

Annex 3

Economic and Financial Analysis

Urban Transport and Electric Bus Investment Project

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2. Economic Analysis – Consolidated Results

Economic and Financial Analysis of Transportation Investments

1. Study Area and Project Stages

The economic analysis evaluates impacts at the level of the entire urban transport system because the benefits of BRT investments emerge through system-wide modal shift rather than from individual components in isolation. Bhutan's 13th Five-Year Plan (FYP) includes budget for 45 electric buses for other urban centers and inter-urban services; the process of acquiring these buses is underway, but 33 of them may potentially be redirected to Thimphu – primarily to replace retiring diesel buses – given the urgent needs of its fleet. For the purposes of this EFA, it is therefore conservatively assumed that the baseline fleet consists of a mix of diesel and electric buses; given projected increases in congestion, this partial fleet transition on its own will not attract modal shift. By financing the charging infrastructure, depot upgrades, and operational learning, together with 50 additional e-buses to reach operational scale, the GCF contribution functions as the catalytic investment that brings the system to critical mass, enabling frequent service on the bus priority system, de-risking the full transition to electric public transport, and crowding in the domestic and commercial resources needed to further expand the fleet. This foundational investment makes subsequent fleet expansion to around 120 buses feasible using domestic or commercial resources, but the resulting benefits remain causally linked to the initial GCF support. As fast, frequent and reliable service attracts ridership, farebox revenues and operating cash flows improve, strengthening the public transport operator's capacity to reinvest and scale up the fleet. Without the GCF-supported buses and infrastructure, the modal shift and the associated economic, climate, and safety benefits would not materialize at scale. Additionally, the lifetime of electric buses is assumed to be 12 years. The GCF-funded 50 electric buses will need to be replaced once they reach the end of their lifetime. To ensure the sustainability and true paradigm shift potential of the project, the impact of the full fleet of buses should be considered rather than considering a piecemeal approach to the economic analysis.

Figure 1: Stages of modal shift enabled by GCF



In line with this system-wide perspective, the financial analysis also considers the gradual expansion of the bus fleet beyond the units directly financed by GCF. While GCF support is appropriately focused on the initial fleet expansion with electric buses and the associated enabling infrastructure, it would be analytically incomplete to assess financial performance under the assumption that system scale, ridership, and revenues remain fixed at the level of the initial investment. The financial model therefore reflects how the GCF-supported fleet contributes to improved service reliability, higher ridership, and stronger farebox and operating cash flows over time, which in turn enhances the public transport operator's capacity to reinvest and support subsequent fleet expansion using domestic budgetary resources or commercial financing. This approach ensures coherence between the economic and financial analyses and allows the project's long-term ridership, revenue, and sustainability dynamics rooted in the initial GCF intervention to be appropriately captured.

2. Financial Analysis of Transport Investments

2.1 Operating Performance of BRT Investments

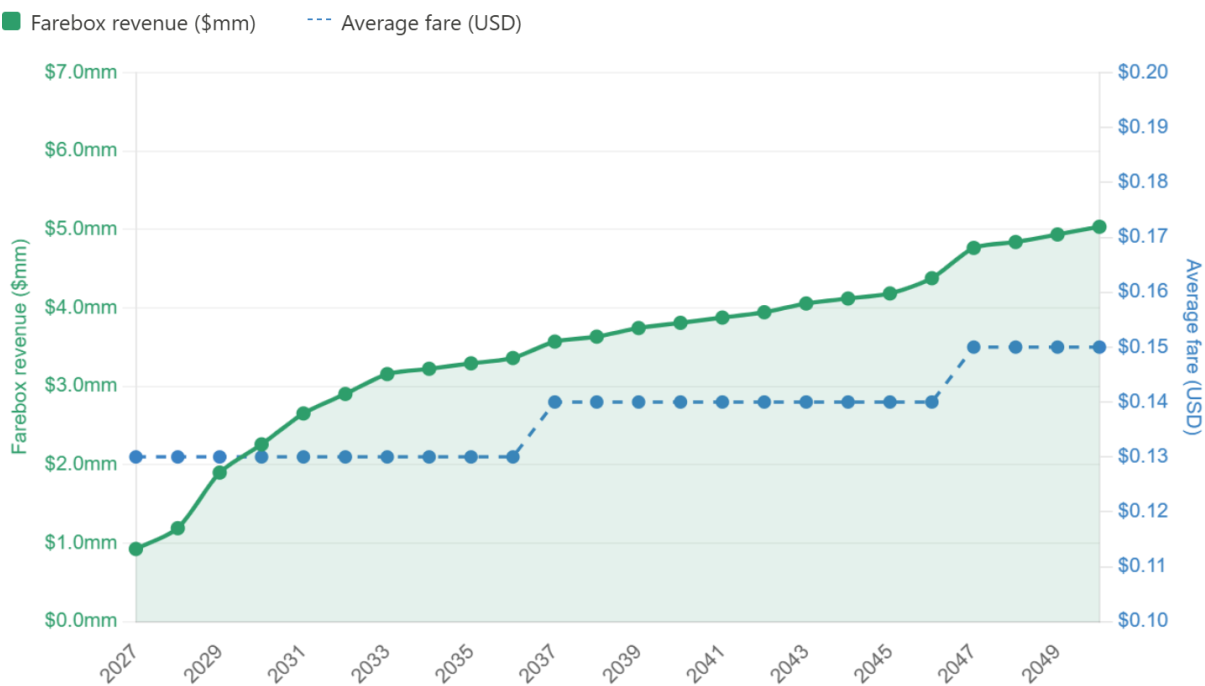
2.11 Farebox Revenues

Farebox revenues constitute the principal operating inflow of the transport investments and are closely linked to ridership levels, service quality, and network coverage in Thimphu. The average fare trajectory assumed in this analysis is grounded in underlying transportation surveys conducted in Thimphu and will continue to be assessed, monitored, and updated as the project progresses through its implementation phases. The average fare is held flat at \$0.13 per passenger through 2036, a deliberate policy choice to lower barriers to public transit use and encourage modal shift away from private vehicles during the critical fleet deployment and network establishment period. The fare then increases modestly to \$0.14 from 2037, and \$0.15 from 2047, reflecting the improved service quality and network coverage available to passengers as the fleet expands, rather than a cost-recovery imperative.

Despite this deliberately conservative fare trajectory, total farebox revenues are projected to grow substantially, from \$0.93 million in 2027 to \$5.03 million by 2050, representing a sixfold increase over the project horizon. This growth is driven primarily by ridership growth due to the expanded fleet and improved service, rather than fare increases, underscoring the project's commercial logic: revenue sustainability is achieved through network scale and modal shift, not through pricing pressure on passengers. The revenue trajectory reflects a period of accelerated growth in the early operational years, with revenues rising from \$1.19 million in 2028 to \$3.16 million by 2033 as the initial fleet reaches full operational capacity, before continuing to grow more steadily through the expansion phase, reaching \$3.57 million by 2037 and \$4.76 million by 2047. This approach recognizes that fare adjustments in Thimphu must remain sensitive to affordability constraints, given the city's relatively low base fare levels and the importance of maintaining transit as an accessible option for all income groups. The assumed trajectory will continue to be evaluated

throughout project implementation, with adjustments made in response to observed ridership patterns, passenger feedback, and the overall financial performance of City Bus Services.

Figure 2: Average fare and farebox revenue trajectory



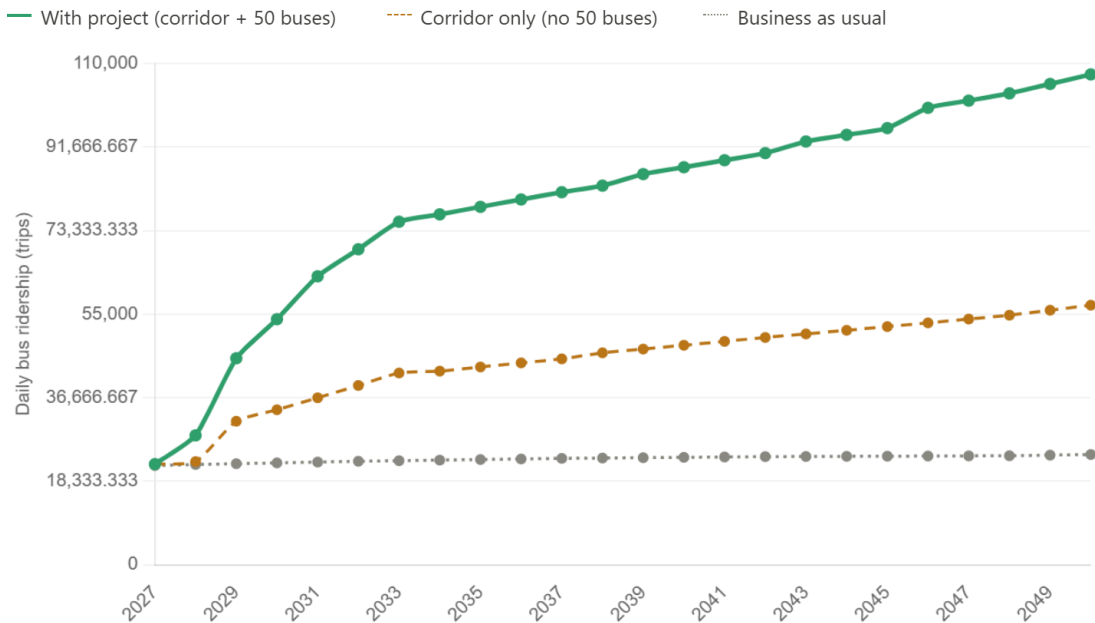
Underlying assumptions on ridership growth and bus trips

Bus ridership in Thimphu is projected to grow significantly under the with-project scenario relative to business as usual. In 2027, both scenarios begin at 22,096 daily trips, reflecting the approximate baseline ridership of the existing network (based on 20,000 trips reported by CBS in 2023). Under BAU conditions, ridership grows slower than the rate of population growth, as traffic congestion and lack of fleet expansion cause deteriorating service, reaching approximately 24,200 trips by 2048. With the project, ridership increases slightly in 2028 (with slightly added capacity from new e-buses in the fleet), before diverging sharply from 2029 as the BPS becomes operational, the fleet continues to expand, and complementary urban mobility policies take effect. By 2033, daily trips reach 75,261, and continue rising, to 103,414 by 2048.

