

## Cost comparison of battery swapping, point charging, and ICE two-wheelers in India

**Authors:** Nibedita Dash and Anup Bandivadekar

**Keywords:** Battery swapping, two-wheelers, total cost of ownership (TCO), consumer incentives, ride-hailing, last-mile delivery

### Introduction

Battery swapping is an innovative electric vehicle (EV) refueling model that can be used by EVs with a detachable battery. Whenever the charge gets depleted, the driver can visit a battery-swapping station and replace the depleted battery with a fully charged one within a few minutes. The batteries are owned, maintained, and charged by the swapping service provider, and the vehicle operator pays a fee for the service.

Organizations in Taiwan and Mainland China have recently been successful in operating battery-swapping services for electric two-wheelers. In Taiwan, Gogoro and Kymco are the leaders in this space. Gogoro has built world's largest battery-swapping network and manages 2,080 battery swapping stations and 750,000 smart EV batteries through its Gogoro Network.<sup>1</sup> In Mainland China, Immotor is the leading battery-as-a-service provider for electric two-wheelers. It operates in more than 50 cities and counts 600,000 daily battery-swapping orders.<sup>2</sup>

India is the biggest two-wheeler market in the world,<sup>3</sup> but currently not many two-wheeler vehicle models in the country support the battery-swapping model. Sun Mobility is a leading provider of battery-swapping services in India, and by the end of 2021, it

1 Gogoro, "Battery Swapping Makes City Living Easy and Clean," (blog), February 23, 2021, <https://blog.gogoro.com/en/battery-swapping-smart-tech-makes-city-living-easy-and-clean-gogoro>.

2 Immotor, "Industry Innovator Immotor Unveils New Product Matrix, Accelerating its Expansion in China and Aiming to Conquer Overseas Markets," December 22, 2020, <https://www.prnewswire.com/news-releases/industry-innovator-immotor-unveils-new-product-matrix-accelerating-its-expansion-in-china-and-aiming-to-conquer-overseas-markets-301197314.html>.

3 "India Overtakes China to Become No 1 in Two-Wheelers Market," *India Today*, May 8, 2017, <https://www.indiatoday.in/auto/latest-auto-news/story/india-overtakes-china-to-become-no-1-in-two-wheelers-market-975916-2017-05-08>.

**Acknowledgments:** This publication is part of NDC Transport Initiative for Asia (NDC-TIA). NDC-TIA is part of the International Climate Initiative (IKI). The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) supports the initiative on the basis of a decision adopted by the German Bundestag. For more visit: <https://www.ndctransportinitiativeforasia.org/>.

Supported by:



based on a decision of the German Bundestag

[www.theicct.org](http://www.theicct.org)

[communications@theicct.org](mailto:communications@theicct.org)

[twitter @theicct](https://twitter.com/theicct)

aims to set up 100 battery-swapping stations in Bengaluru.<sup>4</sup> Additionally, Hero MotoCorp announced a strategic partnership with Gogoro in April 2021 through which Gogoro will establish a battery-swapping network in India and Hero will provide two-wheelers that will work on Gogoro batteries.<sup>5</sup>

Focused on India, this paper evaluates if electric two-wheelers with the battery-swapping option have achieved cost parity relative to electric two-wheelers with only the point charging option or with conventional gasoline two-wheelers.

## Methods

To evaluate the impact of various cost factors on two-wheelers, we estimate the total cost of ownership (TCO) of electric two-wheelers with point charging and battery-swapping options. The results are then compared with the TCO of a conventional gasoline two-wheeler. The cost of ownership is evaluated for the city of Delhi (National Capital Territory [NCT] of Delhi) because Delhi is home to the highest number of registered two-wheelers in any city in India. Further, among the Indian states and union territories, Delhi is at the forefront of driving vehicle electrification.<sup>6</sup> Both central government FAME-II incentives and the Delhi Electric Vehicle Policy, effective from August 2020, are in effect to support electrification of two-wheelers.<sup>7</sup>

For point charging, both the BEV Okinawa iPraise+ and the BEV Ather 450X are considered. For battery swapping, only the BEV Okinawa iPraise+ two-wheeler with detachable battery is considered as a representative vehicle model, because the BEV Ather 450X does not have a removable battery option. For gasoline fueling, the Honda Activa 6G two-wheeler model is considered. Three currently prevalent use cases of two-wheelers in India are considered: personal use, ride-hailing—popularly known as bike-taxi—and last-mile delivery. Table 1 highlights the selected use cases for the different vehicle types with their respective fueling modes indicated by a check mark.

**Table 1.** Selected use cases for the analysis.

Use case	Selected two-wheelers				
	BEV				ICE
	Okinawa iPraise +		Ather 450X		Honda Activa 6G
	Point charging	Battery swapping	Point charging	Battery swapping	Gasoline
Personal use	✓	✓	✓	N/A	✓
Ride-hailing	✓	✓	✓	N/A	✓
Last-mile delivery	✓	✓	✓	N/A	✓

The *personal use* case concerns individual travel needs. The distance traveled is an average of 10,000 km annually, and this requires relatively fewer recharging or refueling events than the other uses. The *ride-hailing* and *last-mile delivery* use cases involve

4 “SUN Mobility Aims to Set Up 100 Battery Swapping Stations in Bengaluru by 2021-end,” *Economic Times*, updated December 22, 2020, <https://economictimes.indiatimes.com/industry/auto/auto-news/sun-mobility-aims-to-set-up-100-battery-swapping-stations-in-bengaluru-by-2021-end/articleshow/79874332.cms?val=3728&from=mdr>.

5 “Hero MotoCorp and Gogoro Announce Strategic Partnership to Accelerate the Shift to Electric Transportation in India,” Gogoro, April 21, 2021, <https://www.gogoro.com/news/Gogoro-Battery-Swapping-India-Hero/>.

6 “At 50 Lakh, Bengaluru Has 2nd Most Number of Two-Wheelers,” *Times of India*, updated January 31, 2018, <https://timesofindia.indiatimes.com/city/bengaluru/at-50-lakhbengaluru-has-2nd-most-number-of-two-wheelers/articleshow/62718089.cms>.

7 Shikha Rokadiya, “FAME-II Revisions Spark Hopes for a Jump in Electric Two-Wheeler Sales in India,” International Council on Clean Transportation (blog), July 28, 2021, <https://theicct.org/blog/staff/fame-ii-revision-india-jul2021>.

longer distances traveled, an annual average of 47,550 km and 36,455 km, respectively, and a greater number of recharging or refueling events. Currently, the personal and last-mile delivery uses are considered private activities, and hence, the two-wheelers used for these activities are registered as private vehicles in India.

The two-wheeler ride-hailing or bike-taxi service is a fast-growing transport segment in India and the regulatory position is still evolving. In 2004, the central Government of India allowed the registration of two-wheelers to be used for hire to carry passengers as “transport vehicles.”<sup>8</sup> Based on this, some state governments have permitted two-wheeler ride-hailing businesses within their jurisdiction for commercial passenger transport purposes. In our TCO analysis, two-wheelers used for ride-hailing purposes are considered as commercial vehicles.

