

RESEARCH NOTE 3

O&M Note 3:

Combined cost recovery for ALTO HSR

Maintenance, operations, fleet capital, and break-even ridership

Total annual (MID)	Per train-km	Break-even	40-year PV
\$2.15B	\$74	12.5M	\$28.6B
<i>at 80 trains/day</i>	<i>combined cost</i>	<i>pax/yr at MID baseline</i>	<i>7% real discount</i>

Worked example: 1,000 km dedicated HSR corridor, Canadian climate, \$0.20 per pax-km yield, 65 per cent load factor. Synthesises Notes 1 (maintenance) and 2 (operations) and adds a third pillar — fleet capital recapitalisation at 25-year trainset life — alongside the combined cost-recovery analysis.

Purpose

This note is the third in a series. The first established a methodology for estimating infrastructure maintenance costs and applied it to a 1,000 km ALTO-scale corridor. The second did the same for operating costs. This note combines the two streams, adds a third — fleet capital recapitalisation — applies a revenue model, and identifies the break-even ridership below which the corridor cannot cover its recurring lifecycle cost from fare revenue.

The note is intended to be standalone. It includes condensed summaries of the methodologies and headline findings from Notes 1 and 2 before proceeding to the fleet-capital analysis in §4 and the combined cost-recovery analysis in §5. Readers wanting the full asset inventories, parameter tables, and diagnostic checklists should refer to the companion notes.

1. The components of lifecycle cost

Recurring lifecycle cost for a high-speed rail corridor decomposes into three streams with fundamentally different cost drivers, sensitivities to traffic, and methodologies for estimation. Modelling them as a single line item — as is common in summary business cases — hides the structure that determines whether cost recovery is achievable.

Dimension	Maintenance (M)	Operations (O)	Fleet capital (F)
What is paid for	Existence of the fixed assets — track, OCS, signalling, structures, stations.	Activity of running trains — crew, energy, rolling stock servicing, station staffing, dispatching.	Periodic replacement of the rolling stock fleet at end of useful life.
Primary driver	Asset inventory and age.	Train-kilometres and passenger volume.	Fleet size × unit price × useful life.
Traffic sensitivity	Low. 77% fixed at typical traffic.	High. 69% variable at typical traffic.	None. Fleet size set by peak service requirement, not utilisation.
Estimation method	Asset inventory × unit cost × climate, terrain factors. Capital recovery factor for renewals.	Unit cost per train-km × annual train-km, plus fixed categories and overhead markups.	Fleet capex annuitised at the social discount rate over useful life. Same CRF formula as infrastructure renewals.
Headline result	\$1.27B/yr MID	\$700M/yr MID	\$180M/yr MID

Where infrastructure cost is dominated by the existence of assets and operating cost by the act of running trains, fleet capital pays for periodic recapitalisation of the trainsets. All three are recurring on different timescales: maintenance and operations are annual; fleet capital is a single large outlay every twenty-five to thirty-five years, annuitised here for comparability.

2. Maintenance costs

Infrastructure maintenance cost has two components that must be modelled separately. Routine maintenance is annual recurring expenditure for inspection, preventive and corrective maintenance. Renewal is periodic capital replacement of long-life components such as rail, ballast, contact wire, and signalling electronics, annuitised over each asset’s useful life.

2.1 Formula

For each asset class on each corridor segment, annual maintenance cost is:

$$c_{a,i} = Q_{a,i} \cdot (\alpha_i + \beta_i \cdot \text{GTKM}_a + \gamma_i \cdot v_a^k \cdot N_a) \cdot f_{\text{clim}} \cdot f_{\text{mix}} \cdot f_{\text{terr}}$$

Renewal capital is converted to equivalent annual cost using the standard capital recovery factor:

$$A_i = K_i \cdot \frac{r(1+r)^{L_i}}{(1+r)^{L_i} - 1}$$

Full asset inventory, unit costs, and useful-life table in Note 1.

