at 1:800)

Terminologies Used:

a) **Meshing**: The partial differential equations that govern fluid flow and heat transfer are not usually amenable to analytical solutions, except for very simple cases. Therefore, in order to analyse fluid flows, flow domains are split into smaller subdomains (made up of geometric primitives like hexahedra and tetrahedral in 3D and quadrilaterals and triangles in 2D). The governing equations are then discretized and solved inside each of these subdomains. Typically, one of three methods is used to solve the approximate version of the system of equations: finite volumes, finite elements, or finite differences. Care must be taken to ensure proper continuity of solution across the common interfaces between two subdomains, so that the approximate solutions inside various portions can be put together to give a complete picture of fluid flow in the entire domain. [7] The subdomains are often called elements or cells, and the collection of all elements or cells is called a mesh or grid. The origin of the term mesh (or grid) goes back to early days of CFD when most analyses were 2D in nature. For 2D analyses, a domain split into elements resembles a wire mesh, hence the name.[8]

b) **Von Mises Stress**: The von Mises yield criterion suggests that the yielding of materials begins when the second deviatory stress invariant J_2reaches a critical value. For this reason, it is sometimes called the J_2-*plasticity* or J_2flow theory. It is part of a plasticity theory that applies best to ductile materials, such as metals. Prior to yield, material response is assumed to be elastic. [9]

c) **Equivalent Strain**: A scalar quantity called the equivalent strain, or the von Mises equivalent strain, is often used to describe the state of strain in solids. Several definitions of equivalent strain can be found in the literature. A definition that is commonly used in the literature on plasticity is

$$\varepsilon_{eq} = \sqrt{\tfrac{2}{3}\boldsymbol{\varepsilon}^{\text{dev}} : \boldsymbol{\varepsilon}^{\text{dev}}} = \sqrt{\tfrac{2}{3}\varepsilon_{ij}^{\text{dev}}\varepsilon_{ij}^{\text{dev}}}$$

$$\boldsymbol{\varepsilon}^{\text{dev}} = \boldsymbol{\varepsilon} - \tfrac{1}{3}\text{tr}(\boldsymbol{\varepsilon})\ \mathbf{1}$$

This quantity is work conjugate to the equivalent stress defined as

$$\sigma_{eq} - \sqrt{\tfrac{3}{2}\boldsymbol{\sigma}^{\text{dev}} : \boldsymbol{\sigma}^{\text{dev}}}$$

Locomotion Parts:

a) **Front wheels:** The front wheels of the wheel chair are used as support wheels and are neither driven nor they help in direction control. The wheels are 10 inch in diameter and are pneumatic so as to be easily replaceable anywhere in case of any event. Also as they are the most suited for off-road purposes, they serve as good shock absorbers. The thickness of the wheels may vary from different manufacturers.

Fig 9. Pneumatic Wheel 10”

b) **Rear Wheels:** The rear wheels are not pneumatic rather made of vulcanized rubber to provide better grip on the driving surface. Also they are of less thickness than the frontals and are almost 20 inch in diameter. The thickness is almost halved and these are wheels that control the speed and the direction of the wheel chair.

Fig 10. Rear wheel

c) **Motor**: There are two motors which drive the left and right wheels independently. The motor power is ranging from 150W to 200 W. The torque rating of the motor is ranging from 50kg-cm to 80kg-cm. The higher torque rating enables the motors to drive the wheel at a higher efficiency and prevents slipping due to the chain link mechanism of power transmission in the wheel.

Fig 11. Side Shaft Motor

d) **Drive Chain:** The drive chain is supported by two gears and linked chain driven by the gear attached to the motor. The smaller gear shown in the figure below is the gear attached to the motor and the bigger one is attached to the wheel which is modified to attach a gear along with it. The gear transmission ratio is 2:1 (bigger: smaller).

