COPENHAGEN CONSENSUS CENTER

BHUTAN ACADEMY

Infrastructure: costs, benefits and value for money

Roads, bridges and mining

Roland Mathiasson

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Which investment buys the most benefit?

- Improve an existing road: follow costs and benefits from start to finish
- Maintenance investment case: compare upgrading and maintenance
- Assess Singyechu against a safe BAU and competing investments
- Apply the same CBA to mining, including health and environmental costs

Improving an unnamed road in Bhutan

An existing road: what would change?

- BAU: routine maintenance of a 10 km road
- Policy: surface, drainage and safety improvements
- 300 vehicles/day; speed 20 → 40 km/h
- Build in 2026; 15 years of benefits



Photo: Paro-Thimphu Highway · context only

Unnamed Bhutan teaching case · real 2026 Nu

Photo: Richard Mortel / Wikimedia Commons

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List every cost and benefit

- Government: construction, design, oversight and future maintenance
- Road users: time, vehicle operating costs and accident risk
- Businesses: supported net gains from genuinely additional activity
- Residents and workers: disruption, land, health and environmental effects
  - **Count changes from BAU; record material effects you cannot yet value**

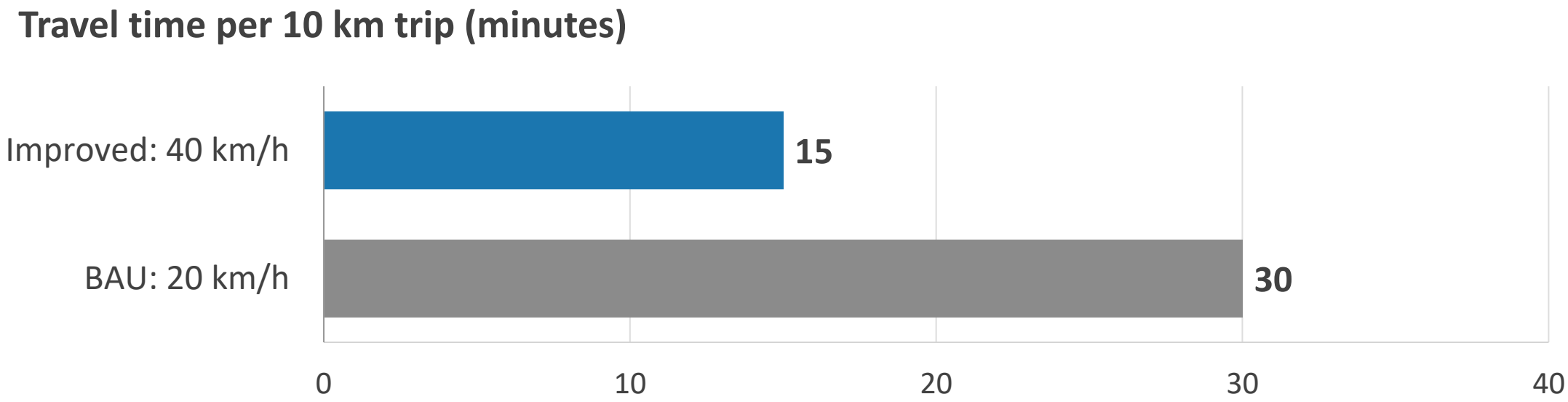
Source: Transport appraisal guidance

Costs today and costs over the road’s life

Teaching assumptions · real 2026 ngultrum

Incremental cost	Calculation / timing
Construction	10 km × Nu 6 million/km = Nu 60 million in 2026
Design and oversight	Nu 2 million in 2026
User disruption during works	Nu 1 million in 2026; separate from later time gains
Routine maintenance above BAU	10 × (Nu 100,000 − Nu 40,000) = Nu 600,000/year
Periodic maintenance	10 × Nu 500,000 = Nu 5 million in years 5, 10 and 15

Time savings: from minutes to money



10/20 = 0.50 h; 10/40 = 0.25 h; saving = 0.25 h

0.25 h × 2 occupants × Nu 100/hour = Nu 50/trip

300 × 365 × Nu 50 = Nu 5,475,000/year

Teaching assumptions: occupancy, time value, traffic and speeds

Source: Transport appraisal guidance

Bhutan needs guidance on the value of travel time

- Nu 100/hour is an illustrative derived from average income / upper-bound work hours
  - **Nu 240,000 ÷ 2,400 hours = Nu 100/hour**
    (US DOT guidance: median household income / 2,080 hours)
- Travel during paid work: use employment costs
  - **Gross hourly pay plus employer costs, adjusted for productive time during travel.**
- Commuting and leisure: value the traveller's time
  - **Provisional local-travel value: 50% × Nu 100 = Nu 50/person-hour. Test 30%–60%.**
- Recommendation: Agree on common appraisal values for travel time

Proposed teaching values in real 2026 Nu. Bhutan would need to approve its own guidance.