2.2 Results for 1,000 km ALTO-scale corridor

Metric	MID scenario
Annual maintenance	\$496M
Annual renewal annuity	\$770M
Annual total (M+R)	\$1,266M
Per route-kilometre per year	\$1.27M
Fixed share of total	77%
40-year PV at 7% real	\$16.9B

3. Operating costs

Operating cost decomposes into eight categories. Three (traincrew, traction energy, rolling stock light/intermediate maintenance) scale with train-kilometres. Three (station operations, network control, insurance) are largely fixed. One (commercial) scales with revenue, and one (G&A) is applied as a markup on direct costs. Note that rolling stock light and intermediate maintenance is in this stream — rolling stock end-of-life replacement is the fleet capital stream of \$4.

3.1 Formula

$$C_{op} = C_{crew} + C_{energy} + C_{RS} + C_{stat} + C_{OCC} + C_{comm} + C_{ins} + C_{GA}$$

In fixed-plus-variable form for sensitivity analysis:

$$C_{op}(N) = C_{op, fix} + c_{op, var} \cdot N$$

Full category-by-category breakdown in Note 2.

3.2 Results for 1,000 km ALTO-scale corridor

Metric	MID scenario
Annual total operating	\$700M
Per train-kilometre	\$24
Variable share of total	69%
40-year PV at 7% real	\$9.3B
<i>Top three categories combined</i>	<i>Crew + RS maint + stations = 51%</i>

4. Fleet capital

Trainsets have finite service lives. After approximately twenty-five to thirty-five years they are retired and replaced. The acquisition capital for the original fleet is therefore not a one-time cost but the first cycle of a periodic recapitalisation that recurs for as long as the corridor operates. Annuitised at the social discount rate over the assumed useful life, this becomes the third pillar of recurring lifecycle cost — distinct from operating cost (which includes light and intermediate rolling-stock maintenance) and from infrastructure maintenance.

4.1 Methodology

The same capital recovery factor used for infrastructure renewals in §2 applies to fleet replacement:

$$C_F = n_f \cdot K_f \cdot \frac{r(1+r)^{L_f}}{(1+r)^{L_f} - 1}$$

where:

- C_F annual fleet replacement annuity (\$/year)
- n_f fleet size (number of trainsets)
- K_f unit capex per trainset (\$)
- L_f useful life of trainsets (years)
- r real social discount rate (7% TBS reference)

4.2 Fleet sizing for the worked example

Fleet size is set by peak service requirement, not by ridership. At 80 trains per day on a 1,000 km corridor with an average commercial speed of 250 km/h, a one-way trip takes four hours; with thirty-minute turnaround at each end, a round-trip cycle is approximately nine hours. Each trainset can complete roughly 1.5 round trips in a fourteen-hour daily service window, so

revenue-service requirement is approximately 26 trainsets. Adding a fifteen-to-twenty per cent reserve for heavy maintenance, mid-life refurbishment, and unplanned unavailability gives a fleet of 30 trainsets. This is consistent with industry-standard daily utilisation of approximately 2,700 train-km per set.

4.3 Unit cost and useful life

Recent high-speed trainset acquisitions from Siemens (Velaro Novo), Alstom (Avelia Liberty), and Hitachi (Frecciarossa 1000) have priced in the CAD \$65–\$75M range per 8-to-12-car set, depending on configuration, maintenance contract bundling, and order size. Central estimate: \$70M per trainset, giving a fleet capex of approximately \$2.1 billion.

Useful life is taken at 25 years for the central case. This is at the shorter end of the defensible range — TGV Sud-Est trainsets served 38 years, ICE 1 approximately 30, Renfe AVE class 100 approximately 25–30. CHSRA planning assumes 35 years. Shorter assumed life is conservative (higher annuity); using 25 years here matches the assumption embedded in the question this note was extended to address.