The breakdown of this growth is instructive. Of the 81,318 additional trips generated by 2048 relative to 2027, only 13 percent are attributable to population growth alone. The remaining 87 percent, approximately 70,697 trips, represent induced demand driven by improved service quality, higher frequency, and supporting policies including parking management and expanded bus lane infrastructure. This distinction matters for the financial and economic case: the project is not simply capturing a growing population, it is actively pulling trips away from private vehicles and generating demand that would not otherwise exist.

Bus mode share rises from 5.8 percent under BAU to 25 percent with the project by 2048, a shift of nearly 20 percentage points. This is a substantial modal shift for a city of Thimphu's size and reflects the combined effect of more attractive, reliable, and frequent service alongside measures that increase the relative cost and inconvenience of private vehicle use. The ridership projections will continue to be monitored and updated as the project is implemented, drawing on actual observed data to refine the underlying demand assumptions.

Figure 3: Comparison of bus ridership with and without project

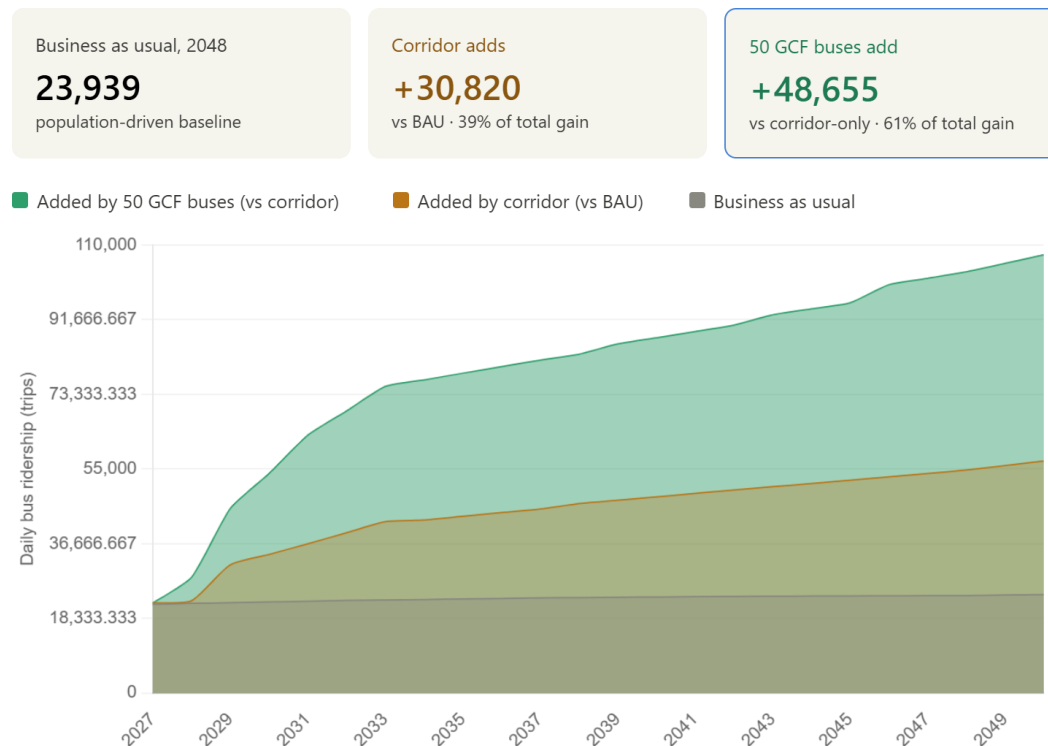


The decomposition shows that the corridor and the 50 buses are complementary, and that both are needed to reach scale. The bus priority corridor establishes the conditions for high-quality service dedicated lanes, priority at intersections, and supporting parking and demand-management policy lifting daily ridership about 30,820 trips above business-as-usual by 2048. But the corridor alone plateaus: without sufficient vehicles it cannot deliver the frequency and reliability that draw travelers out of private cars in large numbers. The 50 GCF-financed buses supply that capacity, adding a further 48,655 daily trips on top of the corridor — 61 percent of the total gain over BAU and the larger single driver of modal shift. Together they push ridership across the threshold at which the frequency–ridership virtuous cycle becomes self-sustaining; with the corridor but without the buses, the system settles at a sub-critical level that captures only a fraction of the achievable shift.

Note that the “corridor-only” projection represents a conservative, “best case” scenario for the BPS without the GCF-financed fleet expansion, assuming that modal shift impacts are sustained despite low frequency of service and increasing overcrowding of the limited fleet. In practice, early

modal shift gains are likely to erode over time as users become dissatisfied, but no quantitative global evidence was available to model this effect.

Figure 4 Decomposition of Thimphu bus ridership growth (2027–2050), showing the 50 GCF buses as the largest single contributor to modal shift — 61% of the gain over business-as-usual by 2048.



2.12 Advertising and ancillary revenues

In addition to fares, the transport system generates supplementary operating inflows from advertising and other ancillary commercial activities. These revenues include on-bus and at-station advertising, branding opportunities, and limited commercial use of terminals and depots where applicable. While modest in comparison to farebox revenues, advertising income provides a stable and diversified revenue stream that grows with fleet size, route coverage, and passenger exposure. As the electric bus system expands and ridership increases, advertising revenues scale proportionally, improving overall operating cash flows. The financial analysis incorporates these revenues as a 5 percent of farebox income, reflecting conservative assumptions drawn from comparable urban bus systems, and recognizes their role in supporting operating sustainability without increasing fares.¹

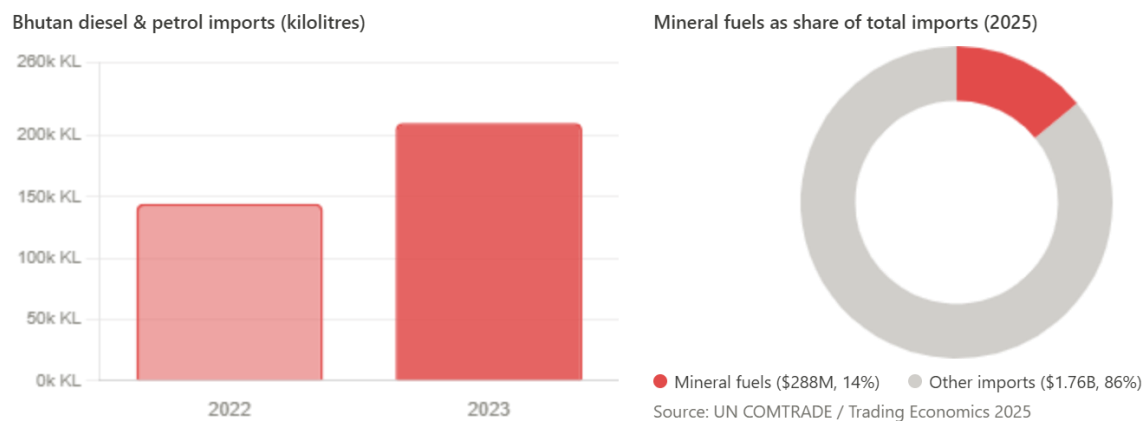
¹ World Bank (2015). *Boosting Mass Transit through Entrepreneurship: Going Beyond Subsidies*. Transport & ICT Note.

2.13 Operating Costs

The operating cost structure of the BRT system reflects well-documented differences between electric and diesel bus technologies. Electric buses benefit from substantially lower energy costs compared to diesel buses due to higher drivetrain efficiency, as electric motors convert a significantly larger share of input energy into traction than internal combustion engines. In addition, Bhutan's electricity tariffs are relatively low and stable given the country's predominantly hydropower-based generation mix, further reducing operating energy costs. Based on observed performance in comparable electric bus systems and conservative benchmarking of energy consumption and unit energy prices, this analysis assumes electricity costs are equivalent to approximately 40 percent of diesel fuel costs.

Beyond direct cost savings, the shift from diesel to electric buses carries significant macroeconomic implications for Bhutan (see figure 5)

Figure 5: Bhutan recent oil import trajectory



Source: Bhutan Environmental Accounts Statistics 2024

As a landlocked country with no domestic petroleum production, Bhutan is entirely dependent on imported fossil fuels for its transport sector, with fuel prices directly linked to international market movements over which the country has no influence. Mineral fuels and oils represent the second largest import category for the country, amounting to \$288 million in 2025 out of total imports of approximately \$2.05 billion, equivalent to around 14 percent of all imports by value. The total volume of diesel and petrol imported rose sharply from 144,340 kilolitres in 2022 to 210,147 kilolitres in 2023, a 46 percent increase in a single year, and the transport sector alone emitted approximately 130 million kilogrammes of carbon dioxide in 2023. This import dependence creates a structural vulnerability in Bhutan's balance of payments, as expenditure on petroleum products represents a recurring and growing outflow of foreign exchange with no domestic substitution available under the current energy system.

Moreover, electric buses have fewer moving parts and simpler drivetrains, which reduces routine maintenance requirements, limits mechanical wear, and lowers servicing frequency relative to

diesel buses. These factors translate into lower maintenance costs per vehicle-kilometer over the operating life of the fleet, partially offsetting the higher upfront capital costs associated with electric bus procurement.

For buses alone, the project provides a relatively small operating cost and fuel savings benefit, by enabling timely retirement of diesel buses (in BAU, they would likely continue running past end-of-life.) However, the large modal shift effected by the expanded e-bus fleet running faster and more frequent service on the bus priority system leads to substantial fuel savings by reducing the use of diesel- and petrol-powered private cars. By substituting diesel and petrol consumption with domestically generated hydropower electricity, the project directly reduces Bhutan's foreign exchange outflows and its exposure to international fuel price volatility. Each e-bus operating over a 12-year service life avoids a material volume of diesel imports that would otherwise need to be procured and paid for in foreign currency. At the fleet scale envisaged under this project, the cumulative import substitution effect is meaningful in the context of Bhutan's economy and directly supports the government's stated objectives of reducing fossil fuel dependence, maintaining carbon neutrality, and strengthening energy security. The government's own projections note that reliance on fossil fuels will continue until electric vehicles become more affordable — this project is a direct intervention to accelerate that transition in the public transport sector, where the economics are most tractable and the scale effect most visible.

Labor and other operating costs.

Labor costs, primarily driver salaries and supporting operational staff, represent a significant and largely technology-neutral component of operating expenditures. Driver staffing requirements are assumed to be similar for electric and diesel buses and are driven by service frequency, route coverage, and operating hours rather than vehicle technology. Driver salaries are therefore modeled consistently across fleet types and grow in line with wage inflation assumptions. Other operating costs, including depot operations, administrative overheads, and minor ancillary expenses, are assumed to scale with system size and activity levels rather than with fuel type.

