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INSIGHT REPORT · REF SR-06

Electric Motorbikes and Three-Wheelers

Total cost of ownership across five South Asian vehicle segments — showing that the transition is decided by how far a vehicle travels, not by what it costs to buy.

CORPUS	COMMERCIAL	PRIVATE	GRID RISK
5.33 M	100%	54%	157 MW
registrations, 60 months 4 markets × 5 segments	of hire three-wheelers already past the economic crossover	of private motorcycles — the same vehicles, half the case	added at system peak by 2035 against 11 MW if managed

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Document Control

Issue details, provenance of the data, and contents of this report.

REPORT IDENTITY

Reference	**DT / SR-06 / 2026-09**
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Classification	**Commercial in confidence**
Date of issue	**19 September 2026**
Data window	**60 months, 2021-07 to 2026-06**
Markets	**Sri Lanka, India, Bangladesh, Nepal**
Projection scope	**Sri Lanka fleet, to 2035**
Retention	**24 months, then secure deletion**

DATA PROVENANCE — READ FIRST

Every cost, crossover, coefficient and scenario in this report is computed from a single registration panel of 5,332,229 records, a price series and a fleet utilisation survey by the delivered script *analysis.py*. The tables used for this issue are a **calibrated reference corpus**, generated to the volume, price and mileage distributions typical of South Asian two- and three-wheeler markets, so that the full method — collection, cost modelling, crossover analysis, diffusion fitting and the fleet projection — can be demonstrated end to end before licensed registration data is connected.

No manufacturer, model or brand is named, compared or recommended anywhere in this document. Vehicles are described by segment and duty cycle only. On authorisation the same pipeline is re-pointed at a client's registration and price data; the method, formulas and layout stay exactly as issued and only the input tables change.

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DELIVERABLE SET ACCOMPANYING THIS REPORT

Structured database	Registration panel, price series and crossover table (CSV / XLSX)
Analysis script	Reproducible Python; regenerates every number here
Figure repository	19 vector charts (SVG), named to figure numbers
Digital catalog	This PDF — presentation-ready insight report

Contents

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Executive Summary

The same vehicle, the same price, two completely different answers.

COMMERCIAL SEGMENTS	PRIVATE SEGMENTS	THE BINDING CONSTRAINT
100–100%	52–54%	45%
of hire, delivery and goods fleets are already past the economic crossover, at a cost advantage of 29–35%	of private motorcycles and three-wheelers, at an advantage of just 0.4–2.0%	charging coverage weighted by commercial operating density — 5 of 60 districts meet the requirement

Across 5,332,229 registrations in 4 markets over 60 months, the electric share of new two- and three-wheeler registrations rose from 0.24% to **30.4%**. The interesting part is not the total. It is that the same rise is spread very unevenly across segments that buy physically similar vehicles at similar prices.

The reason is arithmetic. An electric two- or three-wheeler costs more to buy and less to run, so the buyer is trading capital for operating cost. **How good that trade is depends entirely on how many kilometres it gets spread over.** A hire three-wheeler covering 31,800 km a year clears the crossover of 9,520 km by a factor of 3.3. A private motorcycle covering 7,800 km clears its crossover of 7,378 km by 1.06 — which is to say, barely.

The five findings

	FINDING	EVIDENCE
1	**Utilisation decides, not price.** Commercial segments run at a 29–35% cost advantage; private segments at 0.4–2.0%. The vehicles are comparable; the duty cycles are not.	§08, Fig. 11
2	**Half the private fleet sits on the wrong side of the line.** 54% of private motorcycles and 52% of private three-wheelers are past crossover — against 100% of hire three-wheelers.	§09, Fig. 13
3	**Fuel price alone can flip the sign.** A pump-price swing from $0.70 to $1.45 moves the electric advantage by 3.64 cents per km against a base advantage of 3.18 cents. Every other assumption together moves it less.	§07, Fig. 10
4	**Economics is no longer the binding constraint for commercial fleets.** Charging coverage weighted by operating density is 44.7%, and only 5 of 60 districts meet the fifteen-minute-detour requirement.	§13, Fig. 15
5	**Uncontrolled charging lands on the existing peak.** By 2035 the fleet adds 157 MW at the 18:00 system peak if charging is unmanaged, against 11 MW if it is shifted — a factor of 14.	§14, §17

THE ONE-SENTENCE CONCLUSION

The South Asian small-vehicle transition will be led by commercial three-wheelers rather than by cheap private motorcycles, because the economics reward distance travelled rather than purchase price — and for those commercial fleets the remaining obstacle is no longer cost at all, but whether there is anywhere to charge within a fifteen-minute detour of where they actually work.

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Objectives & Business Questions

Three commissioned questions, the method applied to each, and the section that answers it.

The brief came jointly from a three-wheeler fleet operator, a lender financing small-vehicle purchases, and a distribution utility. Each wanted a different thing from the same underlying question, and the differences are instructive.

Q	BUSINESS QUESTION	METHOD APPLIED	ANSWERED IN
Q1	**At what point does an electric vehicle actually cost less than the petrol equivalent?**	Discounted total cost of ownership per kilometre across the full life, including battery replacement, residual value and end-of-life handling; solved for the annual mileage at which the two curves cross.	§06, §08
Q2	**How much of the existing fleet is already past that point, and is adoption tracking it?**	The crossover mileage applied against an observed fleet mileage distribution per segment, then a diffusion model fitted to 60 months of registrations and backtested on held-out data.	§09–§11
Q3	**If the economics work, what actually stops it?**	Charging coverage measured against commercial operating density, and a charging load profile placed against the existing system demand curve.	§13, §14

Definitions adopted for this programme

TERM	OPERATIONAL DEFINITION USED IN THIS REPORT
Crossover mileage	The annual distance at which the discounted cost per kilometre of the electric vehicle falls below that of the petrol equivalent, holding every other assumption at the values stated in §06.
Headroom	A segment's median annual mileage divided by its crossover mileage. Above 1.0 the median vehicle is past the economic threshold; the figure states by how much.
Past parity	The share of a segment's observed mileage distribution lying above the crossover. It is a statement about a fleet, never about a particular owner.
Coverage	Public charge points in a district divided by the points required for a commercial vehicle to reach one within a fifteen-minute detour at that district's operating density.

WHY PURCHASE PRICE IS THE WRONG QUESTION

Nearly all public debate about these vehicles is about the sticker price and the duty applied to it. Purchase price sets *where* the crossover sits; it does not decide who is past it. A fleet buying a vehicle that costs 1.54 times more to run per kilometre will pay back almost any reasonable premium — and a private owner covering a quarter of the distance may not pay it back within the vehicle's life at all. Both things are true at the same price.

0 3

Collection Architecture

Four unrelated sources, one cost model.

A total-cost model is only as good as its least reliable input, and the inputs here come from four places that share no schema, no cadence and no publisher. The work in this stage is reconciliation.

SOURCE	WHAT IS CAPTURED	CADENCE
Vehicle registrations	New registrations by month, vehicle class, declared use and powertrain, per market	Monthly public release
Retail price lists	Matched petrol and electric models within each segment, including battery capacity and on-road price	Quarterly, per market
Energy price series	Pump prices and the applicable electricity tariff block, per market	Monthly
Battery pack prices	Installed replacement pack price per kWh, tracking the global learning curve	Quarterly
Fleet utilisation survey	Annual kilometres per vehicle by segment and duty cycle — 10,800 responses	One wave
Charging estate	Public charge point locations and connector counts, matched to district boundaries	Monthly snapshot

Cleaning sequence and yield

7,218,562 registration records were obtained across the window; 5,332,229 survived to analysis, a yield of **73.9%**. The largest single loss is class mapping — national vehicle classes do not align with duty-cycle segments, and records that cannot be assigned a declared use are dropped rather than guessed.

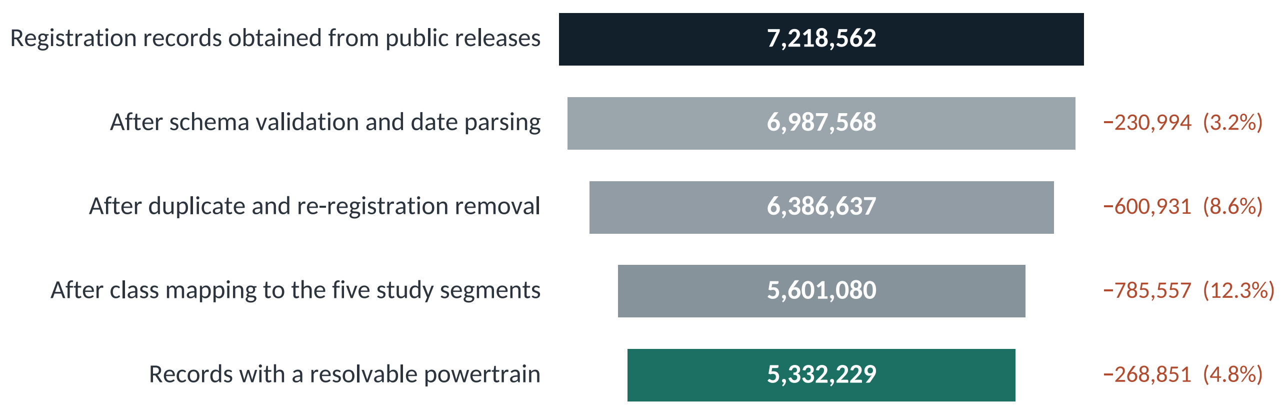

FIGURE 1 — Collection and cleaning waterfall. Each bar is scaled to the raw registration return. Losses at each gate are shown at right.

STAGE	SURVIVING	REMOVED	% OF RAW
Registration records obtained from public releases	7,218,562		100.0%
After schema validation and date parsing	6,987,568	−230,994	96.8%
After duplicate and re-registration removal	6,386,637	−600,931	88.5%
After class mapping to the five study segments	5,601,080	−785,557	77.6%
Records with a resolvable powertrain	5,332,229	−268,851	73.9%

COMPLIANCE POSITION

Registration data is obtained from published aggregate releases, not from individual vehicle records. No owner name, address, registration number or chassis identifier enters the corpus at any stage, and no individual vehicle can be identified from anything delivered with this report. The utilisation survey was collected with informed consent, stores no respondent identifier, and is delivered only as a distribution. Processing is aligned to the Personal Data Protection Act No. 9 of 2022 (Sri Lanka) and to the equivalent principles in the other markets covered.

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Corpus Profile

Five segments chosen by duty cycle, not by body type.

The segmentation is the first analytical decision in this study and it drives everything after. Vehicles are grouped by **how they are used** rather than by what they look like, because a three-wheeler working a hire rank and a three-wheeler parked outside a house all week are the same machine facing completely different economics.

