E-BIKESHARE: PLANNING AND IMPLEMENTATION

SOLUTIONPLUS POLICY PAPER

NSTITUTE FOR TRANSPORTATION AND DEVELOPMENT POLICY

This project has received funding from the European Union Horizon 2020 research and innovation Programme under grant agreement no. 875041

PROJECT PARTNERS

ABOUT

This brochure has been prepared for the project SOLUTIONSplus. The project has received funding from the European Union’s Horizon 2020 research and innovation programme under the grant agreement no. 875041

TITLE

SOLUTIONSplus Impact Assessment Results

PREPARED BY

Stanley Chanzu, Maureen Kinyua, Christopher Kost, Gashaw Abera and Rafik Yani, ITDP

FINANCIAL SUPPORT

Solutionsplus

DISCLAIMER

LAYOUT

Yasin Imran Rony, WI

PICTURES

All the pictures are provided by the ITDP

June, 2024

CONTENTS

1 INTRODUCTION

As cities around the world continue to grow, overreliance on private motor vehicles has led to increasing traffic congestion, road safety challenges, and environmental degradation. To address these issues, many cities have turned to bikeshare systems as a solution. For a charge, members check out a bike by tapping a card or using a smartphone app at one location and return it to a different point. The IT system enables bikeshare systems to offer connectivity for short- to medium-distance trips and improve last-mile access to public transport.

Bikeshare systems have helped jumpstart the cycling culture in many cities, attracting novice cyclists and contributing impetus for the construction of dedicated cycle infrastructure. The introduction of shared e-bikes in urban areas has significantly enhanced the appeal of bikeshare. E-bikes allow users to travel at speeds that are competitive with cars and ridehail. They also offer crucial assistance to riders facing physical challenges and help users navigate difficult terrain. This policy paper explores the planning, implementation, and business model of e-bikeshare systems.

2 BENEFITS OF BIKESHARE

The incentive for launching a bikeshare programme often centres on improving access to opportunities, encouraging cycling, enhancing affordability and offering residents a healthier mobility choice. Bikeshare distinguishes itself from other transport projects in its brief implementation timeline: planning and executing a system within a single mayoral term (i.e., 2-4 years) is viable, allowing for the prompt realisation of public benefits (ITDP, 2018).

2.1 ENHANCED MOBILITY

The proliferation of bikeshare systems in cities is significantly influenced by a desire to improve access to sustainable options for short commutes. Bikeshare proves highly efficient on congested streets where the car experience can be frustrating and where parking availability is limited. Bikeshare becomes an ideal choice in such scenarios, offering users a safe and enjoyable commuting experience.

2.2 BOOST TO CYCLING CULTURE

Bikeshare has been a catalyst for a growing cycling culture in a range of cities, especially those with a nascent cycling culture. Bikeshare lowers the barrier to entry for novice cyclists, allowing new users to try out cycling without having to make the financial commitment to purchase a new cycle. Bikeshare systems also establish a consitituency for new cycle infrastructure.

2.3 SOCIAL EQUITY

Bikeshare plays a significant role in fostering economic development at both the individual and community levels. Research indicates that bikeshare members in the United States have seen a 22 percent decrease in annual household spending related to transport and healthcare expenses. The cost of owning and operating a car amounts to USD 9,100, making it costlier than annual membership in a bikeshare system, priced at UDS 60-150, with extra-hour usage fees ranging from USD 2-4. Bikeshare also has the potential to draw in tourists seeking to explore city destinations, thereby boosting their spending at local businesses.

2.4 PUBLIC HEALTH

Bikeshare has a positive impact on both the physical and mental well-being of the user. Riding a bike contributes to the rider's fitness, in contrast with the passive nature of car travel. Various studies affirm that biking enhances riders' overall well-being and contributes to reduced anxiety and depression levels. A study conducted in Beijing illustrates that the rising prevalence of biking and decreased car emissions reduced health costs, particularly with regard to respiratory and cardiovascular hospital admissions (Lu-Yi & Ling-Yun, 2018). The study also found that bicycling for 30 minutes per day while going to work can reduce heart disease by 82 percent and diabetes risk by 58 percent (Katona, 2015). In a survey that observed the benefits of bikeshare, 30 percent of respondents reported losing weight from using the bikeshare system (Miriam, 2015).

2.5 ENVIRONMENTAL PROTECTION

Bikeshare is a sustainable, eco-friendly alternative to fossil fuel-powered cars. Transport sector-wide energy efficiency gains are possible from replacing highly inefficient fuel-powered vehicle trips with e-bikes or e-scooter trips. Single-occupancy vehicle trips are extremely inefficient because of the energy needed to move the vehicle's weight (in addition to the person inside). Moving an e-bike or e-scooter transporting a single passenger takes much less energy. E-bikes emit one-third the amount of PM per passenger km as motorcycles and half the number of cars (Yanocha & Allan, 2019). Because of the (typically non-renewable) energy required to charge them, e-bikes do emit slightly higher levels of SO2 compared to motorcycles, but these emissions will fall as energy portfolios transition away from dirty sources (ibid).

3 HOW E-BIKES ENHANCE THE APPEAL OF BIKESHARE SYSTEMS

The demand for e-bikeshare is closely linked to user demographics. Following are some of the benefits of incorporating e-bikes into bikeshare systems.

3.1 CONVENIENCE

E-bikes can be the most convenient transport solution for many users. Compared to regular bikes, e-bikes offer faster riding, allowing riders to increase their average speed compared to a conventional bike. E-bikes also allow riders to travel 10 km or more with minimal physical exertion, making e-bikes a valuable alternative to cars for longer journeys. E-bikes require less physical effort, allowing users to conquer hilly parts of cities/ Research has highlighted that slopes exceeding 4 percent pose a challenge for bikeshare users (Iderlina, Richard, Jonathan, & Dorina, 2016). In the UK, the research found that the hilliness or slope, measured as the proportion of 1 km squares in a district with a mean slope of 3 percent or greater, correlates more significantly with bicycle commuting mode share than any other physical environment variable (ibid).

3.2 EXPANDED CYCLIST DEMOGRAPHICS

E-bikes offer a promising solution to enhance mobility for marginalised groups by providing easier access to transport options. Women, the elderly, and students find e-bikes more appealing and accessible than traditional bicycles, whether for connecting to public transport or completing their entire journeys (Samantha, Jennifer, Sara, & Jeffrey, 2019). A study in the Copacabana neighbourhood of Rio de Janeiro, Brazil, revealed that 33 percent of e-bike users are women, while only 25 percent of traditional bicycle users are women (Transporte Ativo, 2014). Affordability and the capability to travel longer distances make e-bikes particularly valuable for those without car access, opening up economic opportunities.

Although e-bikes offer a cheaper alternative to cars, they can still be unaffordable for those with limited incomes. In Brazil, Tembici, a bikeshare operator, partnered with a food delivery app to launch discounted bikeshare plans tailored for delivery workers, featuring special rates for e-bikes across seven major cities (Tembici, n.d.). This program aimed to make e-bikes more attainable for low-income delivery workers, thereby boosting their daily earnings by capitalising on the enhanced speed and range provided by e-bikes.

