

DIY vs Commercial E-bikes: A Cost-Effective Transport Solution for Blue Collar Workers

Abheer Sud

Heritage International Xperiential School, Heritage Avenue, Balola, Gurugram, Haryana 122102, India; abheersud59@gmail.com
Mentor: Zaynah Dhunny

ABSTRACT: Bicycles are an important mode of transport for blue-collar workers in India. They are affordable and provide transportation, but are not as easy and efficient to use as gas-powered vehicles, such as motorbikes. E-bikes are a popular alternative to bicycles and are used by many. However, commercial e-bikes are not affordable for blue-collar workers. A cheaper alternative to commercial e-bikes is DIY e-bikes, where a regular bicycle is converted to an e-bike using a motor, battery, and other components. DIY e-bikes provide users with access to an e-bike but at a lower cost. Using an e-bike over a regular bicycle would help workers with their daily commute, as it is less physically draining and allows for faster travel. This research paper provides a comparative analysis of DIY and commercial e-bikes based on their performance, cost, safety, reliability, and environmental impact. In this research, the method was done by building and testing a DIY e-bike and comparing it with a commercial e-bike. This research will also demonstrate a 53% cost benefit on a DIY e-bike as compared to buying a commercial one.

KEYWORDS: Chemical Energy, Fuel Cells and Battery Development, DIY, E-bike, Battery.

■ Introduction

India has become one of the fastest-growing economies in the world over the last few decades. But even with this formidable progress, poverty continues to be an enormous problem in India. This growth has only supported a small percentage of people, while most of the regular citizens continue to struggle daily.¹ In India, over 20% of workers commute to their workplace using a bicycle, 17% of whom reside in urban areas, and 21% reside in rural areas.²

Additionally, about 31% of rural workers walk an average of 3.5 km to their place of employment, and 25% of workers travel 8 km to their place of employment.³ In a survey consisting of over 600,000 Indian families, a bicycle was owned by over 50%.⁴

India's poverty index, although it has improved in the past decade, still shows a significant number of people all over India below the poverty line. With over 25% of the population below the poverty line in a few states, India is a country where a majority of its population consists of blue-collar workers.⁵

E-bikes (electric bicycles) are a popular mode of transportation, providing the speed and comfort of a gas-powered vehicle. They are a more environmentally friendly mode of transport compared to gas-powered motorcycles. E-bikes can be considered the fastest-growing means of transport market in several regions of the world, especially China.⁶ The worldwide e-bike market is experiencing growth, but varying geographically. An estimated 30 million units were sold in 2012, and the number was estimated to grow to 47.6 million by 2018.⁷ Over 40 million e-bikes were sold globally in 2015, 90% of those sales being in China.⁸ Annual e-bike sales are anticipated to reach over 130 million by 2025, and over 800 million by 2100.⁹ E-bikes still have the power to improve and develop to have a bigger role in international transport systems.

The Indian e-bike market is estimated at only \$27 million. With the highest annual growth rate of 17.68%, it is expected to reach \$60.93 million by 2029.¹⁰ The Chinese e-bike market, accounting for over 90% of the Asia-Pacific e-bike market, currently has a market size estimated at \$10.68 billion and is expected to reach \$12.39 billion by 2029 with an annual growth rate of 3%.¹¹ China has seen an annual growth of 86% in e-bikes in the past decade, now outnumbering gas-powered vehicles by twice the amount.¹² The Japanese e-bike market is estimated at \$0.99 billion and is expected to reach \$1.78 billion by 2029, with an annual growth rate of 12.57%.¹³ The Middle East and Africa e-bike market was valued at \$805 million in 2021. It is projected to reach \$1.27 billion by 2027, with an annual growth rate of 7.89%. E-bike sales and production slowed down as a result of the pandemic in 2020, but the market has regained its momentum and returned to normal. Recently, the demand for e-bikes has started increasing as an attempt to avoid public transport.¹⁴

The European E-bike market is estimated at \$19.36 billion, expected to reach \$29.28 billion by 2029, with a growth rate of 8.63%. A total of around 26 million e-bikes were sold in 2022, with the city, trekking, and mountain bikes being the most popular, accounting for 94% of all e-bike sales.¹⁵

