

## Design and Fabrication of a Stair Climbing Hand Truck

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## Article

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**ABSTRACT**

This topic deals with the designing and manufacturing of a hand truck, which can climb stair with less effort compare to carry it manually. The technical issues in designing of this vehicle are the stability and speed of the vehicle while climbing stairs. However, the steepness of the stairs is also the important concern of this study. The uses of this special vehicle are in the frequent lift of goods such as books for library, medicines for hospital, regular goods of any technical or non technical institutes, or transportation any toxic material for industries and give freedom to the retarded person or paralyzed patients to move anywhere over flat surface as well as stairs. The vehicle has four wheels arrangement to support its weight when it moves over the flat surface. Each set wheel frame consists of three wheels attached with nut and bolt. Using of this vehicle, the labor cost can be reduced as well as huge amount of loads can be transferred uniformly with less power consumption. Moreover, considering some drawbacks due to lack of implementation of all techniques during manufacturing phase the test and trial run showed considerably significant and encouraging results that might help the future researchers to incorporate a gear box and steering mechanism to make the vehicle more versatile.

**INTRODUCTION**

Lifting objects ,loads such as books, food grains etc. to store above the ground level, or even patients to move upper level from ground is not easy job, especially where there is no lifting facilities (elevator, conveyer, etc) Moreover, in most of the buildings in the world does not have elevators or escalators. In this case human labors are considered to be the only solution. Labor is becoming costly as well as time consuming in the developed countries, where growth rate is getting negative. This problem can be solved if a vehicle can lift loads while traveling through stairs. The project introduces a new option for the transportation of the loads over the stair. Most of the buildings of the country are structurally congested and unavailing of elevator facility so it is difficult and laborious to lift up heavy loads. The stair climbing hand truck can play an important role in those areas to lift loads over a short height, like libraries, hospital, and in construction area. The vehicle, which can move upper level through stairs, or run in very rough and rocky surfaces, is called stair climbing hand truck or say stair climbing vehicle.

In the year of 2000, a group of researchers <sup>[1]</sup> introduced a rover type of vehicle to run over stepped path. Using a rhombus configuration the rover had one wheel mounted on a fork in the front, one wheel in the rear and two bogies on each side. Researchers around the world are thinking seriously to redesign such vehicle, which will be economical and affordable. Chang Hsueh-Er <sup>[2]</sup> developed a five wheeler trolley, which was driven by manual power. Anastasias et al. <sup>[3]</sup> and D. Helmick et al. <sup>[4]</sup> designed a robotic carrier with belt driven. No wheel was introduced in his robotic carrier. However, none of them think about automatic vehicle that can carry loads through stairs.

In various research projects all over the world the different locomotion concepts for mobile robots have been analyzed and new concepts have been proposed <sup>[5, 6]</sup>. Good general surveys are provided in <sup>[5,6,7,8,9,10,11,12]</sup>. In <sup>[8]</sup> over 300 mobility concepts and more than

400 navigation concepts have been generated and discussed, yielding to three candidate systems, a symmetrical walker with six identical legs, a four-wheeled vehicle and a so called attached scout concept with six wheels.

In this article the design and manufacturing of a stair climbing hand truck has been presented. The vehicle is designed in such a way that it can climb a stepped path (like stairs) with its modified wheel structure. Not only on the stairs, it also move with load over flat or rocky surface. This is the individuality of this vehicle. Wheeled rollers are the optimal solutions for well structured environment like roads or habitations. But off-the road, their efficiency is very dependent on the typical size of encountered obstacles that have to be overcome in a standard motion mode. This is the case for [13,14,15], which can typically overcome obstacles of their wheel size, if friction is high enough. Adding real climbing abilities to a wheeled rover requires the use of a special strategy and often implies dedicated actuators like [16, 17] or complex control procedure like [18, 19]. During the designing process the main focus was given to design its wheel, and design of size of frame especially for the stair. Normal circular wheel is attached here with nuts and bolts to the frame which guides the set of three wheels are getting power from the manual pulling effort. The planetary wheels are apart by 120°, the modification of the wheel frame was the main task in the project. First straight arm wheel frame (figure 1) was designed, which finally replaced by the wheel frame shown in the figure 2.

## DESIGN AND MODIFICATION

In this project, the final design was an outcome of a sequential analysis and modification of stages which had been started with a simple roller based design. To attain higher efficiency and greater stability the more focus is concentrated on the design of frame and strength of wheels

### A. Modification of roller which only rolls over flat surface to the rollers which can climb the stairs

In the initial design, each single or double wheel set on either side is only capable of moving any vehicle on flat surface, but further study on same topic helps us to carry any goods on vehicle on stepped surface (stairs). In this concept we attached set of three wheels on either side of vehicle rather than single or double wheel. These tree wheels are attached to frame 120° apart with help of nut and bolt.