The two-wheeler models selected are either popular vehicle models already in use or vehicles that can potentially be used in personal and commercial operations, with comparable costs and performance criteria. We assume that for the two-wheeler with battery-swapping option, the vehicle is sold without a battery.<sup>9</sup>

## Cost analysis for two-wheelers: Baseline scenario

The selected vehicle models and their key specifications—in terms of ex-showroom price without purchase incentives, peak power, and gross battery capacities—were all obtained from manufacturer websites and are listed in Table 2. The certified drive-range values for the BEV two-wheelers were obtained from the web portal of the Department of Heavy Industry of the Indian government and the fuel efficiency value for the gasoline two-wheeler, as certified by the Automotive Research Association of India, was obtained from zigwheels.com.<sup>10</sup> These certified range and fuel efficiency values were adjusted to reflect real-world values by considering a 25% increase in the certified energy consumption numbers.<sup>11</sup> Also, for BEV two-wheelers, the net battery capacity was calculated by considering 90% of the gross battery capacity values.<sup>12</sup>

**Table 2.** Selected vehicle models and their specifications.

Manufacturer	Model	Fuel type	Ex-showroom price without purchase incentives (INR)	Peak power (kW)	Certified range / Fuel efficiency	Adjusted range/ Fuel efficiency	Gross battery capacity (kWh)	Net battery capacity (kWh)	Adjusted energy / Fuel consumption (per 100 km)	
Ather Energy	450X	BEV	171,415	6	116 km	93 km	2.9	2.6	2.8 kWh	
Okinawa	iPraise+	BEV	with battery	147,600	2.5	139 km	111 km	3.3	3.0	2.7 kWh
			without battery	112,786						
Honda	Activa 6G	Gasoline	67,843	5.7	60 kmpl	48 kmpl	N/A	N/A	2.1 liter	

8 Notifications under the Motor Vehicles Act, Ministry of Road Transport and Highways, November 5, 2004, <https://morth.nic.in/sites/default/files/NOTIFICATIONS.pdf>

9 “MoRTH Allows Sale and Registration of Electric Vehicles without Batteries,” Ministry of Road Transport and Highways, August 12, 2020, <https://pib.gov.in/PressReleasePage.aspx?PRID=1645394>.

10 “Ather 450X Specifications,” Ather, accessed August 22, 2021, <https://bs-ather-jobs-assests.s3-ap-south-1.amazonaws.com/bpa-assests/450X+Specifications+V6.pdf>; Okinawa Scooters, *Okinawa Power the Change*, accessed August 22, 2021, <https://okinawascooters.com/wp-content/uploads/2020/04/OkinawaBrochurePDF.pdf>; “Activa 6G Brochure,” Honda, accessed August 22, 2021, [https://www.honda2wheelersindia.com/assets/pdf/Activa\\_6G\\_Final\\_Brochure.pdf](https://www.honda2wheelersindia.com/assets/pdf/Activa_6G_Final_Brochure.pdf); “Model under Fame,” Ministry of Heavy Industries, accessed August 22, 2021, <https://fame2.heavyindustry.gov.in/ModelUnderFame.aspx>; “Honda Activa 6G Mileage,” ZigWheels, accessed August 22, 2021, <https://www.zigwheels.com/newbikes/faqs/what-is-the-mileage-of-honda-activa-6g>

11 “What Is Fuel Economy or Car Mileage or Bike Average?” CarBikeTech, July 27, 2020, <https://carbiketech.com/fuel-economy-car-mileage-bike-average/>.

12 “Design & Specifications,” Vehicle Topics, Ather, accessed August 22, 2021, <https://www.atherenergy.com/fag/vehicle/specs>; “Volkswagen ID.3 Pro S,” Electric Vehicle Database, accessed August 22, 2021, <https://ev-database.org/car/1203/Volkswagen-ID3-Pro-S>.

To compare the TCO of the selected vehicle models, we analyzed the impact of vehicle depreciation costs, central and state taxes and fees, vehicle insurance cost, fueling costs, battery replacement cost, vehicle maintenance cost, opportunity cost of fueling, and the incentives for BEVs available from the Government of India and the Delhi government. We also made some standard assumptions primarily based on the use cases. The key variables, input data, and assumptions are outlined below.

For all uses, we assume that vehicles are purchased and owned by the drivers and are subject to an amortization period of 5 years. We based our calculations on vehicle procurement in 2021 and ownership through 2025, and applied a discount rate of 5% to obtain the present value of different costs in the 5-year period, in line with Insurance Regulatory and Development Authority of India (IRDAI) guidelines.<sup>13</sup> We adopted daily 10-hour and 12-hour operational times for ride-hailing and last-mile delivery drivers, respectively.<sup>14</sup> We considered an average daily travel distance of 150 km for ride-hailing trips and 115 km for last-mile delivery trips, for 317 days in a year.<sup>15</sup> For personal use, we estimated an average daily travel distance of 37 km and 269 operational days in a year.<sup>16</sup> It is assumed that the drivers of BEV point charging vehicles will try to meet their daily charging needs first through home charging at night or during other non-business hours for each day of operation. The rest of the charging needs will be fulfilled by using public charging facilities during business hours. In the case of battery swapping, all of the refueling needs are met by exchanging discharged batteries for fully charged batteries at swapping stations.

*Vehicle depreciation cost* is estimated by deducting the residual value of the two-wheeler from the vehicle purchase cost after 5 years of use. The vehicle purchase cost amounts to the ex-showroom price and includes incentives from the central and state governments. Further, the vehicle price assumptions for 2021 also account for the prices of the latest models of conventional vehicles, notably gasoline-powered vehicles that are compliant with the Bharat Stage VI emission standards in effect from April 2020 onward. The residual values of the two-wheeler at different time points are calculated using the insured declared value (IDV) obtained from multiple insurance company portals and shown in Table 3.<sup>17</sup>

---

13 "Standard Form for Two-Wheeler Package Policy", Insurance Regulatory and Development Authority, accessed August 22, 2021, <https://www.irdai.gov.in/admincms/cms/Uploadedfiles/PDNL1617/21-26.pdf>.

14 Tata Institute of Social Sciences, "Understanding Food Delivery Platform: Delivery Persons' Perspective," accessed August 22, 2021, [https://tiss.edu/uploads/files/Online\\_Food\\_Delivery\\_Platform.pdf](https://tiss.edu/uploads/files/Online_Food_Delivery_Platform.pdf); The Energy and Resources Institute, *Emerging Role of Bike (Motorcycle) Taxis in Urban Mobility*, January 2020, [https://www.teriin.org/sites/default/files/2020-03/emerging-role-bike-discussion-paper\\_1.pdf](https://www.teriin.org/sites/default/files/2020-03/emerging-role-bike-discussion-paper_1.pdf).

15 Dialogue & Development Commission of Delhi and Rocky Mountain Institute, *Deliver Electric Delhi*, [https://rmi.org/wp-content/uploads/2020/07/Freight-Report\\_08072020.pdf](https://rmi.org/wp-content/uploads/2020/07/Freight-Report_08072020.pdf); *Emerging Role of Bike (Motorcycle) Taxis in Urban Mobility*.

16 Anumita Roychowdhury, Gaurav Dubey, *The Urban Commute and How It Contributes to Pollution and Energy Consumption*, (Centre for Science and Environment, 2018), <https://data.opencity.in/Documents/Recent/CSE-india-the-urban-commute-Report.pdf>.

17 "Understand the Depreciation Value of Your Two-Wheeler," ICICI Lombard, February 13, 2021, <https://www.icicilombard.com/blog/home-insurance/hoi/understand-the-depreciation-value-of-your-two-wheeler>.