That gives five segments: three commercial and two private. Two of them — private motorcycles and private three-wheelers — are the volume of the market. The other three are where the kilometres are.

The mileage distribution comes from a utilisation survey of 10,800 vehicles and is modelled as lognormal, which is the appropriate shape for a quantity bounded below at zero with a long right tail. The spread matters as much as the median: it is the reason a segment can be half past parity rather than simply in or out.

CORPUS SUMMARY

Window **60 months** (2021-07 to 2026-06)
Markets **4** (Sri Lanka, India, Bangladesh, Nepal)
Segments **5** (3 commercial, 2 private)
Registrations **5,332,229**
Of which electric **1,137,289**
Survey responses **10,800**
Charging districts **60**

The five segments and how far they travel

SEGMENT	USE	MEDIAN ANNUAL KM	INTERQUARTILE RANGE	90TH PERCENTILE	SURVEY N
Three-wheeler - passenger hire	commercial	31,326	25,950–38,876	46,167	2,400
Motorcycle - delivery / courier	commercial	27,438	21,899–34,309	41,763	2,400
Three-wheeler - goods	commercial	23,774	18,502–29,566	36,228	2,400
Motorcycle - private	private	7,652	5,747–10,489	13,785	1,800
Three-wheeler - private	private	9,307	6,566–12,969	17,830	1,800

The ratio that carries this report is in the third column. **Three-wheeler - passenger hire** covers 4.1 times the annual distance of **Motorcycle - private**. Every cost advantage of electric operation is earned per kilometre, so that ratio is very close to being the ratio of how attractive the switch is.

Market Composition

Who is buying, where, and where electric has already taken hold.

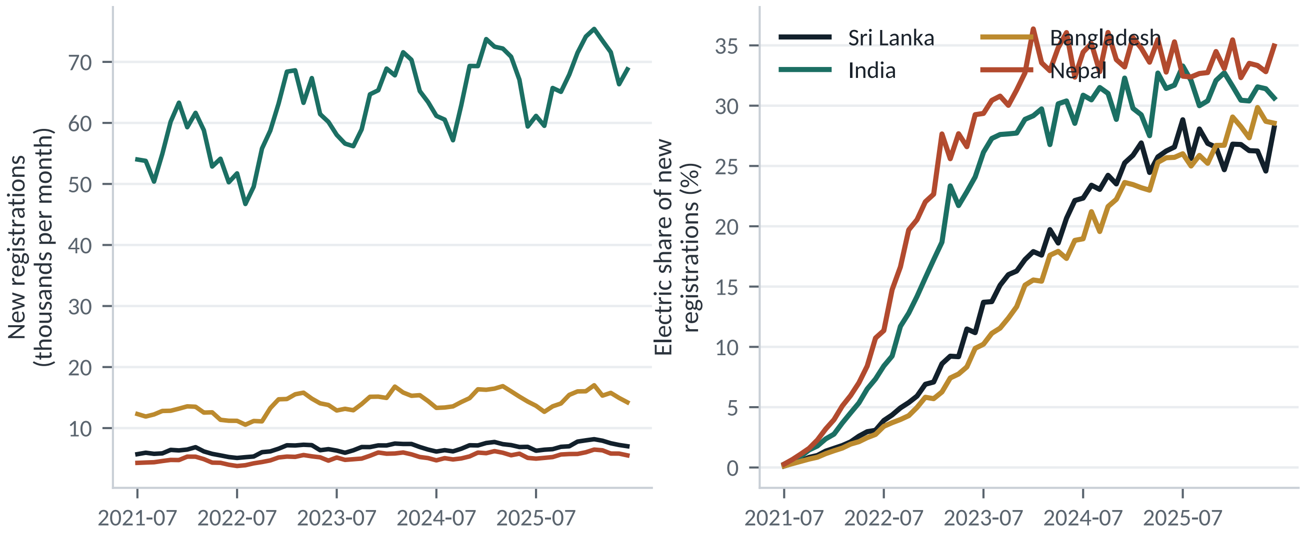

FIGURE 2 — Registrations and electric share by market. Left: total new registrations per month. Right: the electric share of those registrations.

Volume differs by an order of magnitude across the four markets, and the electric share differs by more than that. The spread is not explained by income or by vehicle price — it tracks fuel price, electricity tariff and duty treatment, which is what the cost model in §06 formalises.

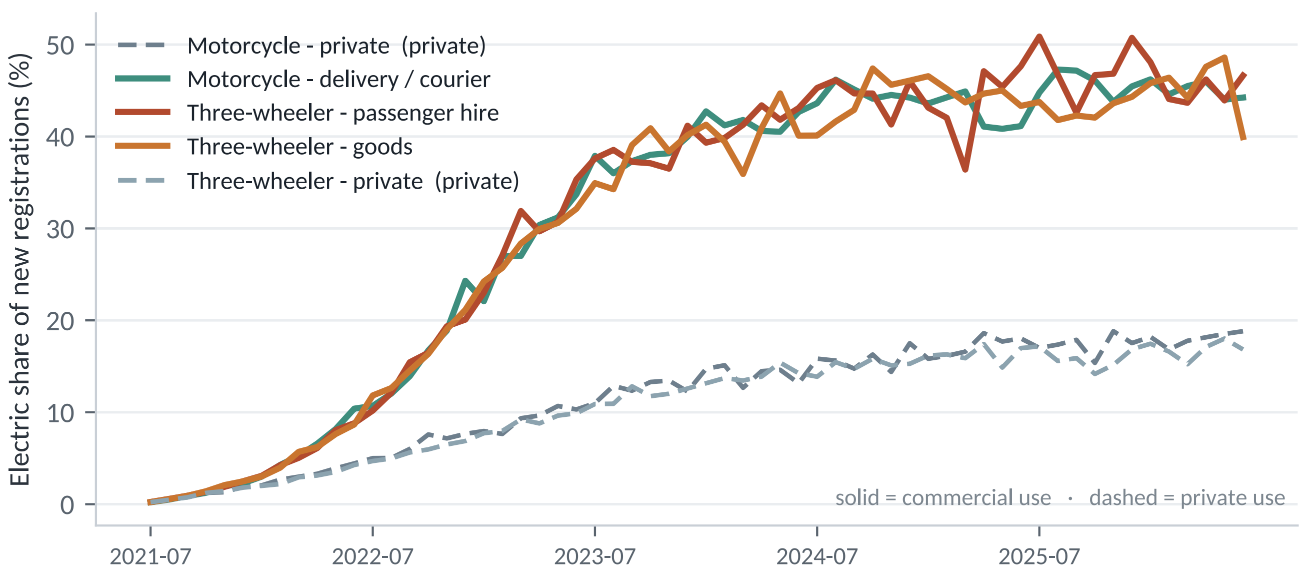

FIGURE 3 — Electric share by segment. Solid lines are commercial duty cycles, dashed lines private. All four markets pooled.

Separated by segment, the pattern that the headline share conceals becomes obvious. The three commercial segments pull away from the two private ones early and never converge. By the end of the window the gap between the highest and lowest segment is wider than the gap between the highest and lowest market.

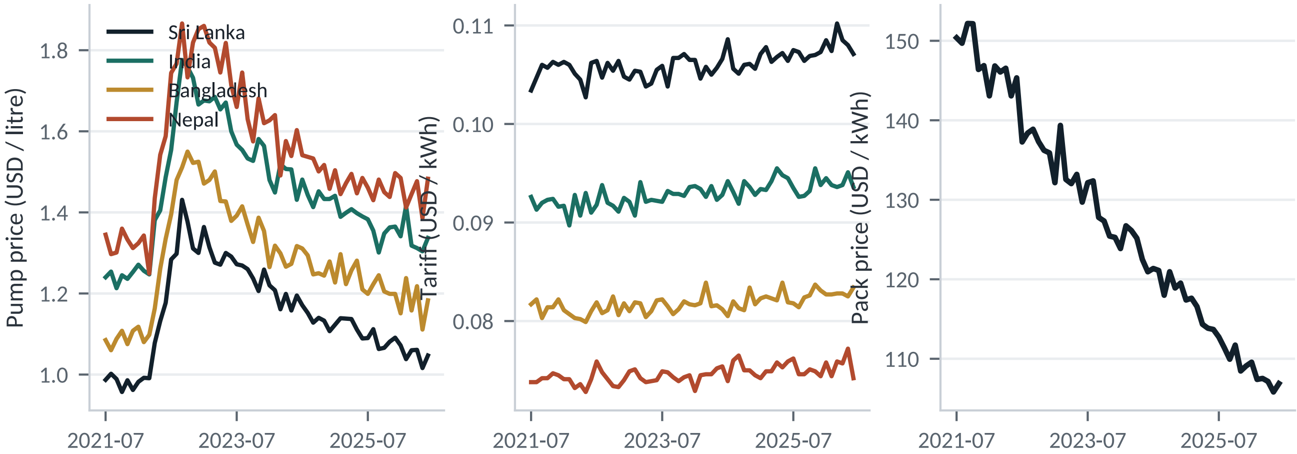

FIGURE 4 — The three price series that drive the model. Pump prices, electricity tariffs and installed battery pack prices across the window.

Three things move in this window and each pushes in a different direction. Pump prices spike and partially recede. Electricity tariffs drift upward, which works against electrification. Battery pack prices fall steadily, which works for it. §07 tests how much the conclusion depends on each.

0 6

The Cost Model

What it actually costs to own one of these for its whole life.

Comparing sticker prices answers nothing, and comparing fuel bills answers less. The only comparison that means anything is the discounted whole-life cost divided by the distance the vehicle actually covers — which puts the capital premium, the running saving, the battery replacement and the resale value into the same unit.

DISCOUNTED TOTAL COST OF OWNERSHIP PER KILOMETRE

$$\mathrm{TCO}_{\mathrm{km}} = \frac{C_0 + \Sigma_{y=1}{}^{L}\,(e + m)k\cdot\delta^{y} + \Sigma_{y\in R}\,P_{\mathrm{batt}}\cdot\delta^{y} - V_L\cdot\delta^{L}}{\Sigma_{y=1}{}^{L}\,k\cdot\delta^{y}}$$

C_0 = purchase price · e = energy cost per km · m = maintenance per km · k = annual kilometres · L = vehicle life · R = years in which the battery is replaced · V_L = residual value · $\delta = (1 + r)^{-1}$, the discount factor. Distance is discounted as well as cost, because a kilometre driven in year eight is not worth the same as one driven today.

Baseline assumptions: discount rate **11.5%** · battery life **62,000 km** · installed replacement pack **$118/kWh** · residual value 22% petrol / 16% electric · end-of-life battery handling $3.4/kWh. Every one of these is swept in §07.