Other maintenance and system level costs.

Additional operating and maintenance costs associated with infrastructure, depots, charging facilities, and ancillary assets are conservatively estimated as a fixed share of capital expenditure. In line with standard practice for urban transport projects, these system-level maintenance costs are assumed at 2.5 percent of the relevant capital stock per year. This approach captures routine upkeep, inspections, and minor repairs while avoiding undue complexity, and it provides a transparent and prudent basis for estimating long-term operating requirements of the BRT system as it expands.

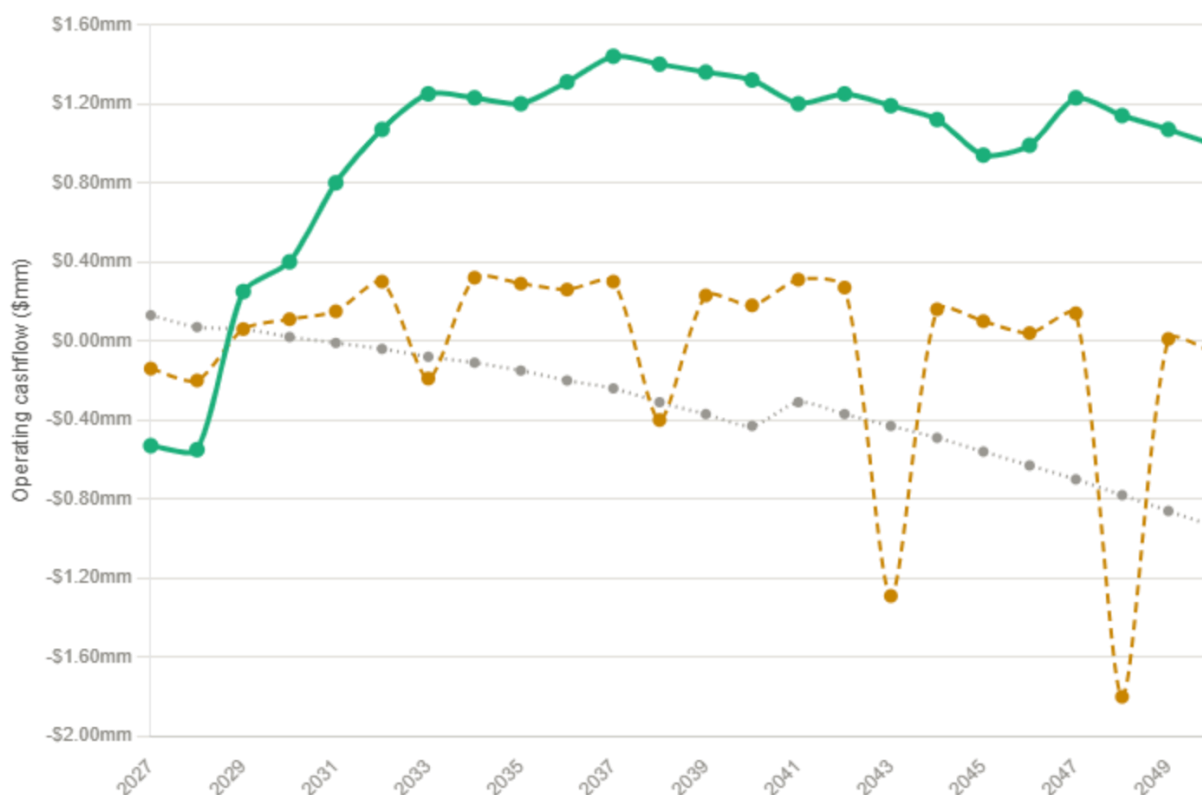
2.14 Operating Performance Summary

The operating cashflow projections demonstrate that financial sustainability is achievable only under the full project. In the business-as-usual scenario, City Bus Services moves from a modest surplus into progressively larger structural deficits, slipping into deficit by 2031 and reaching approximately -\$0.94 million by 2050 as operating costs outpace a largely static farebox.

The corridor without the 50 buses follows a different pattern than a simple weaker-but-similar decline: for most of the appraisal period it hovers close to breakeven, posting modest surpluses in roughly seventeen of twenty-four years, but it is acutely exposed to fleet-renewal cost events, swinging to severe deficits of roughly $-\$1.29$ million in 2043 and $-\$1.80$ million in 2048. These shocks are not absorbed by the underlying operating base, and the scenario closes the appraisal period essentially at breakeven, at about $-\$0.06$ million in 2050. In other words, the corridor alone is not structurally loss-making in the way business-as-usual is, but it lacks the revenue cushion to withstand large, lumpy renewal costs without lurching into deep deficit.

The full project is the only scenario that achieves durable financial viability. After a brief ramp-up dip in its first two years ($-\$0.53$ million in 2027 and $-\$0.55$ million in 2028), operating cashflow turns positive in 2029 and climbs above $\$1$ million by the early 2030s — reaching $\$1.07$ million in 2032 — before peaking near $\$1.44$ million in 2037. It remains positive every year thereafter, absorbing the same renewal-year cost shocks that push the corridor-only scenario into deep deficit: cashflow stays at $\$1.19$ million in 2043 and $\$1.14$ million in 2048, the very years in which the corridor-only scenario falls to its lowest points. This difference is driven by the incremental ridership and farebox revenue generated by the 50 buses, which transform City Bus Services from an operator facing structural decline (under business-as-usual) or acute shock exposure (under corridor-only) into one with the financial depth to remain consistently cashflow-positive — establishing the operating surplus needed to fund fleet replacement and expansion without recurring fiscal support.

.Figure 6 : Operating performance of CBS after transition to e-bus & bus priority system



Values below the breakeven line are operating deficits. \$mm.

■ With project (corridor + 50 buses) - - - Corridor only (no 50 buses) Business as usual

2.2 Capital Flows

2.21 Purchase of E-buses

The capital cost assumptions for electric buses and batteries have been derived from comparable World Bank transport projects in the South and Southeast Asia region. Electric bus unit costs are assumed to decline from \$170,000 in 2027 to \$70,000 by 2033, achieving price parity with diesel buses at \$30,000 by 2035, consistent with Bloomberg NEF projections for urban electric bus markets.² The ~USD 80,000 unit price achieved on the initial Indian procurement reflects a specific, concessionally-priced bilateral arrangement on an essentially bus-only basis; it sits at roughly half the prevailing Indian list price for this vehicle class and is not a prudent planning assumption for a future, internationally-tendered GCF batch procured under competitive rules. Regional benchmarking supports the budgeted unit cost of US\$170,000 per bus as a reasonable working assumption. For e-buses, the midpoint between competitively-available entry-level 9-meter models in the Indian market (up to US\$132,000) and an established mid-tier model, the JBM Ecolife

² Bloomberg NEF (2018). *Electric Buses in Cities: Driving Towards Cleaner Air and Lower CO₂*. Bloomberg New Energy Finance, prepared for C40 Cities.

Electric 9m (US\$194,300), is roughly US\$163,000 — closely matching the US\$170,000 budgeted, with a modest premium added due to customization requirements (see Annex 2: Feasibility Study) and the absence of the capital subsidies reflected in domestic Indian market pricing. Budgeting at US\$ 170,000 therefore anchors the fleet line to replicable, openly-published market pricing rather than a one-off concessional rate, reducing the risk of an under-funded procurement while still sitting at the low end of the global cost range for a new electric bus. “E-Bus Benchmarks” in the EFA excel sheet provides further detail.

2.22 Purchase of Charging Infrastructure

Bus chargers are procured progressively alongside the electric fleet, with each charger estimated to service approximately four buses, ensuring that charging infrastructure scales in line with operational demand. The unit cost of each charger is assumed at \$20,000, with further detail on market price benchmarking provided in the EFA excel (“Charger Benchmarks”). The procurement schedule results in some years where servicing capacity modestly exceeds the active fleet size, reflecting the practical reality that charger acquisitions are made in discrete batches rather than perfectly matched to annual bus additions — this small buffer of unused capacity ensures operational resilience and avoids bottlenecks during peak charging periods.

2.23 Other Ancillary Infrastructure

Beyond the bus fleet and charging equipment, the project includes a range of ancillary infrastructure investments necessary to support safe and efficient BRT operations. Bus terminals and charging infrastructure are provided at key nodes along the corridor, with costs of \$3.67 million in the early years of the project. Bus priority lanes, shelters, and bridges represent the most significant ancillary investment, with costs peaking at \$7.15 million in 2028 as the physical corridor infrastructure is established, reflecting the construction of dedicated lanes, passenger shelters, and structures required to grade-separate the BRT at key intersections. Pedestrian crossings are also included to ensure safe access to bus stops, with an upfront investment of \$1.32 million each in 2027 and 2028. Full details of all ancillary infrastructure cost assumptions are provided in Annex 4.

2.24 MIS/ITS Systems

The project includes investment in Management Information Systems and Intelligent Transport Systems to support efficient and reliable bus operations across the corridor. These systems cover real-time fleet tracking, passenger information, scheduling and dispatch management, and fare collection infrastructure, all of which are essential to delivering a high-quality BRT service that can attract and retain ridership. The MIS and ITS systems are procured in three tranches of \$0.38 million and then \$1.7 million each, reflecting a phased implementation approach that allows the operational systems to be deployed and tested as the fleet and corridor infrastructure come online. Full details of the cost assumptions and system specifications are provided in Annex 4.

2.25 Pedestrianization of Norzin Lam

Capital investment in the pedestrian and corridor environment encompasses the pedestrianization of Norzin Lam, improvements to connecting building alleys and footpaths, and upgraded sidewalks along the bus priority corridor, all designed to improve pedestrian safety, accessibility, and first- and last-mile connectivity to public transport. Roadside drainage is upgraded and linked to Sustainable Urban Drainage Systems to manage stormwater runoff and reduce pluvial flood risk along the corridor, while continuous cable ducts installed beneath sidewalks provide the backbone for real-time passenger information displays and stop lighting. A traffic circulation and management plan for central Thimphu is also included, prioritizing pedestrians and public transport while maintaining emergency and delivery access. All works are constructed to climate-resilient design standards. Full details of the capital cost assumptions for these investments are provided in Annex 4.