3.3 INCREASED BIKESHARE RIDERSHIP

Recent data highlights a significant rise in the popularity of shared e-bikes. In 2022, an analysis of eight bikeshare systems in the United States operated by Lyft revealed a remarkable 107 percent increase in new e-bike riders since their introduction in 2020 (Yanocha, Hagen, & Yuen, 2024). Statistics from the North American Bikeshare Association (NABSA) show a similar trend, with the proportion of bikeshare systems offering e-bikes growing from just under 30 percent to 50 percent from 2019 to 2021 (North American Bikeshare and Scootershare Association, 2022). During this period, shared e-bike trips tripled from around 6 million to 18 million (ibid).

3.4 MECONOMIC DEVELOPMENT

E-bikes offer significant potential for positive economic impact, with the global market projected to grow by approximately 220 percent from 2022 to 2030 (Fortune Business Insights, 2022). E-bikes, therefore, represent a promising opportunity for expanding green manufacturing. China and EU countries have capitalised on this opportunity through domestic production and sales. In the EU, annual consumer purchases of e-bikes range from 5 to 6 million, constituting a significant portion of the bicycle market, totalling approximately 22 million units annually. The EU's e-bike market has maintained robust growth, with an average annual increase of around 30 percent (Ceri & Philip, 2023). Moreover, African countries are witnessing a rising demand for domestic design and manufacturing, with numerous local start-ups offering e-bike fleets tailored for various purposes, such as local deliveries (Emilie, Paschal, Vera-Marie, Annika, & Judith, 2020).

Countries aspiring to lead in sustainable industry can boost domestic e-bike production, enhancing their national supply and potential for global exports. As global electric car production rises, so does the demand for lithium-ion batteries. Prioritising e-bike production in industrial policies can ensure a more equitable and sustainable utilisation of limited battery resources and materials.

4 GLOBAL PRESENCE OF E-BIKESHARE

4.1 GROWTH IN E-BIKESHARE DEPLOYMENTS

Global interest in bikeshare systems is on the rise. Per the Meddin bikeshare map, there are 3,000 bikeshare systems worldwide, boasting an estimated 10 million bikes as of August 2021 (PBSC Urban Solutions, 2021).

Bikeshare has grown rapidly, from 20 new systems deployed in 2008 to 337 in 2018. The average annual growth in e-bikeshare systems from 2008 to 2018 was 79 percent. Over the period from 2018 to 2020, e-BSSs made up almost one-quarter of all bikeshare deployments worldwide (Nikolaos-Fivos, Konstantinos, & Christos, 2020). The number of bikeshare systems with e-bikes increased by 63% translating to an increase in e-bikes fleet in bikeshare systems by 73% between 2021 to 2022 (PBSC Urban Solutions, 2022). Most e-bikeshare systems are located in Europe (59%), followed by the Americas (27%) and Asia (13%) (Parkes, Marsden, Shaheen, & Cohen, 2013).

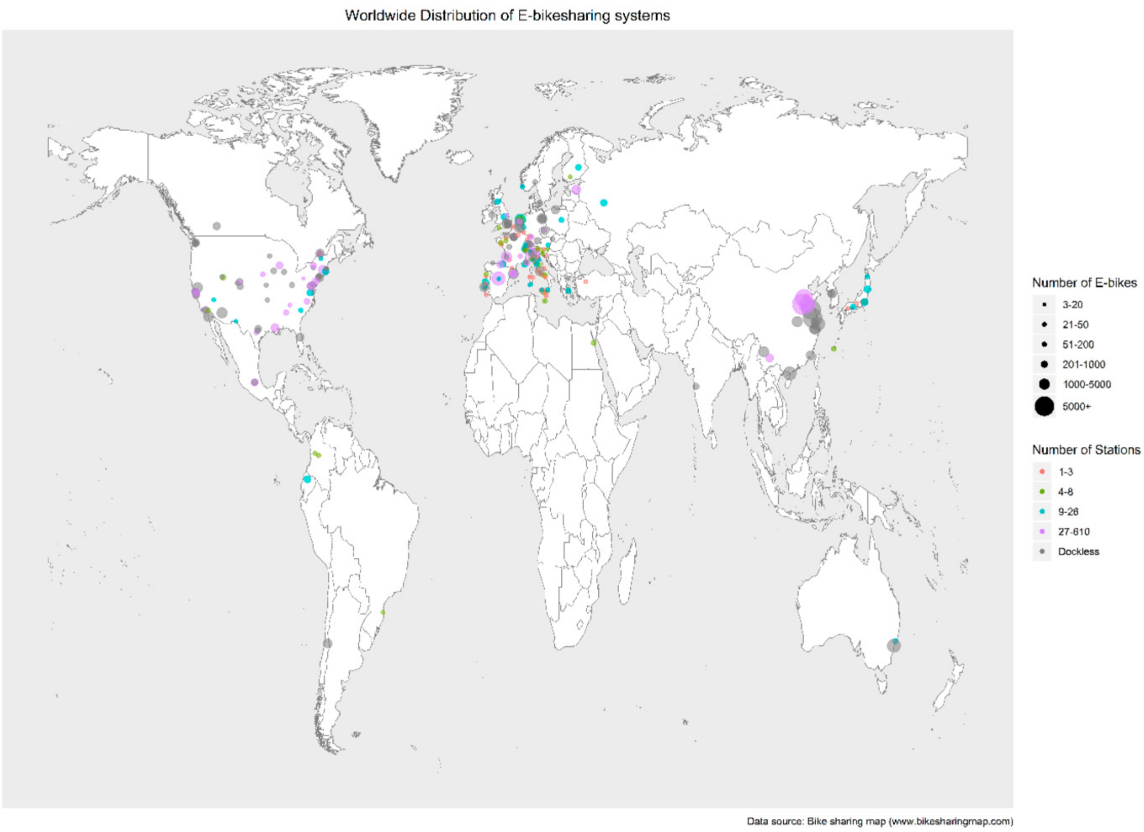

Figure 2. Distribution of electric bikeshare systems (Parkes, Marsden, Shaheen, & Cohen, 2013).

The market for e-bikeshare was estimated to be worth USD 270 million in 2022 and is projected to grow at a compound annual growth rate of 28 percent to reach USD 1,177 million by 2028 (MarketSight Innovations, 2024). Bikeshare platforms that have introduced e-bikes to their fleets, alongside or replacing their manual bikes, are as follows (O'brien, 2021):

- Nextbike gradually introduced electric bicycles into some of its fleets in many countries.
- Smoove launched a bikeshare scheme in Paris in 2018 that incorporates e-bikes into the fleet.
- JCDecaux replaced its Luxembourg manual bicycles with electric ones and introduced some electric bikes into its Brussels fleet.
- Lime often has over 2,000 pedelecs and 1,000 e-scooters in Paris and around 3,000 of each in Rome.
- PBSC, Beryl, RideMovi, Donkey Republic, and Pony have gradually introduced electric options into their operations.
- Some of the dedicated shared e-bike providers include (ibid):
- Bewegen supplies e-bikes to various European fleets, including Portugal and Estonia.
- Freebike highly customisable e-bikes are now in Ireland, Poland, Finland, the UK, and France.
- HumanForest has e-bikes in central London.