**Table 3.** Rates of depreciation for the selected BEV and ICE two-wheelers.

Vehicle's lifetime		Percentage of depreciation		
		BEV Okinawa iPraise+	BEV Ather 450X	Gasoline Honda Activa 6G
	Exceeding six months but less than a year	15%	15%	15%
	Exceeding one year but less than two years	20%	20%	20%
	Exceeding two years but less than three years	30%	30%	30%
	Exceeding three years but less than four years	40%	40%	40%
	Exceeding four years but less than five years	50%	50%	50%

For *vehicle financing*, the loan interest rate, processing fee, maximum loan eligibility, and maximum loan payback periods are considered. In India's two-wheeler vehicle financing space, the interest rates vary widely between different lending entities at different times.<sup>18</sup> We picked a loan offer valid in June 2021 that would finance 100% of the vehicle upfront purchase cost at a 7.85% interest rate for both conventional and BEV two-wheelers for a maximum 5-year loan payback period. Detailed assumptions are in Table 4. The processing fee is estimated at 1% of the financed amount with the minimum and maximum values of INR 500 and INR 10,000, respectively.<sup>19</sup> The equated monthly installments (EMI) are calculated based on annual interest rate, financed amount, and repayment period toward purchase of the vehicle. The interest rate and repayment period being the same for all vehicles, the variation in EMI is due to difference in the finance amounts pertaining to each of the two-wheelers considered for the study.

**Table 4.** Vehicle financing costs and relevant assumptions for vehicles selected.

Financing assumptions	BEV Okinawa iPraise+	BEV Ather 450X	Gasoline Honda Activa 6G
Annual interest rate	7.85%	7.85%	7.85%
Repayment period	5 years	5 years	5 years
Financed amount	100%	100%	100%
Processing fee for gasoline vehicle	N/A	N/A	1%
Processing fee for vehicle with point charging	1%	1%	N/A
Processing fee for vehicle with battery swapping	1%	N/A	
Equated monthly installment (EMI) for gasoline vehicle	N/A	N/A	INR 1,331
EMI for BEV with point charging	INR 1,548	INR 2,190	N/A
EMI for BEV with battery swapping	INR 2,011	N/A	N/A

18 "Two-Wheeler Loan," MyLoanCare, updated October 17, 2021, <https://www.myloancare.in/two-wheeler-loan/>.

19 Bank of India, *Retail Loans - Interest Rate / Processing charges W.E.F. 04-05-2021*, Bank of India, May 4, 2021, <https://www.bankofindia.co.in/UserFiles/File/RBI-Format-ROI-PC.pdf>

Taxes and fees considered include the one-time vehicle registration fee and the goods and services tax (GST)<sup>20</sup> applicable on vehicle purchase.<sup>21</sup> Among the state and local government taxes and fees, road tax and parking charges are considered. The Delhi government offers tax incentives in terms of exemption of road tax on BEV two-wheelers. As notified recently, no one-time parking charges are considered for any of the two-wheeler models.<sup>22</sup> Table 5 contains the values considered for taxes and fees.

**Table 5.** Central and state taxes and fees for vehicles selected.

Tax and Fees Assumptions		BEV Okinawa iPraise+	BEV Ather 450X	Gasoline Honda Activa 6G
Taxes and fees (central)	Goods and services tax (GST)	5%	5%	28%
	Registration fees for BEV personal two-wheelers	waived	waived	N/A
	Registration fees for BEV commercial two-wheelers	waived	waived	N/A
	Registration fees for gasoline personal two-wheelers (Lifetime)	N/A	N/A	INR 1,220
	Registration fees for gasoline commercial two-wheelers (Lifetime)	N/A	N/A	INR 1,220
Taxes and fees for Delhi	Road tax (Lifetime)	waived	waived	INR 3,180
	One-time parking charge (Lifetime) for the vehicle	waived	waived	waived

For *insurance premiums*, we assume that all vehicles are covered by a mandatory third-party damage policy, an own-damage policy, and a mandatory personal-accident policy for every driver. For third-party damage coverage, we assume the premiums specified under the latest order by the IRDAI in 2020 for the fiscal year (FY) 2020–21.<sup>23</sup> The order defines separate rates for conventional and electric two-wheelers in private and commercial use. As mentioned before, we assume that private two-wheelers are used for personal use and last-mile delivery purposes and commercial two-wheelers are used in ride-hailing businesses. Insurance premiums for own-damage vary across insurance providers, and that is accounted for in the insurance estimation for private and commercial conventional and BEV two-wheeler rates provided by Coverfox.<sup>24</sup> Personal accident policy coverage for an owner-driver of a two-wheeler vehicle is also mandated by IRDAI, and we use the current premium rate per year for all vehicles. Table 6 covers the values considered in this regard.

20 “EV Adoption in Two-Wheelers: Is a GST Rate Cut Enough?” *Outlook*, accessed June 14, 2021, <https://www.outlookindia.com/website/story/automobiles-ev-adoption-in-two-wheelers-is-a-gst-rate-cut-enough/335162>

21 “GST rate for Authorised Service Stations for Motor Vehicles Servicing or Repairs,” How to Export Import, January 4, 2019, <https://howtoexportimport.com/GST-rate-for-Authorised-Service-Stations-for-Motor-5687.aspx#:~:text=The%20rate%20of%20GST%20payable,additional%20cess%20than%2028%25%20GST.>

22 “Cars to Get Expensive from 1st Jan–Parking fees Hiked by Up to Rs 75k,” RushLane, December 24, 2018, <https://www.rushlane.com/car-parking-fees-hiked-india-12291596.html>.

23 “Exposure Draft on Revision in Premium Rates for Motor Third Party Insurance Cover for the Financial Year 2020–21,” Insurance Regulatory and Development Authority of India, Ref. No: IRDA/NL/MTP/2020-21/EXDRF, March 5, 2020, [https://www.irdai.gov.in/ADMINCMS/cms/frnGeneral\\_Layout.aspx?page=PageNo4061](https://www.irdai.gov.in/ADMINCMS/cms/frnGeneral_Layout.aspx?page=PageNo4061).

24 Own-Damage Premium for Commercial Cars, Coverfox, accessed June 14, 2021, <https://www.coverfox.com/commercial-car-insurance/?flow=fb&hp=1&hp=1>



**Table 6.** Insurance costs and relevant estimates for vehicles selected.

Insurance type	BEV Okinawa iPraise+	BEV Ather 450X	Gasoline Honda Activa 6G
Third-party premium (annual) for personal use and last-mile delivery (private use)	INR 888	INR 2,792	INR 3,285
Third-party premium (annual) for ride-hailing operation (commercial use)	INR 3,660	INR 3,660	INR 4,305
Personal accident cover (annual) for personal use and last-mile delivery (private use)	INR 1,661	INR 1,661	INR 1,661
Personal accident cover (annual) for ride-hailing use (commercial use)	INR 1,661	INR 1,661	INR 1,661
Own-damage insurance (annual) for personal use and last-mile delivery (private use)	INR 780	INR 1,215	INR 574
Own-damage insurance (annual) for ride-hailing use (commercial use)	INR 780	INR 1,215	INR 1,215

*Fueling costs* are estimated differently for electric and gasoline two-wheelers. Among the electric two-wheelers, fueling cost is determined by whether the vehicle battery is recharged through point charging or battery swapping. Fueling cost for the gasoline two-wheeler is based on the prevalent gasoline rates in Delhi averaged over the 6 months until June 2021.<sup>25</sup> We consider an average value because the gasoline price can change daily, and it has been increasing rapidly, and to unprecedented levels, in 2021.