2.3 Financing Flows and GCF Additionality

2.31 Financing Scenarios

The analysis is structured around two core scenarios. The without-project scenario assumes a continuation of business-as-usual urban mobility: the existing bus operation, including the 33 electric buses procured by the Royal Government of Bhutan, without the dedicated bus priority corridor, supporting demand-management policies, or the fleet expansion required to drive system-wide modal shift. It serves as the counterfactual baseline against which project benefits are measured. The with-project scenario adds the GCF-financed buses together with the BRT corridor and complementary infrastructure and policies, reaching the service frequency and network quality needed to induce modal shift away from private vehicles at scale and enable further expansion in the future.

Within the with-project scenario, two financing structures are compared. The GCF financing scenario blends grant and concessional loan funding: the loan component for buses and chargers is supplemented by IDA financing at 2% interest, while public-goods infrastructure such as bus lanes and pedestrian works is funded through IDA and GCF grants. The no-GCF scenario replaces the GCF loan component for buses and chargers with a commercial lender at 13.5% interest, no grace period, and a 7-year tenor, while the IDA component and the public-goods grant financing remain unchanged. This comparison isolates the financial value of GCF concessionality in making the electric bus transition commercially viable for the City Bus Services of Bhutan.

2.32 Comparison of Scenarios

With and Without Project Scenario

The financial comparison makes a clear case for the project, and the three-scenario structure shows precisely where its value lies.

Under the without-project (business-as-usual) counterfactual – the existing service, including the 33 electric buses already in service, but without the bus priority corridor, complementary demand-management policies, or fleet expansion – City Bus Services faces a structurally deteriorating operating position. From a small surplus of \$0.13 million in 2027, the service slides into persistent

and deepening deficit as operating and maintenance costs outpace farebox growth and bus mode share erodes toward private vehicles, reaching an annual operating loss of \$0.94 million by 2050. With a low base fare and affordability constraints, there is limited room to recover rising costs through fare increases alone.

The full with-project scenario, including the bus priority corridor together with the 50 GCF-financed electric buses, reverses this trajectory. After a brief period of negative operating cashflow in 2027 and 2028 while the fleet is deployed and ridership ramps up, the service returns to positive operating cashflow in 2029 and sustains it for the remainder of the analysis period. Operating cashflow rises above \$1.0 million by 2033 as the fleet reaches operational capacity, peaks at approximately \$1.44 million in 2037, and remains positive every year thereafter, easing to \$0.99 million by 2050 as costs escalate ahead of the first fleet-replacement cycle. This reflects the lower energy and maintenance costs of electric technology combined with sustained ridership growth driven by improved service quality and supporting modal-shift policies. By the final year, the operating cashflow differential between the full project and business-as-usual reaches \$1.93 million the compounding annual cost of inaction.

The intermediate scenario (the Bus Priority corridor but without the 50 buses) confirms that this turnaround depends on the fleet, not the corridor alone. On its own, the corridor never establishes a durable surplus: operating cashflow sits at or below breakeven in most years and is driven into severe deficits in fleet-renewal years, reaching roughly \$1.29 million in 2043 and –\$1.80 million in 2048 before closing at –\$0.06 million in 2050. Only the full project, with the additional capacity and ridership the 50 buses provide, lifts City Bus Services into a financially self-sustaining position. The GCF-financed buses are therefore the decisive element that converts a fragile, deficit-prone corridor into a viable operation.

Beyond the operating financials, the project delivers a substantially lower-emission transport pathway, leveraging Bhutan's hydropower grid, and strengthens climate resilience by reducing reliance on fossil-fuel imports and integrating sustainable infrastructure along the corridor. It therefore offers a financially sustainable, low-emission, and climate-resilient solution that neither the business-as-usual nor the corridor-only scenario can replicate.

The Case for GCF Additionality

Debt Sustainability Risks

Bhutan carries one of the heaviest public-debt burdens among small developing economies. Public and publicly guaranteed (PPG) debt stood at roughly 118% of GDP at the end of FY2024/25, external debt accounts for about 91% of the total, and hydropower loans make up roughly 55% of the external stock.³ The debt is also concentrated by lender and currency: per the Ministry of Finance, hydropower is 60.9% of external debt (56.2% of GDP), Indian-rupee obligations are 65.6% of

³ World Bank & IMF, Bhutan: Joint Bank-Fund Debt Sustainability Analysis, December 2025 (FY2024/25): public & publicly guaranteed debt 118% of GDP; external debt 91% of total; hydropower 55% of external debt. documents1.worldbank.org/curated/en/099031026130038356

external debt, and convertible-currency debt is only about US\$1.12 billion, overwhelmingly concessional, sourced from the World Bank, ADB and JICA. Non-hydro commercial rupee borrowing is just 1.2% of the external stock. The sovereign is unrated by the major international agencies and has no track record of market issuance.

Feasibility of commercial lending

For a project such as the BRT, commercial debt is not simply a more expensive version of concessional debt; it is also a structurally different and far riskier instrument. Three features make it inappropriate for Bhutan's circumstances:

1. **Currency mismatch.** Bhutan's debt is already about two-thirds rupee-denominated and its FX buffers are thin. Commercial debt, whether hard-currency or rupee, adds service obligations that must be met from ngultrum farebox receipts that earn no foreign exchange. With reserves below adequacy and a current account deficit near 19% of GDP (Section 2), the economy has little capacity to absorb new, non-export-generating external obligations.
2. **Punitive pricing.** An unrated frontier borrower financing a standalone, unguaranteed urban-transport asset would face an all-in commercial rate on the order of 13.5%, within a defensible 11.5–16% range against the near-concessional terms on essentially all of its existing stock. On a debt base already near 118% of GDP, coupons of that magnitude compound quickly.
3. **Tenor mismatch and rollover risk.** Commercial lenders extend short tenors to unrated borrowers, while BRT assets serve for 20 years or more. The resulting refinancing risk exposes the project to unknown future rates and to whether commercial creditors will roll over at all a willingness that tends to evaporate precisely when a small open economy is under stress. Bilateral and multilateral partners do not behave this way; commercial capital does.

For a non-FX-earning urban-transport asset in a small, highly indebted, reserve-constrained, recently graduated economy, commercial financing would convert a development project into a sovereign balance-sheet and balance-of-payments liability. Concessional financing with a low coupon, a long tenor, and a grace period is therefore not a cost preference, but a precondition for bankability. This is the core of the additionality case: absent concessional terms, the project is not viable on Bhutan's standalone credit, and pursuing it commercially would itself raise the country's risk of debt distress.

The financial analysis of Component 1.3 illustrates the catalytic role that GCF concessional financing plays in enabling a modal shift that would otherwise remain out of reach for a city of Thimphu's size and fiscal capacity. Two financing scenarios are assessed against identical project fundamentals: one in which GCF provides concessional capital, and one in which the investment relies exclusively on commercial lending at prevailing market rates.

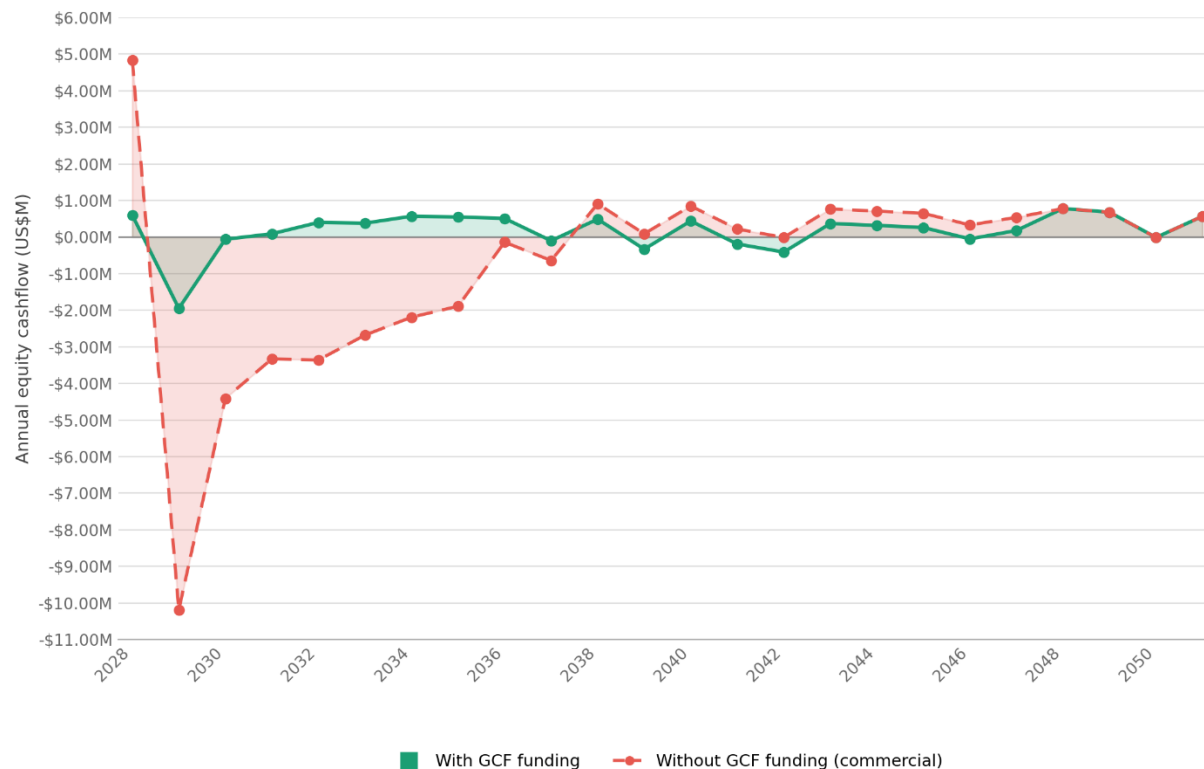
The debt service profiles of the two financing scenarios reveal the practical mechanism through which GCF's concessional terms translate into project viability.

Under commercial financing, annual debt service on the bus fleet and batteries rises sharply to a peak of \$2.47 million in 2030 and remains above \$1.4 million every year from 2029 through 2035, before the seven-year, no-grace loan is fully repaid. This obligation is concentrated entirely in 2029–2035, precisely the years in which the service is still building ridership and operating cashflows remain in early-stage recovery. Under GCF financing, debt service is both lower and very differently timed during this critical window. During the five-year grace period (2028–2032) it stays at or below \$0.15 million per year, and once principal repayment begins it rises to around \$0.53 million, easing slightly through the mid-2030s before reaching a peak of \$0.60 million in 2038, then gradually declining to \$0.54 million by 2046 as the balance is retired over the full twenty-year term.