E-bike sales in Europe between 2007 and 2012 grew by 10 times. In France, sales of traditional bikes dropped 9% while e-bike sales rose by 15%. The current E-bike market size in North America is estimated at \$3.45 billion, the highest in the world. It is expected to reach \$7.54 billion by 2029, with an annual growth rate of 16.91%.¹⁶ The pandemic caused people to develop exercise habits, causing an adoption rate of 3.1%.¹⁶ The current e-bike market in South America is estimated to be \$122 million. With an annual growth rate of 5.82%, it is expected to reach \$160 million by 2029. The e-bike market

in South America is currently emerging, with a few countries having notable unit sales. These sales are a minor fraction of global sales. This is due to the high price and local perceptions of e-bikes being 'premium two-wheelers'.¹⁷

Most modern cities run on a public transportation system; however, the promotion of vehicle-sharing systems or alternative transportation methods has only recently begun. Over 400 cities in the world have car-sharing systems. They are mostly located in Europe, with 80% of the cities. They are also located in North America and Oceania.¹⁸ In 2008, in the city of Amsterdam, 38% of all trips were on a bicycle. With 50% of Amsterdam's residents riding a bike daily, and 85% of its residents riding one at least once a week, bicycles are an important part of the city's transportation. Promoting bicycles in urban transportation requires specific policies and structures, including new traffic rules, construction of cycling paths, parking areas, and overall integration throughout the city. A main concern with bicycle riding is safety. Due to the relatively low amount of physical protection for cyclists compared to residents in cars, cyclists are more vulnerable to accidents. However, these safety concerns are less applicable in the case of electric bicycles, due to their ability to travel at higher speeds, requiring less effort to work, and overall higher mobility.¹⁸ Commercial e-bikes typically feature motors ranging from 250 to over 750 watts, usually achieving speeds from 20 mph to 28 mph for higher-priced models. Most commercial electric bikes could easily achieve a range of over 25 miles on a single charge. While DIY e-bikes can offer similar power ranges and speeds, the efficiency and output can be less predictable, depending on the motor, battery, and other components. It is important to check the battery's specifications (Voltage, Ampere hours, wattage) align with those of the motor.¹⁹ A study conducted showed mixed results when comparing DIY e-bikes to regular e-bikes. Regular e-bikes were found to be designed with more optimized power delivery, motor efficiency, and battery management, as opposed to DIY converted bikes, which had no such systems in place.²⁰ On the other hand, the performance of DIY e-bikes depends largely on the quality of the conversion kit and the user's knowledge and skills. High-quality conversion kits can deliver performance comparable to that of regular e-bikes, but this is not always guaranteed. Moreover, studies suggest that regular e-bikes often provide better integration of components, which can lead to a smoother and more reliable riding experience.⁷ Safety and reliability are critical concerns when using and making DIY e-bikes. Although factory-built e-bikes are subject to stringent safety regulations and standards, most name brands' e-bikes undergo rigorous testing to ensure they meet certain safety standards, which can provide consumers with confidence in their purchase.²¹

E-bikes favor both public health and the environment by helping the public increase their physical activity and by decreasing the emissions of harmful gases.²² While e-bikes are more environmentally friendly than gas-powered bikes, the production and transportation of both commercial e-bikes and regular bikes (that are converted to electric) still generate a significant amount of greenhouse gases.²³ Arguably, the largest environmental impact of commercial e-bikes comes from

lead pollution during the production, recycling, or disposal of lead-acid batteries.²⁴ When looking at the environmental impact of DIY and commercial e-bikes, using a conversion kit is a more environmentally friendly option. This approach minimizes waste and leverages the lifespan of already-produced bikes, which is more sustainable. Manufacturing new e-bikes entails a larger environmental footprint when compared to DIY e-bikes. Although major manufacturers incorporate the most energy-efficient technologies, the full production cycle tends to have a higher carbon footprint due to material extraction, manufacturing, and transportation.²⁵ The emissions from the manufacturing of e-bikes are less relevant to health issues as the manufacturing plants, the source of the emissions, tend to be far away from most of the area's resident population.²⁶ A report showed that negative health effects from manufacturing plants are scaled five times lower than the health effects caused by tailpipe emissions of gas-powered vehicles.¹²

