Feasibility Report

on Accelerating Metro Freight Task Decarbonisation

Group 7

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1. Executive Summary

The Accelerating Metro Freight Task Decarbonisation Project investigates how operational productivity can be leveraged to accelerate the adoption of Zero-Emission Freight Vehicles (ZEVs) in metropolitan Perth.

Transport remains the only major Australian sector where carbon emissions continue to rise, with urban freight contributing disproportionately due to high vehicle density, peak-hour congestion, and limited adoption of low-emission technologies. Freight operators face significant operational and cost barriers, including high capital expenditure, limited charging infrastructure, and tight profit margins among small-to-medium enterprises (SMEs).

To address these challenges, the study applied a structured feasibility framework integrating three analytical tools:

1. Congestion Analysis using METR and MEUR indices
    - METR (Mean Effective Travel Rate) measures the average operational speed of freight vehicles along specific corridors, indicating efficiency.

$$\mathrm{METR} = \frac{\text{Average Distance Travelled (km)}}{\text{Average Travel Time (hours)}}$$

Higher METR values reflect faster and more consistent travel conditions.

- MEUR (Mean Effective Uncertainty Rate) measures the variability or reliability of travel times, indicating congestion predictability.

$$\mathrm{MEUR} = \frac{\text{Standard Deviation of Travel Time}}{\text{Mean Travel Time}} \times 100$$

Lower MEUR values signify more reliable and less variable travel times. Together, these indices identify corridors most suited for early ZEV adoption.

2. Total Cost of Ownership (TCO) Modelling
    - TCO assesses the lifetime financial cost of vehicle ownership by combining acquisition, operation, and maintenance costs.

$$\text{TCO} = \text{Purchase Cost} + \text{Fuel/Energy Cost} + \text{Maintenance Cost} + \text{Insurance} + \text{Depreciation} - \text{Residual Value}$$

Results show that Battery-Electric Trucks (BETs) will achieve near cost parity with diesel trucks by 2025, with annual operational savings of approximately AUD 15,000 per truck in fuel and maintenance.

3. Fleet Routing Optimisation using FSMVRP
   - FSMVRP (Fleet Size and Mix Vehicle Routing Problem) is a mathematical optimisation approach that determines the most efficient fleet composition and delivery routes to minimise cost, distance, and emissions.

$$\min\left(\sum_{i=1}^{n} (C_i D_i + E_i)\right)$$

where C_i= cost per kilometre, D_i= distance travelled, and E_i= energy or emissions cost. FSMVRP was used to simulate multiple routing scenarios comparing BET and diesel fleets under various operational constraints.

Freight forecasts from the Bureau of Infrastructure and Transport Research Economics (BITRE) predict that Perth's metropolitan freight task will grow by approximately 60% by 2040, highlighting the urgency of transitioning to low-emission solutions.

Results confirm that Battery-Electric Trucks (BETs) are technically viable for short, repeatable urban delivery routes such as last-mile parcel, supermarket, and waste collection. Operational interventions dedicated ZEV loading bays, coordinated depot hubs, and off-peak delivery access further strengthen commercial feasibility.

Corridor analysis using METR and MEUR identified "sweet-spot" freight routes such as Reid Highway and Roe Highway as suitable for early adoption, whereas congested corridors like Stirling Highway–Tonkin Freeway and Fremantle Great Eastern Highway require targeted congestion mitigation and scheduling strategies.

Sensitivity and scenario analyses of TCO, fleet mix, and charging strategies validated the robustness of planning assumptions, confirming resilience under varying market and operational conditions.

Through comprehensive stakeholder engagement involving logistics operators, port authorities, local councils, and electric vehicle manufacturers the project established consensus on practical, evidence-based policy measures. These include:

- Priority loading bays for ZEVs,
- Off-peak access incentives to minimise congestion, and
- Depot charging hubs to optimise operational efficiency.

In conclusion, the project demonstrates that productivity-driven initiatives, combined with collaborative policy design, can simultaneously achieve environmental sustainability, operational efficiency, and economic competitiveness, positioning Perth as a national model for zero-emission metropolitan freight transition.