The contrast is sharpest exactly when the project can least afford it. In 2030, the commercial peak year, GCF debt service is about \$0.15 million against a commercial obligation of \$2.47 million — more than sixteen times lower — because GCF is still within its grace period while the commercial loan is already at full stretch. The relationship inverts later in the schedule: by GCF's own peak in 2038, the commercial loan has long since been retired and sits at a residual \$0.18 million, so GCF's \$0.60 million obligation that year is actually around three and a half times higher — the trade-off for spreading repayment over two decades instead of seven. Over the full life of the loan, however, total GCF debt service remains lower than the commercial structure — about \$9.36 million versus \$17.05 million, or just over half — reflecting the difference between 0.75% and 13.5% interest, even though GCF's repayment tail extends roughly a decade beyond the commercial loan's term.

It is this structural difference in the timing and magnitude of debt obligations — GCF's negligible cost during the make-or-break early ramp-up years, traded for a longer but still lower-cost repayment schedule — rather than any difference in the underlying project economics, that determines whether the investment can attract equity, proceed to implementation, and ultimately deliver the modal-shift outcomes the project is designed to achieve.

Figure 7: Comparison of GCF versus non GCF scenario



Annual equity cashflow to project investors, US\$ million. Values below the breakeven line are net equity injections.

Comparing the project's equity cashflow profile with and without GCF support (Figure 7) shows that the difference is not marginal. It is the difference between a financeable project and an unfinanceable one. Both scenarios fund the identical physical project; they differ only in the terms on which the bus fleet and charging infrastructure are financed. Viewed through the lens of debt structure and project risk, the commercial case is not merely less attractive. It is unworkable.

The problem begins with the shape of the debt. Commercial terms of 13.5 percent interest, a seven-year tenor, and no grace period concentrate the debt-service burden into 2028 to 2034, exactly the years when the system is still building ridership and operating revenues are least certain. Annual debt service peaks at roughly \$2.47 million in 2029, and total debt service over the loan's life is around \$17.05 million — nearly twice the \$9.36 million payable under the GCF loan despite financing the same principal. This front-loading forces the equity holder to absorb deep injections precisely when the project can least afford them. After an initial inflow of \$4.83 million in 2027, net equity outflows reach \$10.19 million in 2028, the position remains in deficit every year through 2036, and cumulative net equity injections deepen to roughly \$24.0 million by 2036. Annual flows turn positive in nearly every year from 2037 onward, but the cumulative equity position remains deeply negative — still around \$16.9 million in deficit even by the end of the twenty-four-

year horizon modeled (2050), underscoring how far short of full recovery the commercial structure leaves investors.

These figures translate directly into risk. Debt service that must be met before the revenue base has matured creates acute liquidity and default risk. If ridership ramps up more slowly than projected, a material possibility for a first-of-kind electric transit system, the commercial scenario's early deficits deepen further, and an equity requirement of this scale and timing is unlikely to be met by City Bus Services or the public balance sheet. The short tenor compounds this with refinancing and rollover exposure, requiring full principal repayment within seven years rather than over the asset's operating life, while commercially-priced, typically foreign-currency debt adds exchange-rate risk in an economy with limited domestic capital markets. The concessional structure removes each of these pressures: the long tenor and grace period align repayments with the revenue build, the low interest rate minimizes the cash cost of debt, and the burden is spread across two decades rather than compressed into the riskiest seven years.

The financial metrics confirm what the risk profile implies. Because both equity cashflow streams change sign repeatedly, no single internal rate of return is meaningful for either, so the modified internal rate of return (MIRR), computed at a 12 percent finance and reinvestment rate, is the appropriate measure. Under commercial financing the equity MIRR is just 6.1 percent, little more than half the 12 percent cost of capital, confirming that the commercially financed project would destroy equity value and could not attract investment; its financial net present value is approximately negative \$13.25 million. With GCF support, the equity MIRR rises to 13.0 percent, above the 12 percent hurdle on the same basis, the FNPV is a positive \$0.41 million, and, apart from a single \$1.95 million injection in 2028, annual equity flows remain modest and manageable throughout, never requiring more than \$0.41 million in any other year (the next-largest deficit, in 2041). The resulting improvement, a MIRR uplift of roughly 6.9 percentage points and an FNPV swing of approximately \$13.65 million, measures the value of GCF's intervention.

This additionality is not a subsidy to investors, but the minimum concessional support required to overcome a structural market failure: the prohibitive cost, front-loading, and risk of commercial finance for a transformative, first-of-kind transit investment in a small, landlocked developing economy. It is GCF's concessionality that makes the project viable, bankable, and resilient to the very risks that would otherwise prevent it from reaching financial close.

2.4 Key Risks and Sensitivities

2.41 Operational Sensitivities

Sensitivity of ridership assumptions

The central projection yields approximately 52,000 daily riders in the BPC's first operational year (2029, 17.8% mode share), rising to approximately 103,000 by 2048 (25% share, up from 7.9% at the baseline 2023) roughly a fivefold increase in bus ridership over the analysis period. The three most sensitive parameters are the frequency elasticity, the BRT quality premium, and the LETMP complementary policy premium. Reducing the frequency elasticity from 0.70 to 0.50 (standard

when service transformation is less dramatic) reduces the 2048 figure by approximately 12.5%. Reducing the BRT quality premium from $\times 1.25$ to $\times 1.15$ reduces the 2048 figure by a further 9.7% to approximately 90,000.

Impact of complimentary policies on ridership

The largest single source of uncertainty is the LETMP policy premium, particularly the additional corridor network effect (10 percentage points of the 32% total): if planned additional bus route improvements are delayed or not implemented and the BRT quality premium is at the lower bound, the 2048 projection falls to approximately 88,000 daily riders (21.2% mode share), still representing a substantial modal shift from baseline. On the upside, if more intensive Transit-Oriented Development along the corridor materializes in the later years of the analysis period — shortening average trip lengths and increasing turnover on the system — a further uplift of around 20% is plausible, placing the optimistic bound near 120,000 (~28%). All parameters are adjustable in the EFA's Ridership tab.

2.42 Capital Investment Sensitivities

Electric bus market pricing and procurement

The financial viability of the project is highly sensitive to the capital cost of the electric buses, as illustrated in Figure 8. Under the GCF concessional financing scenario, the project's financial net present value declines by approximately \$0.43 million for every \$10,000 increase in the per-bus price. At the budgeted price of \$170,000, the FNPV is positive at \$0.41 million, but the margin is narrow: the project reaches breakeven at a bus price of roughly \$180,400 and turns negative beyond it, leaving a cost cushion of only around six percent above the budgeted figure.

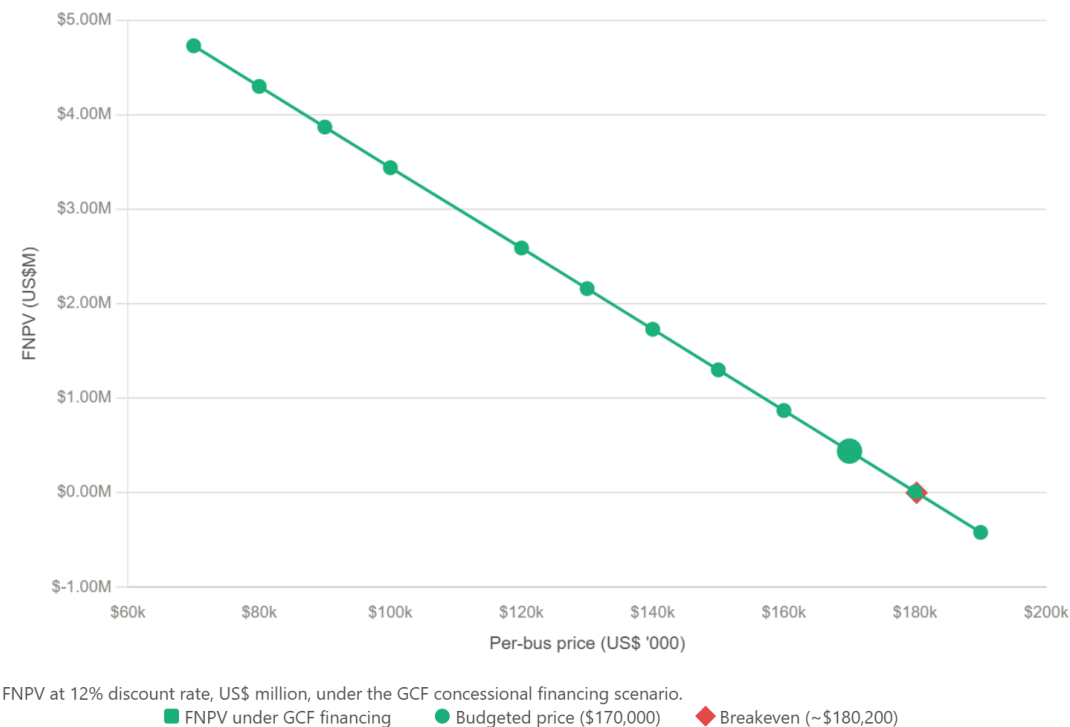
This sensitivity underscores why concessional financing is essential rather than merely beneficial. The positive FNPV shown here is achieved only because of GCF's concessional terms. Under commercial financing, the entire relationship shifts downward by approximately \$13.65 million, placing the FNPV at the budgeted price at around negative \$13.25 million. Because the FNPV responds only modestly to bus price — about \$0.04 million for every \$1,000 — no achievable reduction in the cost of buses, including procurement at zero cost, would be sufficient to return the commercially financed project to a positive FNPV. Concessional finance is therefore the decisive factor that brings the project into a viable financial position at all, and even with that support in place, the limited headroom above the budgeted bus price reinforces the importance of disciplined procurement and cost management throughout implementation.

The Phase 2 expansion economics were tested under three forward price paths for electric buses. Only the parity scenario in which electric bus prices fall to parity with equivalent diesel buses by 2035 yields a positive FNPV, at \$0.41 million. Holding procurement costs constant at today's \$170,000 produces a markedly negative FNPV of \$3.30 million, and even a steady 5 percent annual price decline leaves the expansion underwater at $-\$1.83$ million. The viability of self-funded fleet growth therefore hinges not merely on prices falling, but on them falling far and fast enough to approach diesel parity; a gradual decline is not sufficient on its own. This reinforces that, absent

aggressive cost reductions, Phase 2 will require active procurement strategy, continued concessional support, or a slower expansion path — and it underscores GCF's catalytic role in Phase 1 as the means of buying time for these market conditions to materialize.