4.2 E-BIKESHARE CASE STUDIES

4.2.1 BEIJING

Beijing's e-bikeshare scene has evolved significantly since the mid-2010s, with companies like Bluegogo introducing e-bikes to meet the city's growing demand for eco-friendly transport. However, legal issues, competitive markets, and technical developments led to the closure of Bluegogo in late 2017 (Yang, 2017). Larger bikeshare companies like Mobike and Ofo later added their e-bike models to their fleets in Beijing. In 2019, Mobike, Ofo, and HelloBike diversified into e-bikes in their product lineups. They have become popular among commuters and residents due to their convenience and ability to cover longer distances with less physical effort. Currently, three primary bikeshare services dominate the scene: Didi Bike, Meituan Bike (formerly Mobike), and HelloBike (merged with Ofo) supported by Alibaba and Giant Bicycles. In December 2021, the Beijing Municipal Transport Commission pledged to enhance industry regulations and cap the number of deployed shared bikes in central Beijing districts to 500,000 units (Global Times, 2022).

A survey to understand the factors influencing the choice to switch from existing modes to bikeshare or e-bikeshare in Beijing revealed noteworthy insights. Bikeshare trips averaged 2.9 km, while e-bikeshare trips averaged 4.5 km (Andrew, Christopher, Megan, & Xinmiao, 2016). The results closely aligned with the average distances of morning commute trips, which stood at 3.2 km and 4.5 km for private bikes and e-bikes across Beijing (Guo, Li, Gencheng, Liu, & Quan, 2011). The study concluded that e-bikeshare is more advantageous for longer trips than regular bikeshare (Andrew, Christopher, Megan, & Xinmiao, 2016).

4.2.2 BOGOTÁ

In 2020, Bogotá launched Tembici, a bikeshare program aimed at making cycling a safe, accessible, and sustainable transport option (Masliy, 2023). The system now boasts

1,500 e-bikes out of a total fleet of 3,300 bicycles, accessed from around 300 stations (Villate). For the period from 1-21 May 2024, the system saw a total of 88,868 trips, with an average trip distance of 2.5 km and approximately 68% of the trips being made on e-bikes (Analytics, 2024).

Figure 4: Bogotá's bikeshare system, operated by Tembici.

4.2.3 COPENHAGEN

Copenhagen has been implementing bikeshare initiatives since the 1990s to encourage cycling and reduce car dependency. In 1995, the city introduced Bycyklen, one of the world's first large-scale bikeshare systems, financed through advertising and city funding (Kassirer, 2024). Bycyklen initially operated with manually operated bikes stationed at various locations. Copenhagen's infrastructure is well-equipped to support cycling, with 49 percent of residents opting for bicycles as their primary mode of transport (James, 2024). The city's extensive cycle network includes approximately 359 km of dedicated cycle facilities (European Commission, 2014). Copenhagen envisions an even more bike-friendly future, with urban plans aiming to have 50 percent of work or education-related trips completed on bicycles (VisitDenmark) compared to the 49 percent recorded in 2019 (Sanne & Fred, 2022).

In 2014, Copenhagen launched City Bike (Bycyklen), featuring electric bikes equipped with GPS technology and touchscreens geared towards more touristic and suburbanite use (VeloCittà, 2017). The program has expanded over the years, improving accessibility and availability of bikes for residents and visitors, providing users with an alternative mode of transport for longer distances or hilly terrain. Copenhagen's bikeshare system has contributed to the city's vibrant cycling culture and reputation as a global leader in sustainable urban transport.

Figure 5: Bycyklen e-bikeshare system in Copenhagen (Oresund, 2019).

4.2.4 NEW YORK

New York City began exploring bikeshare in the mid-2000s with small-scale pilot programs and initiatives. The city rolled out its bikeshare system in June 2013 with the launch of Citi Bike, which quickly evolved into one of the largest systems in the United States. Operated by Motivate (later acquired by Lyft), the system offers thousands of bicycles from hundreds of docking stations across Manhattan, Brooklyn, Queens, and Jersey City. Starting with 5,000 bikes in 2013 (Sarah, Lily, Nolan, & Mitchell, 2015), the fleet has grown substantially, reaching 26,383 bikes in 2022 (Citi Bike, 2022). The system has also experienced significant expansion in the number of trips, surging from 1.7 million in June 2017 (Citi Bike, 2017) to 3.3 million in June 2022 (Citi Bike, 2022). The bikeshare system strategically aligns with tourist destinations and major transit areas, witnessing remarkable growth in active stations—from 330 in 2013 (Sarah, Lily, Nolan, & Mitchell, 2015) to 1,670 in 2022 (Citi Bike, 2022)—providing users with a more convenient mobility service.

Citi Bike in New York has introduced new and powerful e-bikes that are exceptionally user-friendly and capable of covering up to 60 kilometres with assisted riding on a single charge. The motor provides a 500-watt boost, and the bikes are equipped with front lights and reflective paint on their frames, resembling street signs (Hurford, 2022). E-bikes have garnered substantial popularity and are used three times more frequently than regular bikes (Surico, 2022). There are expansion plans for the system in New York, with Citi Bike partnering with Lyft in 2018 to reach 40,000 bikes by 2023 and expand the service area by 35 square miles over five years (Frazier, 2021).

Figure 6: E-bikes at a Citibike bikeshare station in New York City.

4.2.5 WASHINGTON, DC

Capital Bikeshare first added e-bikes in 2020 and introduced a new e-bike in 2023 with a 60-mile range, ensuring fewer battery swaps. The system's flexibility allows the users to lock the e-bikes at CaBi docks, bike racks, or light poles. The e-bikes reach a maximum of 32 km/h, in line with speed caps in Washington, D.C. (Pascale, 2023).

The system reported 16 percent of total bikeshare trips in February 2023 to be on the fleet of 300 e-bikes. There are plans to introduce 2,500 more e-bikes into the system over the coming years. The system is supported by a network of 48 km of protected bike lanes and 174 km of bike lanes overall (ibid).

Figure 7: A new model of e-bikes launched in D.C. by Capital Bikeshare is better lit for safer night cycling (ibid).

5 BIKESHARE PLANNING BASICS

Successful bikeshare systems offer a dense network of stations across a coherent coverage area, typically 10 square kilometres or more. Adequate station density is vital for creating a system that serves a robust set of origins and destinations. Station spacing depends on local demand but a general standard of 10-16 stations per square kilometre is advisable (ITDP, 2018). In certain scenarios, areas with higher population density may require more stations than the designated standard, while expansive parks or industrial zones may need fewer stations. Stations should be aligned with other transport modes and rapid transit stops to allow smooth transfers for users.