4.4 Results

Parameter	Value
Fleet size (n_f)	30 trainsets
Unit cost (K_f)	\$70M / trainset
Fleet capex	\$2,100M
Useful life (L_f)	25 years
Discount rate (r)	7% real
Capital recovery factor	0.0858
Annual fleet replacement annuity	\$180M / year
40-year PV at 7%	\$2.4B

4.5 Sensitivity to useful-life assumption

The choice of useful life affects the annuity moderately but not dramatically:

Useful life (years)	CRF at 7% real	Annual annuity
20	0.0944	\$198M
25 (central case)	0.0858	\$180M
30	0.0806	\$169M
35 (CHSRA assumption)	0.0772	\$162M
40	0.0750	\$158M

Moving from 25-year to 35-year assumed life reduces the annuity by \$18M per year (10 per cent). The existence of the replacement cost matters far more than the exact horizon.

5. Combined cost recovery and break-even at pax/yr

Summing the three streams produces the total annual lifecycle cost. Comparing this to fare revenue identifies the break-even service level — the ridership below which the corridor cannot cover its recurring cost from operations.

5.1 Combined cost formula

Total annual cost is the sum of the three components:

$$C_{\text{total}}(N) = C_M(N) + C_O(N) + C_F$$

Collecting fixed and variable parts gives a single linear function of service frequency:

$$C_{\text{OM}}(N) = C_{\text{fix}} + c_{\text{var}} \cdot N$$

For the 1,000 km ALTO-scale MID scenario:

Component	Maintenance	Operations	Fleet capital
Fixed cost (\$M/yr)	\$980M	\$221M	\$180M
Variable per train/day (\$M/yr)	\$3.58M	\$6.00M	—
Combined fixed	\$1,380.8M		
Combined variable per train/day	\$9.575M		

Combined cost(N) \approx \$1,380.8M + \$9.575M \times N , where N is trains per day. At $N = 80$, total \approx \$2,147M per year.

5.2 Revenue formula

Fare revenue scales linearly with passenger-kilometres at a given yield. For uniform service:

$$R(N) = \phi_y \cdot S \cdot LF \cdot N \cdot L \cdot 365$$

where:

- $R(N)$ annual fare revenue (\$/year)
- ϕ_y average fare yield (\$/passenger-km)
- S seats per trainset (450 for the worked example)
- LF average load factor (0.65 baseline)
- N service frequency (trains per day, both directions)
- L corridor length (1,000 km)

5.3 Break-even condition

Break-even is the service level at which revenue equals total cost:

$$R(N^*) = C_{OM}(N^*)$$

Solving for break-even trains per day:

$$N^* = \frac{C_{\text{fix}}}{\phi_y \cdot S \cdot LF \cdot L \cdot 365 - c_{\text{var}}}$$

And converting to break-even annual passenger trips (full-corridor equivalent):

$$P^* = N^* \cdot S \cdot LF \cdot 365$$

The cost recovery ratio (CRR) at any service level is:

$$\text{CRR}(N) = \frac{R(N)}{C_{\text{OM}}(N)}$$

5.4 Break-even at MID baseline

Revenue coefficient (per train/day per year)	\$21.36M
Contribution margin per train/day (revenue – variable cost)	\$11.79M
Fixed cost to recover	\$1,380.8M
Break-even N*	117.2 trains/day
Break-even P* (full-corridor pax/yr)	12.52 million
Break-even passenger-km/yr	12.52 billion

5.5 Cost recovery at 80 trains/day (baseline service)

Total combined cost (M + O + F)	\$2,147M
Fare revenue (\$0.20/pkm, 65% LF)	\$1,708M
Annual deficit	\$439M
Cost recovery ratio (CRR)	0.80

At baseline 80 trains per day, revenue covers 80 per cent of total recurring cost. The \$439M annual deficit is incurred before any allowance for construction debt service or return on capital.