The spread is the striking part: the difference between the best and worst case is over \$5 million of FNPV swinging entirely on the bus-price trajectory, which is a strong, defensible way to frame why procurement strategy is a core risk for the expansion phase rather than a side issue.

Figure 8: FNPV sensitivity to e bus prices (current price)



GCF Commitment fee level

The sensitivity of the financial NPV to the GCF commitment fee is modest in absolute terms — ranging from \$0.47 million at zero commitment fee to \$0.41 million at the assumed 0.75 percent rate, a difference of \$0.06 million across the full range. However, for a project of this scale operating in a small economy with modest early-stage revenues, this nuance deserves some consideration. The commitment fee accrues on the undisbursed facility balance during the drawdown period, meaning its burden falls precisely in the years when the project is most financially vulnerable — before the fleet is fully operational, before ridership has ramped up, and before operating cashflows have stabilized. For City Bus Services, which enters the project with limited reserves and a narrow

financial buffer in the early years, even incremental reductions in the upfront cost of financing carry a disproportionate benefit relative to their absolute magnitude. A lower commitment fee reduces the cash drain during the critical 2027 to 2031 disbursement window, easing liquidity pressure at exactly the point where the project can least afford additional outflows. While the FNPV differential between a zero and 0.75 percent commitment fee is not large enough to alter the overall financial viability of the project, GCF may wish to consider whether the concessional terms on this parameter can be set toward the lower end of its policy range — a small concession on the lender's side that translates into meaningful breathing room for a borrower navigating the most operationally and financially demanding phase of a first-of-kind electric mobility project.

3 Economic Analysis of Transport Investments

3.1 Pedestrianization and Spatial Improvements

Spatial improvements like off-street managed parking provide a conservative 0.1% GDP boost for Thimphu by reclaiming lost productive hours and significantly reducing the traffic generated by vehicles "cruising" for spots. By optimizing existing road capacity, these traffic management measures lower congestion-related fuel import costs and public health expenditures, offering a high-return alternative to expensive new road construction in Himalayan terrain.

Drawing on urban economic literature, we assigned an average amenity value of \$3 per tourist and \$2 per local resident for the pedestrianized zones. This differential reflects tourists' consistently higher willingness to pay (WTP) and greater discretionary spending for aesthetic, experiential urban environments. In contrast, the \$2 local valuation conservatively captures the steady, routine utility derived from daily pedestrian safety and enhanced active mobility.⁴

3.2 Time Savings

The Thimphu BRT project generates significant time savings by facilitating a strategic modal shift from private cars to high-capacity e-buses. By utilizing dedicated bus lanes to bypass mixed traffic, this transition reduces the overall volume of vehicles on the road, drastically cutting the time commuters spend traveling daily distances.

Based on empirical data from a comprehensive local transport study and commuter survey, the economic benefits of travel time savings were calculated by modeling the projected ridership shift from private cars and diesel buses to the new e-bus system. By comparing travel times in dedicated BRT lanes against baseline mixed-traffic conditions, the model quantifies the total aggregate hours saved for all commuters. These time savings are then monetized using the local Economic Value of Time (VoT), derived from average wages, to capture the productivity regained by the economy.

The economic analysis distinguishes between time savings from congestion reduction and time savings from better bus access because they capture different benefit channels. Congestion reduction reflects faster travel speeds for all road users due to reduced traffic volumes, while better bus access captures service-quality improvements specific to public transport, including more direct routes, reduced dwell times, bus priority at intersections, and faster boarding. The assumed average saving of approximately 3 minutes per bus trip per day is conservative and consistent with observed performance improvements in comparable BRT systems. These access-related time savings accrue only to bus users and are therefore estimated separately to avoid double counting with system-wide congestion benefits (see, for example, World Bank BRT Planning Guide; ITDP BRT Standard evaluations; ADB Transport Economic Analysis Guidelines).

⁴ Corbett-Davies, J. (2024). *Street Smart Economics: Assessing the Benefits of Urban Improvements*. Abley Transport Research.

3.3 Fuel Savings

Based on the projected modal shift from private vehicles and taxis to the electrified BRT system, the economic analysis calculates substantial aggregate fuel savings. By applying the baseline vehicle operating costs (VOC) against the reduced volume of fossil-fuel trips, the model quantifies the avoided expenditure on imported diesel and petrol. This shift to high-capacity electric transit not only improves transport efficiency but directly reduces the macroeconomic burden of fuel imports for the city. Figure 5 illustrates that the project progressively reduces diesel and petrol consumption relative to the without-project scenario as modal shift takes hold, while electricity demand rises substantially under the with-project scenario reflecting the substitution of imported fossil fuels with Bhutan's domestic hydropower-generated electricity through modal shift to the electric bus fleet.

3.4 Road Safety

Road safety benefits reflect the reduction in traffic accidents, injuries, and fatalities arising from modal shift to BRT and safer corridor design. These benefits are quantified as avoided accident costs by comparing Business-as-Usual and BRT scenarios using projected traffic volumes and standard unit costs. Annual road safety benefits increase from about USD 0.01 million in the early years of operation (2029, first year of BPC operation) to around USD 1.06 million by 2048 as ridership grows and exposure to higher-risk modes declines. Overall, road safety accounts for roughly 5 percent of total quantified economic benefits under the BRT scenario.

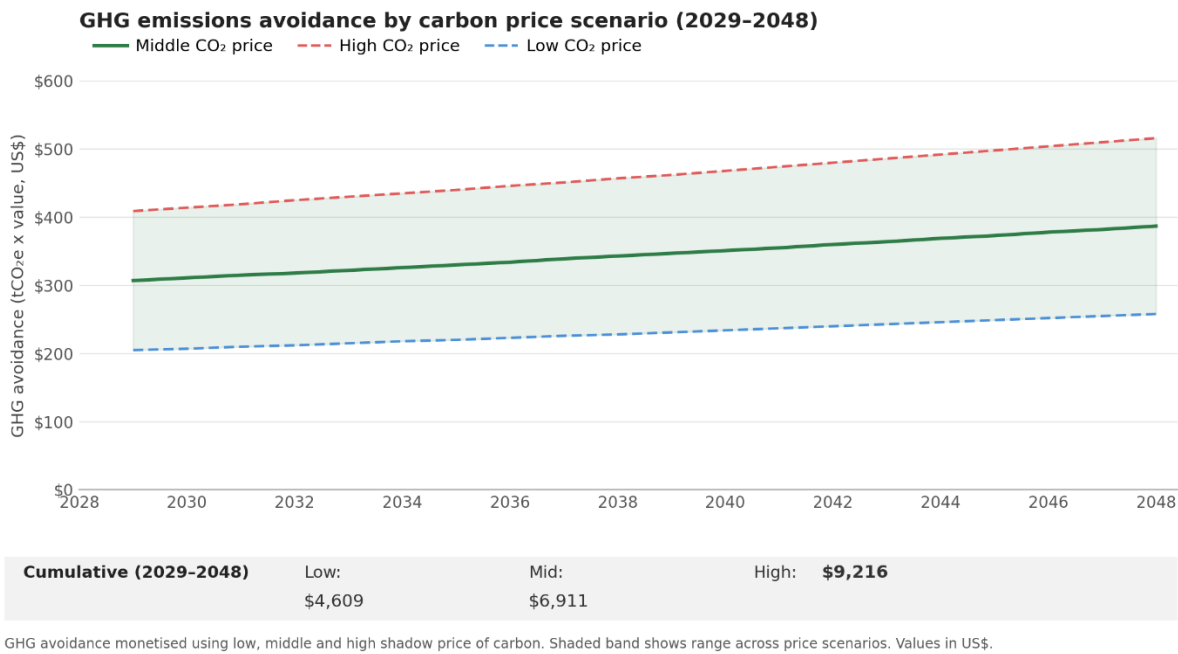
3.5 GHG Emissions Reductions Benefits

GHG emission reduction benefits reflect avoided carbon emissions from modal shift to BRT, improved traffic flow, and the deployment of electric buses. These benefits are estimated in Annex 22, using the CDM AM0031 (Bus Rapid Transit) methodology; the resulting annual avoided CO₂ emissions are then valued in the EFA using a standard carbon price (in high, medium and low price scenarios). Annual monetized GHG benefits rise steadily from USD 0.2 million in early years to around USD 0.26 million per year (under the low price scenario) by the later years of operation as BRT ridership expands. Over the project lifetime, the BRT intervention delivers cumulative emissions reductions on the order of ~70 ktCO₂e, contributing materially to the project's overall economic viability and climate mitigation impact. The figure shows the monetized value of GHG emissions avoided by the project growing steadily across the appraisal period under all three carbon price scenarios, with cumulative avoidance ranging from \$4.6m to \$9.2m depending on the assumed shadow price of carbon.⁵

⁵ World Bank (2024). *Guidance Note on the Shadow Price of Carbon in Economic Analysis*. Climate Change Advisory & Operations, World Bank Group.

At US\$301.9 per tonne of CO₂, the GCF transport investments’ abatement cost sits at the higher end of the range reported for comparable electric bus and BRT transitions in developing country contexts. World Bank analysis of hybrid and electric bus deployment in developing country BRT systems found abatement costs in the range of US\$ 100 to 250 per tonne of CO₂e, placing the LRCP slightly above this benchmark range. This position reflects the relatively limited ridership base of a small Himalayan capital, which constrains the volume of absolute emissions avoided per dollar invested compared to larger urban BRT systems, while the negative Marginal Abatement Cost (using NPV of net costs) of US\$ -119/tCO₂e indicates the project's strong broader economic returns — from cleaner air, flood resilience, and fuel and time savings, among others — confirming that the abatement cost is well justified by the full suite of co-benefits delivered alongside the emissions reductions.