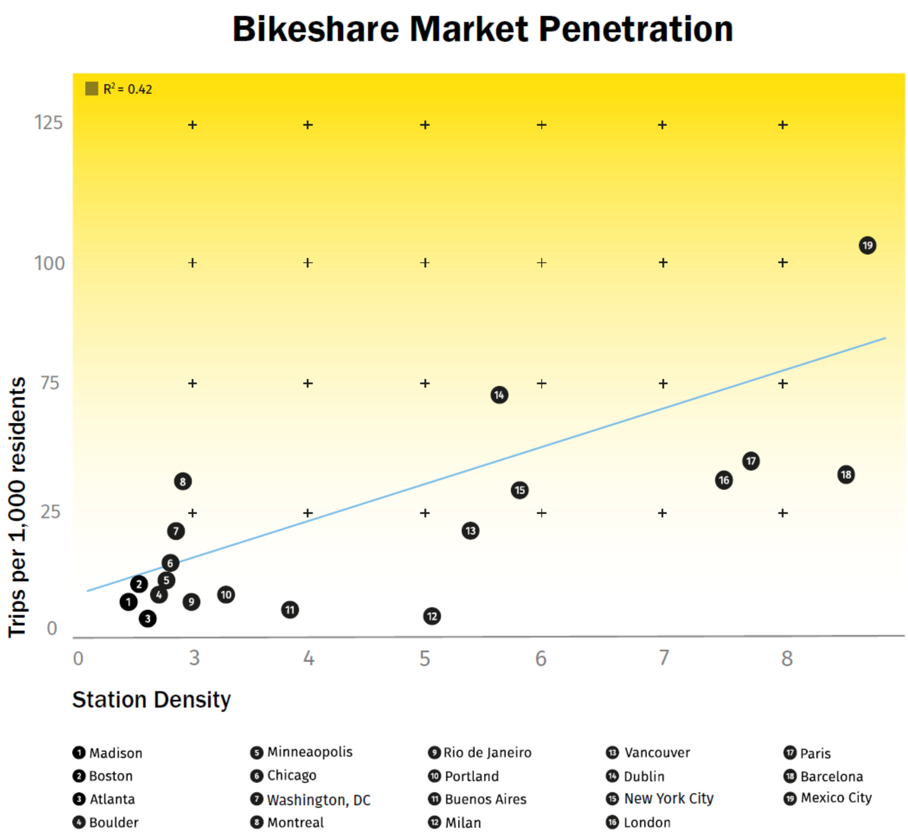

Figure 8. Bikeshare market penetration: a correlation exists between a higher station density and a higher market penetration. (ITDP, 2018).

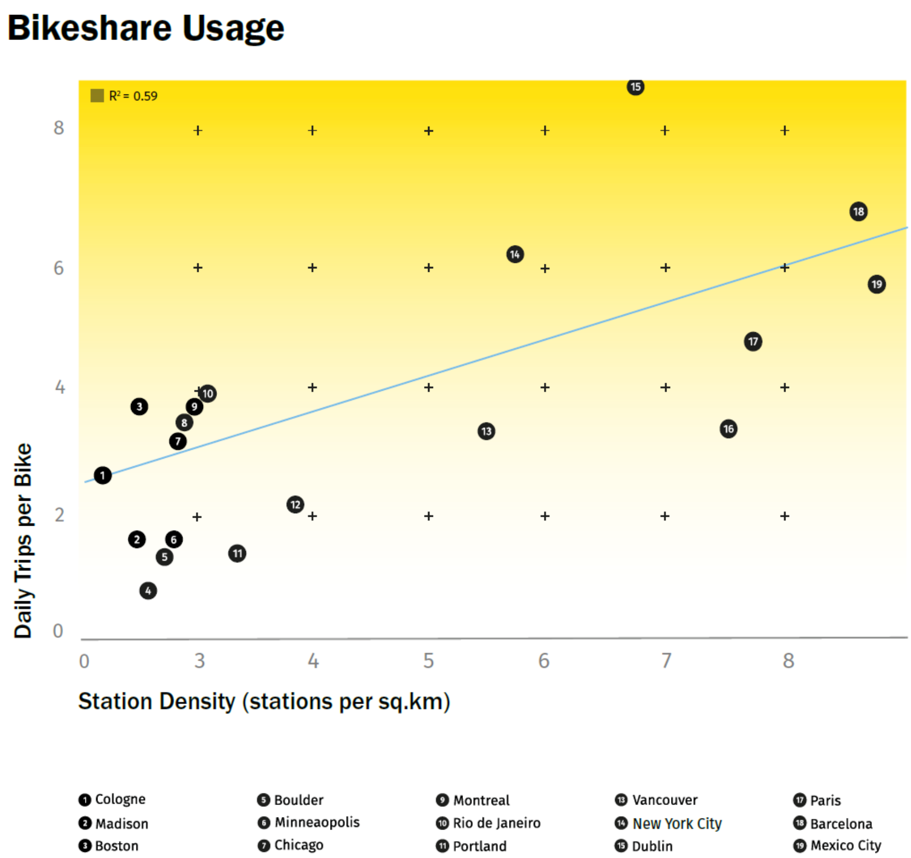

Figure 9: Bikeshare usage: a correlation, albeit weaker, also exists between a higher station density and a higher system efficiency (ITDP, 2018).

6 E-BIKE TECHNOLOGY

Most electric bike drive systems consist of three main components: the motor, drive train, and battery.

6.1 MOTOR

Most contemporary e-bikes utilise brushless DC motors (Roe, 2022). The motor typically weighs between 2-4 kg, making e-bikes potentially heavier than traditional bikes. Motors are equipped with controllers, ensuring the appropriate power flow to the motor based on user input.

6.2 SPEED LIMITATION AND PEDAL PRESENCE

Pedal-assist e-bikes function like traditional bikes, requiring riders to peda way in which directl as they would on a regular bike. These bikes have a pedal sensor that detects the rider's effort and delivers electromechanical power, particularly on steep slopes. Pedal-assist bikes in bikeshare systems typically have a maximum speed above which the motor no longer provides assistance. Speed regulations for e-bikes vary globally. In Europe and Australia, the limit is set at 25 km/h, while in the USA, the pedal assist function operates up to 32 km per hour (Lang, 2023). The UK imposes a maximum speed of 24 km per hour for e-bikes. While e-bikes are designed to stop after reaching a certain speed, users can still travel faster, especially on steep slopes (ibid).

6.3 BATTERY

Often the most expensive component in an e-bike system is the battery. Modern e-bike batteries predominantly use lithium-ion technology. Battery quality is paramount to ensure a better riding experience. A key measure of battery efficiency is the amp hour rating, indicating how far a user can travel on a single battery charge. A standard rate is 10-amp hours, providing a trip range of 32-64 km (Evelo, 2020). Citibike's e-bike can provide a trip range of 96 km on a single charge (CitiBike, 2022), while Bycyklen's e-bike offers a range of 25 km (Climate Technology Centre and Network, 2018). However, several factors can influence the e-bike's range. Speed, for instance, plays a role, with higher speeds leading to increased wind resistance and, consequently, higher energy consumption. Weight is another factor, as a heavier user will require more energy from the e-bike. Geography also comes into play, with hilly areas demanding more energy than riding on level streets, potentially decreasing the e-bike's range (Evelo, 2020).
A laboratory test examined a lithium-ion battery with a voltage of 48.1 V and a capacity of 28 Ah, designed for an e-bike with a 3 kW motor. The test results revealed that, at a constant driving speed of 20 km/h, the e-bike could cover a range of 60 km. With speed dependent on the topography, it achieved an extended range of 85 km (Jarosław & Kamil, 2019).

6.4 POWER MANAGEMENT

Power management software for e-bikes is essential for optimising fleet management, ensuring a good user experience, and maintaining the overall performance of the e-bikes. Some of the key features of power management software for e-bikes include:

- Real-time bike monitoring: This feature allows fleet managers to visualize the state of their bikes in real-time, ensuring optimal service to customers and reducing downtime (Velco, 2023).
- User data analysis: By analysing data collected from e-bikes, fleet managers can understand the use of their fleet, identify high-traffic areas, rush hours, or recurrent journeys and optimise charging strategies accordingly (Velco, 2023).
- Geolocation: Real-time geolocation systems enable fleet managers to monitor their entire fleet of bicycles (Velco, 2023).
- Maintenance management: Cloud-based maintenance management systems (CMMS) can help handle both predictive and corrective maintenance, monitor the maintenance workflow, and collect data for reporting and after-sales relationships with suppliers (Velco, 2023).