One study showed that respondents found e-bikes safer when compared to regular bikes. 60% of all respondents stated that they feel safer on an e-bike rather than on a regular bike.⁷ Their reasons for this lie with the quick acceleration and faster speed, helping with getting out of incidents, keeping up with traffic, and having a better high-speed balance. A study conducted showed that respondents were more likely to obey laws, including traffic lights and stop signs, while using e-bikes due to their acceleration and performance.²⁰ The respondents also stated that the flexibility of an e-bike helps keep the roads safe, as they can easily keep up with road traffic as well as use the sidewalk at a lower speed. Commercial e-bikes offer a significant advantage in terms of warranty and support. They typically come with warranties, often from both the manufacturer and the parts manufacturers. This dual support covers both the bike's and its components' performance and quality. Additionally, service and support for commercial e-bikes is much easier, as many bike brands and shops are equipped to handle specific maintenance and repair needs. In contrast, DIY e-bikes lack warranty coverage, and finding specialized support for them is difficult. Service centers would be less familiar with the huge amount of conversion kits available, making repairs and maintenance a more complex task for bike owners.¹⁹ In a survey comparing DIY and commercial e-bikes, it was shown that the prices of either e-bike varied from \$500 to \$2,500. The most common costs for either option of e-bike were from \$1,000 to \$1,500, with 20% of respondents answering in that range, and the least common costs were from \$2,000 to \$2,500, with only 10% of respondents answering in that range.⁷ Comparing the prices of DIY and commercial e-bikes showed that the conversion kits generally had lower costs than those of commercial e-bikes.

■ Methods

This study was conducted in-house, using a regular bicycle. The DIY kit and battery were purchased from Amazon. This e-bike was assembled to test the difference between a DIY and a commercial e-bike. The creation of this bike allowed the comparison of the two kinds of e-bikes in terms of their respective costs, convenience, range, and speed. Figure 3 rep-

resents the working principle of an e-bike. It applies to both DIY and commercial e-bikes. The motor, controller, throttle, switch, and battery are all electronically connected. The motor is mechanically connected to the freewheel using a chain. While the switch is on and the throttle is turned, the electronic controller sends current from the battery to the motor. The motor is connected to a chain, which drives the freewheel. As the motor starts running, the freewheel spins. The freewheel, connected to the bicycle wheel, causes the bicycle wheel to rotate and the bicycle to start moving. As the throttle is turned more, the controller sends a higher current from the battery to the motor, until it reaches the battery's maximum capacity.

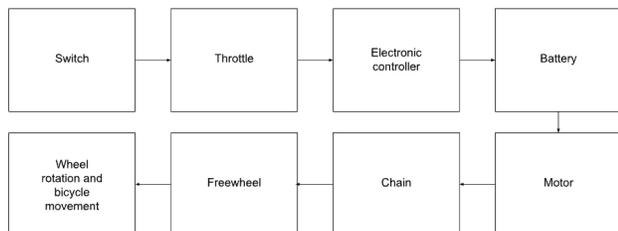


Figure 1: Figure 1 explains how an electric bicycle works. It outlines the sequential process an electric bike undergoes from activation to motion.



Figure 2: Figure 2 provides a labeled diagram of an electric bicycle. The diagram is of a complete electric bicycle made using a DIY Kit. The diagram points to the bicycle's Controller, Motor, Switch, Battery, and Throttle, which are the key components of an electric bicycle.

■ Components

1. DC motor:

A DC motor is one of a class of rotary electrical machines that converts direct current electrical power into mechanical power.²⁷

It provides power to the wheel, and it moves without the need for pedalling.

The motor used for this product was 24V (volts), 250 (watts)



2. Battery:

A battery is required to supply direct current to the motor for it to run.

The battery used in this product was 24V (volts), 7.5Ah (ampere-hours)



3. Controller:

The speed controller of an electric bike is an electronic circuit that not only controls the speed of an electric motor but also serves as a dynamic brake. This controller unit uses power from the battery box and drives it to the motor.

The mechanism of the electronic controller differs depending on whether you own a DIY or commercial e-bike. A DIY bike includes an electric drive system installed on a normal bicycle. A commercial e-bike, more expensive than a DIY bike, provides easier acceleration and affords extra features.²⁷



4. Throttle:

Handlebar grips with a throttle are included in regular conversion kits.