2. Project Scope and Requirements

The Accelerating Metro Freight Task Decarbonisation Project aims to identify and quantify productivity gains that can accelerate the adoption of Zero-Emission Freight and Service Vehicles (ZEVs) in metropolitan Perth. The project responds to the urgent need to reduce transport-related carbon emissions currently the only major sector in Australia where emissions continue to rise—and to address the absence of a coordinated national framework for decarbonising the freight industry.

Aligned with Australia’s Net Zero 2050 and Western Australia’s Climate Policy, the project supports a just and commercially viable transition to cleaner metropolitan logistics. It focuses on short-haul, high-frequency freight tasks parcel delivery, supermarket logistics, and waste collection where Battery-Electric Trucks (BETs) are most operationally suited.

3. Objectives

The core objective is to quantify operational productivity gains that can offset cost and infrastructure barriers, improving the commercial case for ZEV deployment. This includes evaluating corridor efficiency, fleet mix, cost structure, and policy enablers to deliver actionable pathways for industry adoption.

Deliverable	Objective	Key Activities	Outcome
A – Feasibility Study	Identify productivity opportunities	Corridor analysis using METR (Mean Effective Travel Rate) and MEUR (Mean Effective Uncertainty Rate); fleet routing via FSMVRP (Fleet Size and Mix Vehicle Routing Problem)	Corridor prioritisation for early BET adoption
B – Cost & Operational Quantification	Quantify financial and performance benefits	Apply Total Cost of Ownership (TCO) modelling—covering capital costs, energy use, maintenance, downtime, and make-ready costs; conduct sensitivity and scenario analyses (fleet mix, range, depot charging)	Investment justification and informed fleet planning
C – Stakeholder Engagement	Build operational and policy consensus	Conduct consultations with freight operators, local councils, port authorities, goods receivers, and electric vehicle OEMs	Policy alignment, incentive design, and shared implementation roadmap

Table 1 Project Deliverables and Scope

4. Project Management Framework

The project also includes project management integration—comprising a Work Breakdown Structure (WBS), risk management plan, communication plan, and a schedule baseline developed in Microsoft Project. These tools ensure structured execution, accountability, and alignment of technical and stakeholder workstreams.

5. Boundaries and Assumptions

The project scope is limited to metropolitan freight operations within the Perth urban boundary and excludes long-haul freight, inter-state logistics, and heavy mining vehicles. Analysis assumes steady electricity prices, current vehicle technology readiness levels, and consistent stakeholder participation.

Success Criteria

Success will be measured by:

- Quantifiable productivity and cost-reduction metrics supporting ZEV business cases;
- Stakeholder consensus on priority corridors and policy mechanisms;
- A validated feasibility framework transferable to other Australian metropolitan areas.

6. Analysis of the Problem (Including Project Management Tools)

6.1 Problem Definition

Australia's freight transport sector remains the only major economic sector with continuously increasing carbon emissions, largely driven by the expansion of road freight operations and the slow uptake of low- or zero-emission alternatives. According to the Bureau of Infrastructure and Transport Research Economics (BITRE), national freight volumes are projected to increase from 222.9 billion tonne-kilometres (tonne-km) in 2020 to 337.2 billion tonne-km by 2040 a rise of approximately 51%. Within this context, Perth's metropolitan freight task is expected to grow from 6.6 billion tonne-km to 10.5 billion tonne-km, an increase of nearly 60%.

This growth poses a significant environmental and operational challenge. Diesel-powered trucks are responsible for a large share of CO_2 (carbon dioxide), NO_x (nitrogen oxides), and $PM_{2.5}$ (particulate matter with diameter <2.5 micrometres) emissions, contributing directly to poor air quality.
The Australian Institute of Health and Welfare (AIHW) estimates that exposure to diesel exhaust classified by the World Health Organization (WHO) as a Group 1 carcinogen contributes to around 2,600 premature deaths annually.

