Vancouver Island Rail Retrofit Project: A Probabilistic Cost-Benefit Analysis

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Abstract

This study presents a comprehensive cost–benefit analysis (CBA) of retrofitting Vancouver Island's 225-kilometer dormant rail corridor with battery-electric multiple units (BEMUs). Over fourteen weeks, a multi-layered Excel-based model was developed to assess the project's financial, environmental, and social feasibility. The deterministic framework established in the early phases calculated core cashflows, net present value (NPV), and benefit–cost ratio (BCR). Subsequent iterations integrated emissions modeling based on Transport Canada (2023) and BC Hydro (2022), followed by an Accessibility Equity Index (AEI) to measure rural and Indigenous access benefits. Week 13 introduced standardized evaluation metrics uniting cost, emission, and equity indicators. The final probabilistic layer (Week 14) applied sensitivity and distributional analysis to quantify uncertainty in ridership, cost, and policy parameters. Results show an expanded mean BCR of 1.18 and NPV of CAD 12.6 million, suggesting that electrification of the corridor is economically feasible and socially equitable under CleanBC 2030 policy targets.

1. Introduction

The Vancouver Island rail corridor, extending approximately 225 kilometers from Victoria to Courtenay, has remained inactive for more than a decade. Reviving this line through battery-electric multiple units (BEMUs) offers a potential pathway toward low-carbon mobility, regional connectivity, and equitable economic growth. However, previous assessments have largely focused on capital costs and operational feasibility, with limited treatment of environmental externalities, accessibility outcomes, or policy alignment.

To address this gap, the present study develops an integrated modeling framework that combines conventional cost–benefit analysis (CBA) with environmental accounting and social equity evaluation. The model was constructed iteratively over fourteen weeks. Early stages (Weeks 1–6) established deterministic cashflow and cost modules to estimate baseline NPV and BCR. Mid-phase developments (Weeks 7–9) incorporated avoided-emission calculations using Transport Canada's (2023) rail emission factors and BC Hydro's (2022) grid-intensity projections. Weeks 10–12 expanded the framework with an Accessibility Equity Index (AEI), quantifying benefits to rural and Indigenous communities.

Week 13 formalized a unified Evaluation Metrics Framework linking financial, environmental, and social outcomes through normalized indices. Week 14 added sensitivity and uncertainty assessment to test the robustness of results.

This sequential structure allows the analysis to move beyond a static financial appraisal, capturing the dynamic interplay between cost efficiency, decarbonization, and accessibility. The resulting evidence provides a data-driven basis for evaluating whether electrifying the Vancouver Island corridor can advance British Columbia's CleanBC 2030 decarbonization and regional development objectives.

2. Literature Review and Backing Studies

Recent literature underscores the transformative potential of electrified rail in regional transportation decarbonization (BC Hydro, 2022; FRA, 2023). Studies by the OECD/ITF (2022) and UNECE (2021) emphasize that cost–benefit analyses should account for indirect benefits such as carbon avoidance, accessibility, and social inclusion. The EU Agency for Railways (2021) reports fare elasticity values for intercity rail ranging from −0.4 to −0.6, providing parameters for ridership modeling. The Island Corridor Foundation (2020) provides localized CAPEX and O&M benchmarks, while Transport Canada (2023) and CleanBC (2021) establish national and provincial GHG accounting baselines essential for emissions modeling. Together, these sources frame a hybrid analytical approach blending engineering economics, policy analysis, and equity assessment.

3. Data and Methods

Data inputs were derived from validated sources: CAPEX and O&M estimates from Island Corridor Foundation (2020); emission factors from Transport Canada (2023); carbon pricing trajectory from CleanBC (2021); grid intensity projections from BC Hydro (2022); and fare elasticity parameters from the EU Agency for Railways (2021). The analytical framework consists of three sequential models: (1) deterministic CBA using NPV and BCR; (2) expanded CBA integrating emission, road maintenance, and tourism benefits; and (3) Monte Carlo simulation capturing probabilistic variability across financial and social parameters.

4. Results and Analysis

The deterministic CBA yields a base-case expanded BCR of 1.15 and NPV of CAD 12.3 million. Monte Carlo simulation results show a mean BCR of 1.18 with a P10–P90 range of 0.94–1.39. NPV distribution centers around CAD 12.6 million with 80% of outcomes above zero. Sensitivity decomposition attributes approximately 68% of variance to ridership factor and CAPEX uncertainty. Carbon pricing assumptions significantly influence the upper quartile of results, improving mean feasibility by 8%. AEI variability (±0.05) exerts minimal effect (<3%) on aggregate outcomes.

5. Discussion

The findings highlight the importance of probabilistic modeling in infrastructure feasibility studies. Conventional deterministic CBAs can mask underlying volatility, particularly in projects dependent on policy-linked externalities such as carbon pricing. The inclusion of social equity metrics ensures that evaluation extends beyond economic efficiency toward distributional fairness, aligning with Sustainable Development Goals (SDGs) 9 and 11. The results affirm that electrified rail retrofits can be both economically feasible and socially inclusive when supported by renewable electricity and stable policy frameworks.

6. Conclusion and Policy Implications

This study concludes that a BEMU retrofit of the Vancouver Island rail corridor is financially viable under median assumptions and policy-consistent scenarios. With emission reductions of approximately 350 tonnes CO_2 annually, enhanced accessibility for rural and Indigenous populations, and BCR values exceeding 1.0 across most probabilistic outcomes, the project demonstrates strong alignment with CleanBC's decarbonization roadmap. The methodology introduced here—combining deterministic, expanded, and probabilistic CBAs—offers a replicable model for assessing regional transport electrification projects.

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