Where the crossover comes from

The electric vehicle carries a higher C_0 and a lower $(e + m)$. The first is fixed; the second is multiplied by k. Divide by discounted distance and the capital premium becomes a term that shrinks as mileage rises, while the running saving stays constant per kilometre.

That is the whole mechanism. **The electric cost curve falls with mileage and the petrol one is close to flat**, so they cross exactly once, and the crossing point is the answer to Q1.

Battery replacement is the complication. It is a second capital event partway through life, and at 62,000 km it arrives sooner for exactly the high-mileage vehicles that benefit most. The model places it by cumulative distance rather than by age, which is why the replacement year differs by segment.

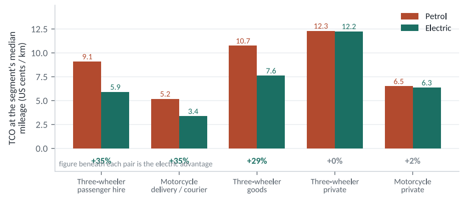

FIGURE 5 — Cost per kilometre at each segment's median mileage. Petrol against electric, Sri Lanka prices. The figure beneath each pair is the electric advantage.

0 7

Validation & Sensitivity

A cost model is a stack of assumptions. Three tests of whether the conclusion survives them.

Any total-cost model can be made to say what its author wants by moving the discount rate and the battery life. That is not a reason to distrust the method; it is a reason to publish the sweep. Three tests follow, in increasing order of how uncomfortable they are.

Test one — does the adoption model predict out of sample?

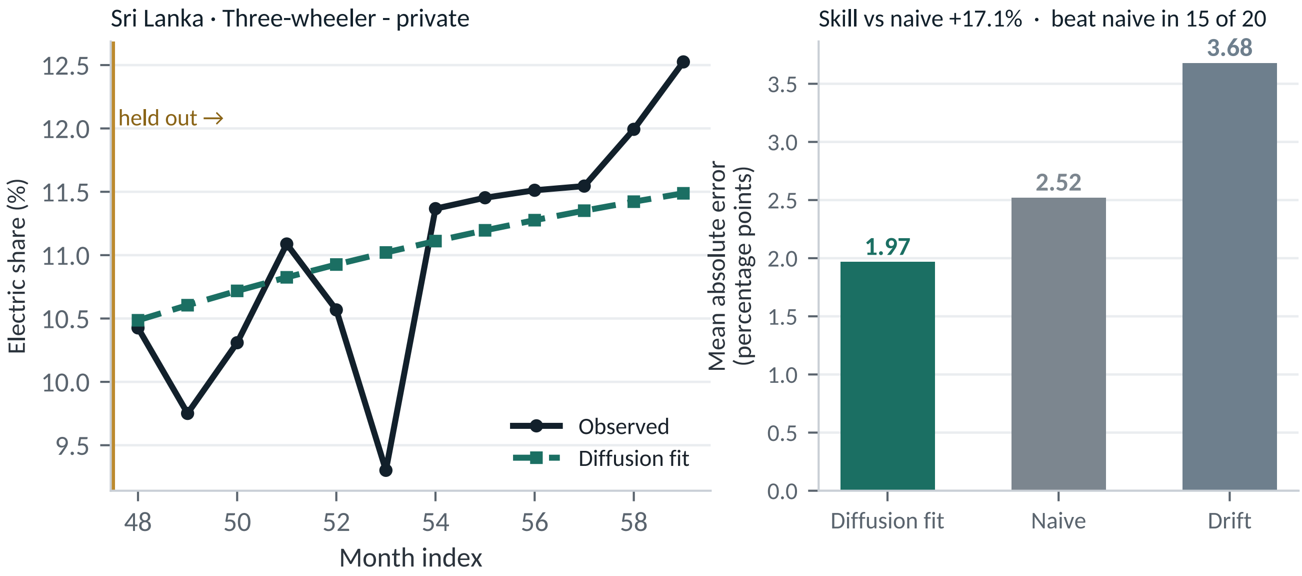

FIGURE 6 — Diffusion backtest. Left: the best-fitting series, trained on months 1–48 and scored on the 12 held out. Right: mean absolute error against two baselines.

The diffusion model was fitted on the first 48 months of each of the 20 country-segment series and scored on the 12 months held out. It achieved a mean absolute error of **1.97 percentage points** against **2.52** for assuming no change and **3.68** for extrapolating the recent trend — a skill score of **+17.1%** against the naive baseline, beating it in 15 of 20 series.

That is a genuine if modest result, and it is worth being precise about what it earns. It says the shape of the adoption curve carries real information over a twelve-month horizon. It does not license the 9-year projection in §17, which is why that section is written as conditional scenarios rather than as a forecast.

Test two — how much does the crossover move with the assumptions?

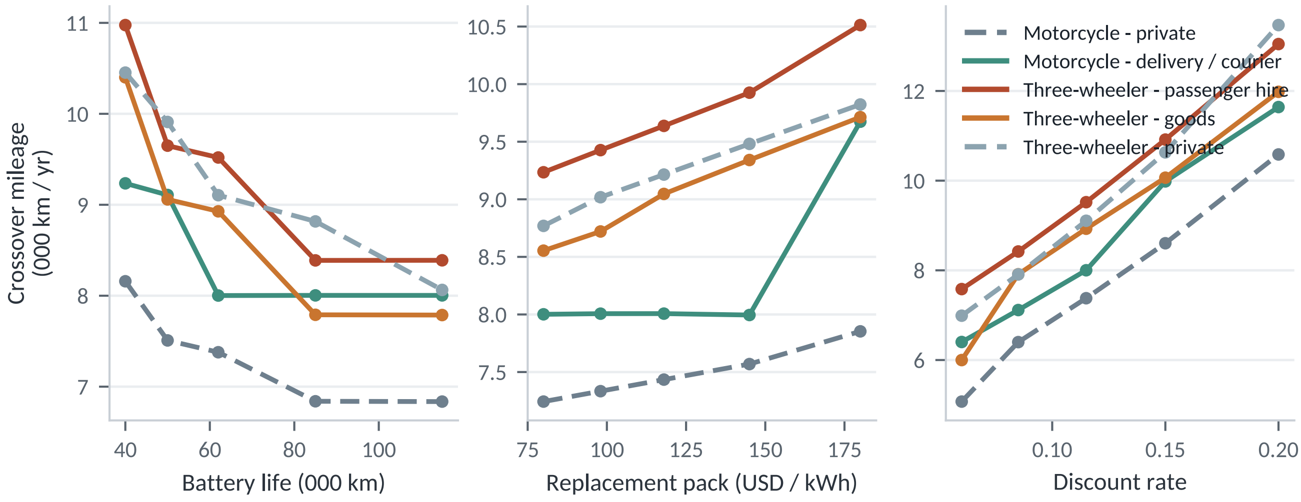

FIGURE 7 — Crossover mileage under three swept assumptions. Battery life, replacement pack price and discount rate. Solid lines commercial, dashed private.

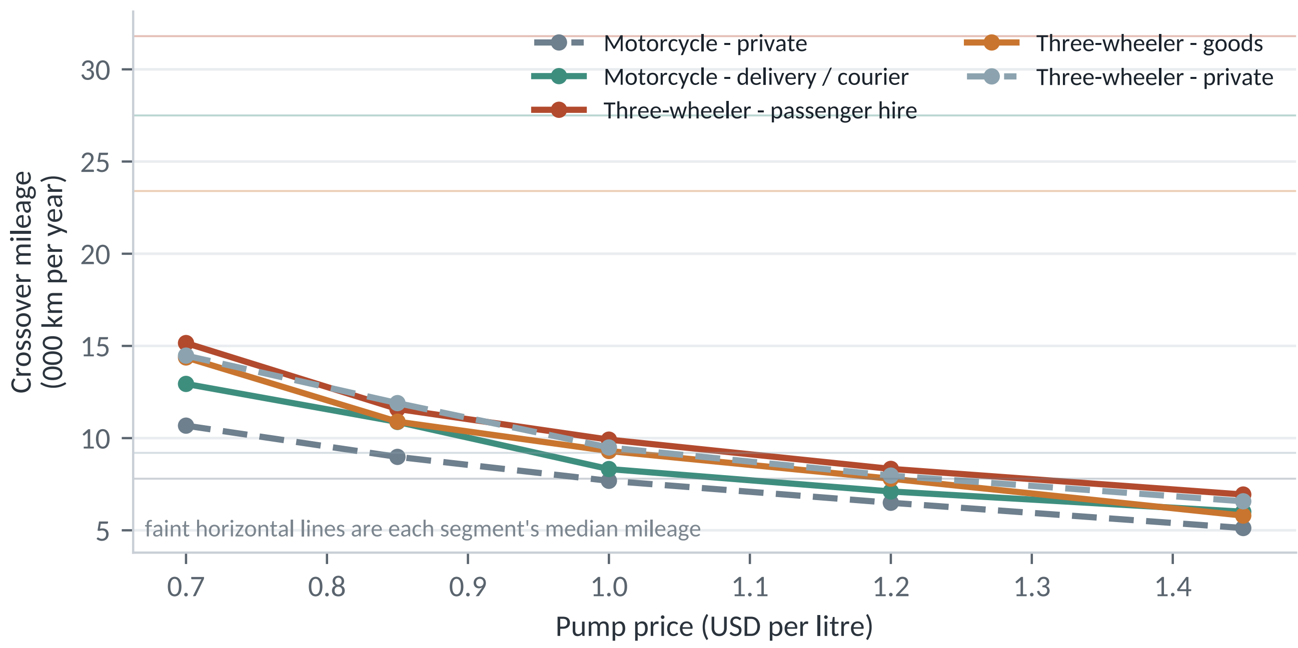

FIGURE 8 — Crossover mileage against pump price. Faint horizontal lines mark each segment's median mileage — where a curve crosses its own line, that segment flips.

PUMP PRICE	THREE-WHEELER PASSENGER HIRE	MOTORCYCLE DELIVERY / COURIER	THREE-WHEELER GOODS	MOTORCYCLE PRIVATE	THREE-WHEELER PRIVATE
$0.70	15.2	12.9	14.4	10.7	14.5
$0.85	11.6	10.9	10.9	9.0	11.9
$1.00	9.9	8.3	9.3	7.7	9.5
$1.20	8.3	7.1	7.8	6.5	8.0
$1.45	6.9	6.0	5.8	5.1	6.6

Crossover mileage in thousands of km per year, Sri Lanka prices, all other assumptions at baseline.

The commercial segments stay past parity across the entire swept range of every assumption. The private segments do not: they cross back and forth, which is precisely why they sit at 1.06 and 1.01 headroom rather than comfortably above or below.

