Zero-Emission-Vehicle Awareness Initiative (ZEVAI)

Knowledge Series 02

ZEV Transit System Planning Guidelines
Do & Don't!

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NRCan – ZEVAI Project

Zero Emission Vehicle Awareness Initiative

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The opinions expressed are those of the authors and do not represent the views of the funding agency.

The aim is to spread Zero-Emission-Vehicle-Awareness within the transit community through a set of Knowledge series presentations, webinar, and reports.

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Knowledge Series 02

e-Bus Transit System Planning Guidelines

Providing support to the ZEV Planning Phase

Knowledge for ZEV planning:
fleet, infrastructure, and operation

Detailed activity-based model for e-Bus implementation

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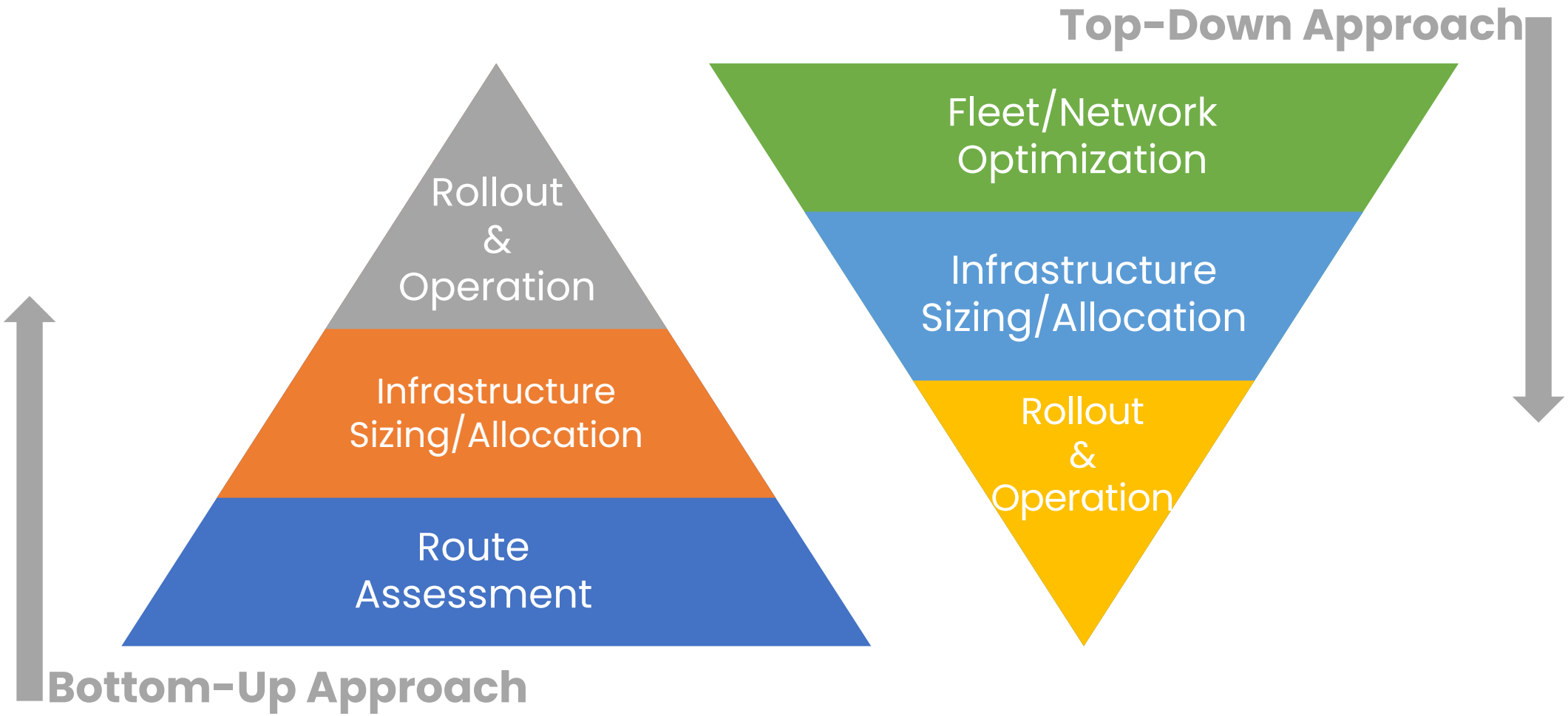
Planning Approaches

