

Design Analysis of Battery-Operated Cargo Bicycle with Adjustable Cargo Space

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Abstract: - An electric cargo cycle which contains an adjustable frame, for changing the size of the cargo space, as well as the bike length is designed and developed. The developed prototype is built by using a normal bicycle as the base, with addition of a self-designed frame for the purpose of carrying cargo bucket. The developed design has a weight of 70 kg with 240 cm, 95 cm and 40 cm as length height and width respectively. The designed cargo bike has a load carrying capacity of 120 kg. The design is powered with 250 W electric motor and can move with maximum speed of 25km/hr. The steering mechanism is rocker arms based. The steering mechanism, cargo bucket and the base frame are made in two parts for commuter convenience. The cargo bucket is front mounted, on a sliding frame that enables one half of the bucket to be slid into the other half. The design has both electric and non-electric driving modes. The design find application for delivering goods, usage for short transport of goods, and industrial work. Also, the electric driven feature helps in climbing elevated terrain and reduces fatigue during the load carrying. Testing of the product was made and was found suitable for the designed parameters

Keywords: Cargo Cycle, Adjustable Frame, Electric Motor, Bicycle,

1. Introduction

Bicycles are the most eco-friendly and cheap source of transport in today's time. They have found their use in all aspects of life, be it personal or commercial. With the ever-increasing population and traffic on the roads, bicycles prove to be a means of travelling through the crowded roads with ease. Also, bicycles now have the capability of carrying small loads in baskets. Modifications are being made and the concept of cargo bicycle has come into picture in the recent times. These bicycles can carry heavier loads and are being used in delivering goods, for shopping purposes or just for transporting things from one location to another. However, when it comes to architecture for bicycle riding, new designs are developed by the designers catering to the requirements of the customers. to get rid of the emissions in congested areas governments are also promoting this mode of transport. Safety standards are developed for each category of electric vehicle type for better safety of vehicle and passenger. (Malik. V etal 2022) (Pandey. S etal 2023) (Vashist. D etal 2022) [1],[2],[3]. Bicycles has shown better maneuverability through the crowded roads due to their compact sizes. Cargo bicycles also prove to be a great advantage for last mile deliveries on small routes. (Cairns, S. et al, 2017) [4] Also, the use of cargo bicycles helps in lowering the number of motorized parcel delivery vehicles on small routes and when the load to be carried is low. This also reduces the chances of the delivery services to suffer from road congestion problems. As the effort required to carry load by the rider increases, a good alternative can be to include electric drive to the cargo bicycle. It helps in making speedy travels while also helping to climb slopes, and providing a low-cost mode of transport. It is a non-polluting method for enhancing the overall riding experience and making the use of the bicycle much better. These can also be a good alternative to engine

powered vehicles for small daily jobs like carrying groceries, etc. (Choubassi, C. et al, 2016) [5] (Klepfer M. et al, 2012) [6]. Hence, looking at the current scenarios and the possible improvements that can be seen in this field in the future, cargo bicycles make a promising product, worth researching and developing on a large scale. The objective of developing the proposed design is to provide a cargo bicycle that has the capability of adjusting the cargo space according to the requirement of the user. This gives it an advantage of having a range of capacity to carry load. Also, it aims at having an electric drive. This gives the bicycle a dual drive capability for improving efficiency of riding. The cargo bicycle can be used in both industrial and personal uses. The objective of the design is to have a cargo bicycle with a frame and cargo space, which can be adjusted according to the users' requirement, along with shortening and lengthening of the bicycle's length. Also, the bicycle shall also feature electric mode for ease of operation during carrying of heavy loads and maneuvering slopes along the road.

Contemporary cities are becoming more and more crowded, polluted and devoid of space. (Decker K. D. et al, 2012) [7], (Jorna R., M. et al, 2013) [8] (Mühlbacher S. et al, 2010) [9]. At the same time, along with the development of e-commerce, the logistic flows are growing rapidly, which is an increasing challenge for city authorities. (Sadhu S., T., et al, 2014) [10] Sustainable development of urban logistics is becoming more and more important for the quality of dwellers life, while the solution of two main problems - congestion and poor air quality is the key to success in this field. (Adams-Prassl, J., et al, 2016) [11] The use of cargo bikes as a means of transport operating at least part of freight flows within the city has a positive impact on both problems. The present work presents the course and results of field research on the use of cargo bikes in urban logistics. (Agency, et al 2019) [12]. The use of cargo bikes to deliver parcels allows to reduce the number of motorized vehicles, (Anderluh, A., et al, 2017) [13]