Sources: US DOT travel-time guidance

World Bank economic-analysis handbook

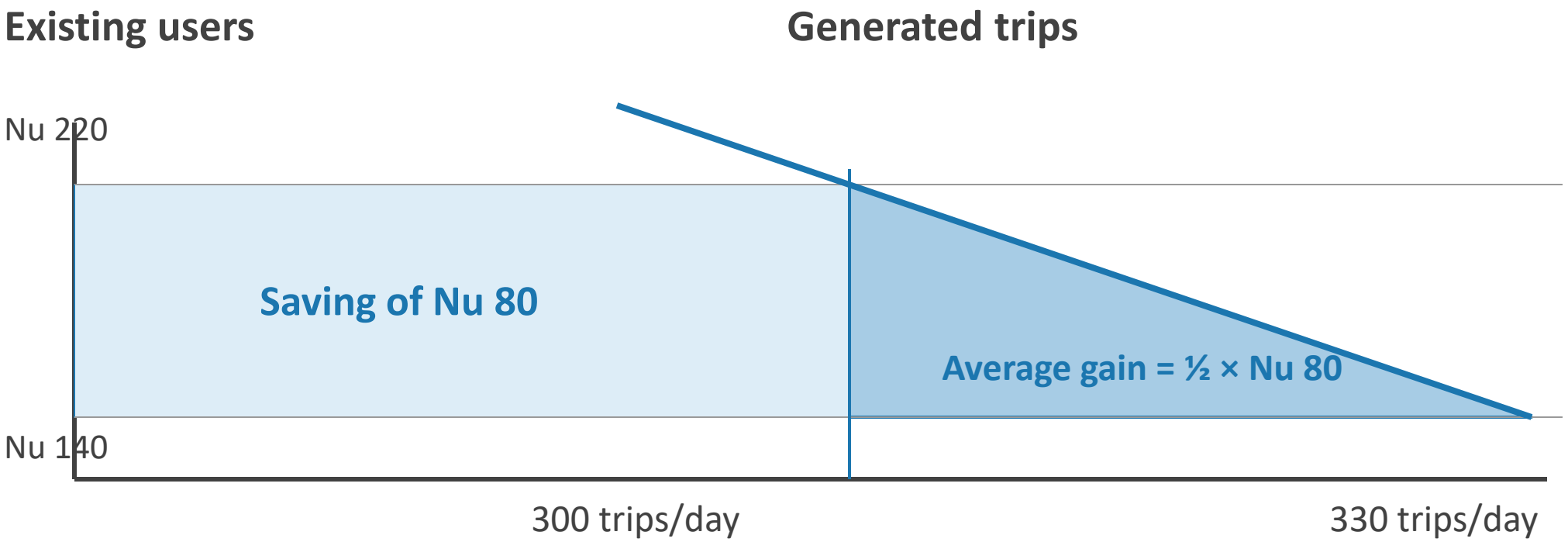
Vehicle costs: distinguish use from maintenance

Teaching assumptions · real 2026 ngultrum

Component	Per trip → annual benefit
Fuel and other operating costs	(Nu 8 − Nu 6)/km × 10 km = Nu 20/trip
Annual operating savings	300 × 365 × Nu 20 = Nu 2,190,000
Vehicle wear and maintenance	(Nu 4 − Nu 3)/km × 10 km = Nu 10/trip
Annual wear savings	300 × 365 × Nu 10 = Nu 1,095,000
Existing-user benefit before safety	Nu 50 + Nu 20 + Nu 10 = Nu 80/trip

Source: Transport appraisal guidance

Additional trips: why use the rule of half?



½ × 30 generated trips × 365 × Nu 80 = Nu 438,000/year

Elasticity 0.275 × (80/220) × 300 = 30 new trips/day (assumed)