Bottom-up OR Top-down



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High-level Planning Approaches

A Top-Down Approach

Stage I

Fleet/Network Planning

Stage II

Infrastructure Planning

Stage III

Operational Planning

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Stage I – Fleet/Network Planning

Buses

- Start with **Network** Feasibility
- Use **winter** energy consumption values
- Consider battery **fading** (6 years or 12 years)
- Estimate required battery size based on the degree of **operational flexibility**
- Assign **spatiotemporal** energy demand scores
  - Energy demand overtime at start/end stops, terminals, depot

- Start with Route Feasibility
- Use summer energy consumption values
- Assume that the battery will be the same for 12 years
- Use different battery sizes for each bus/route
  - No possible bus rotation
- Assign bus energy demand scores

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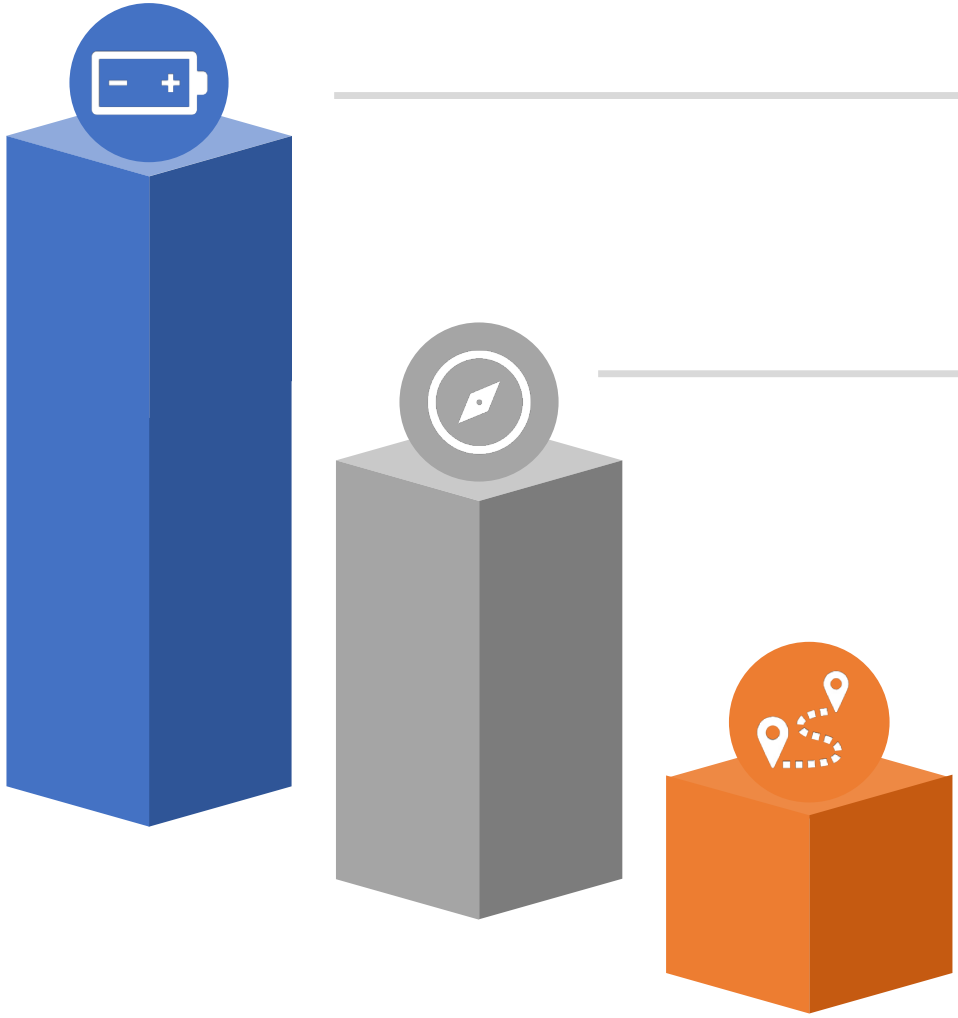
Stage I – Things to consider

Buses



Homogenous batteries/buses or not!