Figure 1: Initial design of Roller based wheel arrangement and wheel frame

### B. Modification of straight to curved wheel frame

The straight wheel frame shown in the figure 1 takes more thrust to tilt the wheel frame to engage next planetary wheel. The length of each arm is high and thus creates vibration and the vehicle would be unstable. In the present design, the wheel frame was made curve so that the front surface of the arm could not collide with the edge of the stair. The optimization of the curvature was done to eliminate above problem. The curve wheel frame (figure 2) also requires less power to tilt compare to straight frame (figure 1).



**Figure 2: Modified wheel frame**

**C. Modified final design**

In the first design, the power transmission to the single or double wheel trolley is useless to climb the stairs due to height factor of stairs creates huge obstacle on the way of vehicle. Also the design of the straight wheel frame became more complicated and was needed modified with its curved-spherical shape to give proper drive, which creates more frictional force. For these reasons, three wheels set on each side of vehicle attached with frame was introduced to provide smooth power transmission in order to climb stairs without obstacles. Frame arrangement is suitable to transmit exact velocity ratio also. It provided higher efficiency and compact layout with reliable service. Easier maintenance was possible in case of replacing any defective parts such as nut, bolt, washer, etc.



**Figure 3: 3D view of wheel arrangement**

In figure 3, the arrangement of vehicle parts such as wheel frame, shaft wheels are shown. The wheel is attached to the wheel frame at three corners of frame and shaft is attached at the center and the planetary wheels are getting power from the human power via centered shaft and bearing arrangement. Two wheel frames are attached both sides of the wheel arrangement.