These connect to the controller to provide variable current readings to the motor, to run at different speeds depending on the activation of the throttle.



5. Mechanical parts:

The required mechanical parts would be an extra freewheel, a chain that fits the teeth on the motor, and a bracket to attach the motor to the bike.



■ Results and Discussion

Table 1: Table 1 presents the multiple speed readings. These readings were taken using different types of speedometers (digital, analog, etc.), and an average of these was used as the speed for further calculations.

	Speedometer 1	Speedometer 2	Speedometer 3	Average (total)
Reading 1	14.5	15	15.6	-
Reading 2	14	17	16	-
Reading 3	15	16	14	-
Average (per speedometer)	14.5	16	15.2	15.23

Table 2: Table 2 shows the calculations performed to deduce the range of the electric bicycle. Common physics formulae for electricity were used to deduce the operating amperes of the motor, which helped provide the time the battery can run for under the load, and finally deduce a suitable range based on the bicycle's average speed.

	Equation	Units	Description
1	$I = \frac{P}{V}$ $I = \frac{250W}{24V} = 10.42A$	<p>P is the power (in watts);</p> <p>V is the voltage (in volts);</p> <p>I is the current (in amps)</p>	<p>Current drawn by the motor from the battery.</p> <p>The motor draws 10.42A of current</p>
2	$t = \frac{c}{I}$ $t = \frac{7.54h}{10.42A} = 0.72h$	<p>t is the time for the battery to discharge (in hours);</p> <p>c is the battery's capacity (in ampere hours);</p> <p>I is the current of the battery (in amperes)</p>	<p>Run=time of battery at maximum output of current</p> <p>The battery will run for 0.72 hours at maximum output</p>
3	$d = s \times t$ $d = 15.23kmh^{-1} \times 0.72h = 10.97 km$	<p>d is the distance (in km);</p> <p>s is the speed (in km/h);</p> <p>t is the time (in hours)</p>	<p>Distance the bike will run on a single charge</p> <p>The battery will take the bike about 11 km on a single charge</p>

The calculations in Table 1 present that the DIY e-bike would travel at a top speed of 15 km/h, with a maximum range of 10.8 km (Table 2). These results allow this DIY-converted e-bike to be compared with commercial e-bikes, helping to assess its performance and application.

The current design delivers functional results, but there is room for improvement. In the future, a key enhancement planned for this model is a self-recharging feature. A dynamo motor, or a generator, converts mechanical power to electrical power. By utilizing the rotation of the wheels when the user is pedaling the bike, the dynamo motor can recharge the battery. This allows the e-bike to be recharged without the need for an electricity connection. Another feature to be added is the ability to use the battery to charge external devices, so electricity can be saved. For this DIY e-bike, the traditional bicycle costs \$70, and the conversion parts cost \$140. It comes to a total of \$210. Compared to a commercial e-bike, starting at \$400 in India, this DIY model is 53% cheaper.

■ Conclusion

Commercial e-bikes are generally found to offer better safety and reliability when compared to DIY e-bikes, due to brand warranties. All internal components are designed to be integrated perfectly with one another, resulting in a safer and more reliable e-bike, although at a high cost. DIY e-bikes provide a similarly efficient and performant product at a much lower cost. They also provide greater flexibility for the customization

of components. DIY e-bikes are also more environmentally friendly, as the production of e-bikes leads to major harmful gas emissions. DIY e-bikes prove to be a much more affordable option when compared to either commercial e-bikes or similar gas-powered vehicles. Using DIY e-bikes, blue-collar workers can get to their respective workplaces more conveniently. It would allow them to be less tired due to the physical stress from pedalling a cycle. They reach their workplace faster due to the higher speeds of an e-bike. They would also feel safer traveling on roads as they would be able to keep up with traffic and swiftly avoid accidents. In conclusion, the sale of DIY e-bike kits can benefit blue-collar workers with their daily travels and make their journeys safer and more comfortable.

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■ Author

Abheer Sud is a high school student pursuing mechanical/electrical engineering in college.

He is enthusiastic about practical applications of physics and enjoys creating innovative gadgets and devices.