Depot charging only or en-route depot!

Fixed routes or interlined operation!

Stage II – Infrastructure Planning

Charging/refueling stations

- Optimize charging location & sizing for the network
- Assess the charging schedule for the entire fleet
- Estimate energy demand overtime from the grid for the entire fleet
- Speak with utility providers on power availability

- Optimize charging location & sizing for each route
- Assess the charging schedule based on individual buses
- Estimate energy demand overtime from the grid per bus
- Plan without knowing utility limits

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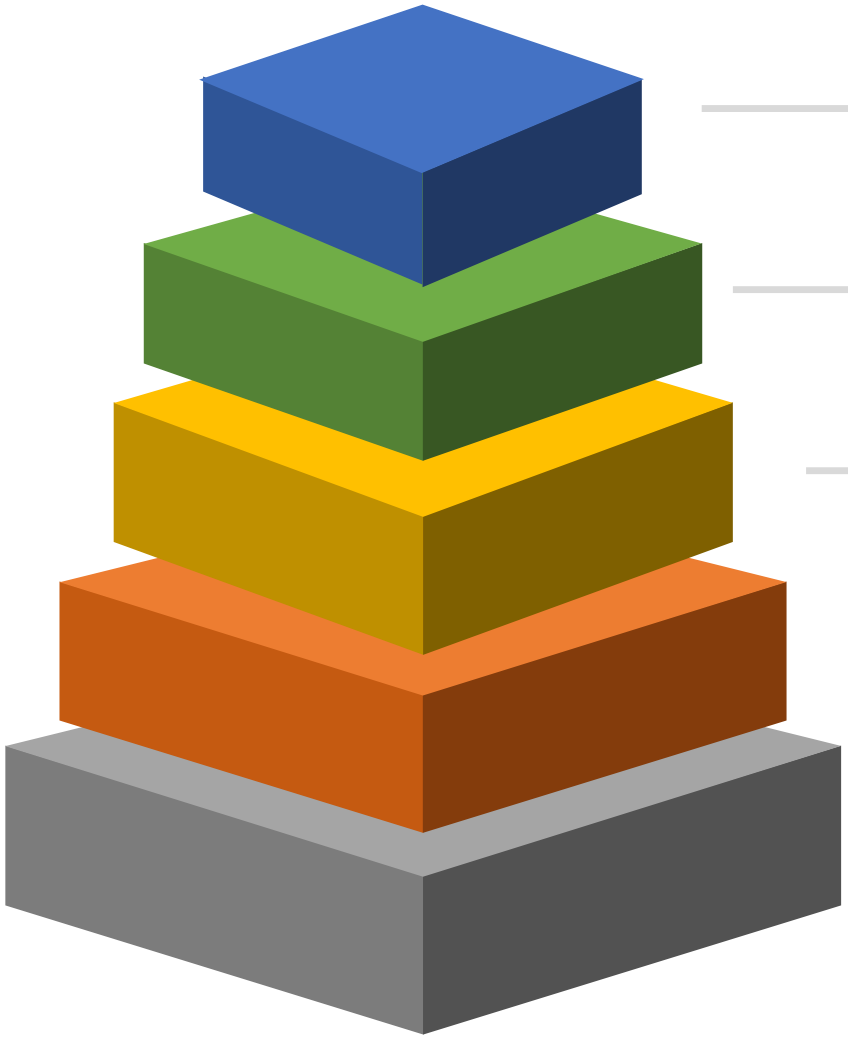
Stage II – Things to Consider

Charging/refueling stations



Number of poles for each charging station

Homogenous or heterogenous charges (Power)

Charging locations en-route vs. depot

Electricity pricing (Time of Use vs. Peak Demand)