The cargo bikes also do not reduce the number of vehicles for the served area, but modify the composition of vehicle types. Low noise, smaller, low emission vehicles increase, while delivery vans are reduced. (Arvidsson, N., et al, 2017) [14] Now-a-days there are so many vehicles on road, which consumes more fuel and also hazards our environment. It is our responsibility to reduce the consumption of fuel and its hazardous emission products. (Transport Policy 2022) [15] Taking this into consideration it is our small step towards reducing the use of more fuel consuming vehicles and attract the eye of people towards its alternatives i.e. Electric cargo bicycle. So, an effort was made to design a cycle which would run on an alternative source and also reducing human efforts called as Battery-Operated Cycle.

The transport services are mostly expensive. There are many rural areas still where there is lack of transportation facility, so general activities like carrying products from the market to the villages becomes difficult. (Bjørnarå, H.B, et al, 2019) [16] The cycle is one of the most commonly used vehicles in the world. Due to the efficiency and less cost, the bicycles are used in a large in both rural and urban areas for both individual purposes as well as for carrying goods. A cargo bicycle is a kind of a bicycle which may have the feature of connecting a trailer/trolley in the front or at the rear part of the bicycle. Nowadays readymade attached cargo bicycles are also available, which can be used for carrying various things. (Boterman, W.R., et al, 2020) [17] These are human powered vehicles designed and constructed for transporting loads. The design includes a cargo area consisting of an open or enclosed box, a flat platform, or a wire.

In the present bicycle design, there is no provision for carrying and holding of load. The proposed design takes care of this issue. The existing cargo bicycle models present in the market have a fixed weight carrying capacity, this area has been explored and variable weight carrying feature is proposed in the new design. The new design also provides a solution for varying the cycle length for ease in travelling between traffic. The proposed mechanism is unique and can be considered in future designs.

2. Methodology

The proposed design was planned to overcome the existing problems as stated above which as a cargo compartment, where space can be adjusted according to the user's need. The design has both electric and non-electric driving modes.

The cargo bucket is front mounted, on a sliding frame that enables one half of the bucket to be slid into the other half, using a mechanism similar to a drawer. The electric driven feature helps in climbing elevated terrain and reduces fatigue during the carrying of load. The design was developed in AutoCad and Solid Works Software as shown in Fig. 1 to 4.

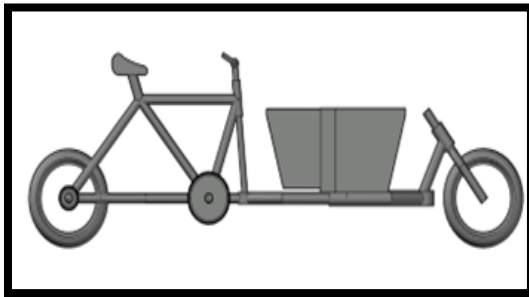


Figure 1.: Isometric View

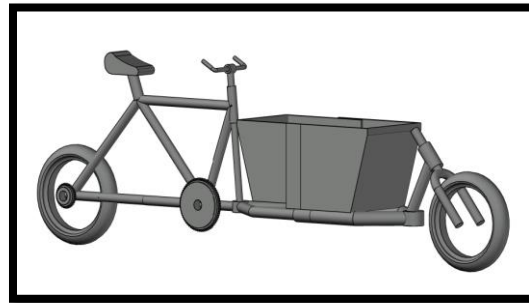


Figure 2.: Right View

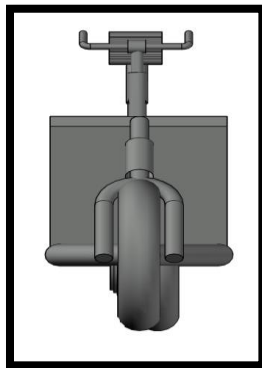


Figure 3.: Front View

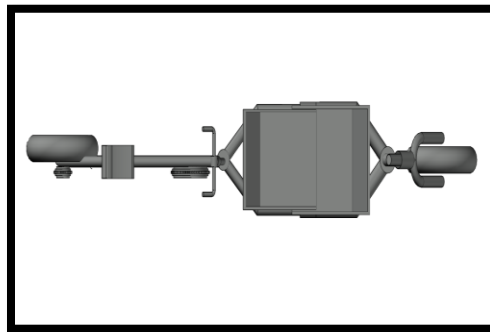


Figure 4.: Top View

The design was made to run on the software for verification

3. Design Calculation

The prepared design is developed with the listed parameters

Mass of vehicle (with occupant), $M = 120 \text{ kg}$

Max. speed, $v = 20 \text{ km/h} = 5.56 \text{ m/s}$ (at zero gradient)