Demand schematic; quantity axis not to scale

Source: Transport appraisal guidance

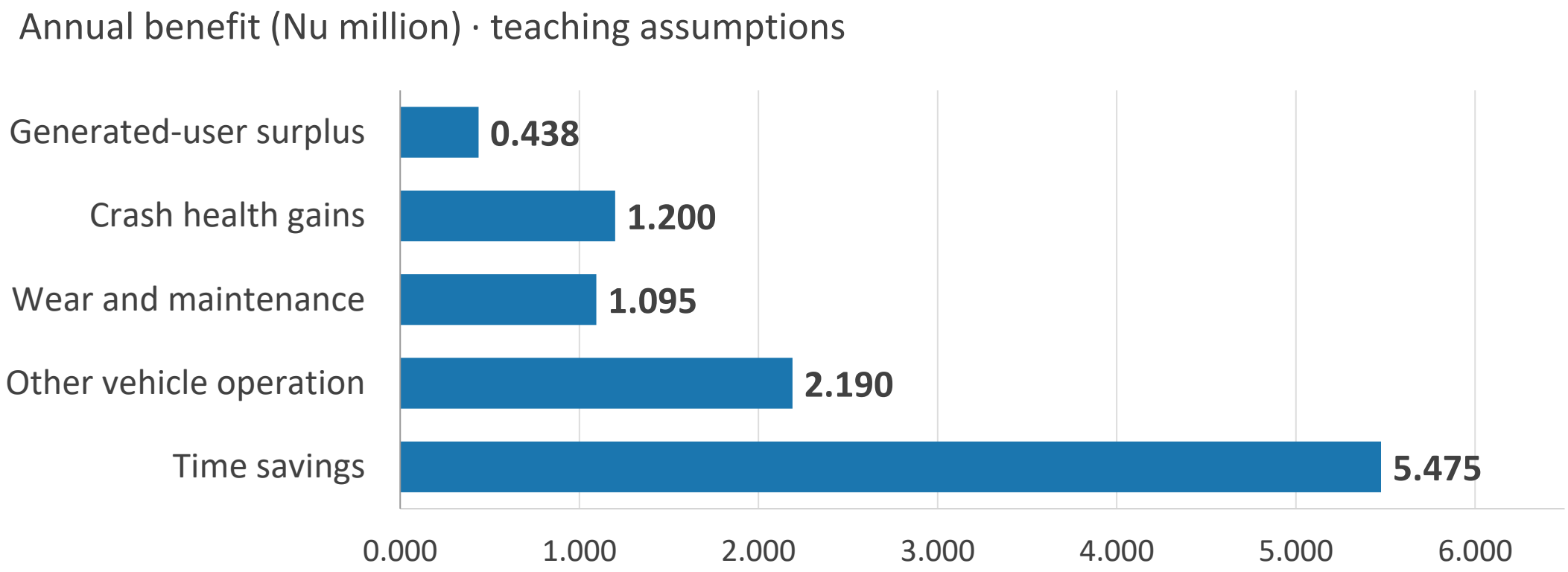
Accidents: avoided or caused by the policy

Expected annual outcome	BAU → policy → change
Deaths	0.15 → 0.12: 0.03 expected deaths avoided
Serious injuries	2.0 → 1.5: 0.5 expected injuries avoided
Healthy years per death / injury	20 years / 2 DALYs (teaching assumptions)
Health gain	0.03 × 20 + 0.5 × 2 = 1.6 DALYs/year
Monetary benefit	1.6 × Nu 750,000 = Nu 1,200,000/year

Faster travel can increase crash harm; safety design must earn its assumed effect

Source: Robinson et al. (2019)

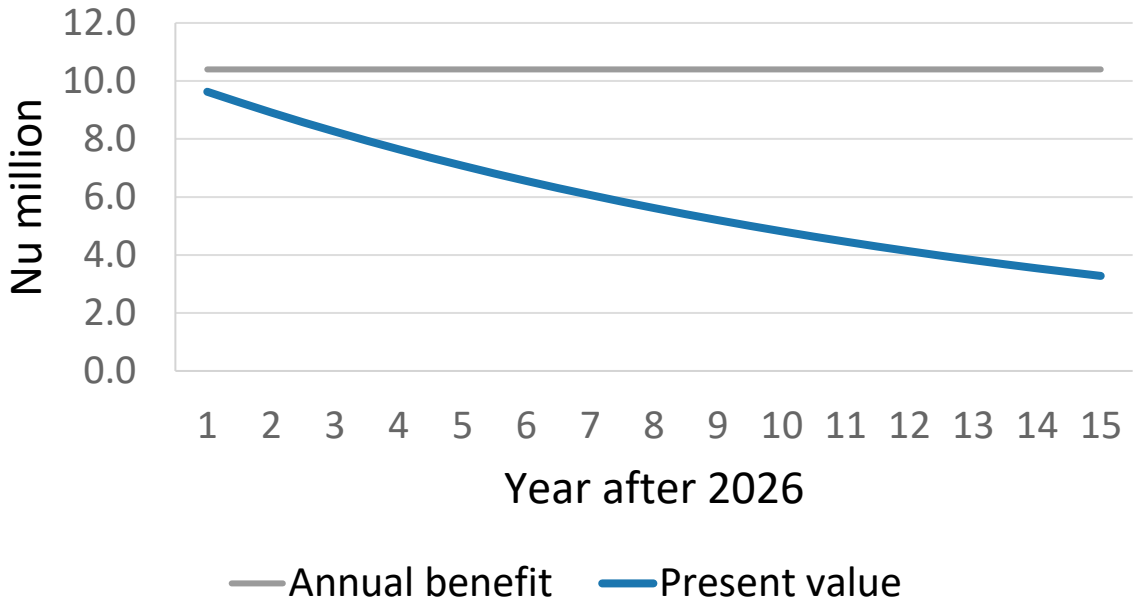
Most road benefits come from existing users