Energy storage system utilization

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Stage III – Operational Planning

Prior to implementation

- Use gas heater to save your energy consumption
- Rotate your buses to harmonize battery fading
- Train drivers for eco-driving
- Consider electricity time of use tariffs and energy storage system
- Optimize the charging schedule

- Use electric heaters for longer routes
- Fix buses to routes
- Drive the e-bus as a diesel bus
- Ignore electricity time of use tariffs and energy storage system
- Charge as needed

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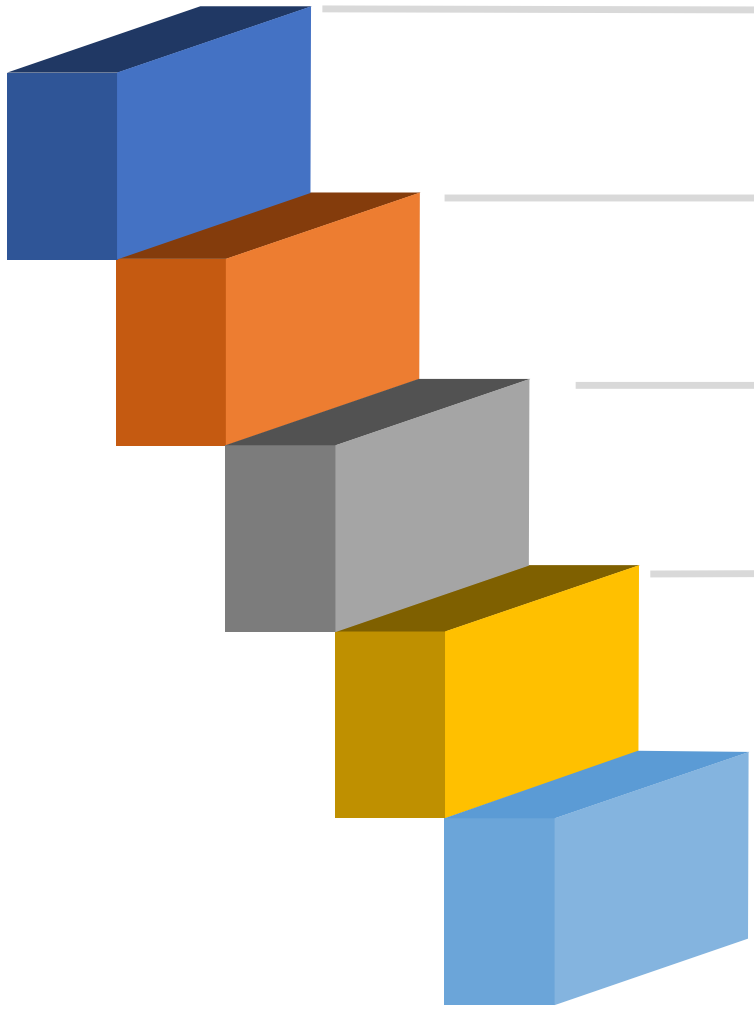
Stage III – Things to Consider

Prior to implementation



Consider battery capacity fading for different battery capacities

Scatter the charging stations (risk distribution)