Figure 9- Value of GHG emissions reductions due to the modal shift at a range of shadow prices



Section 3.6 : Economic Analysis of Flood Resilience Benefits

3.61 Climate risk context

Thimphu sits in a narrow river valley carved by the glacially fed Wang Chhu, making it acutely vulnerable to both pluvial flooding from intense monsoon rainfall overwhelming the urban drainage system and fluvial flooding from the river rising rapidly in response to upstream precipitation and glacial melt. Rapid urbanization has dramatically reduced the natural infiltration capacity of the

land, concentrating runoff and accelerating flood onset. Climate change is compounding these pressures — rising temperatures across the Hindu Kush Himalaya are accelerating glacial retreat and producing more intense and unpredictable monsoon events, with peak flows in glacially-fed rivers expected to increase in coming decades as glaciers enter their peak melt phase. For a city built along a narrow valley with limited space for expansion, even modest increases in flood frequency and severity translate directly into disruption of critical infrastructure, damage to property, and threats to public safety.

3.62 Flood risk modelling results

The flood risk analysis used Fathom pluvial flood data modelled under the SSP3-7.0 climate scenario which was selected as it represents a plausible middle-ground projection for a small, landlocked developing nation such as Bhutan⁶. The bus corridor is exposed to flooding (see figure 2), which could impact the movement and performance of vehicles with and without project. For this analysis, three return periods were analyzed: a 5-year event representing regular seasonal flooding (0.1 m depth in 2030, rising to 0.15 m by 2050), a 10-year event capturing more intense periodic flooding (0.43 m in 2030, rising to 0.5 m by 2050), and a 50-year rare but catastrophic event (1.0 m in 2030, rising to 1.29 m by 2050). The results reveal a consistent and significant intensification of flood depths by 2050 across all return periods (see figure 10), with the 50-year event showing the sharpest increase with a 29% rise in depth, reflecting accelerating glacial melt and more intense monsoon precipitation under climate change. At these depths, vehicle damage is severe: the 50-year 2050 event produces 100% damage to motorcycles, taxis and cars, 60% to buses, and 50% to trucks in the without-project scenario (see figure 11b), underscoring the scale of transport disruption that the BRT and SUDS investment is designed to mitigate.

Figure 10: Exposure of the bus corridor to a 10-year flood

⁶ Fathom (2023). Fathom Global Flood Map 3.0 – Product Specification and Climate Dynamics Framework. (Documents the use of CMIP6 SSP scenarios, including SSP3-7.0, for climate-conditioned pluvial flood hazard modeling at global scale.)

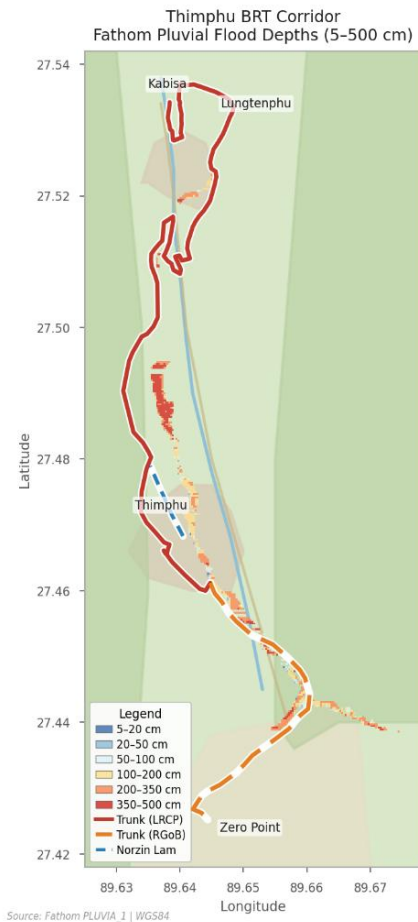
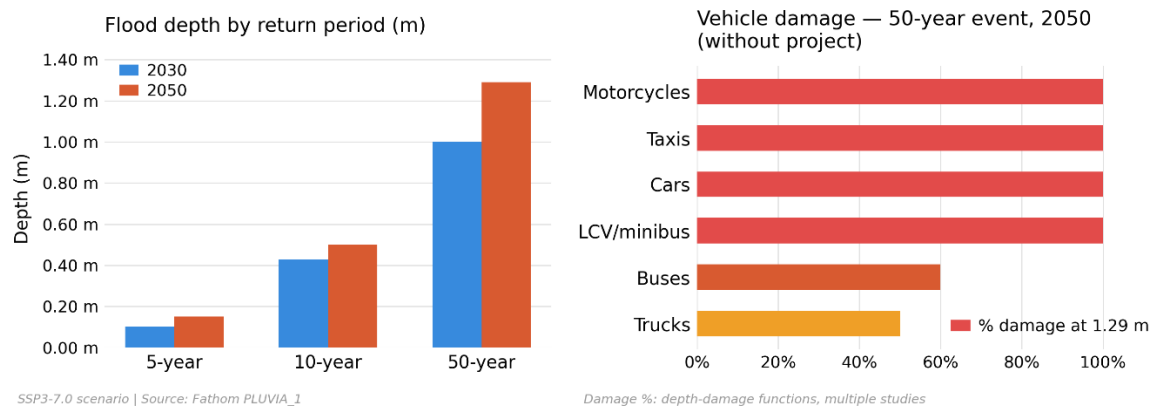


Figure 11a : Increase in the intensity of flooding in Thimphu over time 11b: Vehicle damage without project in extreme flooding scenario

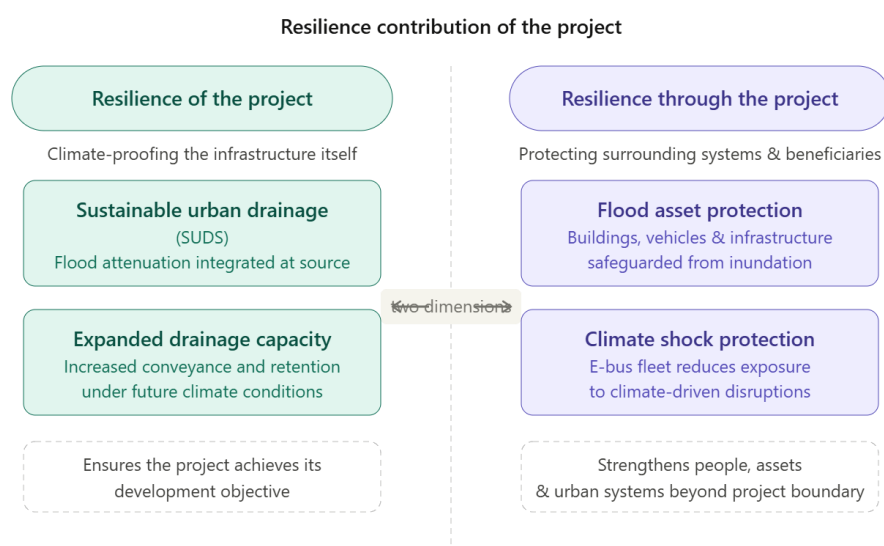


3.63 Measuring and tracking resilience in the project

The project embeds resilience across two complementary dimensions. Resilience of the project refers to the incremental measures integrated into the design of the infrastructure itself. Through

the incorporation of Sustainable Urban Drainage Systems (SUDS) and expanded drainage capacity for roads and public spaces, and flood resilience measures and emergency power backups at bus terminals, the project ensures that its own assets are climate-proofed and capable of withstanding current and future flood conditions — enabling it to achieve its core development objective under a changing climate.

Resilience *through* the project captures the wider protective effect on surrounding systems and beneficiaries. By reducing flood exposure across the settlement zone, the project directly safeguards buildings, vehicles, and critical infrastructure from inundation. In addition, the transition from private vehicle-based transport to an electric BRT system centered on a climate-resilient road corridor reduces the vulnerability of urban transport systems to climate-driven disruptions, strengthening the resilience of communities and urban systems well beyond the immediate project boundary.



3.63 Resilience of the project: incremental cost of resilience measures

The incremental cost of resilience is calculated using asset-specific cost factors drawn from the Miyamoto International engineering study, which provides uplift percentages representing the additional cost of building to a resilient standard above the baseline BOQ.⁷ For the two primary asset classes relevant to this project, the study identifies a 3% uplift for secondary urban roads — achieved through improved drainage provision and barrier installation to reduce flood exposure — and a 1% uplift for urban roadway bridges, where the addition of rock armouring at abutments and piers provides scour protection against flood events. These percentages are applied only to the share of project assets identified as flood-exposed through the geospatial overlay with Fathom flood data, ensuring that the incremental cost calculation reflects only the genuine resilience

⁷ Miyamoto International (2019). *Increasing Infrastructure Resilience Background Report*. Prepared for the World Bank Group.

premium on vulnerable assets rather than the full project scope. The underlying assumption is that these uplifts sit at share of the standard construction costs already captured in the BOQ, isolating the dedicated cost of climate-proofing from what would have been spent regardless.

3.64 Climate resilience benefits of modal shift and SUDS

Against this backdrop, the shift towards a Bus Rapid Transit system represents a coherent strategy for building a more flood-resilient Thimphu. When roads flood, private vehicles incur significant repair and damage costs — depth-damage curves for cars indicate that even moderate flood depths of 0.2–0.3 m can damage 30–50% of a vehicle's value, while motorcycles face near-total loss at depths exceeding 0.5 m (see figure 12).⁸ A BRT system operating on a dedicated corridor is inherently more resilient to these events: buses sit higher off the ground, are maintained by a single operator rather than thousands of individual owners and can be strategically rerouted or temporarily suspended without the diffuse, uncoordinated losses that flood-exposed private vehicles impose on households. The modal shift induced by BRT therefore reduces not just emissions and congestion, but the aggregate vehicle damage burden that floods place on Thimphu's residents and economy.

Sustainable Urban Drainage Systems address the hydrological root of urban flooding by restoring the infiltration capacity that rapid urbanization has stripped away. SUDS elements including permeable pavements, bioretention cells, swales, and detention basins attenuate peak flows, reduce surface runoff volumes entering an already-strained drainage network, and lower flood depths across the urban area. Evidence from coupled hydrological modelling studies shows that well-designed SUDS can reduce maximum inundation depths by up to 29% for distributed source-control measures, and by 50% or more where larger storage elements are incorporated (see figure 10).⁹ Deployed along and adjacent to the BRT corridor, SUDS directly protect the transport infrastructure itself, reducing the frequency and severity of flood events that would otherwise impair bus operations and damage corridor assets.