Total = Nu 10.398 million/year, 2027–2041

Later benefits have a smaller present value

- Bhutan GNI trend: 3.79% × 2 → 8%
- PV = amount in year t / 1.08^t
- Year 1: 10.398 / 1.08 = Nu 9.628m
- Year 5 cost: 5.6 / 1.08^5 = Nu 3.811m



Constant real annual benefits; only their present value declines

Source: World Bank, GNI growth

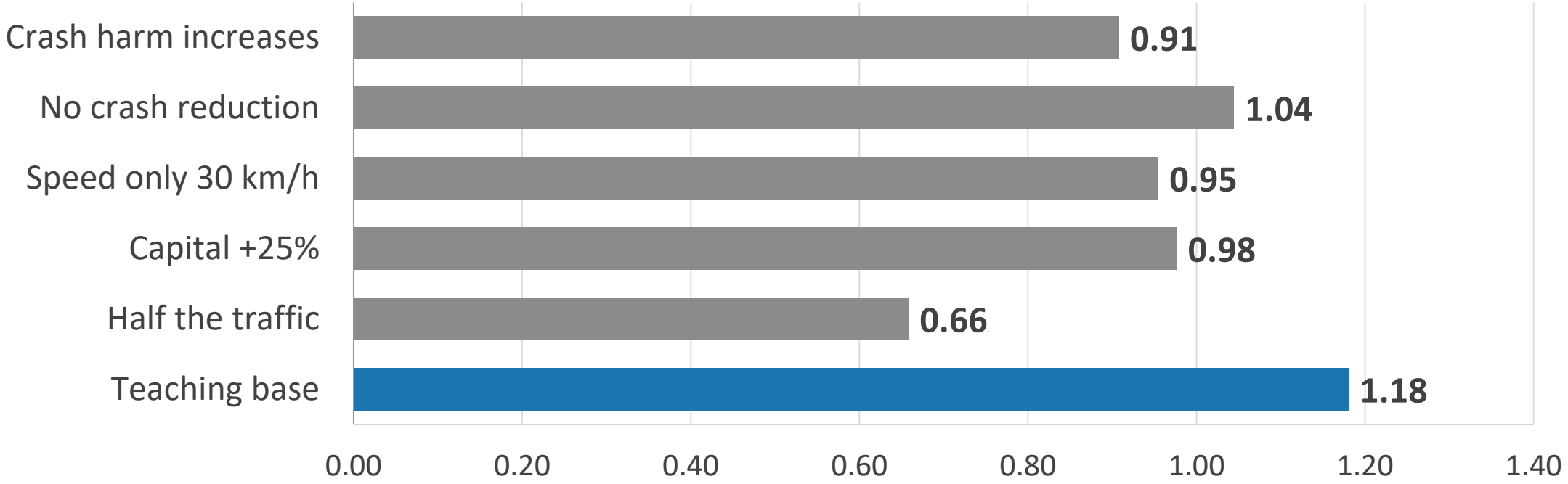
Road result: a modest illustrative return

Present value, real 2026 Nu	Result
Benefits	Nu 89.00 million
Costs	Nu 75.43 million
Net present value: benefits − costs	Nu 13.57 million
BCR: PV benefits / PV costs	89.00 / 75.43 = 1.2

Teaching result only: BCR 1.2; replace assumptions before making a decision

Small assumption changes can reverse the road result

Compare returns, uncertainty and alternative investments



One assumption changes at a time; these are teaching scenarios

Better value may come from the existing network

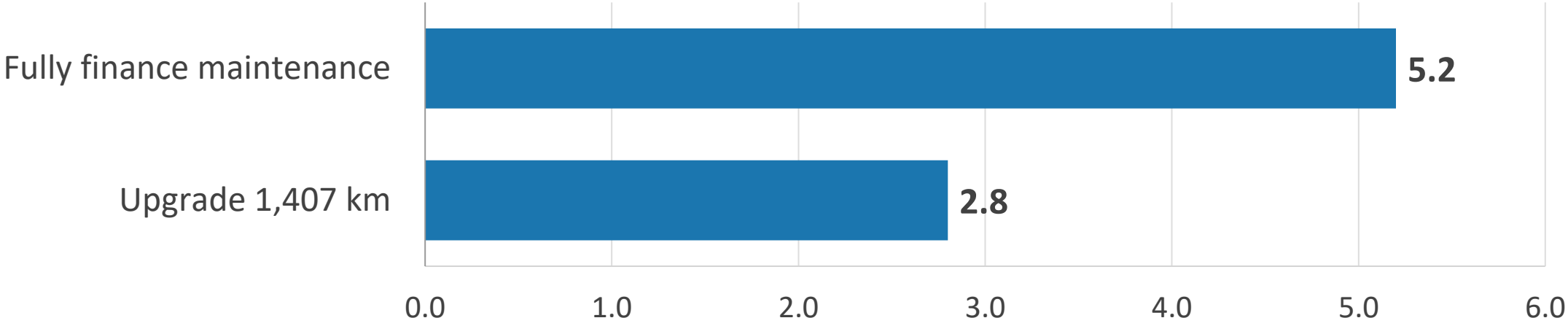
- Compare routine maintenance, rehabilitation and targeted capacity changes
- Identify the binding constraint: pavement, drainage, safety or a bottleneck
- Compare each option with the same realistic BAU
  - **A new road or bridge must deliver benefits beyond the cheaper alternatives**
- Maintenance often protects value already created; test it rather than assume it