In estimating the energy cost associated with electric vehicle recharging, we draw upon the residential and public-charging electricity rates from electricity tariff orders approved by the state of Delhi for FY 2020–21.<sup>26</sup> In determining home-charging cost, residential electricity rates considered correspond to the 201 kilowatt-hour (kWh) to 400 kWh consumption bracket.<sup>27</sup> For public-charging cost, we first assume the latest preferential electricity tariffs specified by Delhi for FY 2018–19 for the electric charging service providers at INR 4.7 per kWh. We further add INR 9 per kWh to the preferential power tariffs as an estimate of the other costs and profit margin per kWh, as charged by charging-service providers in Delhi. Adding up these two components, the total cost of public charging a two-wheeler is determined at INR 13.7 per kWh. This value matches with the tariffs currently being charged by the charging stations in Delhi.<sup>28</sup>

For the BEV Okinawa iPraise+, the only available charging method is slow charging at home and public charging facilities. For the BEV Ather 450X, we consider slow charging at home and fast charging at Ather Grid public charging facilities.<sup>29</sup> Ather currently offers charging the BEV Ather 450X at their Ather Grid public charging facilities for free.<sup>30</sup> We consider this pricing as a promotional offer that will not last for a long time. Therefore, for the BEV Ather 450X public charging cost, we consider the same cost of INR 13.7 per kWh of energy. The energy cost expenditure associated with BEV battery swapping is based on the cost per swapping transaction. We obtained the value of INR 34 per kWh

25 "Petrol Price in India," MyPetrolPrice, accessed June 14, 2021, <https://www.mypetrolprice.com/petrol-price-in-india.aspx?stateId=>

26 "Tariff Orders," Delhi Electricity Regulatory Commission, accessed June 14, 2021, <http://www.derc.gov.in/tariff-orders>.

27 "CSE Releases New Analysis of Electricity Consumption in Delhi during the Lockdown and Un-lockdown Phases," Centre for Science and Environment, accessed June 14, 2021, <https://www.cseindia.org/cse-releases-new-analysis-of-electricity-consumption-in-delhi-during-the-lockdown-10314>.

28 "Charging Locations," ElectreeFi, accessed June 14, 2021, <https://emonitoring.electreefi.com/ChargingStations/LoadChargingStationsGoogleMapView?moc=home#>.

29 "Introducing Ather Grid," Ather, accessed June 14, 2021, <https://www.atherenergy.com/grid>.

30 "You can charge at Ather Grid for free until 31st December 2021," Ather, accessed October 25, 2021, <https://www.atherenergy.com/faq/vehicle/charging>.

of battery using the per-swap rate charged by India’s largest retail swapping service provider Sun Mobility at its swapping kiosks, as collected from a primary survey. Table 7 below lists all the assumptions.

**Table 7.** Fueling costs and relevant assumptions for vehicles selected.

Fuel type	BEV Okinawa iPraise+	BEV Ather 450X	Gasoline Honda Activa 6G
Gasoline fueling	N/A	N/A	INR 90 per liter
Residential overnight charging	INR 4.5 per kWh	INR 4.5 per kWh	N/A
Public charging	INR 4.7 per kWh	INR 4.7 per kWh	
Preferential tariff margin for public fast-charging	INR 9 per kWh	INR 9 per kWh	
Battery swapping	INR 34 per kWh	N/A	

*Battery replacement costs* apply to BEVs with point charging option only, and cost depends on the size of the battery. We assume battery costs of INR 10,047 per kWh in 2021 through INR 7,516 per kWh in 2025, with a 7% year-on-year decrease.<sup>31</sup> Battery-replacement frequency is estimated from the average distance traveled in a year by the two-wheeler and the average battery life in terms of distance traveled. The average distance traveled in a year varies by use case, and the average battery life, in terms of distance traveled of each vehicle, is estimated from the distance traveled by the two-wheeler in each charging-discharging cycle of the entire battery and the total number of battery cycles throughout the battery life. Table 8 captures the battery-replacement cost and the inputs toward estimating it.

The battery-replacement frequency for personal use of both BEVs are greater than the total operating period of 5 years, and that results in a zero battery-replacement cost. For ride-hailing and last-mile delivery use cases, the battery-replacement frequency is less than 5 years for both BEVs. The highest battery-replacement cost of INR 48,355 is borne by BEV Ather 450X for ride-hailing use, and it has the lowest battery-replacement frequency of 2 years. The last-mile delivery use case for the BEV Ather 450X bears the lowest battery-replacement cost of INR 24,001 with 3 years of battery-replacement frequency.

31 “Battery Pack Prices Cited below \$100/kWh for the First Time in 2020, While Market Average Sits at \$137/kWh,” *BloombergNEF*, December, 16, 2020, <https://about.bnef.com/blog/battery-pack-prices-cited-below-100-kwh-for-the-first-time-in-2020-while-market-average-sits-at-137-kwh/>.



**Table 8.** Battery replacement cost assumptions for vehicles selected.

		BEV Okinawa iPraise+	BEV Ather 450X	Gasoline Honda Activa 6G
Battery replacement cost	Personal	INR 0	INR 0	N/A
	Ride-hailing	INR 48,737	INR 48,355	
	Last-mile delivery	INR 24,190	INR 24,001	
Battery replacement frequency	Personal	12 years	10 years	N/A
	Ride-hailing	2 years	2 years	
	Last-mile delivery	4 years	3 years	
Average battery life		111,200 km	92,800 km	N/A
Average distance traveled in a year	Personal	10,000 km		
	Ride-hailing	47,550 km		
	Last-mile delivery	36,455 km		

*Maintenance cost* is estimated from the routine service costs incurred by the vehicle over 5 years for the distance traveled in the different use cases. Supplementing this cost value, an appropriate tax rate is also applied. For the BEV Ather 450X, Ather offers service and maintenance through its service subscription plan. With this plan, the maintenance cost for this two-wheeler is estimated at INR 2,400 per year before taxes for personal, ride-hailing, and last-mile delivery applications.<sup>32</sup> For the BEV Okinawa iPraise+ and the gasoline Honda Activa 6G, the service costs per service schedule were first obtained from vehicle comparison websites like BikeDekho and CarToq<sup>33</sup> and then verified from vehicle dealers based in Delhi. The estimated 5-year maintenance cost is highest for the Honda Activa 6G and lowest for the BEV Okinawa iPraise+ for different applications. The maintenance costs of different vehicles for different applications are in Table 9.

**Table 9.** Maintenance costs for vehicles selected.

		BEV Okinawa iPraise+	BEV Ather 450X	Gasoline Honda Activa 6G
Total maintenance cost	Personal	INR 2,682	INR 12,874	INR 13,947
	Ride-hailing	INR 12,753	INR 12,874	INR 66,318
	Last-mile delivery	INR 9,778	INR 12,874	INR 50,844

The *opportunity cost* of fueling is important because of the revenue losses during the time spent on recharging or refueling. However, there is no opportunity cost for personal use of two-wheelers because there is no revenue loss. For commercial vehicles with battery swapping and gasoline fueling, no opportunity cost is incurred because the time taken for swapping and gasoline fueling is minimal. Hence, we estimate the opportunity cost of fueling only for BEV two-wheelers with the point charging option that are used in ride-hailing and last-mile delivery services. We also assume that the opportunity cost is incurred due to loss of potential income during business or operational hours only. The opportunity cost calculation is based on the average charging duration, number of

32 "Hassle-Free Ownership Plans," Ather, accessed June 14, 2021, <https://www.atherenergy.com/subscription-plans>.

33 "Honda Activa 5G Service Cost," BikeDekho, accessed August 23, 2021, <https://www.bikedekho.com/honda/activa-5g/service-cost>; "Okinawa Praise Electric Scooter Launched in India; Costlier than Honda Activa," CarToq, December 19, 2017, <https://www.cartoq.com/okinawa-praise-electric-scooter-launched-in-india-costlier-than-honda-activa/>.

charging events during business hours per day, and the hourly wage of ride-hailing and last-mile connectivity drivers.