5.6 Cost recovery curve

Sweeping service frequency across the operating range, with the three cost streams stacked and converted to annual passenger trips on the x-axis:

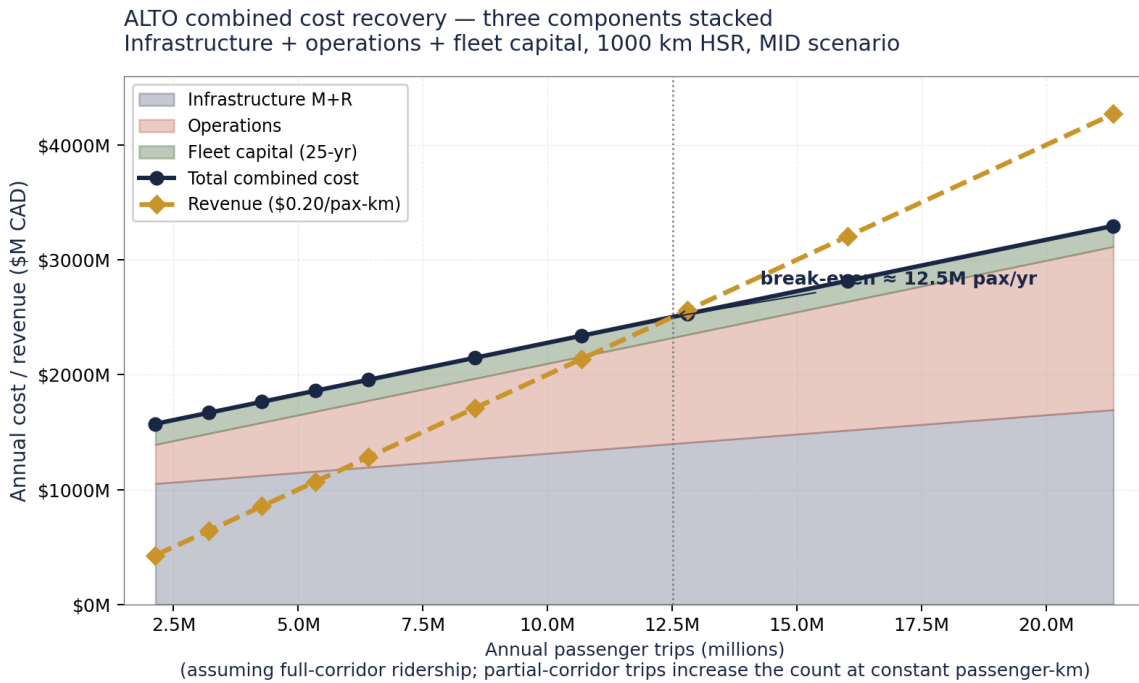


Figure 1. Three-component cost stack — infrastructure M+R, operations, and fleet capital — versus revenue at \$0.20/pax-km with 65 per cent load factor, plotted against annual passenger trips. Break-even occurs at approximately 12.5 million pax per year.

5.7 Sensitivity to yield and load factor

The break-even ridership remains highly sensitive to assumed yield and load factor. The fleet capital pillar raises the fixed-cost floor by 15 per cent, which moves the break-even threshold up by a similar percentage across the parameter space.