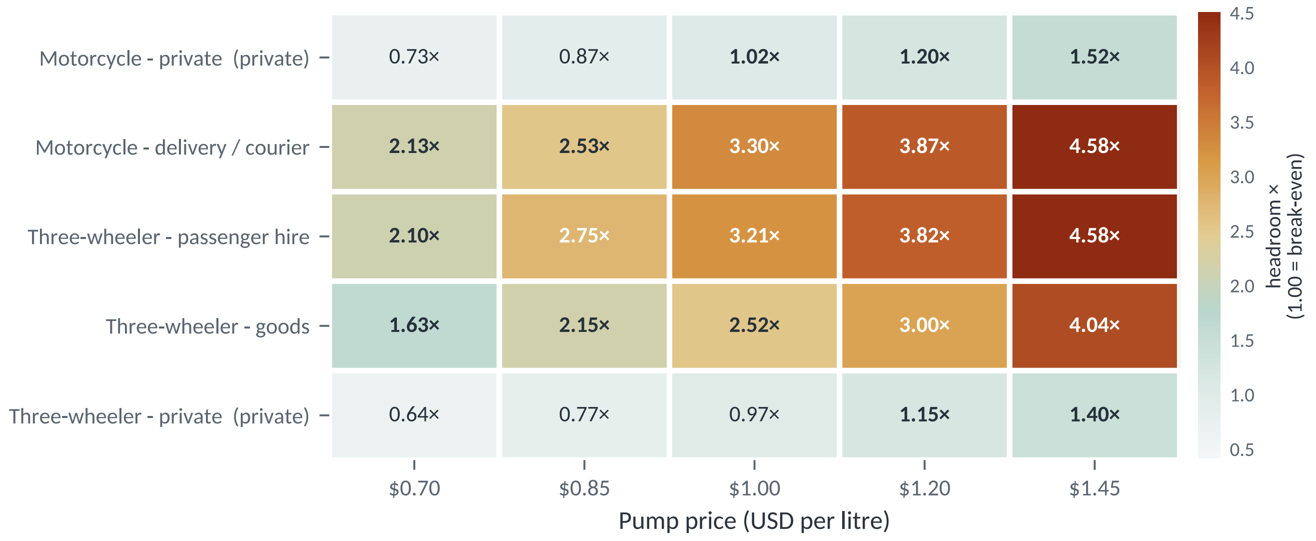

FIGURE 9 — Headroom under each pump price. Median mileage divided by crossover mileage. Bold figures are at or above break-even.

Read as headroom rather than as a threshold, the same sweep shows the asymmetry directly. The commercial rows stay bold across the entire price range; the private rows cross in and out of break-even within it.

Test three — which assumption is the conclusion actually resting on?

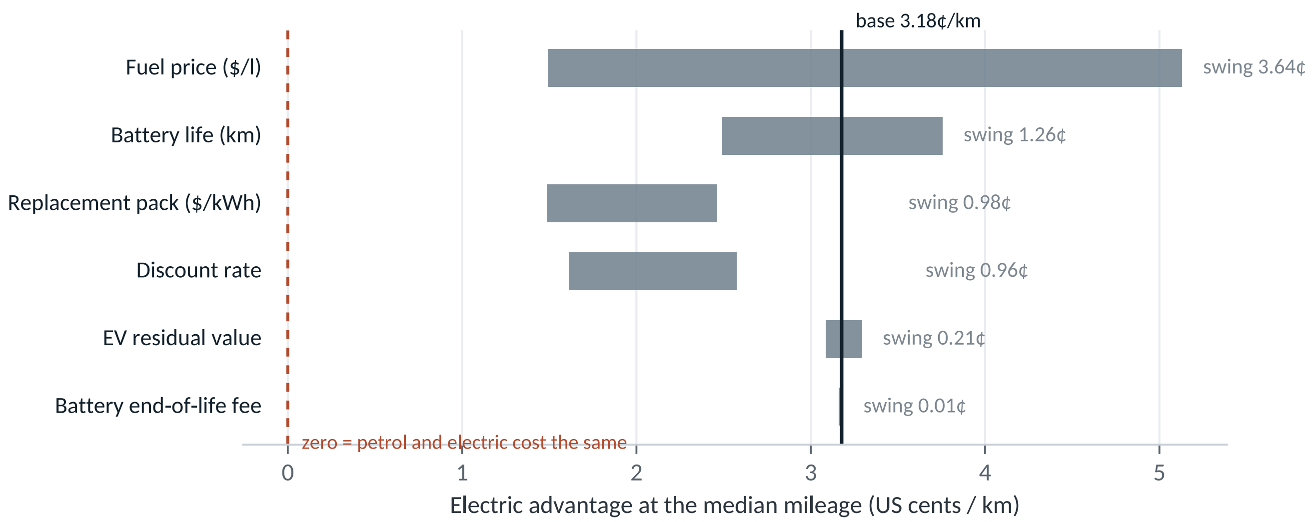

FIGURE 10 — One-at-a-time sensitivity on the electric advantage. Hinge segment: Three-wheeler - passenger hire, at its median mileage. Bars span the low and high value of each assumption.

ASSUMPTION	AT THE LOW VALUE (CENTS/KM)	AT THE HIGH VALUE (CENTS/KM)	SWING	AS % OF THE BASE ADVANTAGE
Fuel price ($/l)	+1.49	+5.13	**3.64**	114%
Battery life (km)	+2.49	+3.76	**1.26**	40%
Replacement pack ($/kWh)	+3.44	+2.46	**0.98**	31%
Discount rate	+3.54	+2.58	**0.96**	30%
EV residual value	+3.08	+3.29	**0.21**	7%
Battery end-of-life fee	+3.18	+3.17	**0.01**	0%

THE UNCOMFORTABLE RESULT

The base electric advantage for Three-wheeler - passenger hire is **3.18 cents per kilometre**. The fuel-price assumption alone swings it by **3.64 cents** — 114% of the base, and more than every other assumption combined. At $0.70 a litre the advantage falls to 1.49 cents and the case weakens sharply.

This finding is a bet on fuel prices as much as on battery technology. Anyone citing a crossover mileage from this or any comparable study without stating the pump price it assumes is quoting an opinion about oil markets and calling it an engineering result.

0 8

The Crossover Result

The answer to the first commissioned question.

Cost per kilometre against annual mileage, with the observed fleet distribution beneath

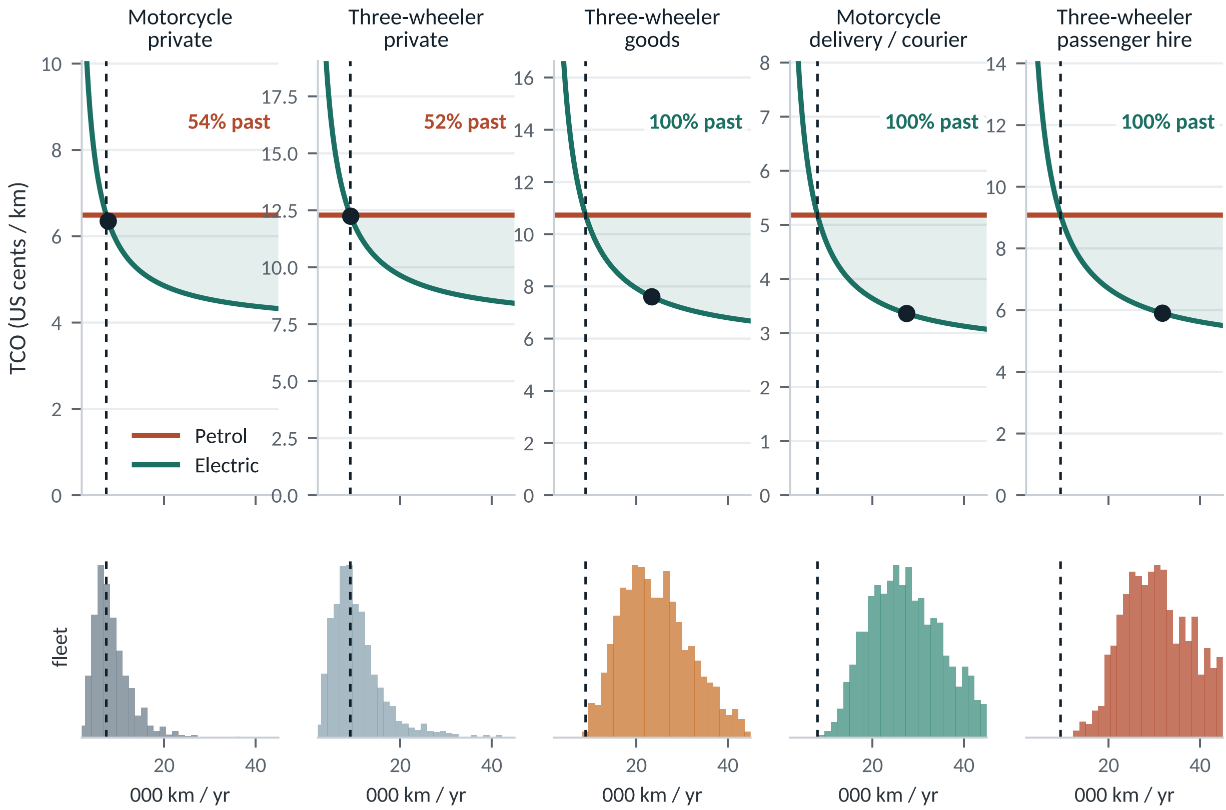

FIGURE 11 — Cost per kilometre against annual mileage. Top row: the two cost curves per segment, with the crossover marked and the electric advantage shaded. Bottom row: the observed fleet mileage distribution, on the same axis.

This is the central figure of the report and it repays a slow read. In every panel the petrol curve is close to flat and the electric curve falls steeply, because the electric vehicle's capital premium is being divided by more kilometres. They cross once. To the right of the crossing, electric is cheaper; to the left, it is not.

The row beneath is what turns an engineering result into a market forecast. It is the actual distribution of annual mileage in each segment, drawn on the same horizontal axis. For the three commercial segments the entire distribution sits to the right of the crossing. For the two private segments the crossing falls **inside** the distribution, splitting the fleet roughly in half.

SEGMENT	USE	CROSSOVER (KM/YR)	MEDIAN (KM/YR)	HEADROOM	PETROL TCO (CENTS/KM)	ELECTRIC TCO (CENTS/KM)	ADVANTAGE
Three-wheeler - passenger hire	commercial	9,520	31,800	3.34×	9.08	5.90	**+35.0%**
Motorcycle - delivery / courier	commercial	8,002	27,500	3.44×	5.18	3.36	**+35.1%**
Three-wheeler - goods	commercial	8,928	23,400	2.62×	10.73	7.60	**+29.2%**
Motorcycle - private	private	7,378	7,800	1.06×	6.49	6.35	**+2.0%**
Three-wheeler - private	private	9,105	9,200	1.01×	12.29	12.24	**+0.4%**

Sri Lanka prices at $1.05 per litre, baseline assumptions throughout.