Consider failure rates for charging equipment

Plan for both en-route and depot charging

Enable multiple poles for each charging station

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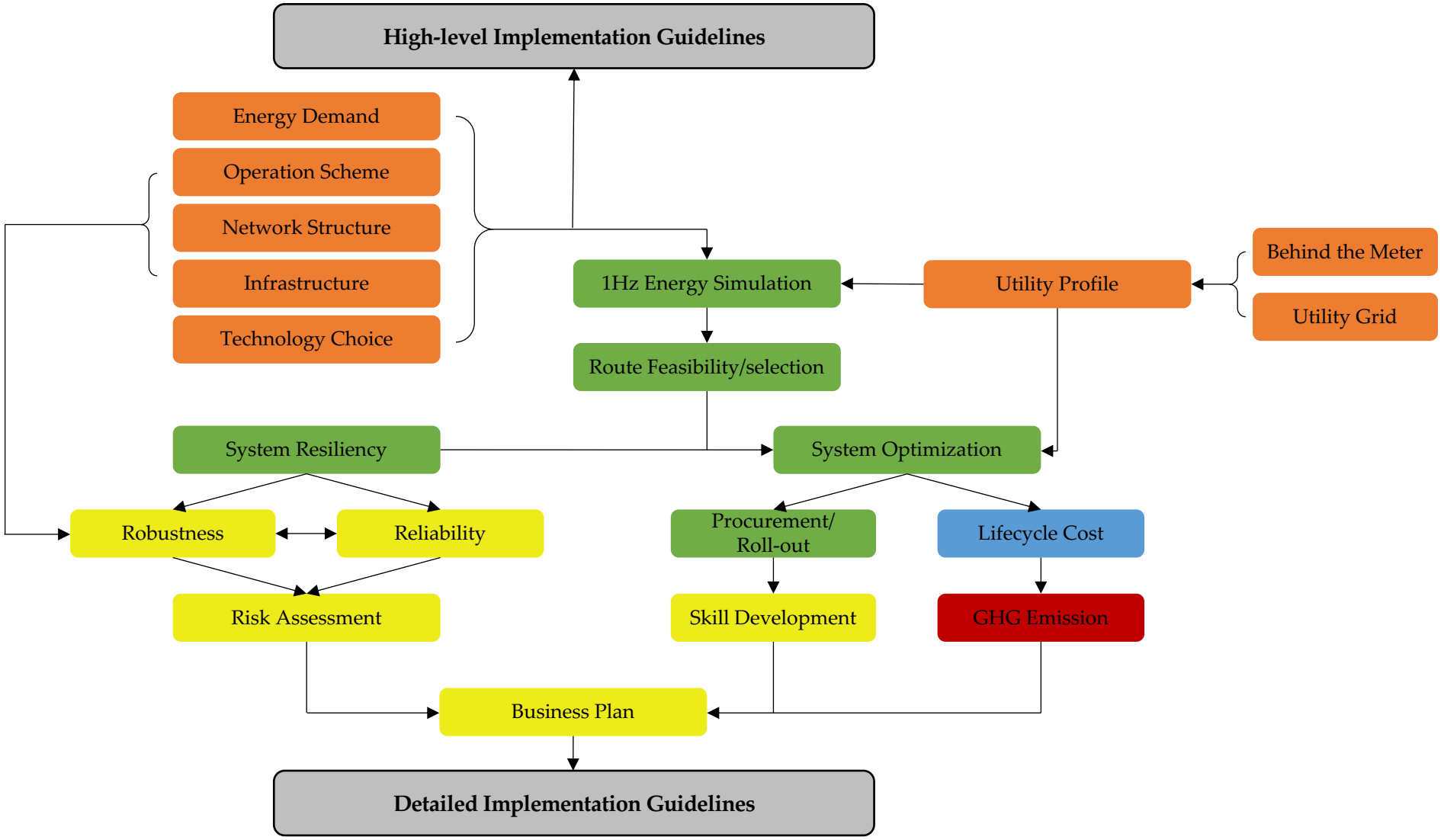
Detailed Guidelines

Implementation Guidelines



System-Level Planning | Operational Planning | Financial Planning | Capacity Assessment | Environmental Benefits

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System-level Electrification Planning

Energy Demand

Energy Demand

- Estimate energy demand per route, per operation time

Operation Scheme

Operation Schemes

- Re-code transit fleet in binary code

Network Structure

Transit Network Structure

- Identify potential candidates for charging station locations

Infrastructure

Infrastructure Assessment

- Identify existing capabilities & expansion capacity

Technology Choice

Technology Choice

- Assess alternative e-Bus technology

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System-level Electrification Planning

Behind the meter

Utility Profile

Behind the meter Analysis

- Evaluate the suitability of utility infrastructure (transformer, wiring, local substation, etc.)