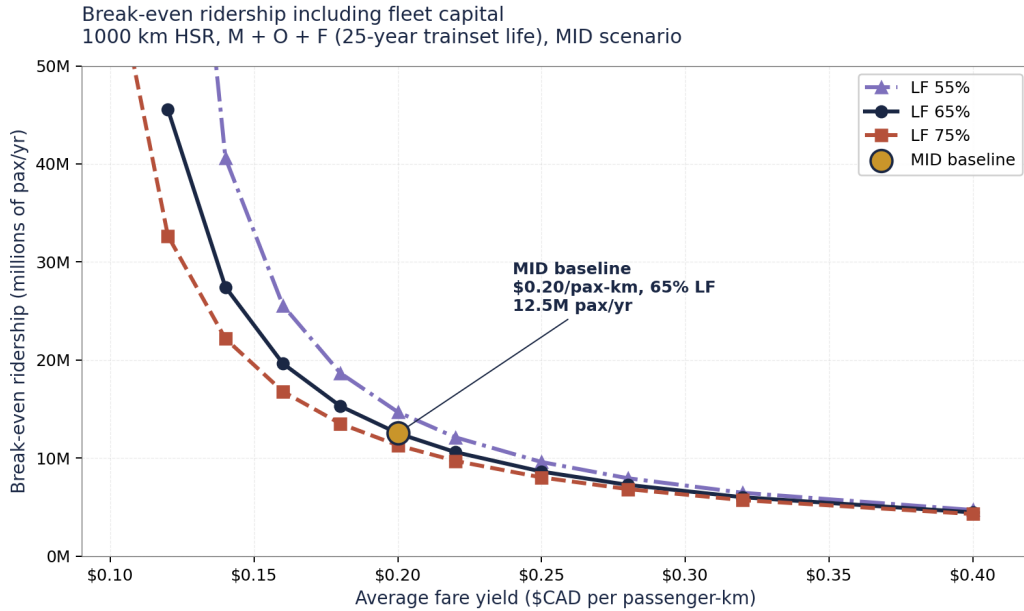


Figure 2. Break-even ridership as a function of fare yield, for three load-factor scenarios, with fleet capital included. The MID baseline (gold marker) sits in the steep part of the curve.

5.8 Break-even matrix

Tabular form of the yield × load factor break-even sensitivity. All figures in millions of annual passenger trips at full-corridor ridership. Em-dash entries indicate scenarios where revenue per train-km is less than variable cost per train-km — no service level achieves break-even.

Yield \$/pkm	LF 50%	LF 55%	LF 60%	LF 65%	LF 70%	LF 75%	LF 80%
\$0.12	—	—	—	45.6	37.6	32.7	29.3
\$0.15	41.3	31.4	26.1	22.9	20.7	19.1	17.9
\$0.18	21.8	18.7	16.7	15.3	14.3	13.5	12.9
\$0.20	16.6	14.7	13.4	12.5	11.8	11.3	10.9
\$0.23	12.2	11.1	10.4	9.8	9.4	9.1	8.8
\$0.26	9.6	9.0	8.5	8.1	7.8	7.6	7.4
\$0.30	7.5	7.1	6.8	6.6	6.4	6.2	6.1

MID baseline (\$0.20 yield, 65% LF) highlighted: 12.5M pax/yr. Adding fleet capital raises every cell relative to the O&M-only matrix in the earlier version by approximately 15 per cent.

6. Implications and diagnostic framework

6.1 The cost-recovery picture

1. **Break-even at MID baseline is 12.5 million annual passenger trips.** Under the assumed \$0.20 per pax-km yield and 65 per cent load factor, the corridor must attract approximately 12.5 million annual passenger trips on a full-corridor basis to cover its recurring cost from fare revenue. Below this ridership level, the corridor operates at a loss before any consideration of construction debt service.
2. **Baseline service runs at a \$439M annual deficit.** At the modelled 80 trains-per-day service with baseline yield and load factor, revenue (\$1.71B) covers only 80 per cent of total recurring cost (\$2.15B). Cost recovery is therefore not achieved at the baseline service level — it requires either higher frequency, higher yield, higher load factor, or a combination of the three.
3. **Fleet capital adds 15 per cent to the break-even ridership.** Including periodic trainset replacement at 25-year useful life moves the break-even threshold from 10.9 million pax/yr (O&M only) to 12.5 million pax/yr. The effect is mechanical: every dollar added to the fixed-cost floor requires roughly \$0.085 of additional annual contribution to recover, which in turn requires roughly 50,000 additional full-corridor passenger trips per year.
4. **The cost-recovery question is determined by ridership, not by cost engineering.** Combined cost rises at a roughly constant slope of \$9.6M per train-per-day per year. Revenue rises at a slope set by yield, seats, load factor, and corridor length. Whether the two lines cross — and at what passenger volume — is decided by ridership outcomes, not by reducing unit costs.