Climbing speed, $v_c = 10 \text{ km/h} = 2.78 \text{ m/s}$

Acceleration, $a = 5.56/20 = 0.278 \text{ m/s}^2$

Frontal Area, $A = 0.38 \text{ m}^2$

Drag coefficient, $C_d = 0.5$

Density of air, $\rho = 1.18 \text{ kg/m}^3$ (at 25°C)

Coefficient of friction, $\mu_r = 0.015$

Acceleration due to gravity, $g = 9.81 \text{ m/s}^2$

Formulae Used:

Acceleration Force, $F_a = M \cdot a$

Drag Force, $F_d = (0.5) \cdot \rho \cdot C_d \cdot A \cdot v^2$

Rolling Resistance, $F_r = M \cdot g \cdot \mu_r \cdot \cos(\theta)$

Gradient Resistance, $F_g = M \cdot g \cdot \sin(\theta)$

Tractive Effort, $F_{trac} = F_a + F_d + F_r + F_g$

Peak Tractive Power required, $P_{trac} = (F_{trac}) \cdot v$

Average power used during operation, $P_{avg} = P_{trac}$

Calculations at Zero degrees slope (Flat surface)

- Acceleration Force $F_a = M \cdot a = 120 \times 0.278 = 33.36 \text{ N}$
- Drag Force: $F_d = (0.5) \cdot \rho \cdot C_d \cdot A \cdot v^2 = 0.5 \times 1.18 \times 0.5 \times 0.38 \times (5.56)^2 = 3.47 \text{ N}$
- Rolling Resistance: $F_r = M \cdot g \cdot \mu_r \cdot \cos(\theta) = 120 \times 9.81 \times 0.015 \times 1 = 17.66 \text{ N}$
- Gradient resistance: $F_g = M \cdot g \cdot \sin(\theta) = 120 \times 9.81 \times 0 = 0 \text{ N}$
- $F_{trac} = 33.36 + 3.47 + 17.66 = 54.49 = 54.5$
- $P_{trac} = 54.5 \times 5.56 = 303 \text{ W}$
- $P_{avg} = 151.5 \text{ W}$

Power provided by motor at different gradient is provided in Table-1

Table-1.: Required motor power at different gradients

Gradients (θ)	F_a	F_d	F_r	F_g	F_{trac}	P_{trac}	P_{avg}
0	33.36 N	3.47 N	17.66 N	0 N	54.5 N	303 W	151.5 W
1	0 N	0.87 N	17.65 N	20.54 N	39.1 N	108.7 W	54.4 W
2	0 N	0.87 N	17.65 N	41.08 N	59.6 N	165.7 W	82.8 W
3	0 N	0.87 N	17.63 N	61.61 N	80.1 N	222.7 W	111.4 W
4	0 N	0.87 N	17.62 N	82.12 N	100.6 N	279.7 W	139.9 W
5	0 N	0.87 N	17.59 N	102.60 N	121.1 N	336.7 W	168.4 W
6	0 N	0.87 N	17.56 N	123.05 N	141.5 N	393.4 W	196.7 W
7	0 N	0.87 N	17.53 N	143.46 N	161.9 N	450.1 W	225.1 W
8	0 N	0.87 N	17.49 N	163.84 N	182.2 N	506.5 W	253.2 W
9	0 N	0.87 N	17.44 N	184.16 N	202.5 N	563.0 W	281.5 W

4. Fabrication

The project started with the modifying of the frame of the bicycle. The front tire assembly was cut and removed. Then, the frame as per the design was fabricated with iron rods, welded into place with arc welding. Then, the cargo bucket was made using a steel metal sheet. The sliders were attached in the two parts of the bucket. The

bucket was then mounted to the frame and welded at the opposite edges. The steering was made in the form of rocker arms, and the links were made adjustable using nuts and bolts, at specific distances. The front wheel was welded to the front of the frame. As shown in Figure 5. & Figure 6.



Figure 5 Adjustable cargo space

Bicycle dimensions:

Weight of the bicycle: 68.9 (~70 kg)

Length of bicycle: 2.4 m

Height of bicycle: 95 cm

Width of bicycle: 40 cm

Weight carrying capacity: 120kg



Figure 6. Adjustable cargo space with frame

Charger:

Voltage - 24V, Current - 2Ah

Charging time - 3 to 4 hrs

Battery:

Voltage - 24 V, Current - 10Ah

Type - Lithium Ion

There are two way of traveling from this Cargo bicycle as follows:

- Manual way while peddling the peddle
- Electrical while using battery power towards the motor.