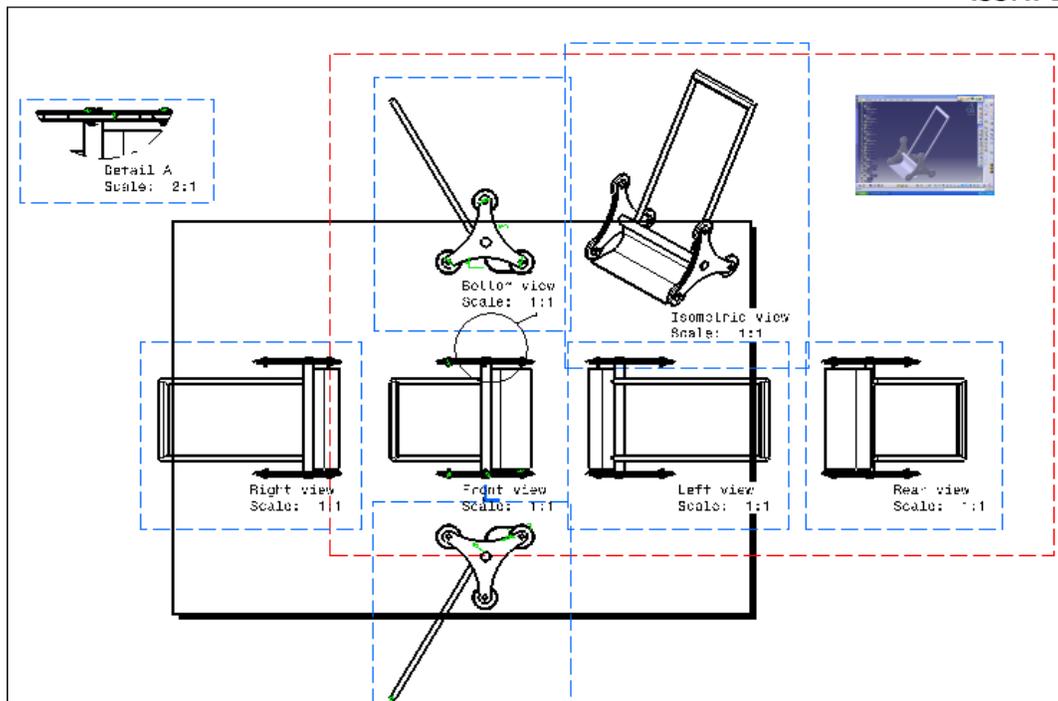


Figure 4: Orthographic view of wheel and shaft arrangement

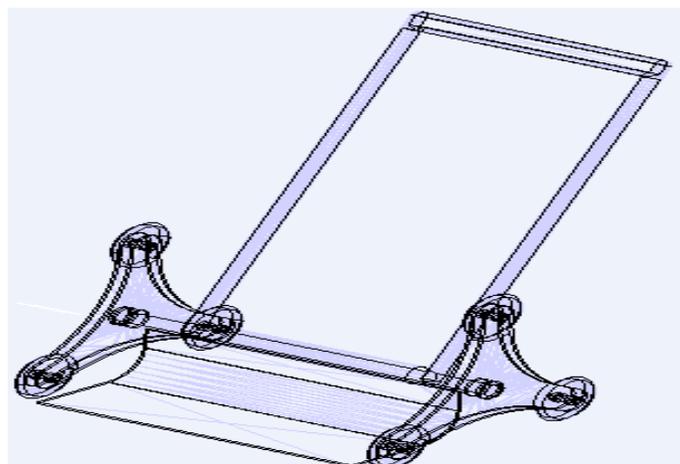


Figure 5: Assemble drawing of the wheel and shaft arrangement

Figure 4 shows all parts required a single shaft. Two similar shafts are need for a four wheeler stair climbing vehicle. The assembly of the parts is shown in figure 5

### RESULTS AND ANALYSIS

It was found that the vehicle was moving well over the stair. It can move on flat surface uniformly at 20 rpm without any fluctuation and there was no variation of speed over steps. It was observed that there was very low noise and vibration over flat surface or stair. It was observed that the vehicle was disturbed when it faced the stair of different step sizes. This was because of the shape and size of the wheel frame. Therefore for a range of stairs size can be considered for this vehicle. Although, different sizes step are not usually available in building design. It showed good performance when the step size was uniform. Here in this project separate frame can be used to move over the stair of different size and shape, which made its use over wide range of size of stairs. From the test run of the vehicle it was seen that the maximum height the vehicle could climb the stair whose inclined angle was 44° maximum. If the inclination is more than 44° it would fail to climb the stair. In building construction, very few stairs are generally available having inclination more than that i.e.44°. The smooth ramp angle ( $\theta_s$ ) was not listed for the vehicle. But it can be easily predicted that stair inclined angle ( $\theta$ ) is less than that

of ramp ( $\theta_s$ ).

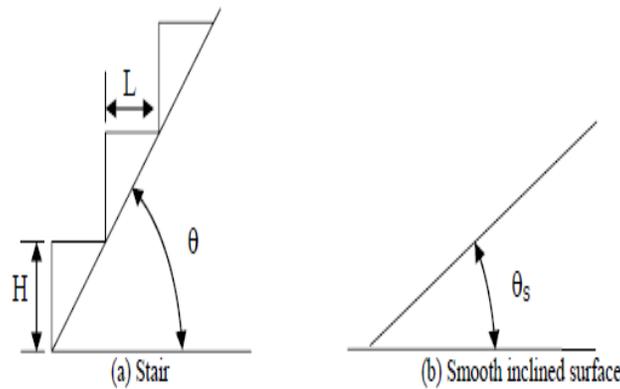


Figure 6: Maximum climbing angle, ( $\theta$ ,  $\theta_s$ )

The velocity of the vehicle during climbing the stair was higher than that on the flat surface as the wheel frame (higher radius) was used to climb stair. The velocity of the vehicle on the stair was 55 in/hr. However; the speed of the vehicle running on a ramp was not measured. This speed should not be higher or equal to the speed on the horizontal surface. From the above discussion, it could be summarized that considering some of the limitations, the vehicle was an effective alternative to transport loads using stairs. Some limitations could not be avoided because of the lacking in technological availability. This pioneer project, with a little further improvement, was hoped to be succeed to meet up the demand of carrying loads over the stair.

#### Recommendation for Future Researchers

A sensor and steering wheel can be implemented to move around the stairs. Sensor and moter would be a replace of a manual power, which runs the frame wheel. A suspension system could be incorporated to minimize shock and vibration. Using a timer circuit, the movement would be more precise, accurate and easy to operate. With the help of timer circuits, the vehicle could run over a predetermined step size smoothly without using any switch Single motor could be used to move over both the flat and tread of the stairs. It might be done by introducing an elongated shaft aligned with the wheel frame by using a spring, the shaft was resisted by an obstacle, and it forced the key to enter inside the notches of the frame. As a result, the whole frame was bound to rotate along the axis of the axle.

#### CONCLUSIONS

Though this project had some limitation as a first step of making any Stair Climbing hand truck , it was a pioneer project. During the test run of this project, it was realized that it would capable of carrying heavy load without suffering any deformation or local fractures if it would go into real world production at an ideal scale. Though the initial cost of the project seemed to be higher but more accurate manufacturing would shorten this.

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