6.5 THROTTLE CONTROL VS PEDAL ASSISTANCE

On throttle-control bikes, a user can activate the motor by pressing a throttle lever or turning a grip on the handlebar. Regardless of how intensely they pedal, a throttle gives the rider complete control over the motor's power output at any given moment. By contrast, a pedal assist system (PAS) or torque sensor allows riders to control the e-bike through pedalling instead. Torque sensors often involve changes to the bottom bracket, not only to detect if the rider is pedalling but also to gauge the force applied to the cranks. On the other hand, cadence PAS sensors can be mounted on a normal crankset, signalling whenever the pedals are in motion. The presence of pedal assist can influence the classification of the e-bike (see section 8.2).

6.6 CHARGING SYSTEMS AND OPERATION

A vital part of any e-bikeshare system is its charging system, ensuring that e-bikes are always ready for customers. The system comprises charging stations, management software, and power systems (Guangyou, Zhiwei, & Sumei, 2022). Some systems employ battery swapping, where a swapping team collects spent batteries and replaces them with charged batteries. Some station-based systems charge bikes at the stations. It is not necessary for all stations to have grid connections, as long as an adequate number of frequently accessed stations have charging capabilities. For example, Lyft electrifies only a select few docking stations. This reduces the number of miles that battery-swapping vehicles need to travel, cutting costs and improving efficiency (Lyft, 2023).

Charging management software controls the charging process of e-bikes. Usually web-based, this software enables operators to monitor the real-time charging status of each e-bike. The software enables monitoring of e-bike locations, assistance levels, and custom sensor input (Kiefer & Behrendt, 2016). Various charging strategies can be employed to optimise power consumption and meet battery needs: binary linear programming aims to minimize costs and power consumption while adhering to battery charge and demand constraints. Key variables include the assignment of bikes to users, the charging statu of docks, the presence of docks (Campbell, Jiao, & Sibille, 2014). The problem is framed as a binary linear optimization problem and can be solved using tools like Matlab's optimization toolbox. Dynamic programming can be isused for for systems with highly periodic demand patterns (ibid).

Smart charging technology is another strategy, enabling e-bikes to be charged during off-peak hours when electricity rates are typically lower, thereby minimising operational expenses for the e-bikeshare system. To reduce costs, e-bikeshare systems can explore alternative energy sources like solar power to mitigate electricity costs (Cherry, Worley, & Jordan, 2010).

Figure 9: A staff undertaking battery swapping at a bikeshare station in New York City

Figure 10: Solar-powered bikeshare station in Berlin, Germany (Efthimiadis, 2012).

Operational challenges in e-bikeshare charging systems include balancing e-bikes among charging stations and managing costs. To address these challenges, some e-bikeshare systems employ a central management system that monitors each e-bike's location and charging status, making decisions on relocating specific e-bikes to different charging stations using GPS tracking and physically moving them with a fleet of vehicles (Osorio, Lei, & Ouyang, 2021).

6.7 MAINTENANCE

E-bike share maintenance is an important aspect of ensuring the longevity and reliability of electric bikes used in bikeshare systems. Maintaining an electric bike ensures smooth, efficient, and safe operation, ultimately extending the battery's and motor's lifespan. While the routine care for an e-bike aligns with a regular bicycle, certain components, particularly those in the drivetrain (like cranks, chains, and sprockets), are subject to higher stresses and increased wear (McKnight, 2022).

Some companies offer full-service and preventive maintenance for e-bikeshare systems for a fixed monthly fee (Connectbike, 2023). Cloud-based maintenance management systems (CMMS) like the one offered can enhance e-bike fleet operations by providing 24/7 diagnostics of all components, instant remote view on battery levels, and immediate backup of technical problem information collected on a bike (eBikeLabs, 2019). Connected e-bikes can also assist with maintenance by establishing maintenance levels according to distance travelled or date of purchase, informing the cyclist of improper use or storage, and offering predictive maintenance to anticipate future breakdowns (Velco, 2023).

Some practical recommendations for effective e-bike maintenance include chain lubrication, washing precautions, and battery longevity techniques (McKnight, 2022). Chains on electric bikes typically require more frequent lubrication than those on regular bicycles. When it comes to cleaning any bicycle, electric or not, it is advisable to avoid using a strong jet wash. While e-bike batteries and motors are sealed to prevent water entry, the force of the water may potentially breach the seals. It is important to keep all connections closed by leaving the battery in its housing, turning off the e-bike system before washing, and refraining from charging during this process.

6.8 SAFETY

E-bikes use lead-acid and lithium-ion batteries, with lead-acid being less flammable and cheaper but causing lead pollution (Liu, Zhang, Yang, Chen, & Liu, 2023). Lithium-ion batteries are lighter, hold more energy, last longer, and charge faster. However, they cause most e-bike fire incidents due to their high sensitivity to high temperatures and water seepage. National authorities can prevent these fires by introducing, disseminating, and enforcing existing standards for e-bikes and batteries. The EU has a Batteries Regulation (Official Journal of the European Union, 2023), while the U.S. has UL 2849 covering e-bike electric shock risk during charging and potential electrocution hazards (UL Solutions, 2022); and UL 2271 standards that focus on battery system safety for small e-mobility devices (UL Standards , 2018). Lawmakers in the US have introduced legislation to ensure higher safety levels by taking faulty lithium-ion batteries off the market and setting consumer guidelines. China has a standard for e-bike batteries, but implementation and enforcement are lax. A compulsory standard for lithium-ion e-bike batteries is developing, but lead-acid batteries will not be covered.

6.9 END-OF-LIFE MANAGEMENT FOR BATTERIES

National governments should ensure responsible battery recycling and disposal, especially as e-bike use expands. The EU has taken a comprehensive approach to battery recycling, addressing it through the European Green Deal. The U.S. has not taken a coordinated approach, with private sector firms leading the way in recycling shared batteries. National governments should also improve the recovery of other materials used in e-bikes, such as electric motors, which have a large environmental footprint due to copper use in motor production.

EV batteries undergo hundreds of charging/discharging cycles, in addition to a wide range of temperatures and other factors that influence their life span. It is not advisable to use the battery when its capacity drops to 80% (Zhu et al., 2021) or sometimes 70% when it begins its 'second life'. Several second-life strategies are available (Zhu, et al., 2021) :

- Reduction: altering industrial production to reduce hazardous waste and essential resources with high economic relevance yet at risk of scarcity.
- Reuse: It gives the retired battery packs a second life by using them for less demanding applications like low-speed bicycles, motor cars, and charging devices where chargers or power outlets are unavailable. It is better in terms of financial and environmental aspects than recycling because it extends the material's life cycle.
- Restoring: It is a method of reusing and recycling where batteries are taken apart, and the materials used for the cathode are repaired and partially reused for battery manufacturing without any processing.
- Recycling: extracting and processing valuable raw materials. It is the most studied process in many countries and regions due to its complex technology, which depends on extracting valuable raw materials from consumed battery cells.
- Incineration: using some battery materials as fuel for other processes like burning, which produces toxic gases that poison the air.
- Disposal: landfill the batteries.