Figure 12: Depth damage curves by vehicle type

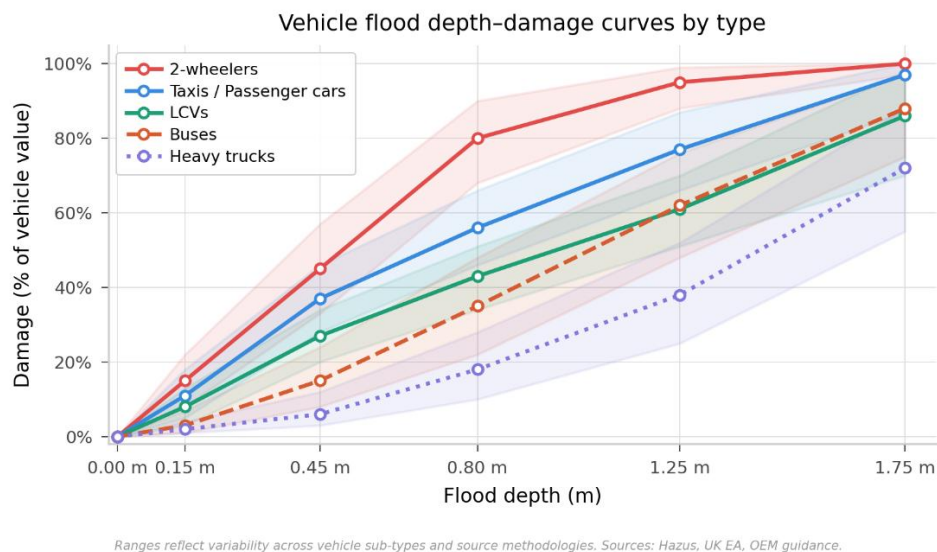
⁸ Golmohammadi, R. & Shokoohi, A. (2024). *Distributive Assessment of Vehicle Damage in Flash Floods*. *Water Resources Management*.

(Applies HAZUS-based curves showing severe damage to cars and two-wheelers at shallow flood depths.)

⁹ Lashford, C., Charlesworth, S., Warwick, F., & Blackett, M. (2020).

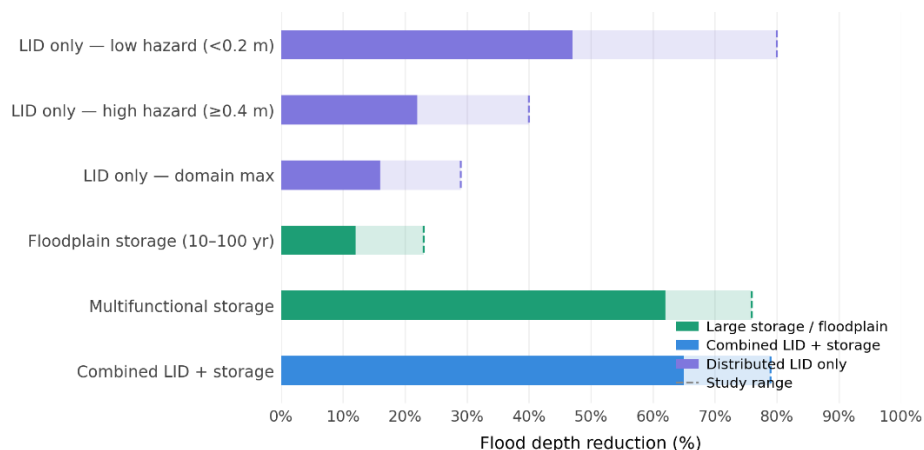
Modelling the role of SuDS management trains in minimising flood risk.

Water, 12(9), 2559.



Shaded bands represent the plausible range across vehicle sub-types and source variability. Mid point values used for central estimates. Source: Hazus, UK EA and OEM guidance

Figure 13 Impact of SUDS on flooding intensity



Sources: Wu et al. (2018) Shenzhen; Ferreira et al. (2020) Portugal; SWMM-LISFLOOD scenario analysis. Ranges reflect variation across storm return periods and coverage scenarios.

3.65 Flood resilience benefits assessment for vehicles

The economic benefits of flood resilience were assessed by combining Fathom pluvial flood depth projections under the SSP3-7.0 scenario with vehicle-specific depth-damage functions drawn from Hazus, the UK Environment Agency, and OEM guidance. For each return period and time horizon, the flood depth at the corridor was applied to the damage functions to estimate the share of each vehicle type's value destroyed or requiring repair, generating annual expected repair costs across the full vehicle fleet. The analysis demonstrates that by shifting trips from private vehicles onto the BRT corridor and reducing

flood depths through SUDS infrastructure, the project produces substantial savings in user-borne repair costs. Cars account for the overwhelming share of avoided costs given their high exposure, large fleet numbers, and steep damage curves at moderate flood depths, with cumulative savings across the 2029 to 2048 appraisal period approaching US\$ 63.2 million in total across all vehicle types. These savings represent a direct financial benefit to Thimphu's households and businesses, costs that would otherwise fall on individual vehicle owners rather than being pooled or insured, making the flood resilience case for the LRCP investment highly tangible at the user level.

3.66 Flood resilience benefits to surrounding built environment

Built environment exposure in Thimphu was estimated by resampling Fathom flood hazard data from 1 arcsecond to 3 arcseconds using nearest-neighbor interpolation to match the resolution of the Global Human Settlement Layer (GHSL), consistent with the World Bank methodology of Rentschler, Salhab & Jafino (2022).¹⁰ The GHSL was used at its original resolution with no correction factor applied, and built-up area was taken as the direct sum of pixel values. Depth-damage functions were then applied to translate inundation depth into fractional asset loss under two scenarios — without resilience and with resilience — where the latter introduces a protection height h_p below which damage is substantially reduced (Figure 14).

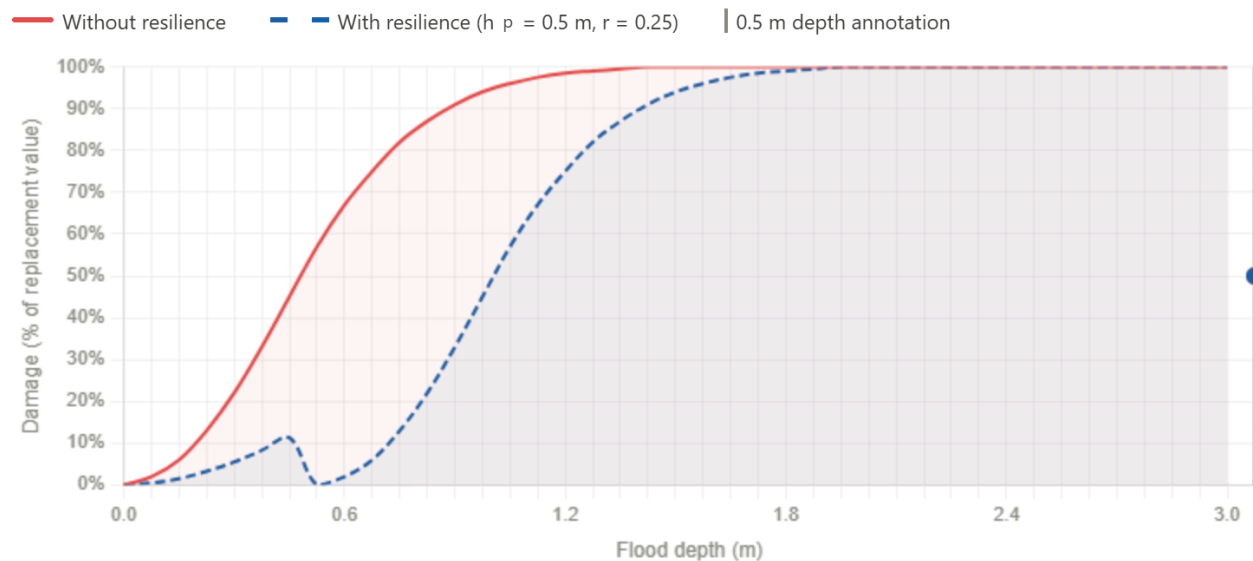


Figure 1 — Depth-damage functions for residential building stock, Thimphu. Dashed vertical line marks 0.5 m flood depth.

¹⁰ Schiavina, M., Freire, S., Carioli, A. & MacManus, K. (2023). GHS-BUILT-S R2023A — GHS built-up surface grid, derived from Sentinel-2 composite and Landsat, multitemporal (1975–2030). European Commission, Joint Research Centre (JRC). PID: <http://data.europa.eu/89h/9f06f36f-4b11-47ec-abb0-4f8b7b1d72ea>. doi:10.2905/9F06F36F-4B11-47EC-ABB0-4F8B7B1D72EA

Replacement values for exposed building stock were estimated by triangulating construction cost benchmarks from the Bhutan Schedule of Rates, residential market values from National Statistics Bureau surveys, and unit cost comparators from World Bank and UNDP project appraisals; damage fractions were applied to the resulting asset value raster at each return period to produce aggregate expected annual damage estimates in both scenarios. It should be noted that GHSL captures building footprints only, not total floor area: for the typical 3–5 storey construction prevalent in Thimphu, actual built floor area may be 3–5 times greater than the footprint sum, meaning this analysis likely underestimates total economic exposure.

3.7 Economic Analysis Consolidated Results

The modal shift investment component of the LRCP project generates a strong economic return across all scenarios, with an economic NPV ranging from \$25.2 million to \$26.53 million depending on the carbon price assumption applied, and an economic IRR of 22.4% to 22.9%. These returns reflect the combined benefits of travel time savings, vehicle operating cost reductions, GHG emissions avoidance, and critically, the avoided cost of flood damage to vehicles, a benefit that accrues directly to households and businesses in Thimphu rather than to the operator. Flood resilience benefits amount to \$64.14 million, driven by two complementary pathways. The larger share reflects the reduction in flood-exposed private vehicles that modal shift delivers: as cars and motorcycles leave the road network and passengers shift to BRT, the aggregate vehicle damage burden from increasingly intense pluvial flood events under climate change falls substantially, and since depth-damage curves indicate that private vehicles suffer severe or total loss at moderate flood depths, even a partial reduction in fleet exposure generates large economic savings at scale. The remainder captures avoided damage to the built environment: by reducing inundation depths across Thimphu's residential and commercial building stock — much of it traditional earthen and stone construction with steep depth-damage curves — the resilience intervention curtails structural losses that would otherwise compound across successive flood events, with benefits concentrated in the central valley corridors where building density and flood exposure overlap most acutely.

Despite this strong economic performance, the project is not financially viable without concessional support. Commercial lending yields a financial NPV of -\$13.25 million, making GCF participation essential to bridge the gap between economic and financial returns that is characteristic of public transport investments where significant benefits accrue to users and society rather than flowing through the operator's income statement.