Fig 12. Drive Chain

e) **Battery:** The batteries used in these wheel chairs are the rechargeable NiMH (Nickel Metal Hydride) batteries as they can withstand various environmental factors way better than other batteries. Also these are durable in nature and can give us a better performance as compared to other battery types. The battery used in this vehicle is 4 sets of 24V DC supply, 4500 -5500 mAh (milli-Ampere hour) which provides us a constant running capacity of around 140 minutes which is enough for a normal person for his/her daily routine. Also since these batteries are chargeable and have a very high number of charge – discharge cycles, they can be used over a long period of time without being replaced, hence further reducing the maintenance costs. Also these batteries are much more environment friendly as they contain no cadmium and contribute more towards eco-friendliness.

Fig 13. NiMH battery set with connector wires

Controlling Parts:

a) **ATMEGA 8 Controller:** The low-power Atmel 8-bit AVR RISC-based microcontroller combines 8KB of programmable flash memory, 1KB of SRAM, 512K EEPROM, and a 6 or 8 channel 10-bit A/D converter. The device supports throughput of 16 MIPS at 16 MHz and operates between 2.7-5.5 volts. [12] This was selected because of the low power consumption and low costs.

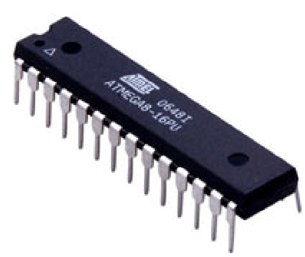

Fig 14. ATMEGA 8 Microcontroller

b) **L298 Motor Driver:** The L298 is an integrated monolithic circuit in a 15-lead Multiwatt and PowerSO20 packages. It is a high voltage, high current dual full-bridge driver de-signed to accept standard TTL logic levels and drive inductive loads such as relays, solenoids, DC and stepping motors. Two enable inputs are provided to enable or disable the device independently of the input signals. The emitters of the lower transistors of each bridge are connected together and the corresponding external terminal can be used for the connection of an external sensing resistor. An additional supply input is provided so that the logic works at a lower voltage.

Fig 15. L298 Motor Driver IC

Control Mechanisms:

The robotic wheel chair is controlled using the ATMEGA 8 microcontroller and L298 motor driver IC using the PWM (Pulse Width Modulation) and PID (Proportional Integral Derivative) feedback control. Usage of the PWM helps us to manipulate the speed of the individual motor i.e. increase or decrease as per the requirement. The PID adds in an extra factor of control over the speed control via feedback mechanism. The accuracy and sensitivity of the speed manipulation is increased significantly with the usage of PID along with PWM. The direction of the wheel chair is controlled by the PWM control of the motors. When the individual has to turn in any direction he/she may press the corresponding button while keeping the forward motion intact. The controller will register the user input and will command the motors to increase or decrease the speeds accordingly. For turning left, the motor on the left rotates at a slow speed as compared to the one in right. For turning right, the right motor rotates slowly than the left one.

Control Circuit:

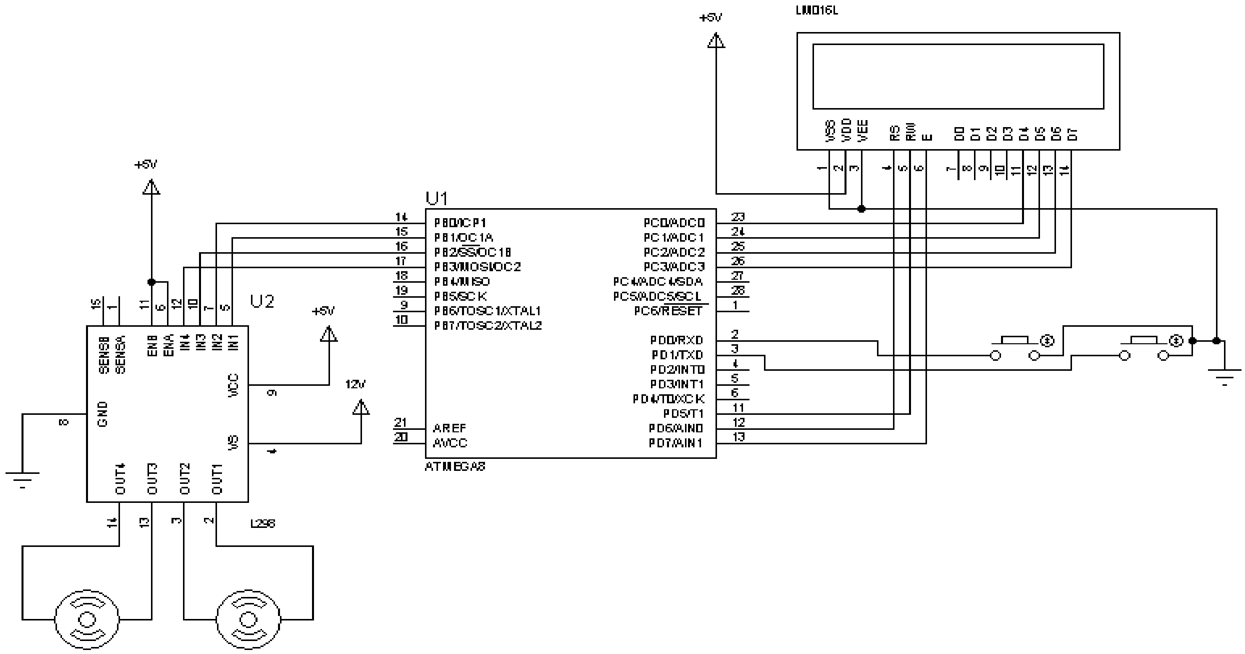

Fig 16. Control Circuit

Control Algorithm:

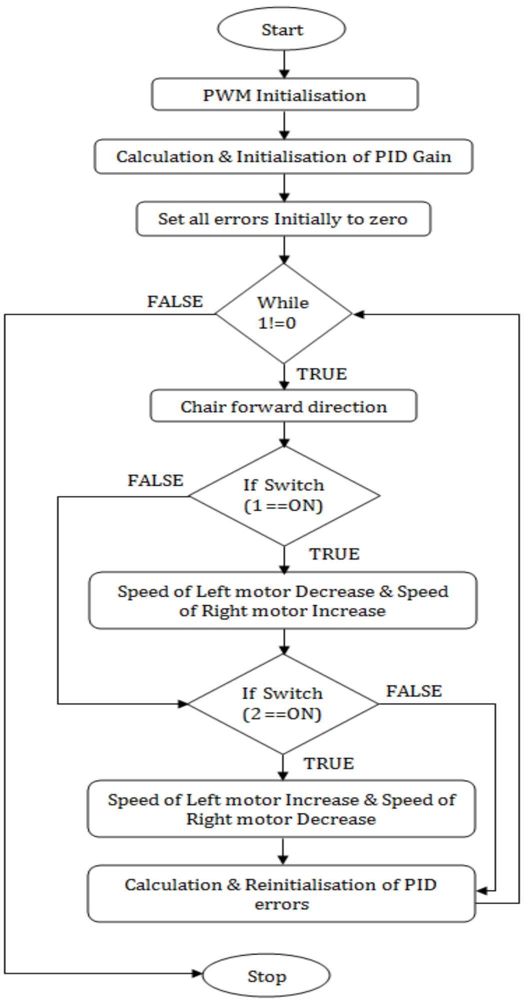

Fig 17. Control Algorithm

Final Design:

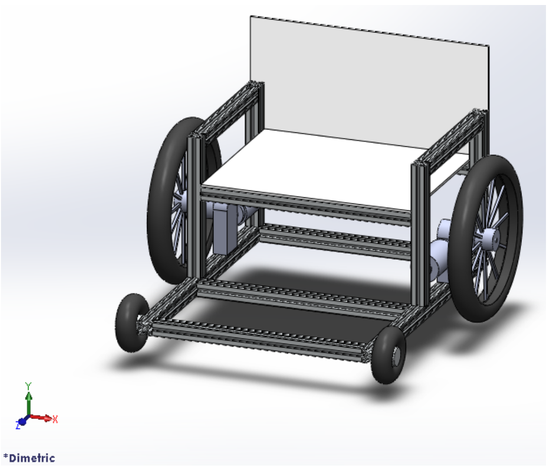

Fig 18. Final Dimetric View

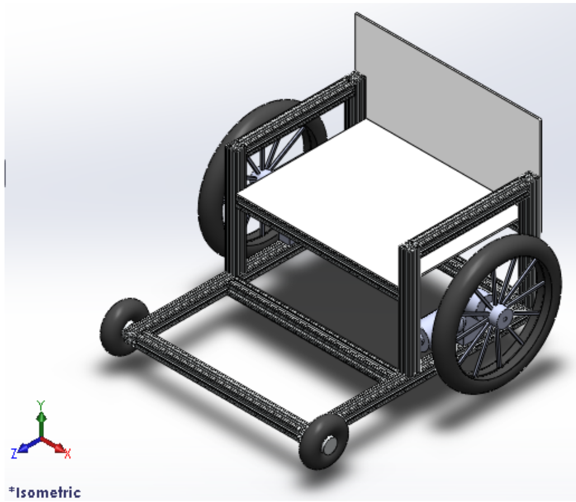

Fig 19. Final Isometric View

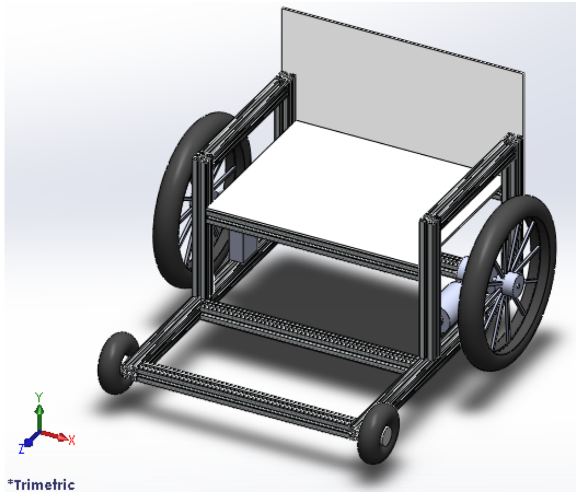

Fig 20. Final Trimetric View

Results and Discussion:

The designs for the mechanical as well as electronics circuit have been designed for a new model of the robotic wheelchair, which is very much cost friendly as well as environment friendly. The overall cost of this model is estimated to be around INR 25,000 as compared to INR 45,000 in the current market. [13] This will lead to a trend of shift of disabled people towards the robotic wheelchair in the developing countries where there can be external support provided by the Government Support Organizations and NGOs like Red Cross, etc.

The price of the wheelchair can further be reduced when produced in high quantities and subsidy is provided by the government in order to distribute a large number of support equipment to a large population of disabled people.

The future scope for this research is aimed at designing a similar robotic wheelchair but with the ability of moving in any terrain, be it uphill, downhill, loose sands, watery slurry etc. This shall make it rugged and take the research to a new level for the betterment of facilities for the physically challenged.

Furthermore, the control of the wheelchair can be changed i.e. it can be designed to be controlled via a wearable glove like structure giving the freedom from the usage of switches and buttons etc.

Conclusion:

In this paper, by integrating new materials and technology we have successfully a new and improved design for the robotic wheelchair for the assistance of the disabled people. This design is compared against other existing designs and this is observed that our design is highly cost effective and improved quality. Further research and development may lead to global acceptance and manufacturing of the wheelchairs using this design.

Acknowledgements:

Dr. Rajesh Singh received his B.E degree in Electronics & Communication from Dr. BR Ambedkar University Agra, India, M.Tech (Gold Medalist) in Digital Communication from Rajeev Gandhi Technical University Bhopal, India & also completed Ph.D. in wireless personal area network design and simulation using ZigBee transceiver module. He is currently associated with Baddi University of Emerging Sciences and Technologies, Baddi, Himachal Pradesh, India in the Department of Electrical & Electronics Engineering as the head of the department. Dr. Singh has published 30 papers in national/ international conferences/ journals. He is also the reviewer of ICEOE conference.

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Aadhar Rastogi is pursuing his B. Tech in Automotive Design Engineering from University of Petroleum and Energy Studies Dehradun, India.

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