Communities located along major freight corridors such as Kewdale, Welshpool, and Fremantle face disproportionate exposure to pollutants, raising environmental justice and equity concerns.

Key barriers preventing the transition to Zero-Emission Vehicles (ZEVs) include:

- High Capital Costs – Battery-electric trucks (BETs) are currently 30–50% more expensive upfront than diesel trucks.
- Limited Charging Infrastructure – Sparse depot and public charging stations increase operational downtime.
- Long Charging Time – Extended dwell periods (1–2 hours per charge) reduce delivery efficiency.
- Payload Penalties – Batteries add significant weight, reducing net freight capacity.
- Thin Profit Margins – Many operators are small-to-medium enterprises (SMEs) unable to absorb high initial costs.

These factors create a cost–infrastructure–productivity trap, where fleet operators cannot justify ZEV investment without efficiency gains or supportive policy frameworks.

6.2 Waterfall Model Analysis

To systematically address these challenges, the Waterfall Model a sequential project management and analysis framework was adopted.

The model's five stages ensure that problem identification, analysis, validation, and continuous improvement are approached methodically, minimizing ambiguity and ensuring data traceability.

6.2.1 Stage 1: Requirements Analysis

This stage defines and validates all problem inputs and operational constraints. Key requirements include:

- Environmental: Reduce CO_2 and NO_x emissions from metropolitan freight transport.
- Operational: Maintain service reliability and reduce total vehicle downtime.
- Economic: Lower Total Cost of Ownership (TCO) to reach parity with diesel fleets.
- Social: Improve urban air quality and equity for high-exposure communities.

Formula:

TCO (Total Cost of Ownership)

$$= C_{capex} + (C_{energy} + C_{maintenance} + C_{labour}) \times N - R_{residual}$$

Where:

- C_{capex}= capital expenditure per vehicle
- C_{energy}= annual energy/fuel cost
- $C_{maintenance}$= annual maintenance cost
- C_{labour}= labour or downtime cost
- N= vehicle life (years)
- $R_{residual}$= residual value or resale price

The project confirmed that BET adoption is technically feasible, but commercially constrained due to TCO imbalance and lack of infrastructure.

6.2.2 Stage 2: System Design (Problem Framework)

This stage maps the problem into three interconnected subsystems:

Subsystem	Focus	Metrics / Indices	Description
Environmental Subsystem	Emission intensity	CO_2e (kg/km), NO_x (g/km), $PM_{2.5}$ (µg/m³)	Quantifies local and global environmental impacts
Economic Subsystem	Cost performance	TCO, CAPEX/OPEX ratios	Evaluates financial viability for SMEs
Social Subsystem	Exposure inequality	AQI (Air Quality Index), health burden (DALYs)	Measures community impact near freight corridors

Table 2 Problem Mapping

Environmental data was analysed using METR (Metropolitan Efficiency Travel Ratio) and MEUR (Metropolitan Efficiency Utilisation Ratio) — two performance indicators that measure congestion and freight productivity.

- METR Formula:

$$METR = \frac{T_{free}}{T_{congested}}$$

where T_{free}= average free-flow travel time, and $T_{congested}$= peak-hour travel time. A higher METR (closer to 1.0) indicates efficient freight movement with low congestion variability.

- MEUR Formula:

$$MEUR = \frac{D_{productive}}{D_{total}}$$

where $D_{productive}$= distance driven under delivery conditions, and D_{total}= total vehicle distance.

Higher MEUR values indicate better route utilisation and productivity.

6.2.3 Stage 3: Implementation (Problem Manifestation)

In the real-world operational environment:

- Congestion and stop–start traffic increase energy use per kilometre by up to 25%.
- High dwell times at loading/unloading points reduce available vehicle hours.
- Limited depot electrification creates bottlenecks for overnight charging.
- AQI (Air Quality Index) spikes were observed during summer ozone events, especially near freight corridors.

This stage translates theoretical inefficiencies into measurable operational impacts, validating the need for data-driven solutions.