Source: Malawi transport study

Published evidence and a Bhutan bridge

Malawi: maintenance has the higher published return

Published BCR at 8% · source-reported Malawi appraisal



Upgrading: costs MWK 277,286m; benefits MWK 764,893m

Maintenance: costs MWK 36,796m; benefits MWK 192,097m

The published results describe Malawi; apply the method to Bhutan

Source: Malawi transport study (2021)

What Malawi teaches—and what transfers

- In the published case, vehicle operating savings dominate upgrading benefits
- Maintenance avoids deterioration and later reconstruction
- The method transfers to Bhutan; the published BCR does not
  - **Bhutan needs its own traffic, engineering costs and BAU**
- Additional tourism requires a causal pathway and net benefit calculation

Source: Malawi transport study (2021)

Singyechu: define the actual decision

Supplied June 2026 appraisal	What it establishes
Existing crossing	190 ft Bailey bridge, installed October 2025
Reported concern	Overloaded industrial/mining traffic; sagging and sway
Proposed investment	Replace with a permanent 45 m, two-lane bridge
Construction estimate	Nu 86.85 million; approximately 18 months
Missing economic evidence	No quantified traffic, delay, crash benefit or BCR

Singyechu: what benefits would replacement add?

Incremental benefit pathway	Evidence needed against safe BAU
Time and reliability	Traffic, delays, closures and alternative routes
Vehicle and freight costs	Load restrictions, trip costs and usable capacity
Safety	Expected crash risk with each feasible option
Additional production	Net output gains caused by improved access
Compare the options	Replacement, maintenance or restrictions; full costs

Missing benefit estimates: compare options and identify the decisive evidence

Singyechu: preliminary judgment, below one

- Working conclusion: everything points to a BCR below 1
  - **This remains a preliminary assessment; supplied reports do not quantify a BCR**
- Test the benefits of replacement against a feasible, safe BAU
- Count only additional net mining or industrial output enabled by the bridge
- Reassess if credible traffic, closure-risk or safety benefits change the picture

Mining: production gains and external costs

Mining starts with the additional operation

- Define an expansion, improved practice or closure decision
- BAU: what would the mine produce and spend without the policy?
- Value incremental output and subtract the resources needed to produce it
- Include people affected outside the mine: air, water, land and climate
  - **Jobs, exports, royalties and tax revenue are not separate net social gains**