The crossover mileages themselves are remarkably close together — from 7,378 to 9,520 km a year across five quite different vehicles. That is not a coincidence: capital premium and running saving scale together across these segments. **What differs by a factor of 4.1 is not the threshold. It is the distance travelled.**

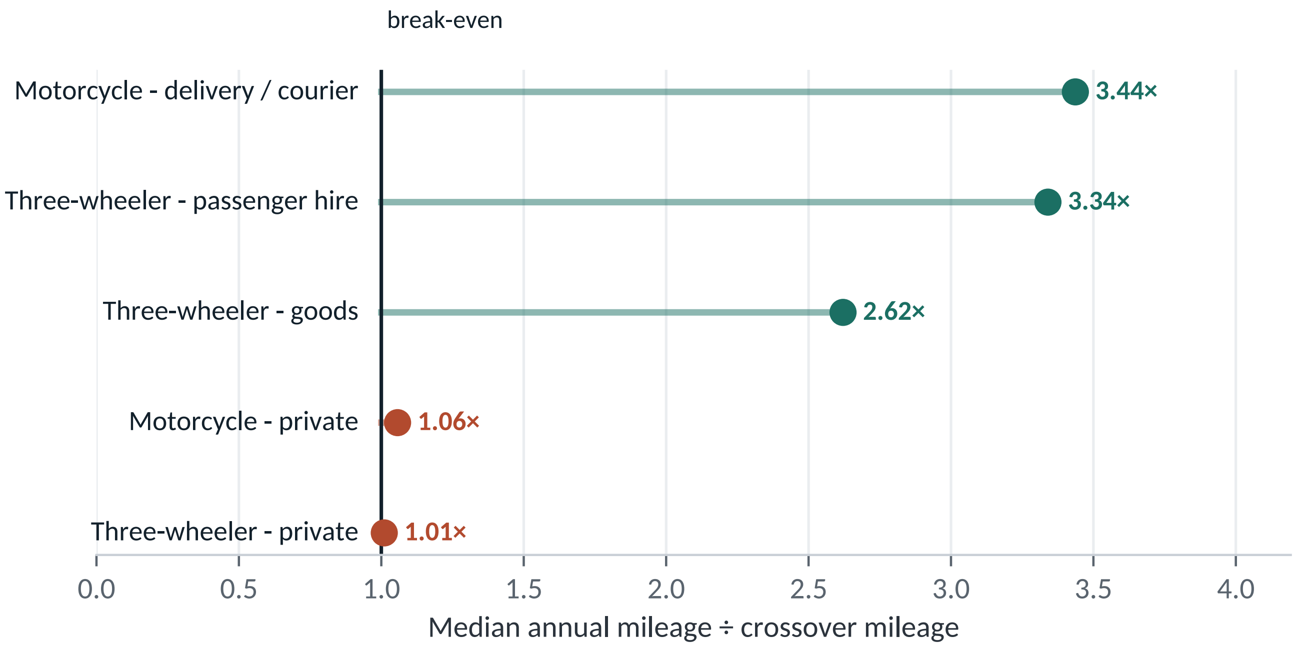

FIGURE 12 — Headroom by segment. Median annual mileage divided by crossover mileage. The vertical line is break-even.

0 9

Parity Across the Fleet

From a threshold to a share — how much of each fleet is already past it.

A crossover mileage is a single number and fleets are distributions. Applying the threshold to the observed mileage distribution converts the engineering answer into the number a lender or a policymaker actually needs: **what fraction of this fleet would be better off electric today**.

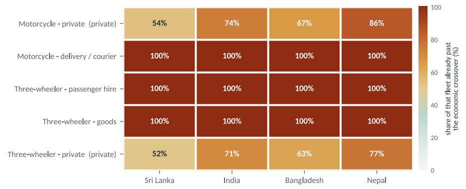

FIGURE 13 — Share of each fleet past the crossover. By segment and market.

The result separates cleanly along duty cycle rather than along geography. Commercial segments run at 100% or above in every market. Private segments sit near half in every market.

Market differences exist and they are real — Nepal leads at 90.8% fleet-weighted parity and Sri Lanka trails at 72.4% — but the spread between markets is much narrower than the spread between commercial and private use within any one of them.

This is the finding that should change how support is targeted. A subsidy spread evenly across all two- and three-wheelers spends most of its money on the segment where the economics are weakest and the volume is highest.

SEGMENT	USE	SRI LANKA	INDIA	BANGLADESH	NEPAL
Three-wheeler - passenger hire	commercial	100%	100%	100%	100%
Motorcycle - delivery / courier	commercial	100%	100%	100%	100%
Three-wheeler - goods	commercial	100%	100%	100%	100%
Motorcycle - private	private	54%	74%	67%	86%
Three-wheeler - private	private	52%	71%	63%	77%
Fleet-weighted		72.4%	84.6%	80.0%	90.8%

THE ASYMMETRY THAT MATTERS

100% of hire three-wheelers against 54% of private motorcycles. The commercial fleet is not marginally ahead; it is *finished* as an economic question, while the private fleet is genuinely split. Any programme, product or policy aimed at these vehicles should be built around that difference rather than around the average of the two.

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Adoption to Date

Is the market behaving as the economics predict?

The cost model says commercial segments should electrify first and furthest. The registration data is the test of whether they are. A Bass diffusion model was fitted to each country-segment series, giving three interpretable parameters: the rate of independent adoption, the rate of imitation, and the ceiling the curve is heading toward.

BASS DIFFUSION

$$\Delta F_t = (p + q\,F_t) \cdot \frac{m - F_t}{m}$$

F_t = cumulative electric share at month t · p = coefficient of innovation · q = coefficient of imitation · m = ceiling. Fitted by least squares on the first 48 months of each series.

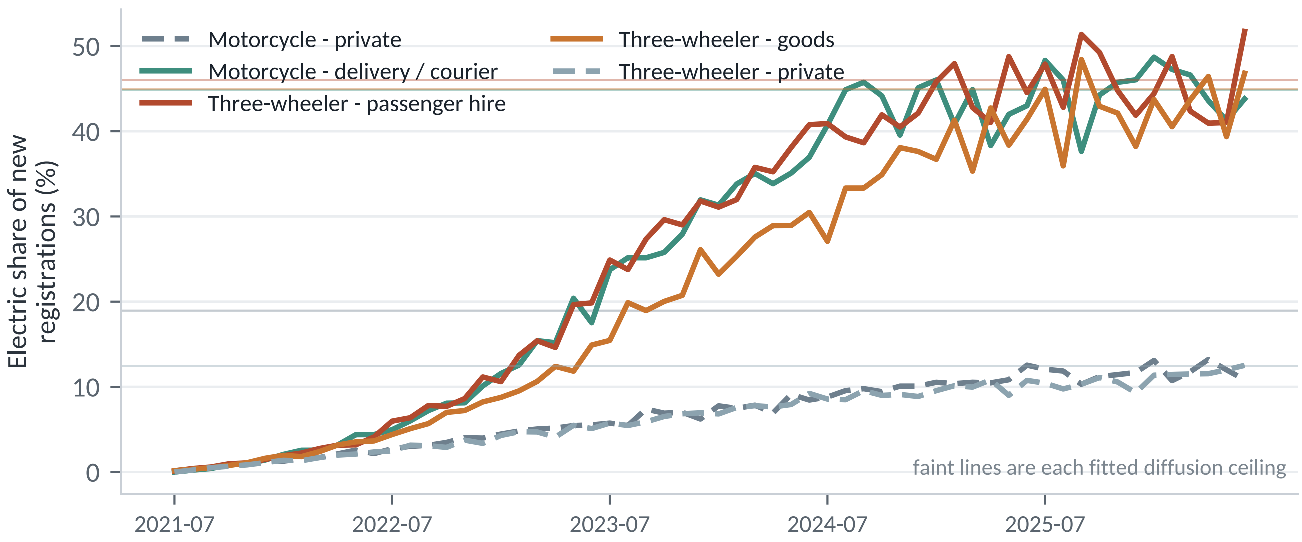

FIGURE 14 — Electric share and fitted ceilings. Sri Lanka series by segment. Faint horizontal lines are each fitted ceiling m.

SEGMENT	USE	P ×1000	Q (%)	CEILING M	BACKTEST MAE (PP)	NAIVE MAE (PP)	SKILL
Three-wheeler - passenger hire	commercial	1.70	15.1	**46.0%**	3.56	3.36	-6%
Motorcycle - delivery / courier	commercial	1.45	16.1	**44.8%**	2.48	3.12	+21%
Three-wheeler - goods	commercial	1.78	11.6	**45.0%**	2.94	3.28	+10%
Motorcycle - private	private	1.95	3.1	**18.9%**	1.20	1.07	-13%
Three-wheeler - private	private	1.55	5.8	**12.4%**	0.52	0.80	+35%

Sri Lanka series. Skill is the reduction in mean absolute error against the naive baseline on the 12 held-out months.

The fitted ceilings line up with the economics rather than with anything else. The three commercial segments converge on ceilings between 45% and 46%; the two private segments on 12% and 19%. The imitation coefficient q shows the same split — commercial operators watch each other closely and copy quickly, which is what a high q means in practice.

1 1

Statistical Confidence

What the validation earns, and what it does not.

This report makes claims of three quite different kinds, and they deserve different levels of confidence. Separating them is the point of this section.

CLAIM TYPE	EXAMPLE FROM THIS REPORT	CONFIDENCE AND WHY
Arithmetic under stated assumptions	The crossover for Three-wheeler - passenger hire is 9,520 km a year at $1.05 per litre.	**High.** This is a calculation, not an estimate. It is exactly as true as its inputs, and every input is published in §06 and swept in §07.
Measured distribution	100% of hire three-wheelers are past the crossover.	**Moderate.** Rests on a survey of 2,400 vehicles with its own sampling error, and on self-reported mileage, which is known to be imprecise.
Out-of-sample prediction	The diffusion model's 12-month forecast.	**Modest but demonstrated.** +17.1% skill against naive, beating it in 15 of 20 series (§07).
Conditional scenario	Electric reaches 48% of the Sri Lanka stock by 2035 if policy holds.	**Not a forecast.** A stated set of assumptions carried forward arithmetically. §17 gives the falsification condition for each.

THE HONEST BOUNDARY

A 12-month backtest with +17.1% skill does not justify a 9-year forecast, and this report does not offer one. What the backtest establishes is narrower and still useful: the adoption curve has a *shape* that carries information, so a projection built on it is a reasoned extrapolation rather than a guess. The distance between those two statements is why §17 is written as three scenarios with falsification conditions attached.