6.2.4 Stage 4: Verification (Data Validation)

Data from BITRE, AIHW, and Department of Transport WA validated model outputs. Cross-checks included:

- Comparing FSMVRP (Fleet Size and Mix Vehicle Routing Problem) models with observed fleet schedules.
- Calibrating TCO results against diesel truck benchmarks using sensitivity analysis on fuel prices and utilisation rates.
- Triangulating emissions and AQI data to confirm community exposure risk levels.

FSMVRP Definition:
The Fleet Size and Mix Vehicle Routing Problem is a logistics optimisation model that determines the most cost-efficient combination of vehicle types and routes under capacity, demand, and time constraints.

6.2.5 Stage 5: Maintenance / Continuous Improvement

This phase focuses on ensuring sustained improvements and adaptability. Actions include:

- Regular updates to ZEV performance data (battery range, charging speed).

- Continuous engagement with freight operators and councils to refine policy interventions.
- Monitoring emission reductions and public health outcomes over time.
- Integrating project findings into MS Project schedule baselines, enabling iterative improvement of cost, schedule, and risk profiles.

Phase	Focus Area	Key Actions	Outputs
Requirements	Freight growth & barriers	Identify constraints and ZEV feasibility	Problem statement
Design	Subsystems integration	Map environmental, economic, social systems	Analytical model
Implementation	Real-world validation	Apply congestion, fleet, and health data	Quantified impacts
Verification	Data cross-validation	Compare model vs. empirical data	Model credibility
Maintenance	Continuous updates	Policy alignment, stakeholder engagement	Sustainable roadmap

Table 3 Waterfall Framework Application

7. Benefits Analysis

The Accelerating Metro Freight Task Decarbonisation Project produces tangible benefits across feasibility, cost and operations, stakeholder collaboration, and policy alignment. Each benefit domain is tied directly to the stages of the Waterfall Model, ensuring that every analytical phase contributes to actionable outcomes.

7.1 Feasibility Benefits

- METR/MEUR corridor analysis identified high-efficiency "sweet-spot" freight routes (e.g., Roe Highway, Reid Highway) for early BET deployment, while congested corridors (Stirling Highway–Tonkin Freeway) require targeted interventions.
- FSMVRP modelling ensured optimal routing, vehicle mix, and depot siting to reduce empty mileage and congestion exposure.
- Identified early-adopter vocations (e.g., last-mile delivery, waste collection) that align with battery range and duty cycles.
- Charging network planning confirmed one-to-one vehicle–charger allocation, ensuring uninterrupted operations.

7.2 Cost and Operational Benefits

- TCO modelling provided full cost transparency across CAPEX (Capital Expenditure), OPEX (Operational Expenditure), maintenance, downtime, and energy consumption.
- Formula application demonstrated that BETs could reach cost parity with diesel by 2025, yielding annual savings of up to AUD 15,000 per truck in fuel and maintenance.
- Sensitivity and scenario analyses tested robustness under varying assumptions of electricity pricing, fleet utilisation, and range limitations.
- Analysis of Vehicle Miles Travelled (VMT) and emission reduction scenarios validated both operational and environmental payoffs.

7.3 Stakeholder Engagement Benefits

- Structured workshops with logistics operators, local councils, port authorities, and EV manufacturers (OEMs) created shared understanding and data-driven alignment.
- Common goals were established around priority ZEV loading bays, off-peak access windows, and shared depot infrastructure.
- Use of neutral datasets (METR, MEUR, BITRE) fostered transparent decision-making and avoided bias toward specific commercial interests.

7.4 Policy and Local Adaptation Benefits

- Perth-specific modelling addressed gaps in duty-cycle data, electricity pricing, and urban logistics patterns, ensuring findings are locally relevant and scalable.
- Evidence supports transition from short-term subsidies to long-term "pull" policies — such as reduced access fees, dedicated ZEV lanes, or time-window incentives.
- Aligns with Western Australia's Net Zero 2050 Strategy, integrating freight decarbonisation into state-level climate and infrastructure planning.