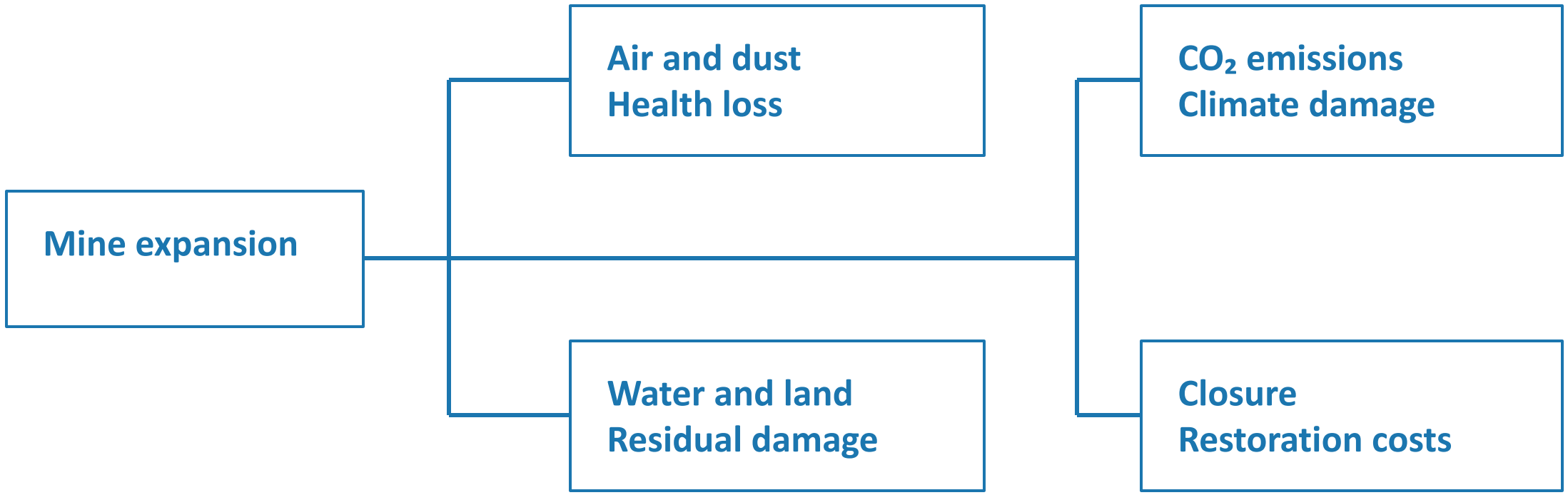
Source: IFC environmental guidance

Mine expansion: a transparent teaching scenario

Increment above no expansion	Teaching assumption
Output / price	100,000 tonnes/year × Nu 1,000/tonne = Nu 100m/year
Start and operating life	Nu 20m setup in 2026; operate 2027–2036
Extraction and transport resources	Nu 70m/year, including labour and energy
Compliance and independent oversight	Nu 2m/year + Nu 1m/year
Closure and rehabilitation	Nu 10m at end of year 10

Source: IFC environmental guidance

Mining affects people beyond the mine



Each pathway needs a physical change, a value and a timing assumption

Source: IFC environmental guidance

Air pollution: emissions are not DALYs

Health pathway	Teaching illustration
Exposure change	Model extra $PM_{2.5}$ exposure for residents and workers
Supported annual burden	4 YLL + 1 YLD = 5 DALYs/year (assumed)
Value the health loss	5 × Nu 750,000/DALY = Nu 3,750,000/year
Timing	Monetary loss in each operating year; discount to 2026
Keep distinct	No separate VSL benefit; no climate damage in these DALYs

Source: WHO air quality guidance

Source: Robinson et al. (2019)

Tol's meta-study of Social Cost of Carbon: total damage caused by emitting one additional ton