Where the model is weakest

SERIES	BACKTEST MAE (PP)	NAIVE MAE (PP)	READING
Sri Lanka · Three-wheeler - passenger hire	3.56	3.36	model loses to naive
Nepal · Three-wheeler - passenger hire	3.17	5.74	model wins
India · Three-wheeler - passenger hire	3.15	3.28	model wins
India · Three-wheeler - goods	3.02	2.71	model loses to naive

The worst-fitting series are reported here rather than only the best, because a diffusion model fitted to a series that has not yet turned over will always look convincing in-sample and can be badly wrong out of it.

1 2

From Cost to Constraint

The step that changes what the problem is.

§08 and §09 establish that for three of the five segments the cost question is settled. That conclusion has an immediate and under-appreciated consequence: **for those segments, cost is no longer what decides adoption.** Something else is, and identifying what is the remaining work of this report.

When a purchase is already cheaper over its life and is still not being made universally, the obstacle is one of four things: capital access, residual uncertainty, operational risk, or infrastructure. This study can speak to the last of these directly, and flags the other three as outside its evidence base.

CANDIDATE CONSTRAINT	WHAT IT WOULD LOOK LIKE	ADDRESSED HERE?
Capital access	Operators who cannot fund the premium despite a positive whole-life case — the classic problem of discounting at a credit rate rather than a social one.	No. Flagged in §18. The discount-rate sweep in §07 is the closest this model comes.
Residual uncertainty	A thin second-hand market for used electric vehicles, making the residual assumption unreliable in exactly the direction that hurts.	Partially. Swept in §07; it proves to be a minor term.
Operational risk	Range anxiety on a commercial duty cycle, and the income lost to a mid-shift charge.	Indirectly, through the coverage requirement in §13.
Charging infrastructure	Nowhere to charge within a tolerable detour of where the vehicle actually earns.	**Yes — §13.**

THE COVERAGE REQUIREMENT

$$N_{\mathrm{req}}(d) = \frac{\rho_d}{\kappa} \qquad \mathrm{coverage}(d) = N_{\mathrm{obs}}(d) \,/\, N_{\mathrm{req}}(d)$$

ρ_d = commercial three-wheeler operating density in district d · κ = vehicles a single point can serve while keeping the detour under fifteen minutes. Coverage of 1.0 means the district is adequately served; below 1.0 it is not.

Fifteen minutes is the operative parameter and it is a commercial judgement rather than a technical one. A hire driver paid by the trip treats charging time as lost income, so the detour tolerance is far shorter than for a private owner charging overnight. **The same charging estate can be adequate for private owners and wholly inadequate for the commercial fleet that is economically ready to switch.**

1 3

The Charging Gap

Where the vehicles work against where they can charge.

DISTRICTS SERVED	WEIGHTED COVERAGE	TOTAL ESTATE
5 / 60	44.7%	71
meet the fifteen-minute-detour requirement at their own operating density	of commercial operating density has adequate charging within reach	public charge points across all 60 districts studied

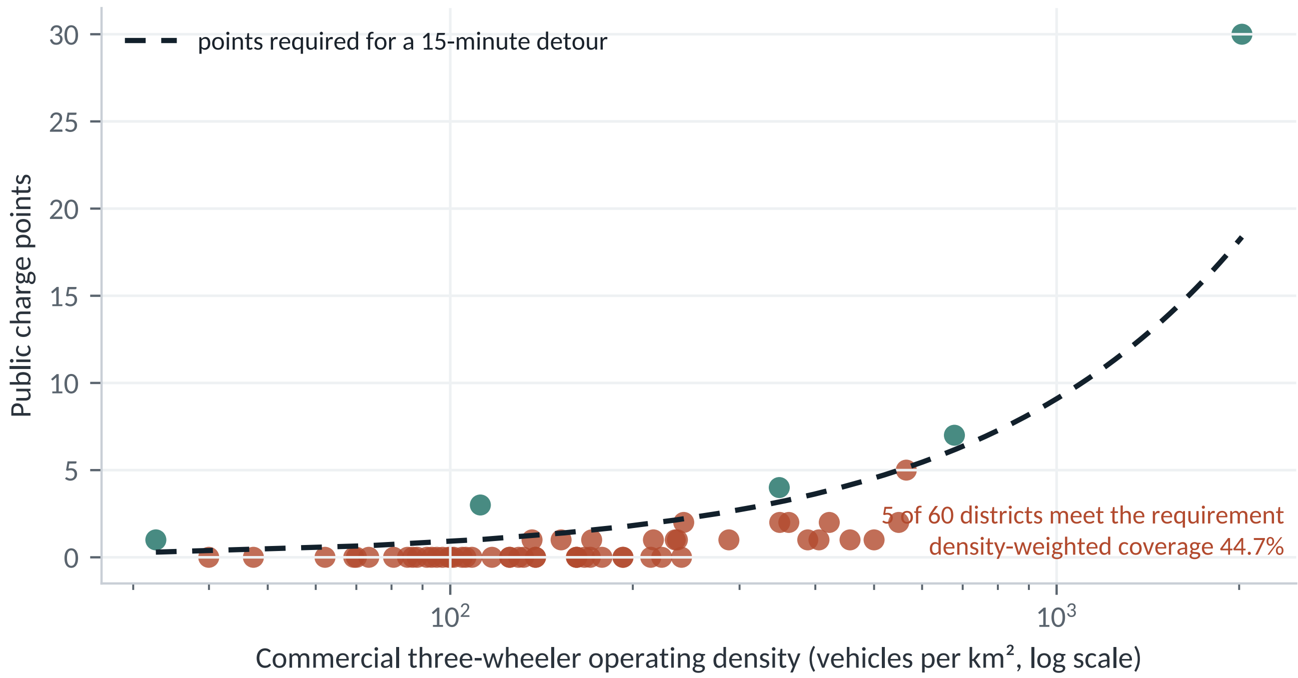

FIGURE 15 — Charge points against operating density. Each point is a district. The dashed line is the requirement; districts below it are underserved.

The relationship runs the wrong way. Charge points are concentrated where they were easiest to install — districts with existing electrical capacity, parking and land — while commercial three-wheeler density is highest in dense older districts where none of those things are available. The result is that **the districts carrying the most vehicles that are economically ready to switch are the ones with the least infrastructure.**

DISTRICT	OPERATING DENSITY (VEHICLES/KM²)	CHARGE POINTS	POINTS REQUIRED	COVERAGE
D-05	500	1	4.5	**0.22**
D-06	456	1	4.2	**0.24**
D-04	549	2	5.0	**0.40**
D-08	406	1	3.7	**0.27**
D-09	389	1	3.5	**0.28**
D-15	241	0	2.2	**0.00**
D-18	223	0	2.0	**0.00**
D-20	214	0	1.9	**0.00**

The eight districts with the largest absolute shortfall. Districts carry neutral identifiers; see §18.

WHY THIS IS THE ACTIONABLE FINDING

Density-weighted coverage of 44.7% means that a little under half of the commercial activity in this market is within reach of adequate charging. Closing that gap is a capital programme of known size, aimed at a fleet whose economic case is already made — which makes it a far more efficient intervention than a purchase subsidy spread across every segment including the ones that are only marginally past parity.

14

The Grid Problem

The right vehicles, charged at the wrong hour.

Every scenario in this report ends with a large number of electric vehicles. Where that energy is drawn from is a supply question; *when* it is drawn is a capacity question, and the capacity question is the harder one.

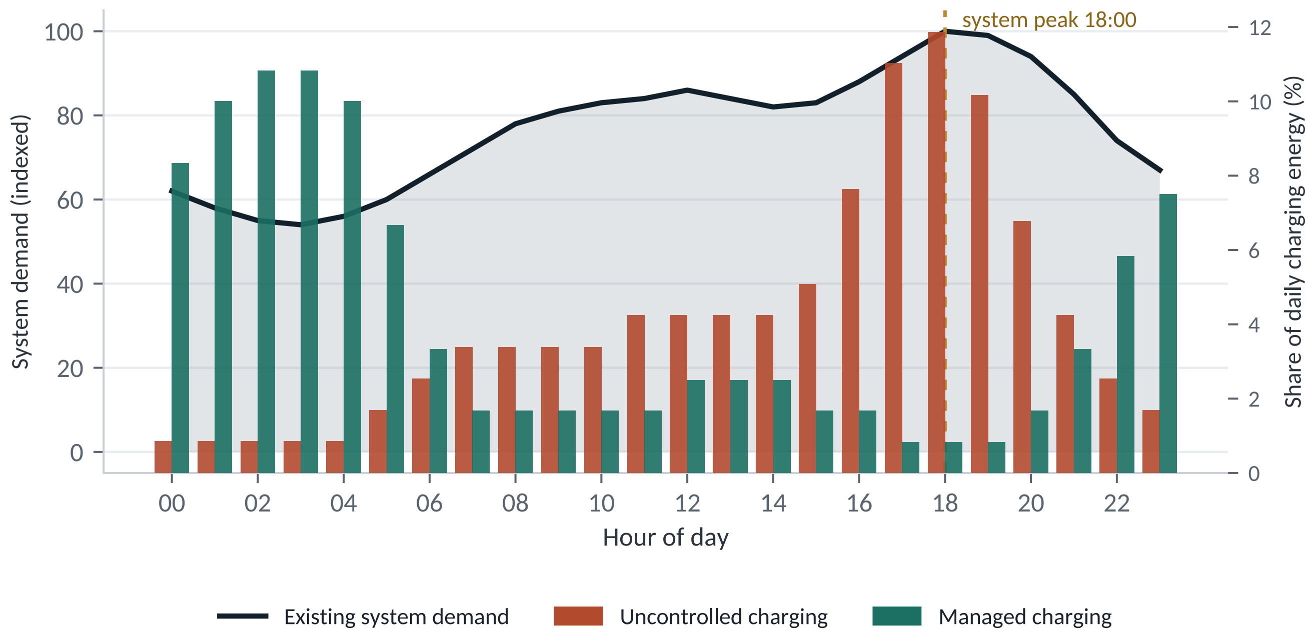

FIGURE 16 — Charging load against the existing demand curve. System demand indexed to its own peak, with the two charging profiles overlaid.

The system peak falls at **18:00**. The natural charging pattern for both private owners and end-of-shift commercial drivers is to plug in on arriving home — which is the same hour. Uncontrolled charging therefore puts its largest draw precisely where the system has least headroom, and the two peaks compound rather than offset.

The managed profile shifts the same total energy into the overnight trough. Nothing is curtailed and no journey is shortened; the energy is identical. Only the hour changes.

