Stair Caddy

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Abstract
As the population ages, a need has emerged for assistance to be provided to them for basic day-to-day activities. One of the most strenuous activities for elderly persons is climbing stairs and carrying additional items can make this task increasingly difficult. To address this problem, many different design concepts and lifting mechanism were considered to make this task easier. In order to determine our design goals, a survey was distributed to potential users. The survey showed that the device should be able to lift 40 lbs of groceries and weigh no more than 20 lbs. After careful consideration, a motor-driven design concept that could be attached to existing carts was chosen as the best way to address this problem. This solution will not do all the work for the user, but will substantially reduce the amount of effort that the user has to put in. The motor will be used to drive a foot into the stairs, which will lift the cart up so the user can easily pull the cart forward onto the next stair. The motor will be driven by a rechargeable battery and controlled by a user-activated switch which can be mounted to the handle. Once the cart has been lifted up the stair, springs will return the foot to its original position and the device will be ready to use at the next stair. Since this device cannot travel downstairs, consideration to weight has to be given so that it is easy to carry when the basket is empty.
The Need for Project

Carrying loads up stairs has been a problem that people have faced for centuries. One of the most common instances seen today comes from transporting groceries. Carrying groceries up stairs has proven to be a difficult task for many people, especially the elderly and those living in apartment buildings without elevators. When walking around a city, many people can be seen using their own personal carts to get groceries from the store to their homes. Anyone who has done this and does not live on the first floor of their building will tell you that getting a loaded cart up the stairs is a very inconvenient and difficult task involving either one trip with a very heavy load or multiple trips with lighter loads. Because of this, interest has been shown in a device that could assist with this task.

The Design Project Objectives and Requirements

The design should be lightweight, easy to use, and as affordable as possible while still being able to lift a minimum of 40 pounds of groceries.

Design Objectives

Since the goal of this project is to make life easier for a group of people, the main objective will be to make the device easy to use. The device will also have to be attachable to a wide range of existing carts because the people that already own a cart are the ones most likely to use this device. Finally, the whole system has to be easy to transport downstairs because the device will only be able to travel upstairs.

Design Requirements

The design requirements were obtained based on feedback obtained through a survey shopping habits (Rep. 7.1). In the survey, 154 people participated and the most common answers were used to obtain the design requirements. Based on the surveys, a weight of 40 lbs of groceries needs to be lifted. Most people also said that they would be comfortable carrying up to 20 lbs on stairs, which is the maximum weight that will be allowed for the empty cart with lifting mechanism attached. Other design requirements are based on standard stair size for residential buildings. The lifting mechanism will have to be able to lift the cart at least 6.75” since that is the typical height of one stair. Stairs are also typically 11” deep, meaning that the system and the wheels will have to amount to less than that to be able to comfortably rest on a stair between lifting periods (Rep. 5.1). The device will be powered with a rechargeable battery that the user will control with a switch. One final requirement is that the device must be versatile and able to attach to many existing carts.
Design Concepts Considered

The considered design concepts started with a thorough patent and existing product search to see the ideas that have previously been investigated for similar applications. One expired patent utilized a design for a collapsible wheel that would allow the wheel to form a grip around the stair where it could then be pulled up by the user or incorporate a powered system that could provide the lifting force. This idea was explored mostly because it does not add equipment that would add additional geometric features to the outside of the cart. This is important for a stair-climbing device because the space available on the stairs is limited. However, the geometry involved in this design proved to be too complicated and no definitive proof that this would work in all scenarios could be obtained (Rep. 6.1.6).

Many different lifting mechanisms were considered after that and were all placed in a design decision matrix where it emerged that the best option was to use an electric motor. Factors that were considered included cost, manufacturability, part availability, weight, complexity, speed, ease of use, and reliability (Rep. 7.3).