6.2 Yield and load factor sensitivity

1. **Break-even remains highly sensitive to yield assumptions.** A 25 per cent reduction in yield (from \$0.20 to \$0.15 per pax-km) nearly doubles required break-even ridership at baseline load factor — from 12.5M to 22.9M pax/yr. At yields below \$0.13 per pax-km the system cannot break even at any service level under low load-factor assumptions.
2. **Load factor moves break-even by similar magnitudes.** Reducing load factor from 65 to 55 per cent at baseline yield moves break-even from 12.5M to 14.7M pax/yr. The combined sensitivity to both parameters compounds.
3. **European HSR comparators do not necessarily transfer.** SNCF TGV averages approximately €0.14 per pax-km with 70 per cent load factor on long-haul routes. Trenitalia Frecciarossa is in the same range. A Canadian assumption of \$0.20 per pax-km is above the European average and requires explicit justification by route economics, demographic profile, and competitive mode pricing.

6.3 Implications for the ALTO economic case

1. **Published ridership forecasts must be tested against the break-even threshold.** If the proponent's mature-year ridership forecast is below 13 million annual passenger trips at full-corridor equivalent, the corridor cannot cover its recurring cost from fare revenue at the modelled yield. If it is below 17 million at full-corridor equivalent, the cost-recovery margin is too thin to absorb the normal range of forecasting error.
2. **The cost-recovery surplus, when achieved, must still service construction debt.** Even at service levels well above break-even, the surplus generated is the resource available to service construction debt. The proponent's public estimates of capital cost in the \$40–\$80B range translate to an additional \$2.5–\$5B per year in debt service at typical infrastructure finance rates — multiples of the O&M and fleet-capital surplus available at any plausible service level.
3. **The HPR alternative changes the cost structure, not the revenue line.** Shared-corridor approaches such as the High Performance Rail (HPR) framework reduce the fixed-infrastructure floor by sharing assets with existing freight or conventional passenger traffic. They may also reduce fleet capital — shared corridors typically operate smaller trainsets at lower per-set capex. The revenue line is set by the same ridership and yield assumptions. If HPR reduces the attributable fixed-cost floor by 40 to 60 per cent, the break-even ridership falls into a much lower range.

6.4 Diagnostic framework for proponent cost-recovery claims

When reviewing any HSR business case, the following questions identify whether the cost-recovery claim is auditable.

1. **Are all three cost streams disclosed separately?** Maintenance, operations, and fleet capital have different drivers and sensitivities. A single bundled "O&M" or "lifecycle cost" figure is not auditable.
2. **Is fleet replacement included?** Business cases that treat rolling stock as a one-time acquisition capital cost without amortising it over useful life systematically understate recurring cost by approximately 10 per cent.
3. **What useful life is assumed for trainsets?** 25 to 35 years is the defensible range. Assumptions above 35 years should be supported by reference to mid-life refurbishment programmes and OEM service-life specifications.
4. **What yield and load factor are assumed?** Both must be disclosed and benchmarked against international comparators. A yield above \$0.20 per pax-km requires demographic, competitive, and route-specific justification.
5. **Has the ridership forecast been independently validated?** International experience (Flyvbjerg, Skamris Holm, and Buhl, 2005): HSR ridership forecasts are routinely 30 to 50 per cent above out-turn in the first decade of operation.

6. **What is the cost recovery ratio at the central ridership forecast?** $CRR < 1$ means recurring cost cannot be self-funded. CRR between 1.0 and 1.2 is a thin margin susceptible to forecasting error. $CRR > 1.5$ indicates genuine surplus for construction-debt service.
7. **Is the HPR alternative quantified for comparison?** If a shared-corridor alternative is available, its cost-recovery analysis should be presented alongside the dedicated-HSR option using the same yield, load-factor, and ridership assumptions.