We obtained the average charging duration of a full, slow-charging session for the BEV Ather 450X and the BEV Okinawa iPraise+ as 5.75 hours and 4.5 hours, respectively, from the manufacturer websites. BEV Ather 450X also supports fast charging of the vehicle battery, and we obtained the value of 1.75 hours for a full fast-charging session of this two-wheeler from the Ather website and customer care support personnel.

For the hourly wage, we estimate that the ride-hailing drivers earn around INR 650 per day in 10 working hours and last-mile delivery drivers earn approximately INR 533 per day by working 12 hours a day.<sup>34</sup> Accordingly, we estimated the opportunity cost as INR 65 and INR 44 per hour for ride-hailing and last-mile delivery drivers, respectively. The relevant assumptions are listed in Table 10.

**Table 10.** Opportunity costs and relevant assumptions for vehicles selected.

		BEV Okinawa iPraise+	BEV Ather 450X	Gasoline Honda Activa 6G
Personal use	Battery swapping	—	—	N/A
	Point charging	—	—	
	Refueling	N/A	N/A	—
Ride-hailing	Battery swapping	—	—	—
	Point charging	INR 65 per hour	INR 65 per hour	N/A
	Refueling	N/A	N/A	—
Last-mile delivery	Battery swapping	—	—	—
	Point charging	INR 44 per hour	INR 44 per hour	N/A
	Refueling	N/A	N/A	—
Slow charging duration		4.5 hours	5.75 hours	N/A
Fast charging duration		N/A	1.75 hours	N/A

*Purchase incentives* are offered by the central government of India for BEV two-wheelers with a battery. The FAME II program<sup>35</sup> provides a one-time purchase incentive of INR 15,000 per kWh of battery capacity for two-wheelers. However, no incentive is available for purchasing two-wheelers without batteries that are suitable for battery swapping. Additionally, the Delhi government offers an upfront cost-reduction incentive of INR 5,000 per kWh with a maximum limit of INR 30,000 per BEV two-wheeler with a battery.<sup>36</sup> In the case of vehicles without batteries, a purchase incentive of 50% of the total incentive amount is applicable to promote battery swapping in two-wheelers. The Delhi Electric Vehicle Policy, 2020 also offers a scrappage incentive of INR 5,000 to the registered owner of an electric two-wheeler upon their scrapping and de-registering of an old, conventional two-wheeler registered in Delhi. The scrappage incentive is available only upon evidence of matching contribution from the dealer or manufacturer and confirmation of the scrapping and de-registration of the conventional two-wheeler.

<sup>34</sup> *Understanding Food Delivery Platform: Delivery Persons' Perspective; Emerging Role of Bike (Motorcycle) Taxis in Urban Mobility*

<sup>35</sup> Ministry of Heavy Industries and Public Enterprises, "Publication of Notification in Gazette of India (Extraordinary) Regarding Phase-II of FAME India Scheme," (March 8, 2019), <https://dhi.nic.in/writereaddata/uploadfile/publicationnotificationfame%20ii%208march2019.pdf>; Ministry of Heavy Industries and Public Enterprises, "Corrigendum," REGD. No. D. L-33004/99, (June 11, 2021), <https://dhi.nic.in/writereaddata/UploadFile/FAME%20II%20-%20Polict%20modifications.pdf>

<sup>36</sup> Government of National Capital Territory of Delhi, Transport Department, "Delhi Electric Vehicles Policy 2020," (August 8, 2020), [https://transport.delhi.gov.in/sites/default/files/All-PDF/Delhi\\_Electric\\_Vehicles\\_Policy\\_2020.pdf](https://transport.delhi.gov.in/sites/default/files/All-PDF/Delhi_Electric_Vehicles_Policy_2020.pdf)

## Results

Based on the values and assumptions above, TCO values are derived for the selected vehicles for the three use cases over a 5-year operating period. The results create a baseline scenario. These TCO values are then normalized over the average distance traveled in 5 years to obtain the average cost per km values. The results are presented according to use case and type of charging or refueling options.

### Upfront cost of the vehicle

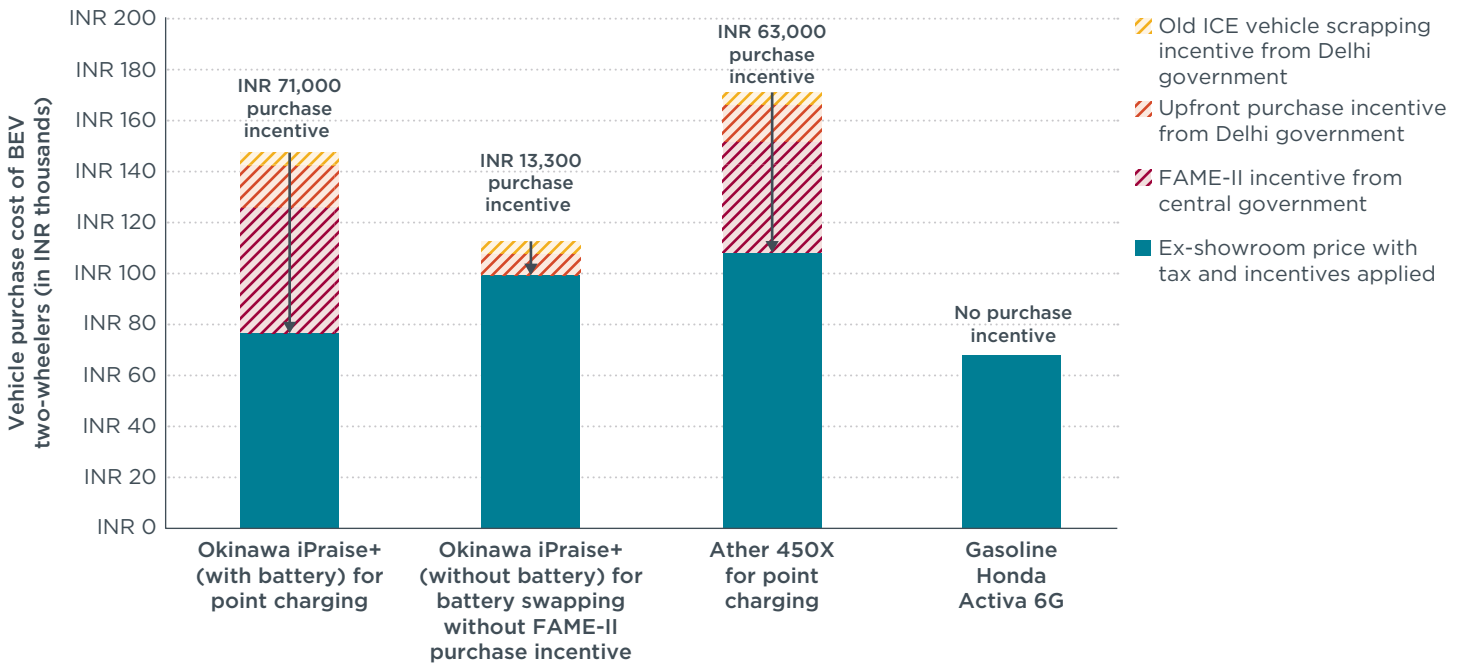
We derive the upfront purchase costs of BEVs based on the effect of central and state government incentives in place. For the gasoline two-wheeler, the upfront purchase cost is same as the ex-showroom price. The vehicle depreciation costs used in the estimation of TCO are in turn derived from the upfront purchase cost of a vehicle. The depreciation costs reflect the remaining value of a vehicle after use, considering 5 years of use in the context of the study.