Empirical mean, 2010 US$/tonne of carbon

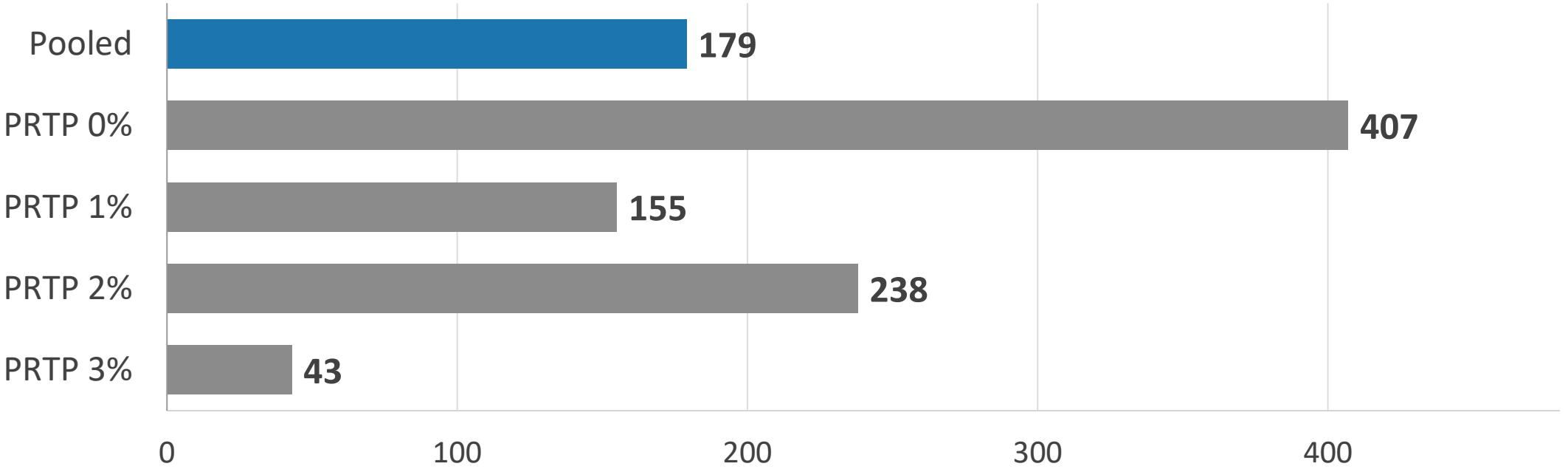


Illustration uses the pooled empirical mean: US$179/tC

PRTP = pure rate of time preference; different study subsets, not one model

Source: Tol (2023), meta-analysis

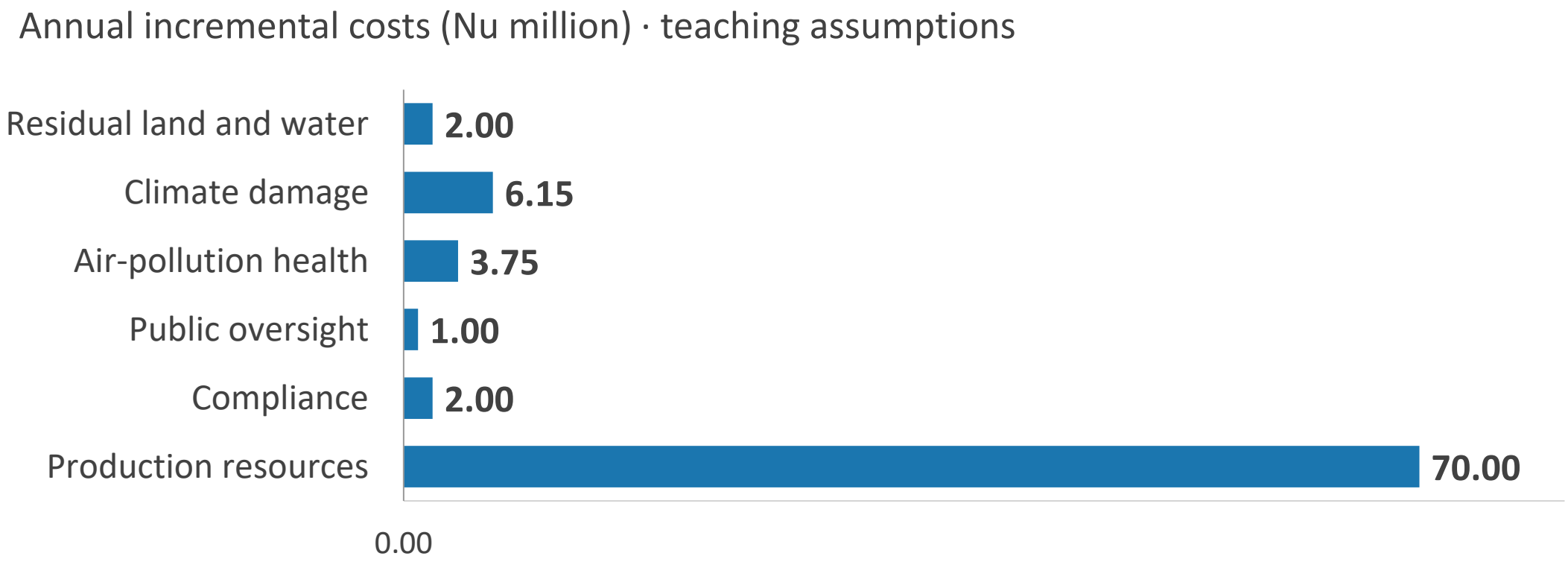
Carbon: convert the units before multiplying

Conversion step	Teaching substitution
Carbon → carbon dioxide	US$179/tC × 12/44 = US$48.82/tCO_2
2010 dollars → 2026 dollars	US$48.82 × 1.40 = US$68.35/tCO_2
Dollars → ngultrum	US$68.35 × Nu 90/US$ = Nu 6,151/tCO_2
Additional annual emissions	1,000 tCO_2/year × Nu 6,151 = Nu 6.15m/year

Inflation ×1.40 and Nu 90/US$ are assumptions; no emission-year uplift is applied