7. Caveats and limitations

- The model is steady-state. Ramp-up years typically have higher per-train-km cost and lower revenue, so the deficit is larger in early years.
- Break-even is computed on recurring lifecycle cost ($M + O + F$) only. Adding construction debt service (\$2.5–\$5B per year at proponent’s capex estimates) shifts the break-even threshold substantially upward.
- Fleet capital uses a 25-year useful life as the central case. Industry practice ranges from 25 to 35 years; the longer end reduces the annuity by approximately 10 per cent.
- Trainset unit cost (\$70M) is a central estimate from recent acquisitions and may not reflect the specific procurement model or order size of a Canadian fleet purchase. Smaller orders typically attract a 10–20 per cent unit-cost premium.
- Ridership is reported on a full-corridor-equivalent basis. Real corridors have partial-corridor trips; if average trip length is shorter than corridor length, the actual passenger-trip count at break-even is higher than the full-corridor figure.
- The revenue model uses a single average yield and load factor. Real systems use yield management; resulting blended averages can differ from the assumed flat rate by 10 to 20 per cent.
- Fare elasticity is not modelled. Higher frequency service typically raises both yield and load factor, modestly improving cost recovery at higher service levels.
- Unit costs and elasticity coefficients are central estimates from CHSRA, SNCF, ADIF, and HSIPR benchmarks. Firm Canadian figures would require disclosure of infrastructure-manager engineering rate cards, Ontario electricity commitments, and rolling-stock OEM service agreements.

Sources

Documents are organised by topic. Where applicable, document identifiers and publication years are given to support replication and citation in submissions.

Cost-benefit methodology and discount rates

- Treasury Board of Canada Secretariat. Canada's Cost-Benefit Analysis Guide for Regulatory Proposals. BT58-5/2022E-PDF. 2022. (publications.gc.ca/pub?id=9.910204).
- Treasury Board of Canada Secretariat. Policy on Cost-Benefit Analysis. 2018, current. Directs use of the social opportunity cost of capital as the central discount rate, with social discount rate sensitivities.
- Boardman, A.E., Moore, M.A., and Vining, A.R. "The Social Discount Rate for Canada Based on Future Growth in Consumption." *Canadian Public Policy* 36, no. 3 (2010): 325–343. Argues 7–8 per cent is too high for intragenerational projects; recommends 3.5 per cent.
- HM Treasury (UK). *The Green Book: Central Government Guidance on Appraisal and Evaluation*. 2022 edition. London. UK reference rate 3.5 per cent declining.
- Office of Management and Budget (US). Circular A-4: Regulatory Analysis. 2003, updated 2023. Reference rates 7 per cent (opportunity cost) and 2 per cent (social rate of time preference, post-2023 revision).

Infrastructure maintenance and renewals

- International Union of Railways (UIC). *Lasting Infrastructure Cost Benchmarking (LICB): 20 Years of Benchmarking 1996–2015*. Paris, 2016, and subsequent annual data updates. Canonical European source for per-route-km maintenance and renewal cost benchmarks.
- International Union of Railways. *High-Speed Rail Atlas 2024*, sixth edition. Paris, 2024. (uic.org/passenger/highspeed).
- European Parliament and Council. Directive 2012/34/EU establishing a single European railway area, and Commission Implementing Regulation (EU) 2015/909 on the modalities for calculating the cost directly incurred as a result of operating the train service.
- CATRIN consortium. "Cost Allocation of Transport Infrastructure Cost," Deliverable D8: Rail Cost Allocation for Europe. EU Sixth Framework Programme, 2009. Source for the fixed/variable maintenance cost coefficients used in §4 of Note 1.
- Independent Regulators' Group – Rail (IRG-Rail). *Overview of the Implementation of Direct Costs in Europe*. Annual reports, most recently 2024.
- Office of Rail and Road (UK). *Network Rail Access Charging Framework, Control Period 7 (2024–2029)*. London, 2023.
- Bundesnetzagentur. *Trassenpreissystem 2026 — Beschluss BK10-22-0098 zur Festlegung der Entgelte für Schienenwegnutzung*. Bonn, December 2025.
- European Court of Auditors. *A European high-speed rail network: not a reality but an ineffective patchwork*. Special Report 19/2018. Luxembourg.

Operating cost models and benchmarks

- California High-Speed Rail Authority. *2024 Business Plan: Operations and Maintenance Cost Model Documentation*. Sacramento, May 2024. (hsr.ca.gov).
- California High-Speed Rail Authority. *2024 Business Plan: 50-Year Lifecycle Capital Cost Model Documentation*. Sacramento, May 2024. Source for lifecycle methodology including rolling-stock recapitalisation over a 50-year horizon.
- Federal Railroad Administration. *High-Speed Intercity Passenger Rail (HSIPR) Best Practices: Operating Cost Best Practice Report*. US Department of Transportation, 2011.
- SNCF Réseau and SNCF Voyageurs. *Rapport financier annuel (annual financial reports)*. Most recent: 2024 reports published April 2025.