The purchase price of a BEV two-wheeler with the battery-swapping option is less than a BEV with point charging because battery-swapping vehicles are sold without a battery. The upfront cost before incentives of the BEV Okinawa iPraise+ with battery swapping is INR 1.1 lakhs in Delhi, 24% less than the upfront cost of the BEV Okinawa iPraise+ with point charging option, which costs INR 1.5 lakhs. The BEV Ather 450X with point charging costs INR 1.7 lakhs, whereas the gasoline Honda Activa 6G costs INR 67,800 in Delhi. So, before incentives are applied, the BEV Okinawa iPraise+ with battery swapping is still 66% costlier than the gasoline Honda Activa 6G.

For the BEV Okinawa iPraise+ with point-charging option, after applying all the incentives, including FAME-II amounting to INR 49,500, the Delhi upfront purchase incentive of INR 16,500, and a scrapping incentive of INR 5,000 on an old ICE vehicle from Delhi, the vehicle purchase cost becomes INR 76,600. The upfront purchase cost of the BEV Ather 450X model with point charging of INR 1.7 lakhs becomes INR 1.1 lakhs after considering the incentives of INR 43,500, INR 14,500, and INR 5,000 from FAME-II, the Delhi upfront purchase incentive, and the Delhi old ICE vehicle scrapping incentive, respectively. Thus, the actual purchase costs of the BEV Okinawa iPraise+ and BEV Ather 450X with point-charging option are reduced by 48% and 37%, respectively, from their original upfront costs due to incentives.

However, for the BEV Okinawa iPraise+ with battery-swapping option, the FAME II incentive is not available. The Delhi upfront purchase incentive of INR 8,300 is available, and that is 50% of the value of purchase for a vehicle with point charging. A vehicle scrapping incentive of INR 5,000 is also applicable under the 2020 Delhi Electric Vehicle Policy. With application of these two incentives, the vehicle purchase cost is estimated at INR 99,500. Thus, the purchase cost of Okinawa iPraise+ with battery-swapping option reduces by only 12%. Figure 1 illustrates the relevant incentives and derived vehicle purchase costs for the selected BEVs.

## Delhi City (2021)



**Figure 1.** Vehicle purchase cost for the selected BEV two-wheelers in NCT of Delhi in 2021.

## Cost comparison of selected models with different charging options and use cases

### TCO: Personal use

For the personal use case, the gasoline two-wheeler bears the highest TCO and the BEV Okinawa iPraise+ with point charging is most cost-attractive in terms of the average cost per km out of all the options. The gasoline Honda Activa 6G has a TCO of INR 1.7 lakhs and a cost per km of INR 3.44, as shown in Figure 2. The BEV Okinawa iPraise+ with battery swapping is next highest in terms of cost, with a TCO of INR 1.4 lakhs and a per km cost of INR 2.72. The third is Ather 450X with point-charging mode, with a TCO of INR 1.1 lakhs and a cost per km of INR 2.21. The lowest-cost option turns out to be Okinawa iPraise+ with point-charging option, having a TCO of INR 74,000 and per km cost of INR 1.47.

## Personal use total cost of ownership (TCO) for two-wheelers in 2021 in Delhi

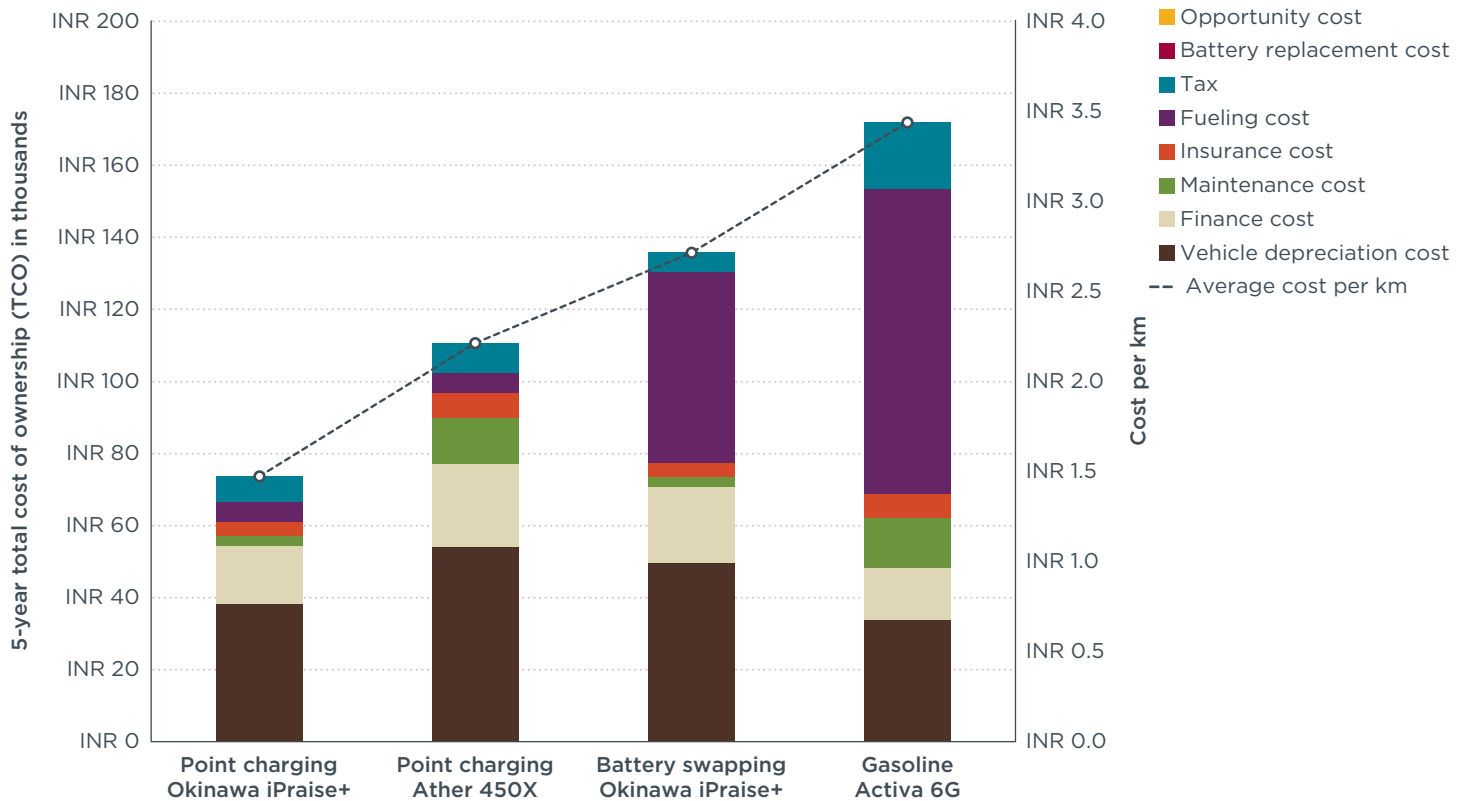


Figure 2. 5-year TCO of selected two-wheelers in personal use in NCT of Delhi.

In terms of cost components for the BEVs with point charging, vehicle depreciation cost is the highest contributor to TCO, and that is followed by finance cost. For the BEV with battery swapping, fueling is the largest cost component, amounting to INR 53,000, and that is followed by its vehicle depreciation cost at INR 50,000. The gasoline two-wheeler has the highest fueling cost among all the selected models at INR 85,000.