Source: Tol (2023), meta-analysis

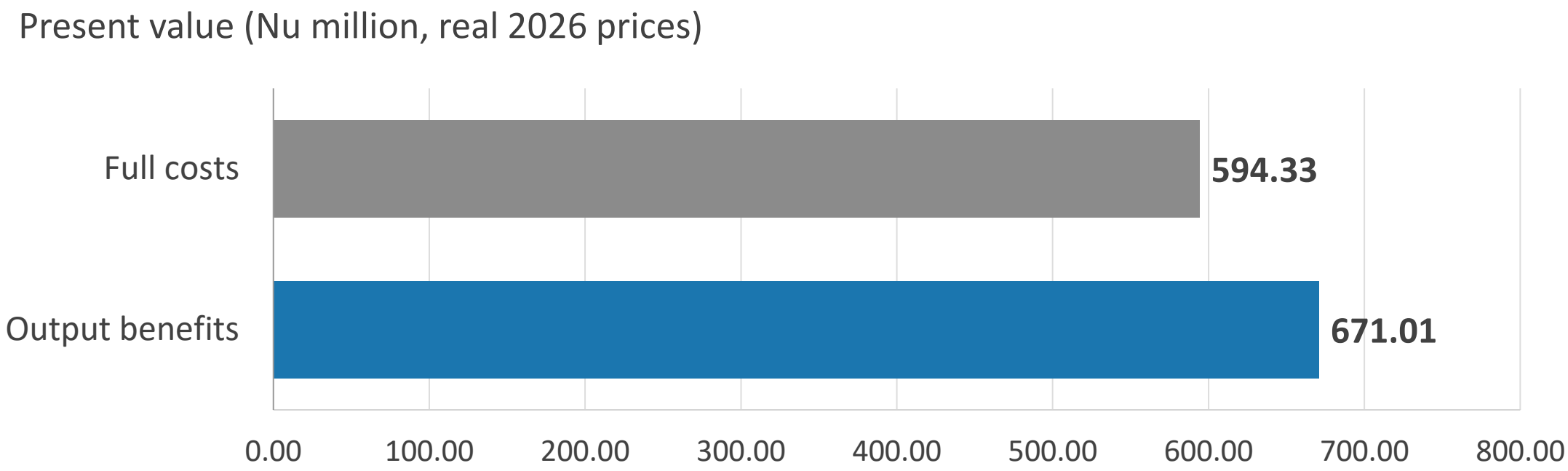
Mining: the costs beyond production



Annual output = Nu 100m; annual full costs = Nu 84.90m

Plus Nu 20m setup and Nu 10m closure in year 10

Mining: compare output with all social costs



BCR = 671.01 / 594.33 = 1.1

Teaching result; full costs include setup, closure and external damage

What would make the mine decision credible?

- Local production, resource costs and realistic commodity prices
- Exposure and health effects for workers and residents
- A funded closure plan, water treatment and long-term monitoring
- Net additional emissions
- Ownership, distribution and any public subsidy made explicit

Apply the method to a Bhutan decision

A short appraisal that can guide a decision

- State the intervention and realistic business-as-usual
- List every incremental cost and benefit, whoever experiences it
- Calculate physical changes before valuing them
- Show timing, discounting, BCR and the assumptions that change it
- Compare a new asset with maintenance and targeted improvements

Discussion: improve the road appraisal

Question	Evidence or calculation to add
Traffic and time	Count vehicles, trip purpose, occupancy and delays
Additional activity	Specify net surplus beyond already-counted transport gains
Safety	Estimate risk changes with induced traffic and higher speed
Costs	Engineering estimate; construction disruption; maintenance funding
Decision	Which cheaper alternative achieves most of the benefit?

Reference calculations

Road present values: reconstruct the sums

Term, all values in Nu million	Substitution at 8%
15-year annual-flow factor	$\Sigma\ t = 1 \ldots 15$ of $1/1.08^{t} = 8.5595$
PV benefits	$10.398 \times 8.5595 = 89.00$
PV routine maintenance	$0.600 \times 8.5595 = 5.14$
PV periodic maintenance	$5 \times (1.08^{-5} + 1.08^{-10} + 1.08^{-15}) = 7.29$
PV total costs	$63.00 + 5.14 + 7.29 = 75.43$

Teaching case; constant annual streams in real 2026 Nu

Mine present values: reconstruct the sums

Term, all values in Nu million	Substitution at 8%
10-year annual-flow factor	$\Sigma\ t = 1\ldots10$ of $1/1.08^{t} = 6.7101$
PV output benefits	$100 \times 6.7101 = 671.01$
PV annual resource and external costs	$84.9011 \times 6.7101 = 569.70$
PV final closure	$10 / 1.08^{10} = 4.63$
PV total costs	20.00 setup + 569.70 + 4.63 = 594.33

Teaching case; all benefits and costs incremental to no expansion

Health value: the same approximation as Health

Robinson transfer step	Input / result
2015 reference and Bhutan PPP income	US$57,900; Bhutan US$7,520; VSL/income multiple 160
Base transferred VSL/income multiple	160 × (7,520/57,900)^0.5 = 57.66
Real per-capita growth to 2026	1.3735; multiple grows by 1.3735^0.5 → 67.58
2026 local income approximation	US$4,521.3 × Nu 90 = Nu 406,917
VSL and healthy-year value	Nu 27.50m / (0.5 × 73.8 years) = Nu 745,228

Round to Nu 750,000/DALY; provisional 2026 transfer, not an observed Bhutan value

Source: Robinson et al. (2019)

Source: Bhutan budget, projections

Public sources for reading and reuse

- Transport appraisal: user benefits and the rule of half
- Malawi: published upgrading and maintenance appraisal
- Robinson et al. (2019): benefit-cost reference guidelines
- Tol (2023): social cost of carbon meta-analysis
- WHO / IFC: air quality and environmental safeguards

Transport appraisal guidance

Robinson et al. (2019)

WHO air quality guidance

Malawi technical report

Tol (2023)

IFC environmental guidance