7 FINANCIAL IMPLICATIONS

Capital expenses for a bikeshare system include assets such as bicycles, stations (if applicable), the control centre, IT system components, maintenance equipment, and vehicles for rebalancing and servicing. Compared to a regular bikeshare system, costs for a bikeshare with e-bikes would differ due to the following:

- Capital cost of the bikes: The cost per e-bike is at least 50 percent higher than the cost per regular bike.
- Charging equipment: The system requires charging facilities, whether in the form of battery cabinets or in-station charging.
- Redistribution costs: A bikeshare where e-bikes are charged centrally may entail higher operating costs because operator crews need to replace depleted batteries in addition to the maintenance and redistribution functions that would be part of any bikeshare system.

ITDP team conducted market research to determine typical prices for bikeshare bicycles. The search was limited to bikes that are fit for purpose in bikeshare systems, with features such as internal wiring, Internet of Things (IoT) connectivity, and protected drive chains. For the sake of privacy, ITDP has anonymised the names of the companies.

Table 7: Bicycle prices market study. (Source: Data from the market sounding, 2023-2024)

SUPPLIER	PRICE, REGULAR BIKE (USD)	PRICE, E-BIKE (USD)
Company 1	700	1,100
Company 2	2,600-2,700	3,500-4,000
Company 3	800-1,600	1,400-3,000
Company 4	-	570
Company 5	-	650-1000

With the e-bikes being slightly costlier to the bikeshare systems compared to regular bikes, operators can recoup part of the investment by pricing e-bikes higher than regular bikes. For example, Tembici in Bogota charges COP 4,800 for a mechanical bicycle for a 15-minute journey with an additional charge of COP 150 per additional minute (Tembici, 2024). The same system charges COP 8,300 for an e-bike for a 15-minute journey with an additional COP 300 per additional minute (ibid). For a single ride, Capital Bikeshare in Washington, D.C., charges USD 1 to unlock a bike and USD 0.05/min and USD 0.15/min for classic and e-bikes, respectively (Lyft Inc., 2024). In New York, Citi Bike charges USD 4.79 for a 30-minute single ride on a classic bike and an extra USD 0.30/min for an e-bike (Lyft Inc., 2024).

8 SUPPORTING POLICIES

E-bikes are gaining popularity, but their development is still in its early stages. Expanding the e-bikeshare system requires support from local and national government policies or strategies. It also requires alignment with the city's transport and climate vision and goals. National policies should classify e-bikes vis-à-vis other types of vehicles. Fiscal can incentivise e-bike use through preferential electricity tariffs for e-vehicle charging and exemptions in import duties, excise duty, and VAT for e-bikes and regular bikes.

8.1 CYCLE INFRASTRUCTURE DEVELOPMENT

Developing a complete network of cycling infrastructure can facilitate a safe, convenient, and comfortable cycling experience. Without an adequate cycle network, many users may not consider using an e-bikeshare system, even if the system offers a high level of service and affordable user fees. Cycle facilities must cater to multiple groups of cyclists, not just those already riding but also more cautious users who might be willing to ride in the presence of a well-designed and complete cycle network.

On larger streets with speeds over 30 km/h or daily vehicle volumes over 1,000 (average daily traffic, or ADT), separate cycle tracks are needed. On smaller streets where motor vehicles and cyclists share the same space, motor vehicle volumes and speeds should be contained for safe and comfortable conditions for cyclists. If vehicle volumes exceed 1,000 vehicles per day (i.e., around 50 vehicles per direction at the peak hour), speeds should be no higher than 30 km/h in the absence of a cycle track. Traffic calming measures, including speed bumps, tabletop crossings, chicanes, and neckdowns, can help reduce vehicle speeds. The cycle network can also comprise greenways providing dedicated space for walking and cycling along waterways and other open spaces.

8.2 CLASSIFYING E-BIKES AND OTHER TYPES OF 2-WHEELERS

E-bike classification helps establish what kinds of vehicles can use dedicated cycle infrastructure. Traffic regulations should treat e-bikes as bicycles rather than motor vehicles and establish limits for e-bikes' weight, width, speed, and power in isolation from internal combustion engine two-wheelers.

The EU classifies e-bikes as bicycles with pedal assist and a 25 km/h power cut-off. In China, e-bikes must have functional pedals and can be either throttle- or pedal-assisted, with a maximum speed of 25 km/h (Government of the People's Republic of China, 2021). In the U.S., an electric bicycle is defined as a "two- or three-wheeled vehicle with fully operable pedals and an electric motor of less than 750 watts, whose maximum speed ... is less than 20 mph [32 kph]" (Congress, U.S., 2002). U.S. states further classify e-bikes according to speed and the presence of a throttle.

8.3 IMPORT TARIFFS AND TAXES

E-bikes are often seen as recreational vehicles, impacting their taxation and regulation. Countries also impose import taxes to encourage local manufacturing. However, these taxes increase the implementation cost of bikeshare systems. In the US, most complete bicycles are subject to an 11% tariff, making bicycles a highly taxed product. Similar high tariffs apply to components, with many having an 8–10% tariff (Logemann & Banayan, 2020). In Brazil, e-bikes are taxed at 35% compared to 10% federal tax on conventional bikes (Pinto, 2022). In Europe, regulators have imposed tariffs on imported Chinese e-bikes to protect the manufacturers against clearance at a time of rising global trade tension (Brunsden & Pooler, 2018).

Fiscal incentives can reduce bike costs, making bikeshare more feasible. Governments can enhance the availability of e-bikes by lowering or eliminating import taxes on e-bikes made elsewhere or providing incentives to encourage domestic producers. Reduced import tariffs are a good way for governments to support emerging modes. In Brazil, for example, since 2015, electric vehicles and their parts have been free from the 35% vehicle import tax (Montoya, 2023).