System Specifications

With 24V 10AH Lithium Ion Battery the cycle can cover 25km in a single charge. The vehicle can achieve a maximum speed of 22 km /hr. The maximum load capacity is 160kg. Charging time is 4 hours with type II charging. The other parts include Battery Level Indicator, Horn, Light Switch, On Off Switch, 24V 250W Motor Controller Battery & Controller Bag, Connect Cable, Throttle Set, LED Head Light With Inbuilt Horn, Brake Lever, Mounting Plate, Long Axle, Chain, Freewheel, Welding Rods the complete assembly of the same is shown in figure 7



Figure 7. Over View Of ECBC.

The complete assembly consists of Bicycle Frame, Fork, Seat Post, Handlebars, Crank set, Chain, Stem, Bottom Bracket, Front Wheel, Rear Wheel, Front & Rear Callipers, Brake Cable, Cargo Box, Pedals, Saddle, Reflectors, Motor 250W, controller and other electrical components

Motor Specifications:

- Rated Voltage: 24 Volt DC
- Rated Power: 250W
- RPM (after Reduction) – 400rpm.
- Rated Current – 10.41A
- Full load current – 14.2A
- Under voltage protection: 20.5V
- Torque Constant – 9 Nm (90 kg-cm)

Controller Specifications:

- Voltage: DC 24V
- Under Voltage: 20V $\pm$ 1
- Current Limit: 21A $\pm$ 1
- Power: 250W .

Battery Specifications:

- 24v 10ah lithium ion battery pack.
- 7s4p combination is used in this battery pack.
- use of 7s 20a high quality bms.

Kit Includes:

- 1 x 24V 250W DC Geared Motor
- 1 x Controller 24V 250W
- 1 x 24v 2a lithium Charger
- 1x 24v 10ah lithium ion battery
- 1 x Chain
- 1 x Throttle Set
- 1 x Led Head Light With Inbuilt Horn
- 2 x Brake lever
- 1 x Mounting Plate
- 1 x Nut Bolts
- 1 xFree Wheel.
- 1x free wheel adaptor.
- 1x led fog light.
- 1x double threaded hub.
- 1x anti clockwise free wheel

Electronic Circuit Kit Diagram

A battery, a motor, sensors, electric control, and a drive unit was installed on the fabricated design. It enables the advantages of an E-bike while riding a regular bike.

Seating Arrangement

Finding the optimal seating position depends on the rider's body size, the frame size and frame geometry of the cargo Cycle and the settings of the handlebar and the seat. Seating arrangement is shown in Figure 8

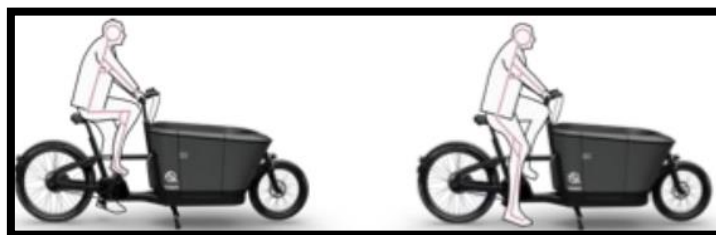


Figure 8. Seating position of rider

5. Testing and Deployment

The developed design was made on run on different gradients and was found to be in agreement with the data as per the design calculations.

6. Conclusion

The developed design a reliable solution for daily needs of the general public and delivery personnel / street vendors. The adjusting capacity of the cargo space helps in changing the size of the bicycle as per requirement of

carrying things. Also, the rider can peddle the bicycle when required, while using the electric mode when carrying heavier weights or when climbing slopes. This type of product is scarcely available or non-existent in the current market and thus, can be a great prospect for future developments. For delivery, a cargo bike can be much faster. Traffic will be much less of an issue and finding a parking space will never be a problem. For the right scenario, a cargo bike will outpace a car or motorcycle for efficiency in delivery. The cargo bike is only available in one size, but it is well-suited for people from 160 to 190 cm tall. This is made possible by the continuously adjustable saddle, whereby the sloping seat tube not only adjusts the seating position upwards but also backwards, thus changing the reach – roughly the distance between the rider's centre of gravity and the handlebars. Hence, battery operated cargo bicycle with adjustable cargo space can help the society to improve the daily basis needs and workloads.

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