In terms of cost per km, the Okinawa iPraise+ with battery swapping is costlier than the Okinawa iPraise+ and Ather 450X with point charging by INR 1.24 and INR 0.5, respectively. This is due to the unavailability of the FAME II incentive and higher per-unit swapping cost in the battery-swapping option. Because the distance traveled in personal use is low, and there is less vehicle utilization than in commercial uses, the battery-swapping model is not cost competitive at present. If battery-swapping costs decline in the future, and the central government extends the FAME II incentive to battery-swapping models, electric two-wheelers with battery swapping could become more economical for personal use.

### TCO: Ride-hailing operation

In ride-hailing, the BEV Okinawa iPraise+ with the battery-swapping option is the most cost-attractive in terms of per km cost of ownership, and the gasoline Honda Activa 6G has the highest cost per km. As shown in Figure 3, the Okinawa iPraise+ with battery swapping also has the lowest 5-year TCO at INR 3.5 lakhs, or an average per km cost of INR 1.46. This is followed by the Ather 450X with point-charging option, which incurs a TCO of INR 3.6 lakhs or INR 1.52 cost per km. The average cost per km for the Okinawa iPraise+ with point-charging option is at INR 1.73, and it has a TCO of INR 4.1 lakhs. The highest TCO is from the gasoline Honda Activa 6G, INR 5.5 lakhs or INR 2.29 per km.

### Ride-hailing use total cost of ownership (TCO) for two-wheelers in 2021 in Delhi

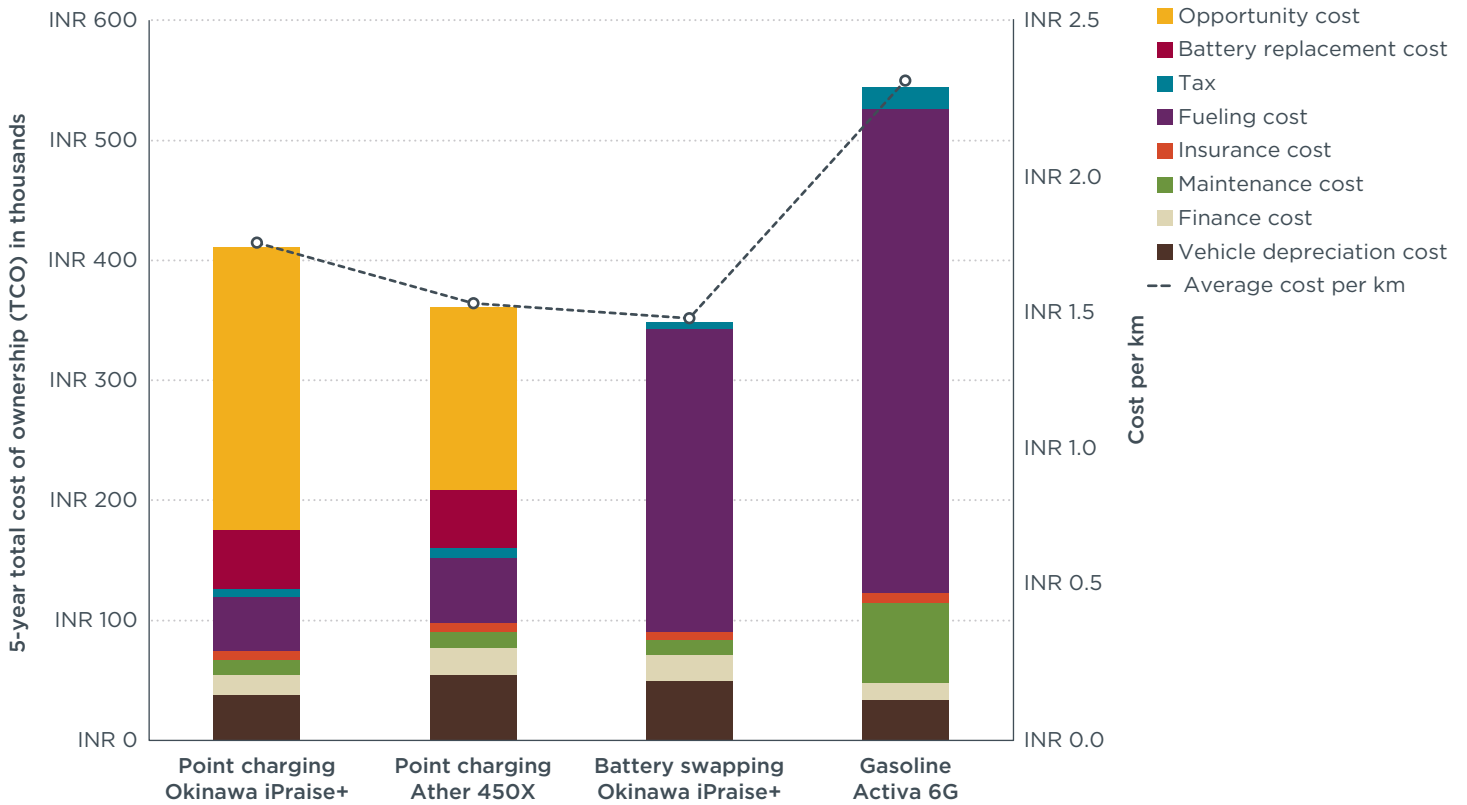


Figure 3. 5-year TCO of selected vehicles for ride-hailing drivers in NCT of Delhi.

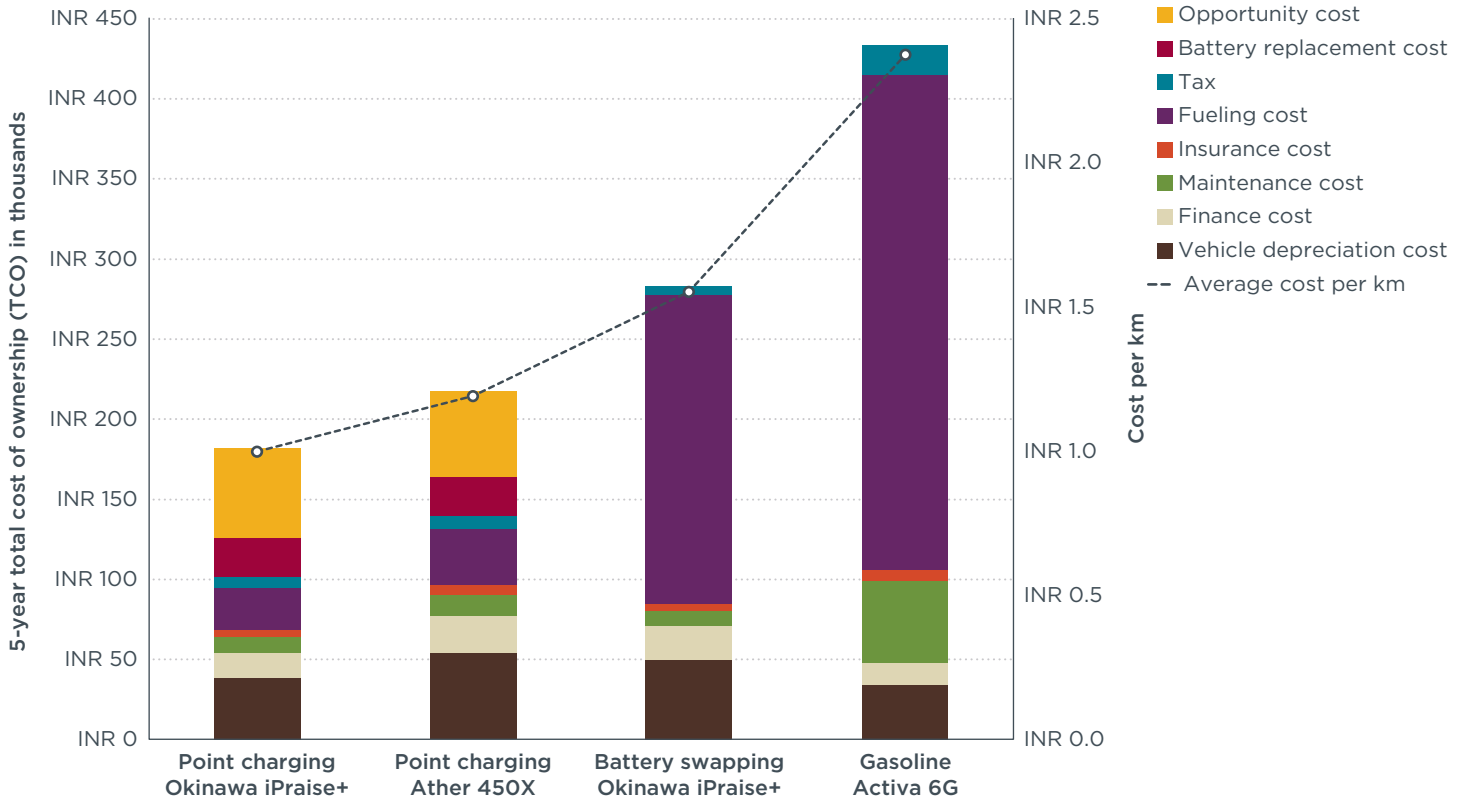
The component costs illustrated in Figure 3 reveal the high opportunity cost for the BEV Okinawa iPraise+ with point charging at INR 2.4 lakhs or INR 0.99 cost per km. For the BEV Ather 450X, the same cost is INR 1.5 lakhs or INR 0.64 cost per km. The higher opportunity cost for the BEV Okinawa iPraise+ is attributed to availability of only slow charging, which means longer charging time during operation and hence greater opportunity cost. For the BEV Ather 450X, meanwhile, fast charging is available.