9 WORKS CITED

1. Analytics, T. (2024). Operación Bogotá. Retrieved May 2024, from https://lookerstudio.google.com/u/0/reporting/95edeca6-2930-41e1-9743-f4099c27054e/page/p_ak0lvg272c
2. Andrew, A. C., Christopher, R. C., Megan, S. R., & Xinmiao, Y. (2016, June). Factors influencing the choice of shared bicycles and shared electric bikes in Beijing. Transportation Research Part C: Emerging Technologies, 67, 399-414.
3. Brunsden, J., & Pooler, M. (2018). Financial Times - Brussels imposes tariffs on imports of Chinese electric bicycles. European Bicycles Manufacturers Association. Retrieved from https://ebma-brussels.eu/financial-times-tariffs-on-chinese-electric-bicycles/
4. Campbell, A. A., Jiao, K., & Sibille, J.-B. (2014). Retrieved from Optimal Charging and Vending of Shared Electric Bikes: https://ecal.berkeley.edu/files/ce295/projects/S14/campbell_jiao_sibille_290_report.pdf
5. Ceri, W., & Philip, A. (2023, May 23). Video call interview. (D. Yanocha, Interviewer)
6. Cherry, C., Worley, S., & Jordan, D. (2010, August 1). Electric Bike Sharing--System Requirements and Operational Concepts. Retrieved from OSTI.GOV: https://www.osti.gov/biblio/1024211
7. Citi Bike. (2017). June 2017 Monthly Report .
8. Citi Bike. (2022). June 2022 Monthly Report .
9. Citi Bike. (2022). November 2022 Monthly Report.
10. CitiBike. (2022). New York, Meet Your New Ebike. Retrieved May 2024, from https://ride.citibikenyc.com/blog/new-york-meet-your-new-ebike#:~:text=Double%20the%20battery%20life.&text=The%20new%20battery%20holds%2060%20miles%20on%20a%20single%20charge.
11. Climate Technology Centre and Network. (2018, October 15). Bycykelen. Retrieved May 2024, from https://www.ctc-n.org/products/bycykelen
12. Congress, U.S. (2002). Public Law 107–319, 107th Congress. Retrieved from https://www.congress.gov/107/plaws/publ319/PLAW-107publ319.pdf
13. Connectbike. (2023). Retrieved from https://connectbike.uk/
14. eBikeLabs. (2019). Retrieved from https://ebikelabs.com/e-bikes-sharing-how-cloud-based-maintenance-management-system-cmms-can-enhance-e-bike-fleet-operations/
15. Efthimiadis, T. (2012). Solar powered municipality bicycle station, Berlin. Retrieved from https://www.flickr.com/photos/telemax/7189032406/
16. Emilie, M., Paschal, G., Vera-Marie, A., Annika, B., & Judith, O. (2020). African Electric Bicycles Start-up Booklet. SolutionsPlus.
17. European Commission. (2014). Copenhagen - European Green Capital. Retrieved from https://ec.europa.eu/environment/europeangreencapital/wp-content/uploads/2012/07/Copenhagen-Short-Leaflet_Web.pdf
18. Evelo. (2020, September 3). How Much Range or What Size Battery Do I Need For My Electric Bike? Retrieved January 2024, from https://evelo.com/blogs/learn/how-much-range-or-what-size-battery-do-i-need-for-my-electric-bike#:~:text=The%20benchmark%20standard%20of%20battery,that%20such%20a%20broad%20sp-ectrum.%E2%80%9D
19. Fortune Business Insights. (2022). Electric Bike Market Growth & Trends | Industry Analysis 2030.
20. Frazier, R. S. (2021, October 5). Everything You Need to Know About Citi Bike. Retrieved January 2024, from https://www.bicycling.com/skills-tips/a37858744/citi-bike-faqs/
21. Gautham, R. C., Peter, V. D., Francesca, G., Ajay, J., Pavol, B., & Olindo, I. (2020, July 10). Sustainable E-Bike Charging Station That Enables AC, DC and Wireless Charging from Solar Energy. Energies, 13(14).

22. Global Times. (2022, January 5). Beijing city to incorporate bike-sharing companies into transport credit system. Retrieved January 2024, from https://www.globaltimes.cn/page/202201/1245153.shtml
23. Government of the People's Republic of China. (2021, September 6). [Safety Technical Code for Electric Bicycles]GB17761-2018. Retrieved from http://gxt.nmg.gov.cn/hdjl/hygq/202201/t20220106_1990549.html
24. Guangyou, Z., Zhiwei, Z., & Sumei, L. (2022, 5 15). Location optimization of electric vehicle charging stations: Based on cost model and genetic algorithm. Energy, 247.
25. Guo, J., Li, X., Gencheng, W., Liu, X., & Quan, Y. (2011). Beijing Transportation Development Annual Report. Beijing Transportation Development Research Center.
26. Hurford, M. (2022, May 9). A New Fleet of Improved Citi E-Bikes Hits the Streets in NYC. Retrieved January 2024, from https://www.bicycling.com/news/a39945527/citi-bike-new-e-bike-nyc-bikeshare/
27. Iderlina, M.-B., Richard, B., Jonathan, C., & Dorina, P. (2016, December). How does our natural and built environment affect the use of bicycle sharing? Transportation Research Part A: Policy and Practice, 94(ISSN 0965-8564), 295-307.
28. ITDP. (2018). The Bikeshare Planning Guide. Retrieved from Institute for Transportation & Development Policy: https://www.itdp.org/wp-content/uploads/2021/05/2018-Bikeshare-Planning-Guide.pdf
29. James, T. (2024). What makes Copenhagen the world's most bicycle friendly capital? Retrieved May 2024, from VisitCopenhagen: https://www.visitcopenhagen.com/copenhagen/activities/what-makes-copenhagen-worlds-most-bicycle-friendly-capital
30. Jarosław, J., & Kamil, S. (2019, July 15). A dedicated battery for an electric bike. Retrieved January 2024, from ITM Conferences: https://www.itm-conferences.org/articles/itmconf/abs/2019/05/itmconf_zkwe2019_01033/itmconf_zkwe2019_01033.html
31. Kassirer, J. (2024). How Copenhagen Became a Cycling City. Retrieved from Tools of Change: https://toolsofchange.com/en/case-studies/detail/752#:~:text=In%201995%2C%20Copenhagen%20introduced%20City,by%20inserting%20a%20refundable%20coin.
32. Katona, A. (2015). Szentendre Bike Share Feasibility Study.
33. Kiefer, C., & Behrendt, F. (2016). Retrieved from https://ietresearch.onlinelibrary.wiley.com/doi/10.1049/iet-its.2014.0251
34. Lang, H. (2023, September 29). Do Electric Bikes Have Speed Limiters? [EXPLAINED]. Retrieved January 2024, from Discerning Cyclist: https://discerningcyclist.com/electric-bike-speed-limiters/
35. Liu, M., Zhang, K., Yang, Y., Chen, Z., & Liu, W. (2023). Life cycle environmental and economic assessment of electric bicycles with different batteries in China. Retrieved from Journal of Cleaner Production: https://doi.org/10.1016/j.jclepro.2022.135715
36. Logemann, A., & Banayan, N. (2020). The American Bicycle Industry And U.S. Trade Policy. Retrieved from People for Bikes.: https://wsd-pfb-sparkinfluence.s3.amazonaws.com/uploads/2020/12/2021_tradeagenda_booklet_reducedv1.pdf
37. Lu-Yi, Q., & Ling-Yun, H. (2018). Bike Sharing and the Economy, the Environment, and Health-Related Externalities. Sustainability, 10(4), 1145.
38. Lyft. (2023). Retrieved from https://www.lyft.com/blog/posts/electrifying-just-20-of-bike-share-stations-could-drastically-reduce
39. Lyft Inc. (2024). Citi Bike for just $4.79. Retrieved May 2024, from Citi Bike: https://citibikenyc.com/pricing/single-ride
40. Lyft Inc. (2024). Plans & pricing Getting started: it's so easy. Retrieved May 2024, from capital bikeshare: https://capitalbikeshare.com/pricing
41. MarketSight Innovations. (2024, April 23). e-Bike Sharing Market [Latest Report] With Future Demand and Growth Analysis to 2032. Retrieved May 2024, from Linkedin:

https://www.linkedin.com/pulse/e-bike-sharing-market-latest-report-future-demand-rgkme
42. Masliy, L. (2023). Bicycling for Sustainable Urban Mobility: Comparing Urban Bicycling for Sustainable Urban Mobility: Comparing Urban Transformations in Paris and Bogotá Transformations in Paris and Bogotá . Retrieved from https://scholarship.claremont.edu/cgi/viewcontent.cgi?article=1318&context=pomona_theses
43. McKnight, J. (2022, November 4). Electric bike maintenance: how to look after your ebike. Retrieved 2024 January, from bikeradar: https://www.bikeradar.com/advice/workshop/electric-bike-maintenance
44. Miriam, R. (2015). Bike Sharing: a review of evidence on impacts and processes of implementation and operation. Bristol: University of the West of England.
45. Montoya, W. G. (2023). EV import subsidies divide Brazil's auto industry. Retrieved from https://www.laprensalatina.com/ev-import-subsidies-divide-brazils-auto-industry/
46. Nikolaos-Fivos, G., Konstantinos, N. G., & Christos, S. I. (2020, June 5). Spatio-Temporal Trends of E-Bike Sharing System Deployment: A Review in Europe, North America and Asia. Retrieved from MDPI: https://doi.org/10.3390/su12114611
47. North American Bikeshare and Scootershare Association. (2022). 3rd Annual Shared Micromobility State of the Industry Report.
48. O'brien, O. (2021, October 1). Which operators are running shared e-bike schemes in Europe? Retrieved May 2024, from Zag Daily: https://zagdaily.com/tech/which-operators-are-running-shared-e-bike-schemes-in-europe/#:~:text=Nextbike%2C%20one%20of%20the%20world's,new%20bicycles%20and%20e%2Dbikes.
49. Official Journal of the European Union. (2023). Regulation (EU) 2023/1542 of the European Parliament and of the Council of 12 July 2023 concerning batteries and waste batteries, amending Directive 2008/98/EC and Regulation (EU) 2019/1020 and repealing Directive 2006/66/EC. Retrieved from EUR-Lex: https://eur-lex.europa.eu/eli/reg/2023/1542/oj
50. Oresund, N. (2019). 20190111_Bycykel_Kongens_Nytorv_Kobenhavn_0029. Retrieved from Flickr: https://www.flickr.com/photos/newsoresund/45853711735/in/photolist-77KnVz-8jHzB9-mSRzfo-7bzwaV-2cRWfYP-J5nmFm-TeLvgT
51. Osorio, J., Lei, C., & Ouyang, Y. (2021). Optimal rebalancing and on-board charging of shared electric scooters. Retrieved from https://www.sciencedirect.com/science/article/abs/pii/S0191261521000552
52. Parkes, S. D., Marsden, G., Shaheen, S. A., & Cohen, A. P. (2013). Understanding the diffusion of public bikesharing systems: evidence from Europe and North America. Journal of Transport Geography: Volume 31, 94-103. Retrieved from ScienceDirect.
53. Pascale, J. (2023, March 20). Capital Bikeshare Getting 700 New E-Bikes; Bowser Celebrates Completion Of 9th Street Bikeway. (WAMU) Retrieved May 2024, from DCist: https://dcist.com/story/23/03/20/capital-bikeshare-getting-700-new-e-bikes-bowser-celebrates-completion-of-9th-street-bikeway/
54. PBSC Urban Solutions. (2021, October 27). The Meddin Bike-Sharing World Map. Retrieved January 2024, from https://www.pbsc.com/blog/2021/10/the-meddin-bike-sharing-world-map
55. PBSC Urban Solutions. (2022). Bogotá Embraces PBSC Bikes and E-Bikes. Retrieved from PBSC Urban Solutions: https://www.pbsc.com/blog/2022/10/blog/2022/09/bogota
56. PBSC Urban Solutions. (2022). The Meddin Bike-sharing World Map. Retrieved from https://bikesharingworldmap.com/reports/bswm_mid2022report.pdf
57. Pinto, V. M. (2022, May 04). The Law and electric bicycles. Retrieved May 2024, from Portal do Transito e mobilidade: https://www.portaldotransito.com.br/coluna/normas-e-legislacao/lei-e-as-bicicletas-eletricas/

58. Roe, D. (2022, April 15). Everything You Want to Know About E-bike Motors, Explained. Retrieved January 2024, from https://www.bicycling.com/bikes-gear/a25836248/electric-bike-motor/
59. Samantha, J. L., Jennifer, L. D., Sara, E., & Jeffrey, M. C. (2019, May). "If I had a regular bicycle, I wouldn't be out riding anymore": Perspectives on the potential of e-bikes to support active living and independent mobility among older adults in Waterloo, Canada. Transportation Research Part A: Policy and Practice, 123, 240-254.
60. Sanne, V., & Fred, D. (2022, August 10). Facts and lessons from the transferred solutions. Retrieved from Handshake: https://handshakecycling.eu/facts-and-lessons
61. Sarah, M. K., Lily, G.-K., Nolan, L., & Mitchell, L. M. (2015). Citi Bike: The First Two Years. Robert F. Wagner School of Public Service, New York University . New York: Rudin Center for Transportation.
62. Surico, J. (2022, May 5). The E-Bike Effect Is Transforming New York City. Retrieved January 2024, from Bloomberg: https://www.bloomberg.com/news/features/2022-05-05/as-e-bikes-surge-new-york-city-tries-to-keep-up
63. Tembici. (2024). Tembicer, by bike everything is closer to you. Retrieved May 2024, from Tembici: https://tembici.com.co/en/
64. Tembici. (n.d.). Plans. Retrieved from ifood Pedal: https://ifood.tembici.com.br/planos/
65. Transporte Ativo. (2014). Contagem de Ciclistas Avenida Atlântica – Copacabana Rio de Janeiro .
66. UL Solutions. (2022). E-Bikes Certification: Evaluating and Testing to UL 2849. Retrieved from UL Solutions: https://www.ul.com/services/e-bikes-certification-testing-ul-2849
67. UL Standards . (2018). UL 2271 ANSI/CAN/UL/ULC Standard for Batteries for Use In Light Electric Vehicle (LEV) Applications. Retrieved from UL Standards & Engagement: https://www.shopulstandards.com/ProductDetail.aspx?productId=UL2271_2_S_20180907
68. Velco. (2023). Retrieved from VELCO FLEET, BIKE RENTAL MANAGEMENT SOFTWARE: https://velco.tech/en/solution/velco-fleet/
69. VeloCittà. (2017, February). Case study Copenhagen: Bike sharing workspace. Retrieved January 17, 2024, from http://mobility-workspace.eu/wp-content/uploads/7.-Copenhagen_DK_case-study_final.pdf
70. Villate, G. M. (n.d.). Byke Shared System (SBC) in Bogotá Results after a great year! Tembici.
71. VisitDenmark. (n.d.). Facts and Figures on Cycling in Denmark. Retrieved January 2024, from https://www.visitdenmark.com/press/latest-news/facts-and-figures-cycling-denmark
72. Yang, Y. (2017). China's bike-sharing bubble bursts as Bluegogo fails. Retrieved from Finincial Times: https://www.ft.com/content/cc1107e8-cb5f-11e7-ab18-7a9fb7d6163e
73. Yanocha, D., & Allan, M. (2019). The Electric Assist: Leveraging E-Bikes and E-Scooters For More Livable Cities. New York: ITDP. Retrieved from https://www.itdp.org/wp-content/uploads/2019/12/ITDP_The-Electric-Assist_-Leveraging-E-bikes-and-E-scooters-for-More-Livable-Cities.pdf
74. Yanocha, D., Hagen, J., & Yuen, E. (2024). E-bikes: Charging Toward Compact Cycling Cities. ITDP.
75. Zhu, J., Mathews, I., Ren, D., Li, W., Cogswell, D., Xing, B., . . . Bazant, M. Z. (2021). End-of-life or second-life options for retired electric vehicle batteries. Science Direct. Retrieved from ScienceDirect: https://www.sciencedirect.com/science/article/pii/S2666386421002484

solutions plus