Utility Profile

- Assess the utility generation capacity per time (10-15 min)

System-Level Planning

Holistic system-level planning of e-Bus implementation.
Provide accurate planning decisions based on the unique features of each transit network

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Operational Planning

System-Level Planning

- 1Hz Energy Simulation
- Route Feasibility/selection
- System Resiliency

System Optimization

Simulation-based Energy Modelling

- e-Bus feasibility assessment digital model can estimate required energy consumption, cost of operation, & energy demand

e-Bus Optimal Route Selection

- Consider route characteristic impacts on energy demand and maximizing e-Bus energy utilization

e-Bus Transit System Resiliency

- Assess the system reliability in two phases: pre-implementation & post-implementation

e-Bus System Optimization that addresses the uncertainty associated with e-Bus operation

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Lifecycle Assessment

System Optimization

Lifecycle Cost

Lifecycle cost models should accommodate parameters such as:

- Fleet Size
- Technology Choice
- Roll-out Plan
- Battery Cost Depreciation
- Infrastructure Cost
- Maintenance Cost
- Electricity/Fuel Cost
- Operator's Cost

Environmental Benefits

GHGenius Model which includes system-level GHG reduction from transitioning diesel buses to e-Buses & GHG reduction per passenger kilometer travelled

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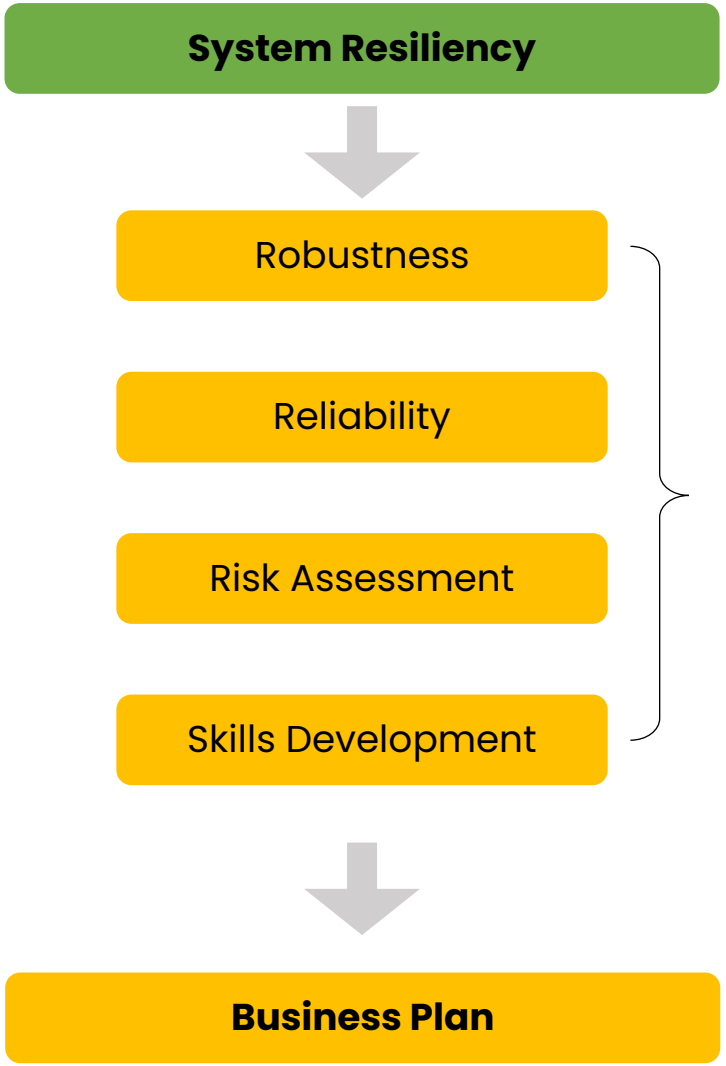
e-Bus System Robustness & Resiliency



Robustness is the system's ability to manage errors during implementation

Reliability is the probability of the system to function acceptably

Risk Assessment of High & Low Impact Risks:

- "Guinea Pig" Syndrome & Technology
- Human Resources Cost & Union Regulation

e-Bus Skills Development

- Analyze best practices, transit agency needs, & existing programs to develop guidelines of skills for e-Bus implementation.