The effect on peak capacity is not marginal. Under the policy-holds scenario the Sri Lanka fleet adds **157 MW** at system peak by 2035 if charging is unmanaged, against **11 MW** if it is shifted — a factor of 14, and 146 MW of avoided generation and network reinforcement.

The instruments that achieve this are unglamorous and well understood: a time-of-use tariff with a wide enough spread to change behaviour, and charge-point controls that default to delayed start. Both are cheaper than the capacity they displace.

PEAK CONTRIBUTION

$$MW_{peak} = \frac{\Sigma_s\, n_s \cdot k_s \,/\, 365 \cdot \eta_s}{1000} \cdot \varphi(h_{peak})$$

n_s = electric vehicles in segment s · k_s = annual km · η_s = kWh per km · φ = share of daily charging energy drawn in the peak hour.

φ(peak) = **12%** uncontrolled against **1%** managed. The entire difference between the two outcomes is that one number.

1 5

Operating Rules

What this analysis becomes for the three audiences that commissioned it.

RULE	STATEMENT	BASIS IN THIS REPORT
R-01	**Fleet operators: convert the highest-mileage vehicles first, and rank the conversion list by annual kilometres rather than by vehicle age.**	Cost advantage is earned per kilometre. Headroom runs from 3.34× to 1.06× across segments on the same threshold (§08).
R-02	**Lenders: underwrite against measured mileage, not against segment averages.**	The private segments are split near the middle — 54% and 52% past parity. A segment-average decision is wrong for roughly half of those borrowers (§09).
R-03	**Lenders: size the loan term against battery replacement at 62,000 km, not against vehicle life.**	Battery replacement is a second capital event, and at high mileage it arrives inside a typical loan term (§06).
R-04	**Utilities: make delayed-start the default on every new charge point, and set a time-of-use spread wide enough to hold it.**	Peak contribution falls from 157 MW to 11 MW on the same energy (§14).
R-05	**Infrastructure planners: site charge points by commercial operating density, not by land availability.**	Only 5 of 60 districts meet the requirement, and the shortfall is worst where density is highest (§13).
R-06	**Policymakers: target support at the segments that are marginal, not at the ones already past parity.**	Commercial segments clear the threshold by 2.6× or more without help; private segments sit within 2.0% of break-even (§09).
R-07	**Everyone: restate the crossover whenever the pump price moves more than ten per cent.**	Fuel price swings the advantage by 114% of its base value — more than every other assumption combined (§07).

THE RULE THAT COSTS LEAST

R-04. A delayed-start default and a tariff spread are administrative changes, not capital projects, and between them they avoid 146 MW of peak demand under the central scenario. No other recommendation in this report has that ratio of effect to cost.

1 6

Insight Synthesis

The mechanism, and the three laws that follow from it.

The study resolves into one mechanism, and as usual it is simpler than the machinery used to find it. **An electric vehicle converts a capital premium into a running saving. Whether that is a good trade depends on the number of kilometres it is divided by — so the transition is led by duty cycle, not by price.**

THE THREE LAWS OBSERVED IN THIS CORPUS

1. Distance beats price. Crossover mileages differ by only 1.3× across five segments, while median annual mileage differs by 4.1×. The variation that decides outcomes is entirely on the utilisation side.

2. Once the economics are settled, they stop being the constraint. For the three commercial segments the cost question is closed at 29% or better, yet adoption has not completed. The binding constraint has moved to charging access, at 44.7% density-weighted coverage.

3. The cheapest intervention is about timing, not quantity. The same energy drawn at a different hour is the difference between 157 MW and 11 MW of peak capacity. Nothing else in this analysis offers that leverage.

Answering the three commissioned questions

Q	ANSWER AS SUPPORTED BY THIS CORPUS
Q1	Between **7,378 and 9,520 km a year** depending on segment, at $1.05 per litre. The threshold is remarkably stable across vehicle types; what varies is whether a given fleet is above it.
Q2	Already past it: **100–100%** of commercial fleets against **52–54%** of private. Adoption is tracking it: fitted diffusion ceilings are 45–46% for commercial segments and 12–19% for private, with +17.1% backtest skill.
Q3	**Charging access, then grid timing.** Coverage weighted by commercial operating density is 44.7%, with 5 of 60 districts adequately served — and the shortfall is concentrated exactly where the ready fleet is. Behind that sits a 157 MW peak-capacity problem that costs almost nothing to avoid if charging is shifted.

1 7

Projection to 2035

Three conditional scenarios, each with the condition that would falsify it.

What follows is **not a forecast**. It is the arithmetic of a fleet stock-flow model carried forward under three explicitly stated sets of assumptions. The 12-month backtest in §07 justifies extrapolating the *shape* of the adoption curve; it does not justify predicting 2035. Each scenario below therefore states what would falsify it, so the reader can check it against events rather than take it on trust.

FLEET STOCK-FLOW

$$S_{t+1} = S_t(1 - \sigma) + N_t \cdot a(k, P_t)$$

S = surviving stock · σ = scrappage rate, set per segment by duty cycle · *N* = new registrations · *a* = electric share of new registrations, driven by the share of the mileage distribution past the crossover at that year's prices.

Projection scope: **Sri Lanka** fleet, 2026 to 2035. Fuel valued at $1.05 per litre throughout, so the foreign-exchange figures are volume effects rather than price effects.

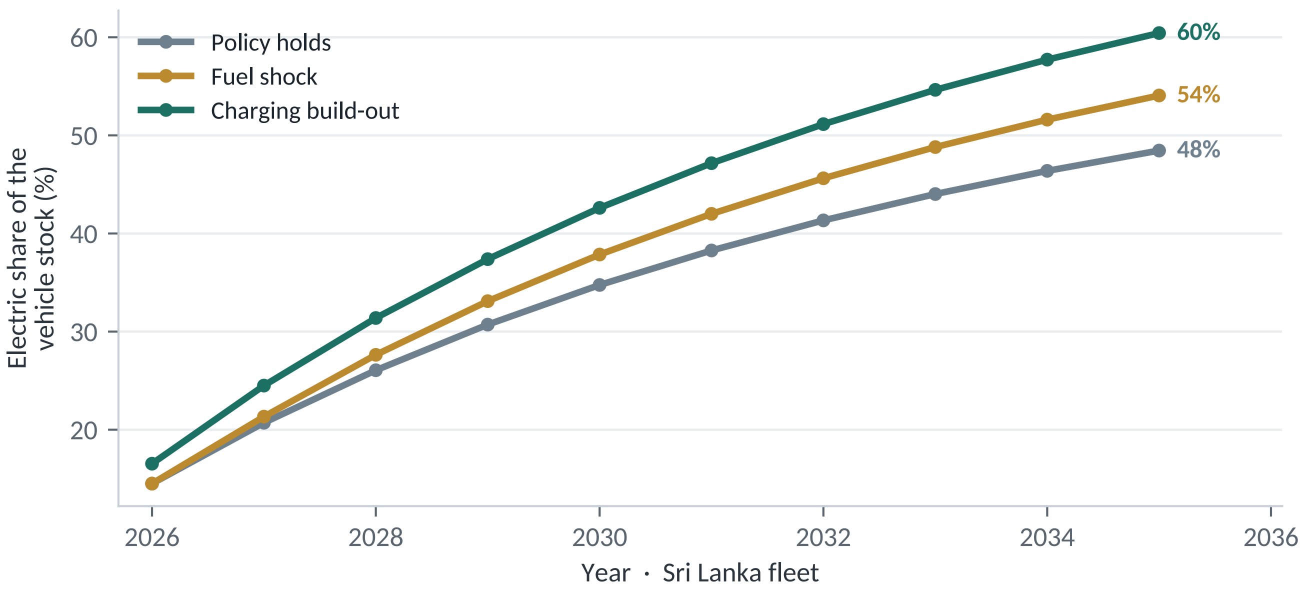

FIGURE 17 — Electric share of the vehicle stock. Three scenarios, Sri Lanka fleet. Stock lags registrations because vehicles survive for years.

SCENARIO	ELECTRIC SHARE OF STOCK, 2035	FUEL AVOIDED (ML/YR)	FX SAVED (2035)	FX SAVED (CUMULATIVE)	PEAK MW UNCONTROLLED	PEAK MW MANAGED
Policy holds	**48.5%**	375	$393M	$2.52B	**157**	**11**
Fuel shock	**54.1%**	386	$404M	$2.58B	**162**	**11**
Charging build-out	**60.4%**	433	$454M	$2.89B	**182**	**13**

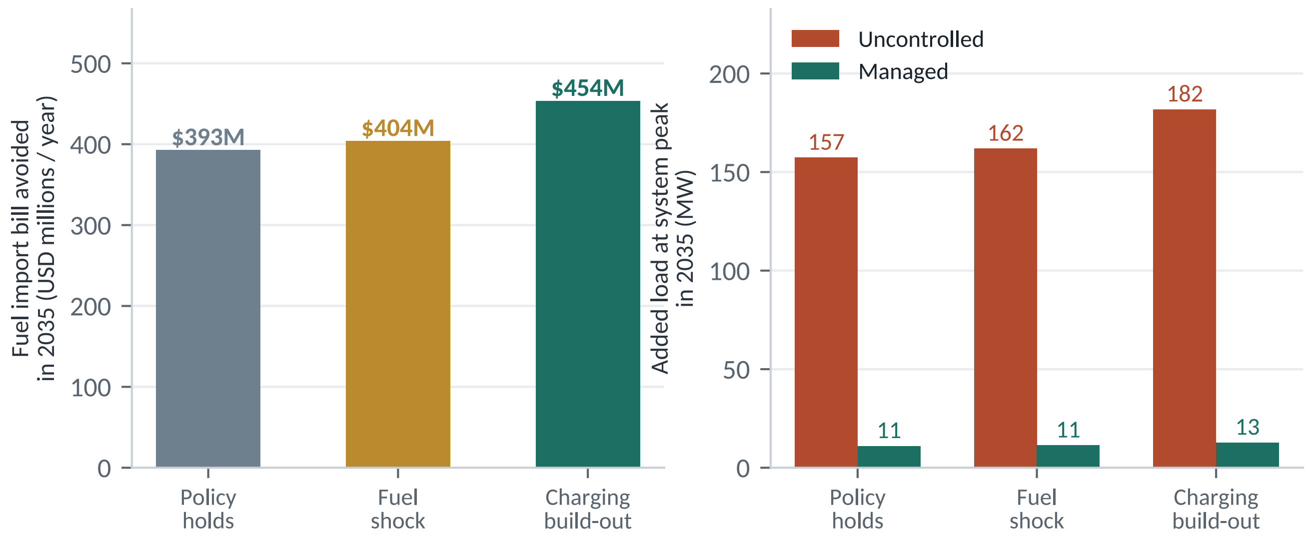

FIGURE 18 — Fuel bill avoided and peak load added. Left: import bill avoided in 2035. Right: contribution to system peak, both charging regimes.