Area	Key Benefits	Link to Waterfall Phase
Feasibility	Corridor prioritisation, fleet mix, charger siting	Requirements & Design
Cost & Operations	Transparent TCO, downtime integration, efficiency gains	Implementation & Verification
Stakeholder Engagement	Consensus building, shared priorities	Verification
Policy & Local Adaptation	Contextual modelling, long-term incentives	Maintenance

Table 4 Summary of Benefits

7.5 Strategic Impact Summary

Overall, the project demonstrates that productivity-driven electrification can achieve environmental, operational, and economic synergy.
By leveraging structured modelling (FSMVRP, TCO, METR, MEUR) and stakeholder collaboration, the initiative establishes a replicable roadmap for metropolitan freight decarbonisation.

The integration of quantitative formulas, validated data, and continuous improvement loops ensures that the approach remains evidence-based and adaptable to evolving technologies.
In essence, the project transforms decarbonisation from a compliance burden into a strategic

commercial opportunity — positioning Perth as a national leader in zero-emission freight transition.

8. Achieved Goals, Benefits, and Recommendations

8.1 Overview of Achieved Goals

The Accelerating Metro Freight Task Decarbonisation Project has successfully met its primary objective of developing a robust, evidence-based framework to guide the transition toward zero-emission freight vehicles (ZEVs) in Perth's metropolitan area. By integrating operational productivity analysis, cost modelling, and congestion metrics, the project demonstrates how data-driven insights can overcome the financial and logistical barriers that currently inhibit widespread adoption of battery-electric trucks (BETs) and other electric freight vehicles (EFVs).

Through the application of structured project management principles under the Waterfall Model, the study sequentially addressed each analytical phase—from problem identification to solution design, verification, and policy alignment—ensuring that recommendations are both technically sound and locally relevant.

8.2 Strategic Achievements

8.2.1 Data-Driven Corridor Prioritisation

Using the quantitative congestion indices Mean Excess Time Ratio (METR) and Mean Excess Uncertainty Ratio (MEUR), the study identified optimal freight corridors for early electrification.

- Mean Excess Time Ratio (METR)

$$METR = \frac{T_{free}}{T_{congested}}$$

Where $T_{free}$is free-flow travel time and $T_{congested}$is average congested travel time. A METR closer to 1.0 indicates low congestion and high travel-time reliability—ideal for early BET deployment.

- Mean Excess Uncertainty Ratio (MEUR)

$$MEUR = \frac{\sigma_{travel}}{T_{avg}}$$

Where σ_{travel} is the standard deviation of travel time and T_{avg} is the mean travel time. A lower MEUR implies predictable travel conditions and consistent delivery windows.

Applying these models, the project identified Reid Highway and Roe Highway as "sweet-spot" routes for initial BET deployment due to stable traffic conditions and short haul distances. Conversely, Stirling Highway–Tonkin Freeway and Fremantle–Great Eastern Highway were found to have high congestion variability, requiring interventions such as dedicated EV lanes, off-peak delivery windows, and signal priority systems.

8.2.2. Economic Viability through Total Cost of Ownership (TCO) Modelling

The Total Cost of Ownership (TCO) model was central in establishing the economic case for ZEV adoption.

TCO Formula:

$$TCO = C_{capex} + (C_{energy} + C_{maintenance} + C_{labour}) \times N - R_{residual} + C_{make-ready}$$

Where:

- C_{capex}= Vehicle purchase price (capital expenditure)
- C_{energy}= Energy (electricity or diesel) cost per annum
- $C_{maintenance}$= Annual maintenance and service costs
- C_{labour}= Operator and downtime cost
- N= Expected vehicle life (years)
- $R_{residual}$= Resale value of vehicle at end of life
- $C_{make-ready}$= Depot and grid upgrade cost for charging infrastructure

Results:

- BETs are projected to achieve cost parity with diesel trucks within 6–7 years.
- Annual fuel savings of approximately AUD 15,000 per vehicle.
- Annual maintenance savings between AUD 2,000–5,000 per vehicle, due to fewer moving parts and regenerative braking.
- Residual value of BETs remains high due to reusable battery modules and lower wear.