Implementation of Business Plan which includes short-term & long-term planning decisions that cover Operation, Fleet Procurement, Infrastructure Upgrades, Rolling Out Strategy

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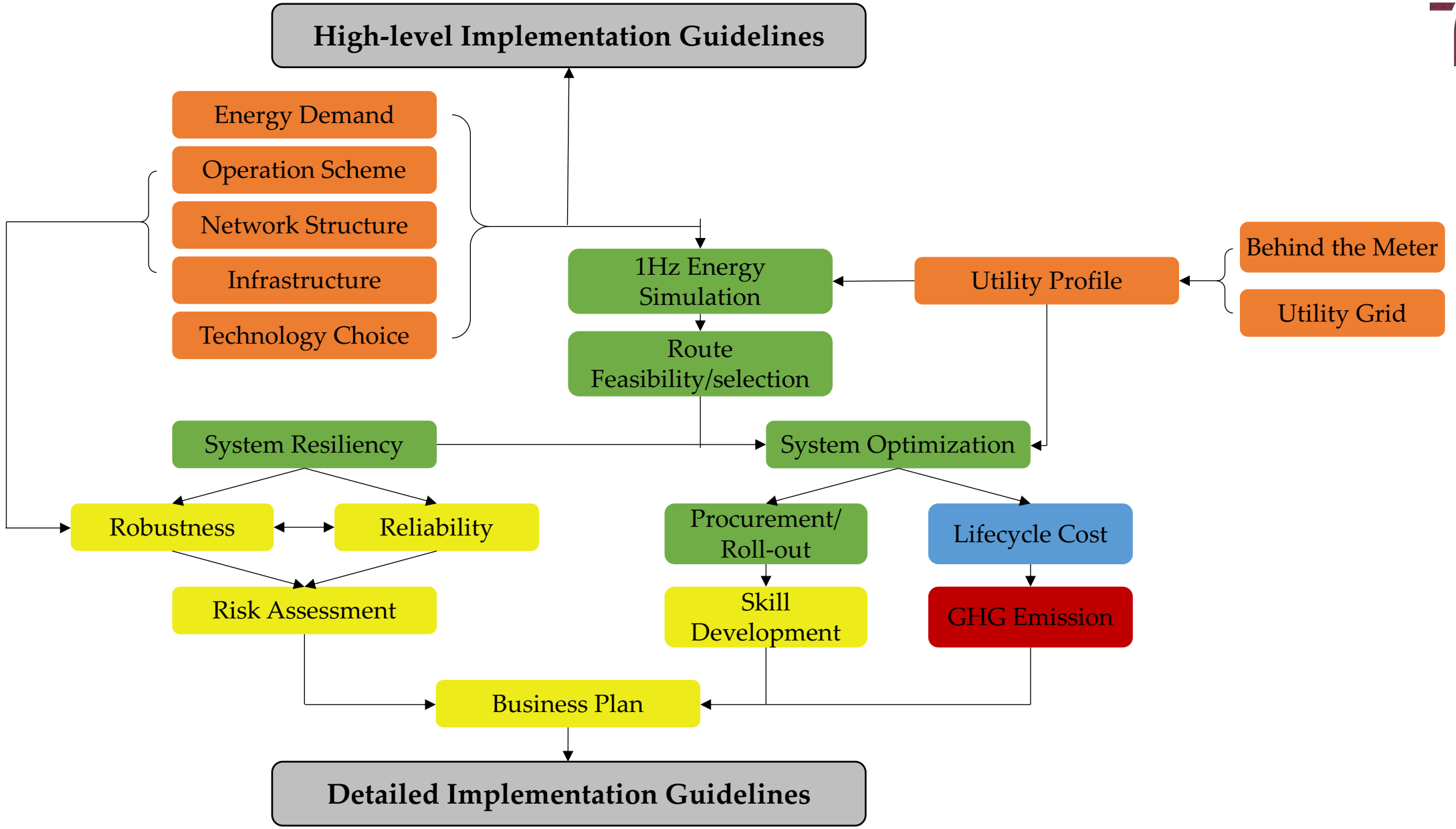
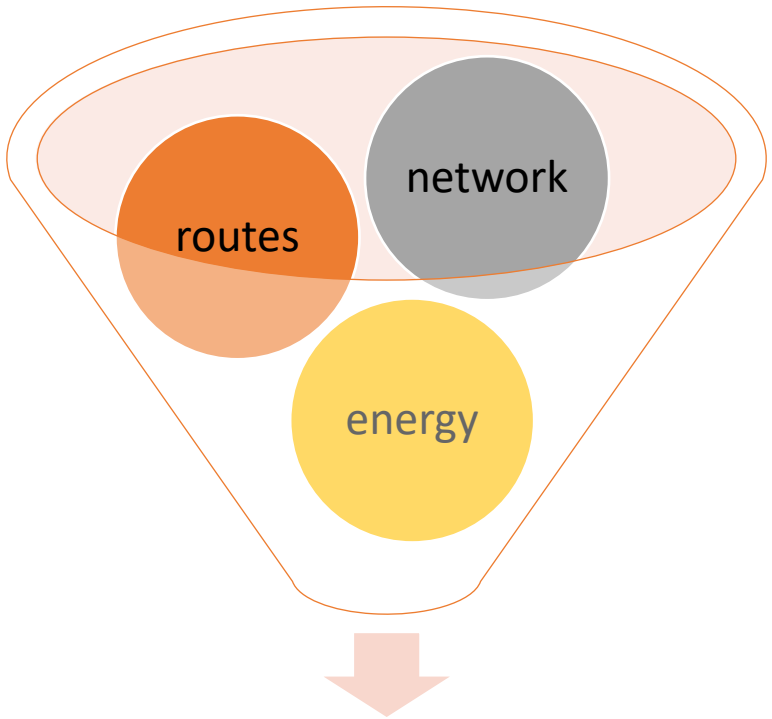
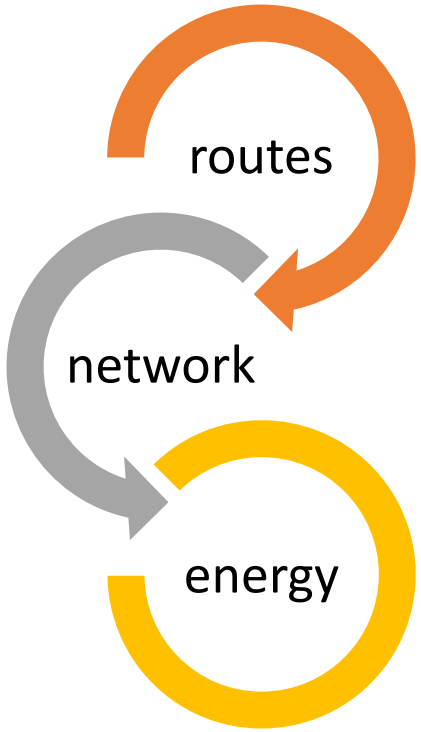

High-level Implementation Guidelines
Energy Demand
Operation Scheme
Network Structure
Infrastructure
Technology Choice
1Hz Energy Simulation
Route Feasibility/selection
Utility Profile
Behind the Meter
Utility Grid
System Resiliency
System Optimization
Robustness
Reliability
Procurement/ Roll-out
Lifecycle Cost
Risk Assessment
Skill Development
GHG Emission
Business Plan
Detailed Implementation Guidelines
System-Level Planning
Operational Planning
Financial Planning
Capacity Assessment
Environmental Benefits

Concurrent Vs Sequential

All e-Bus implementation stages are concurrent
&
should not be addressed sequentially



e-Bus analytical Activities
Simultaneously



e-Bus analytical Activities
Sequential

Coming soon

Knowledge Series 03

The Perspective of Transit Providers

The missing links to move forward!

hank you

TRiP

Transit Research-Informed Practice

Contact Us

Full report: https://www.researchgate.net/publication/364180204_Zero-Emission-Vehicle_Awareness_Initiative_ZEVAI_Knowledge_Series_02_ZEV_Transit_System_Planning_Guidelines