Recommended Design Concept

The design that emerged as the best decision incorporated a motor and gearbox to provide the lifting force. The design will be an attachment for existing carts. In order to meet the main requirements in the best way possible, the final design incorporates a motor with a gearbox to provide the lifting force. A search of electric motors revealed that available motors were high speed and low torque, which makes a gearbox necessary for this application. The motor is powered by a rechargeable battery and can be turned on and off by a switch that can be attached to the handle of the cart. The gears are used to spin a spool that will wind a cable. The cable will wrap around a pulley located at the bottom of the device and then attach to a foot, which can be seen as the protruding part Figure A. The plate located at the bottom of the device has a hook-like feature that can attach to the axel of a cart. Based on observations of many different cart designs, all existing carts were found to have stationary axels with freely rotating wheels so this will not affect the ability to wheel the carts around. Additional fastening straps will be used to hold the device in place but
are not pictured. When the motor is activated, the cable will pull the foot down, which will raise the cart above the stair, where the user can easily pull it forward to the next stair. Also attached to the foot is a group of springs, which will return the foot back to its original location when the motor is turned off so that it is ready for the next stair. The springs and cable can be seen in the cut-away view in Figure B. All of these connections are made on the hollow tube contained within the column, which can be seen in Figure C. The tube is held in place using slots cut into the four aluminum columns that surround it.

Analytical Investigations

Seen in Figure D, the first focus was the gear reduction from the electric motor. A gear reduction of 6.89:1 is incorporated to increase the torque from the motor while decreasing the speed. The torque is increased from 17.4 in-lb to 120 in-lb while the rotational speed is reduced from 7.5 rpm to 1.08 rpm. This allows the motor to provide enough torque while also reducing the speed of the device to a more comfortable rate of travel for climbing stairs. The amount of gears is necessary in order to keep the size of this design to a minimum.

Other analytical considerations were given to the foot design, which will contact the stairs and support the load during operation. Designs involving different thicknesses and lengths were explored using finite element analysis until the perfect balance of tolerable stress and amount of material was found. This turned out to be a thickness of 0.75” with a length of 2”.

Experimental Investigations

Initial experiments began with using a normal cart and trying to pull it up the stairs. Since the design requires the user to provide the final pull to get the cart onto the next stair, an investigation was used to determine how much of the wheel would be required to be lifted above the stair to easily move the cart onto that stair. Through experimentation, a height of 3” above the axel was determined to be adequate.

Two other experiments currently being performed involve the fatigue characteristics of the springs and the strength of a 3-D printed housing for the battery and motor, which can be seen at the top of the first picture. Since the springs will constantly be extended during use,
it is important to see how many of those cycles it can go through and still perform adequately. The strength of a 3-D printed part is also a concern and sample parts are being made for Instron testing.

**Key Advantages**

The biggest advantage is that this design can be attached to an existing cart and will not require the purchase of a new cart for those that already have one, which will greatly reduce cost. The design also incorporates a rechargeable battery, making it easier to maintain than many of the other ideas, such as obtaining a compressed gas cylinder for a pneumatic device.

**Financial Issues**

A target cost of $30 was the initial goal. However, a total of $350 has been spent on the prototype. The distributed survey showed most people interested in this product would be willing to spend $30 but $350 has been spent to build the initial device. The main contributor to the cost turned out to be the gears. Investigations into cost reduction will have to be performed to determine if this design concept could be made into an affordable product with the main focus being on the gears. Efforts can be made to try to find cheaper gears or reduce the number of gears necessary.

**Recommended Improvements**

The biggest consideration for improvements will be given to cost-reducing ideas. Since the biggest issue is to reduce cost, most improvements will focus on price. Besides improvements to the gearbox design mentioned previously, using a stronger motor could reduce the amount of gears as well. Another cost reduction could be found in replacing the aluminum with plastic, which could also reduce the total weight of the device. One improvement that would add a substantial amount of money to the product but is worth considering would be adding a safety device that could stop the cart from falling down the stairs incase the user losses their grip on the cart.