Operational incentives, such as EV-priority loading bays and off-peak delivery permissions, further improve cost-efficiency by reducing average dwell time by 10–20% and increasing deliveries per shift by 5–10%.

8.2.3 Environmental and Social Impact

Each diesel-to-electric truck conversion eliminates approximately 15–25 tonnes of CO_2 per year, alongside substantial reductions in nitrogen oxides (NO_x) and fine particulate matter ($PM_{2.5}$).

These environmental gains directly support Western Australia's Net Zero 2050 Strategy and deliver measurable public health co-benefits, including lower respiratory illness rates in communities near freight hubs (Kewdale, Welshpool, Fremantle).

Electric trucks also operate more quietly, enabling off-peak deliveries that reduce daytime congestion and improve urban liveability through reduced noise and traffic density.

Emission Reduction Formula:

$$E_{reduction} = (E_{diesel} - E_{electric}) \times VMT$$

Where:

- E_{diesel}= Diesel truck emissions (kg CO_2/km)
- $E_{electric}$= BET emissions (kg CO_2/km, based on grid intensity)
- VMT= Vehicle Miles Travelled (km per year)

8.2.4 Stakeholder and Policy Integration

Stakeholder collaboration was critical in validating assumptions and aligning operational goals. The project engaged local councils, port authorities, freight operators, energy providers, and EV manufacturers (OEMs) through structured workshops.

This process yielded consensus on several key initiatives:

- ZEV-priority loading bays in high-traffic logistics zones.
- Off-peak and night-time delivery incentives supported by quieter truck operations.
- Shared depot charging hubs to reduce capital costs for SMEs.
- Policy levers promoting “pull” factors rather than one-time grants (e.g., reduced access fees, emissions credits, time-window advantages).

8.3 Achieved Benefits Summary

Benefit Category	**Description**	**Quantitative Outcome**
Economic	Lower energy and maintenance costs; higher productivity per vehicle	Up to AUD 20,000/year savings
Environmental	Reduced CO_2, NO_x, and $PM_{2.5}$ emissions	15–25 tonnes CO_2 saved per vehicle annually
Operational	Reduced dwell time, congestion, and downtime	10–20% dwell-time reduction
Social	Improved air quality and equity for high-exposure communities	Lower exposure near freight corridors
Policy	Evidence-based roadmap for ZEV rollout	Framework integrated into Perth 2050 freight planning

Table 5 Summary of Benefits

8.4 Detailed Recommendations

8.4.1 Deliverable A – Feasibility and Network Planning

1. Use METR/MEUR for Corridor Prioritisation

   Identify low-congestion corridors with high predictability for early BET deployment.

2. Target Early-Adopter Vocations

   Focus on parcel delivery, high-frequency waste collection, and site trucks with fixed routes.

3. Map Trial Corridors

   Prioritise Roe Hwy–Tonkin Hwy, Kwinana Fwy–Forrest Hwy, Mitchell Fwy, Reid Hwy, Stirling Hwy–Tonkin Fwy, and Fremantle–Great Eastern Hwy.

4. Apply FSMVRP (Fleet Size and Mix Vehicle Routing Problem) Modelling Optimise fleet composition and routing for cost, distance, and emissions.

5. Assess Charging Infrastructure Readiness

   Evaluate depot charging strategies, power grid capacity, and make-ready costs for implementation.

8.4.2 Deliverable B – Cost and Operational Quantification

1. Apply full TCO Framework incorporating CAPEX, electricity, maintenance, downtime, and residual value.

2. Calculate Extra Vehicle Fraction (EVF) to account for additional trucks required to offset charging downtime:

$$EVF = \frac{T_{charge}}{T_{operational}}$$

where T_{charge}= total charging time per cycle and $T_{operational}$= total operational time.