- Renfe Operadora and ADIF Alta Velocidad. Cuentas anuales (annual accounts). Spanish HSR operating cost benchmark.
- Almujibah, H., and Preston, J. “The Total Social Costs of Constructing and Operating a High-Speed Rail Line.” *Frontiers in Built Environment* 5 (2019): 79. doi:10.3389/fbuil.2019.00079. Source for the Riyadh–Dammam reference case used in Note 2.
- Office of Rail and Road (UK). *European Benchmarking of GB Train Operating Companies (TOCBench)*, 2021. London.
- International Energy Agency. *The Future of Rail: Opportunities for Energy and the Environment*. Paris, 2019. Reference values for HSR specific energy consumption.

Rolling stock procurement and lifecycle

- Siemens Mobility. Velaro Novo platform documentation and procurement announcements (Eurostar, ICE 3neo, Egyptian National Railways orders, 2022–2025).
- Alstom. Avelia Liberty trainset for Amtrak Acela: 2016 contract award (US\$2.0 B for 28 sets), 2020 and 2024 cost update reports.
- Hitachi Rail STS and Trenitalia. Frecciarossa 1000 (ETR 1000) platform documentation; Iryo (Spain) and Frecciarossa Italy operational data.
- CRRC and JR East. Shinkansen N700 / N700S series technical and lifecycle documentation, including 13–16 year heavy refurbishment cycles and 25–30 year service-life assumptions.
- International Organization for Standardization. ISO 55001:2014, Asset Management — Management Systems Requirements. Geneva, 2014.

Demand forecasting accuracy in rail megaprojects

- Flyvbjerg, B., Skamris Holm, M.K., and Buhl, S.L. “How (In)accurate Are Demand Forecasts in Public Works Projects? The Case of Transportation.” *Journal of the American Planning Association* 71, no. 2 (2005): 131–146. Sample of 210 projects in 14 nations: 9 out of 10 rail forecasts overestimate ridership, average overestimation 106%.
- Flyvbjerg, B., Skamris Holm, M.K., and Buhl, S.L. “Underestimating Costs in Public Works Projects: Error or Lie?” *Journal of the American Planning Association* 68, no. 3 (2002): 279–295.
- Flyvbjerg, B., Bruzelius, N., and Rothengatter, W. *Megaprojects and Risk: An Anatomy of Ambition*. Cambridge: Cambridge University Press, 2003.
- Flyvbjerg, B., and Cowi. *Procedures for Dealing with Optimism Bias in Transport Planning: Guidance Document*. UK Department for Transport, 2004. Source for reference-class forecasting methodology in rail demand estimation.

ALTO project documentation and Canadian context

- Transport Canada. High-Speed Rail Initiative briefing materials, Section 08. Government of Canada, 2025–2026. Cost estimate range \$60B–\$90B in 2024 dollars; corridor scope Toronto–Peterborough–Ottawa–Montréal–Laval–Trois-Rivières–Québec City; up to 1,000 km.
- ALTO and Cadence consortium (CDPQ Infra, AtkinsRéalis, Keolis, Systra, SNCF Voyageurs, Air Canada). Pre-Development Agreement, signed 19 March 2025; co-development phase budget \$3.9 billion over five years.
- VIA HFR / ALTO. *Business Case Summary*, 2025. Disclosed cost estimate \$60B–\$90B (2024 dollars).
- Transport Action Canada. *Commentary on the Cadence development contract and projected delivery timeline*, 2025.
- Independent Electricity System Operator (Ontario). *Industrial electricity rate publications and 18-Month Outlook reports*. Source for the \$0.105/kWh blended industrial price used in §3.

Companion notes in this series: Note 1 (Infrastructure Maintenance Costs) and Note 2 (Operating Costs). Both available from the same source as this note.