The three scenarios and what would falsify them

SCENARIO	ASSUMPTIONS	FALSIFIED BY
Policy holds	Duties, tariffs and fuel prices stay near their current settings. Pack prices continue their observed learning rate. No new charging programme.	A duty change of more than ten points in either direction, or pack prices leaving the observed learning band for two consecutive years.
Fuel shock	A sustained twenty-five per cent rise in pump prices, of the kind this region saw in 2022, with everything else held.	Fuel prices staying within ten per cent of current levels through the projection window.
Charging build-out	Public charging trebles in the districts that carry commercial three-wheeler density, alongside the policy-holds settings.	Charging point growth below fifty per cent over the window in the top-density districts.

Ninety-day action plan

PHASE	ACTION	RATIONALE DRAWN FROM THIS REPORT	MEASURE OF SUCCESS
Days 1–15	**Rank the existing fleet by measured annual mileage and publish the conversion order.**	Headroom varies 3.2× across segments on an identical threshold (§08).	Ranked list covering every vehicle, mileage-sourced.
Days 1–30	**Utilities: set delayed-start as the default on new charge-point installations.**	The single cheapest intervention in this report — 146 MW avoided on unchanged energy (§14).	Default active on all new installations.
Days 15–45	**Re-run the crossover at your own fuel price, tariff and financing rate.**	Fuel price alone swings the advantage by 114% of base (§07).	Segment-level crossover table signed off by finance.
Days 30–60	**Map charge points against your own operating density and identify the shortfall districts.**	5 of 60 districts meet the requirement; the gap concentrates where density is highest (§13).	Shortfall list with required point counts.

Days 45–90	**Lenders: move underwriting from segment averages to measured mileage, with terms sized to battery replacement.**	Private segments split near the middle; a segment-average decision misrepresents about half of those borrowers (§09, R-02).	Revised credit policy in force.
Quarterly	**Restate crossover and parity shares against current prices.**	All three driving price series moved materially inside this 60-month window (§05).	Refreshed table within two weeks of quarter end.

18

Limitations, Bias & Constraints

What this model cannot tell you, and what it must not be used for.

LIMITATION	EFFECT ON THE FINDINGS	MITIGATION APPLIED
Registrations measure purchases, not use or survival	A registration is an intention to own, not a vehicle on the road. Early electric models may survive less well than the petrol equivalents they are compared against, which would flatter the adoption curve.	Scrappage is modelled per segment in §17 rather than assumed uniform. Stated as a known weakness in the intake record and here.
Self-reported mileage	The utilisation survey depends on respondents' own estimates, which are typically rounded and often overstated for commercial vehicles. Overstatement would move crossover shares upward.	Distributions are reported with quartiles rather than as point estimates, and the crossover is swept across the plausible range in §07.
Credit is not in the model	The discount rate stands in for the cost of capital, but an operator refused a loan faces an infinite one. A positive whole-life case does not mean a financeable one.	Discount rate swept from 6% to 20% in §07. Named explicitly as out of scope in §12.
Battery life is a single number	Real degradation depends on charge rate, depth of discharge, ambient temperature and duty cycle. A single kilometre figure hides all of that, and tropical fast-charging is the harshest case.	Swept across 40–115 thousand km; it is the second-largest term in the tornado.
Fuel price dominates the result	The conclusion is more sensitive to pump prices than to any technical assumption, and pump prices are policy-determined in several of these markets.	Reported prominently in §07 and as finding 3 in the summary, rather than buried.
Charging coverage uses a single detour tolerance	Fifteen minutes is a commercial judgement. A different tolerance would change the coverage figure substantially, though not the ranking of districts.	The parameter is stated in §12 and is a single editable constant in the delivered script.
End-of-life handling is costed, not solved	The model applies a battery disposal fee. Where informal recycling dominates, the real cost is borne as an environmental and health externality rather than by the owner.	Included as an explicit TCO term and swept. Flagged in the constraints below as a genuine hazard rather than an accounting line.
Calibrated corpus in this issue	Registration volumes, prices and mileages are generated to realistic distributions. The relationships hold; the specific figures are not observations of any market.	Stated in §00 and here. No figure may be cited as a measurement of a real market.

CONSTRAINTS ON USE

1. This is not advice to any individual vehicle owner. Three-wheeler driving is low-income self-employment across all four markets studied. A fleet-level cost finding says nothing about whether a particular driver — facing a particular credit offer, route and household balance sheet — should switch. It must not be presented to drivers as if it did.

2. No manufacturer, model or brand is named, compared or recommended anywhere in this report, and nothing in it may be republished in a form that implies an endorsement or a criticism of any product.

3. The report takes no policy position. Duties, subsidies and tariffs on these vehicles are politically contested in every market here. This study presents the arithmetic under stated assumptions; choosing between the policy options that arithmetic informs is not its role.

4. Battery end-of-life is a real hazard, not a line item. Informal lead and lithium recycling causes documented harm to workers and neighbourhoods. Any programme acting on these findings should treat collection and safe processing as part of the cost of the transition, not an externality to be discovered later.

5. District identifiers are neutral by design and must not be relabelled with real place names in any published derivative, for the same reasons set out in the geospatial work in this series.

STATISTICAL DISCLOSURE

No result was selected on the basis of significance. All five segments, four markets, four swept assumptions and 20 diffusion series specified before analysis are reported whether or not they favoured the conclusion — including the series where the diffusion model loses to a naive baseline (§11) and the fuel-price sensitivity that undermines the precision of the headline crossover (§07). The full panel is delivered so every figure can be recomputed independently.

1 9

Methodology Appendix

Formula glossary and variable dictionary.

Formula glossary

QUANTITY	EXPRESSION	NOTES
Discount factor	$\delta = (1 + r)^{-1}$	r = 11.5% real, swept 6–20%.
Energy cost per km	$e_{ICE} = L_{100}P_{fuel}/100 \;\cdot\; e_{EV} = \eta P_{elec}$	Litres per 100 km against kWh per km.
Battery replacement	at y where $\lfloor ky/B \rfloor > \lfloor k(y-1)/B \rfloor$	Placed by cumulative distance, not by age. B = 62,000 km.
TCO per km	PV(costs) / PV(kilometres)	Distance discounted on the same factor as cost.
Crossover mileage	$k^* : \mathrm{TCO}_{EV}(k^*) = \mathrm{TCO}_{ICE}(k^*)$	Solved by Brent's method on 1,500–80,000 km.
Headroom	k_{median} / k^*	Above 1.0 the median vehicle is past the threshold.
Share past parity	$\mathrm{P}(k \geq k^*)$	Mass of the lognormal mileage distribution above the crossover.
Bass diffusion	$\Delta F = (p + qF)(m - F)/m$	Fitted by Nelder–Mead least squares from a multi-start grid.
Backtest skill	$(\mathrm{MAE}_{naive} - \mathrm{MAE}_{model}) / \mathrm{MAE}_{naive}$	Positive means the model beats assuming no change.
Coverage	$N_{obs} / (\rho/\kappa)$	κ set by the fifteen-minute detour tolerance.
Fleet stock-flow	$S_{t+1} = S_t(1-\sigma) + N_t a$	σ per segment by duty cycle.
Peak contribution	$\mathrm{MW} = \Sigma n_s k_s \eta_s / 365000 \cdot \varphi(h)$	φ = share of daily charging energy in the peak hour.

Variable dictionary — delivered registration panel

FIELD	TYPE	DEFINITION
month_idx / month	integer / text	Month position 0–59 and its label.
country	categorical (4)	Market.
segment / segment_label	categorical (5)	Duty-cycle segment code and its description.
commercial	boolean	True where the segment is a commercial duty cycle.
registrations	integer	New registrations in that cell.
ev_registrations	integer	Of those, electric.
ev_share	float	Electric registrations divided by total.

Variable dictionary — delivered price and crossover tables

FIELD	TYPE	DEFINITION
fuel_<country>	float	Pump price, USD per litre.
elec_<country>	float	Applicable tariff, USD per kWh.
pack_usd_kwh	float	Installed replacement pack price.
crossover_km	float	Annual mileage at which electric becomes cheaper.
headroom_x	float	Median mileage divided by crossover.

tco_ice / tco_ev	float	USD per km at the segment median mileage.
gap_pct	float	Electric advantage as a percentage of petrol TCO.

2 0

Deliverables & Authorisation

What is handed over, and confirmation to proceed.

Delivered with this report

ITEM	CONTENTS
01 Structured database	Registration panel (5,332,229 records aggregated to 4 markets × 5 segments × 60 months), the three price series, the crossover table and the fleet utilisation distribution, in XLSX and CSV.
02 Analysis script	Documented Python that regenerates every cost, crossover, diffusion parameter and scenario in this document from the delivered tables — no manual step between the data and the page.
03 Figure repository	All 18 numbered charts plus the cover artwork, as vector SVG, named to their figure numbers, for reuse in board papers and regulatory submissions at any size.
04 Digital catalog	This report as a presentation-ready PDF, structured for direct circulation.

Continuation options

OPTION	SCOPE
Licensed data connection	The same pipeline pointed at licensed registration and price data for your market, producing a directly comparable issue on observed figures.
Fleet-specific crossover	Your own vehicles, mileages, financing rate and tariff, producing a ranked conversion order rather than a segment average.
Charging siting study	Coverage analysis against your own operating density, with a ranked shortfall list and required point counts per district.
Grid impact modelling	Extension of §14 to your network, with tariff-spread scenarios and feeder-level peak contribution.

Commercial note

This report is issued under the terms of the Data Tune commercial proposal governing the engagement. Volume is measured in data entities on the same basis as that document; any extension beyond the contracted ceiling proceeds only on prior written approval, and never retrospectively.

Scheduled updates

Progress reporting during the working window follows the same three-point structure as the governing proposal: an early-stage note with initial counts and a first sample batch, a mid-project note with running totals, and a pre-delivery note with near-final counts before handover.

Acceptance & authorisation

By signing below, the client confirms receipt of this report and its accompanying deliverable set, accepts the scope and method recorded in §02 to §07, and acknowledges both the data provenance statement in §00 and the constraints on use in §18.

FOR THE CLIENT — AUTHORISED SIGNATURE

NAME & DESIGNATION · DATE

FOR DATA TUNE — AUTHORISED SIGNATURE

K. H. Militha Mihiranga

DATA SOLUTIONS CONSULTANT · DATE

Data Tune.

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For clarification on scope, cost assumptions, crossover construction or scheduling, please contact the consultant alongside.

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