Although the BEV Okinawa iPraise+ with battery swapping does not have any opportunity cost associated with it, fueling cost is the highest contributor to its TCO and amounts to INR 2.5 lakhs in total or INR 1.06 per km. The per km fueling cost for the BEVs with point charging are INR 0.19 and INR 0.23 for the BEV Okinawa iPraise+ and the BEV Ather 450X, respectively. The gasoline two-wheeler has the highest fueling cost at INR 1.7 per km or INR 4 lakhs in total.

#### TCO: Last-mile delivery

Figure 4 shows the 5-year TCO and cost per km for selected last-mile delivery vehicles in Delhi. The gasoline Honda Activa 6G has the highest TCO of INR 4.3 lakhs or cost per km of INR 2.38. This is followed by the BEV Okinawa iPraise+ with battery swapping, which has the second highest ownership cost of INR 2.8 lakhs or per km cost of INR 1.55. The BEV Ather 450X with point charging bears the third highest TCO at INR 2.1 lakhs or per km cost of INR 1.19. The Okinawa iPraise+ with point charging is the most cost-attractive vehicle, with an average per km cost of INR 1 and a TCO of INR 1.8 lakhs.

## Last-mile delivery use total cost of ownership (TCO) for two-wheelers in 2021 in Delhi



**Figure 4.** 5-year TCO for selected vehicles for full-time last-mile drivers in NCT of Delhi.

Among the various cost components of the TCO in Figure 4, the BEV Ather 450X and BEV Okinawa iPraise+ with point charging bear opportunity costs of INR 53,500 and INR 56,200, respectively. Apart from home charging during non-business hours, public charging is needed to fulfil the total energy requirement of these vehicles for this use case. While the BEV Okinawa iPraise+ has a real battery range of 111 km, which is higher than the 93-km range for the BEV Ather 450X, the public charging time for the Okinawa iPraise+ is considerably higher (4.5 hours) than that of Ather 450X (1.8 hours). As a result, their opportunity cost values over the 5-year period are similar.

Additionally, the BEV Ather 450X has a battery-replacement cost of INR 24,000, which is almost equal to the battery-replacement cost of INR 24,200 for the BEV Okinawa iPraise+. This is due to the BEV Ather 450X having a shorter battery life; replacement was determined at 3 years frequency, and this is shorter than the BEV Okinawa iPraise+, estimated at 4 years frequency. Both vehicles have the same average annual distance traveled for this use case.

The gasoline Honda Activa 6G has the highest fueling cost at INR 3.1 lakhs over the 5-year ownership period or a per km cost of INR 1.7. The BEV Okinawa iPraise+ with battery-swapping option incurs the second-highest fueling cost of INR 1.9 lakhs or a per km fueling cost of INR 1.1. BEVs with point charging have a comparatively lower fueling cost of INR 27,000 and INR 35,000 for the BEV Okinawa iPraise+ and BEV Ather 450X, respectively, and that corresponds to a per km cost of INR 0.15 and INR 0.19, respectively.

## Discussion and conclusion

The 5-year TCO analysis reveals a number of trends, including that two-wheelers with battery swapping are costlier than two-wheelers with point charging for the personal and last-mile delivery use cases. The BEV Okinawa iPraise+ with battery swapping is



costlier than the BEV Okinawa iPraise+ with point charging and the BEV Ather 450X with point charging by 85% and 23%, respectively for the personal use case. For last-mile delivery, the BEV Okinawa iPraise+ with swapping is costlier than the BEV Okinawa iPraise+ and the BEV Ather 450X with point charging by 36% and 23%, respectively. However, the opposite is true in the case of ride-hailing operation, where the BEV Okinawa iPraise+ with swapping clearly makes economic sense. Here the battery-swapping model is cheaper than both BEVs with point charging, by 15% compared with the Okinawa iPraise+ and 3% compared with the Ather 450X. For all three use cases, BEV two-wheelers with point-charging and battery-swapping options are considerably cheaper than the gasoline two-wheeler.

Additionally, the total cost of fueling is less for two-wheelers with point charging than for the two-wheeler with battery swapping because the per unit cost of point charging is less than that of battery swapping. The fueling cost is the largest cost contributor across all types of uses for the battery-swapping option. If this cost reduces, the battery-swapping model will start looking more cost-attractive because it has the advantages of zero opportunity cost and zero battery-replacement cost.

We conclude with the following observations:

- » If 50% of the central government's FAME II incentive were also offered to BEV two-wheelers with the battery-swapping option, then after incentives, these vehicles would become cheaper in terms of upfront cost than those with point-charging mode and would be comparable to the gasoline two-wheeler.
- » Already the BEV two-wheeler with battery swapping incurs less TCO and cost per-km values than the gasoline two-wheeler across all use cases.
- » As the average daily distance traveled increases, the BEV with battery-swapping option gives better economic results relative to the point-charging and gasoline vehicle options. The cost per km value for the BEV Okinawa iPraise+ with the battery-swapping option is much higher than the point-charging BEV options in personal use. However, this cost difference decreases in the last-mile delivery use case, as vehicles travel longer distances on average. In the ride-hailing operation use case, where average daily distance traveled is the highest among the three cases, the TCO of the BEV Okinawa iPraise+ with battery swapping is the lowest among all the vehicles considered in the study.
- » Currently, the per kilowatt hour charging cost in battery-swapping option is INR 34, much higher than that of the point-charging option at INR 13.7. With more scale and competition, this cost difference would reduce, and the TCO of BEV two-wheelers with battery swapping would become attractive in more use cases relative to point charging.