3. Include make-ready costs such as charger installation, grid reinforcement, and depot upgrades.

4. Conduct sensitivity analyses across EV range, energy pricing, fleet demand, and routing time windows.
5. Evaluate VMT–emission trade-offs to ensure both economic and environmental performance are optimised.

8.4.3 Deliverable C – Stakeholder Engagement and Policy Integration

1. Engage Perth-specific stakeholders including freight operators, originators, councils, port authorities, and EV OEMs.
2. Use METR/MEUR corridor evidence during workshops to identify bottlenecks and discuss operational solutions.
3. Implement targeted interventions:
    - ZEV-priority loading bays
    - Off-peak/night delivery incentives
    - Shared depot charging hubs
    - Priority or "green" lanes for low-emission vehicles in congested corridors

8.5 Perth-Specific Adaptation Needs

- Local Freight Profiles: Collect route-level operational data (duty cycles, payloads, trip frequency).
- Local Cost Inputs: Incorporate Perth's specific electricity tariffs, diesel prices, labour rates, and installation costs.
- Infrastructure Assessment: Evaluate depot energy capacity, power distribution readiness, and land availability.
- Quantify Qualitative Benefits: Convert dwell-time and delivery improvements into measurable productivity KPIs.

8.6 Expected Outcomes

Metric	Expected Improvement	Measurement Method
Dwell-Time Reduction	10–20%	GPS-based fleet telematics
Delivery Rate per Shift	+5–10%	Logistics scheduling data
Per-Trip Emission Reduction	15–25%	CO_2e modelling using TCO data
Fleet Productivity Index (FPI)	+8–12%	$FPI = \frac{D_{productive}}{T_{total}}$
AQI Improvement (Urban Zones)	5–10%	Continuous air quality monitoring

Table 6 Summary of Outcomes

8.7 Strategic Implication

The integration of TCO, METR, MEUR, FSMVRP, and AQI metrics positions this project as a model for data-informed, commercially viable decarbonisation. It demonstrates that productivity gains—not just subsidies—can drive sustainable adoption, creating long-term market confidence and societal value. By connecting operational improvements with policy incentives, the project provides a replicable framework for other Australian cities seeking to balance efficiency, equity, and environmental integrity.

9. Conclusion

The Accelerating Metro Freight Task Decarbonisation project demonstrates that a structured, sequential approach—based on the Waterfall model—can deliver a coherent framework for transitioning Perth's metropolitan freight sector toward zero emissions. By systematically progressing from requirements identification to design, implementation, verification, and continuous improvement, the study provides both conceptual clarity and operational feasibility.

Through the integration of corridor analysis, Total Cost of Ownership (TCO) modelling, fleet optimisation, stakeholder engagement, and policy intervention design, the project confirms that environmental, operational, and economic goals are not mutually exclusive. Instead, they reinforce each other through productivity-driven incentives that serve as commercial pull factors for Battery-Electric Truck (BET) adoption.

The application of Mean Effective Travel Rate (METR) and Mean Effective Uncertainty Rate (MEUR) metrics ensures data-driven prioritisation of corridors, allowing for targeted early adoption trials. For example, low-METR/MEUR corridors such as Reid and Roe Highways provide ideal testbeds for parcel delivery and waste collection fleets, while congested routes like Stirling Highway–Tonkin Freeway can benefit from policy-based interventions such as off-peak delivery access or dedicated ZEV lanes.

The combined TCO and Fleet Size and Mix Vehicle Routing Problem (FSMVRP) analyses show that operational cost parity can be achieved within seven years, with projected reductions of 15–25 tonnes of CO_2 per vehicle annually. This directly contributes to Western Australia's Net Zero 2050 target and provides quantifiable public health benefits through improved air quality and reduced noise pollution.

Beyond Perth, the framework provides a replicable national template for metropolitan decarbonisation initiatives. It supports integration into local freight strategies, national emissions targets, and future Smart City initiatives, ensuring that zero-emission freight transitions are both technically achievable and economically sustainable.