What Hinders the Adoption of Battery Electric Buses in Transit:
A Techno-Economic Analysis

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McMaster University
The Social Costs and Benefits of Electric Mobility in Canada

- Consumer
- Fleet
- Transit
- Geographic
- Environment
- Infrastructure
- Economic
- Integration
Bus Transit In Canada

2014 Canadian Transit Fleet Size

- Over 300
- 100-300
- 50-99
- < 50

- Group 1 ( > 2,000,000)
- Group 2 (400,001 - 2,000,000)
- Group 3 (150,001 - 400,000)
- Group 4 (50,000 - 150,000)
- Group 5 ( < 50,000)
RESEARCH FOCUS 1
REVIEW OF ALTERNATIVE POWERTRAINS
Review e-Bus Technology
Mapping e-Bus Technology

- Purchase Price
- Maintenance Cost
- Running cost
- Infrastructure Cost
- Total Cost of Ownership
- WTT GHG Emission
- TTW GHG Emission
- WTW GHG Emission
- WTT Energy Consumption
- TTW Energy Consumption
- WTW Energy Consumption
- Range
- Availability
- Acceleration Time (0-30 Km/h)
- Infrastructure Installation
- Refuelling/Recharging Time

- ICE Diesel
- FCEB Hydrogen - Central NGSR
- BEB - Overnight Electricity - EU mix
- BEB - Opportunity Electricity - EU mix
Research Findings

• Hybrid, CNG and the so-called Clean Diesel will not achieve substantial reductions in GHG emissions

• Battery electric technology should be couple with electricity profile that produces no more than 600 tCO2e/GWh (Canada is 150)

• Electric buses are feasible for operation, despite the high capital cost

The Key question is

What Hinders the Adoption of E-buses in Canadian Transit?
RESEARCH FOCUS 2
WHAT HINDERS THE ADOPTION OF E-BUS?
# Participants

<table>
<thead>
<tr>
<th>Transit Provider</th>
<th>City, Province</th>
<th>Population Served</th>
<th>% of National Ridership</th>
<th>Fleet Size</th>
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<tr>
<td>TTC</td>
<td>Toronto, ON</td>
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Attitude Towards the e-Bus

I would certainly be pushing that the electric bus would be the way that we need to go down the road. But we don’t like to be the guinea pigs with technology.

GRT, Region of Waterloo.

Show me a city that’s done it. Show me their experience, show me their mileage, maintenance history. That’s where we’re going to get the real information.

Metro Transit, Halifax.

The “Guinea Pig” Syndrome

Technology Anxiety

Risk & Safety Concerns

Lack of Canadian operational data
We got a new bus that goes out for 22 hours or so a day. And our range for one of those buses is 400 miles. Just before we get into those electric buses we talked about, we’re not even close.

TTC, Toronto.

I don’t think it will be usable for every service, there’ll be very specific ones... it will take a lot of work to work through the steps of how you select your routes I think.

Calgary Transit, Calgary.
Decision-Making & Fleet Management

We’re very risk-adverse ... when you’re dealing with a large volume of public funds, electric buses really got to be a proven technology and a cost-effective technology I think
Metro Transit, Halifax

We purchase new vehicles to replace old vehicles that were built in the early 80s. Environmentally it made more sense to replace more of those with new clean diesel than replacing a smaller number with a hybrid that was only marginally more fuel efficient”
Winnipeg transit, Winnipeg.
Developing A Business Case

“...Well typically I think it would come top-down... doing those things in isolation don’t really help, you know? …There needs to be something on a more... on a higher level I think Calgary Transit, Calgary.

There’s nothing like having a successful operation over a period of time that yields positive benefits to have other people want to jump on. There needs to be targeted efforts at a controlled number of locations to make the changes necessary for this to, really work. Winnipeg Transit, Winnipeg.”
Service Providers Perspective

- Attitude towards E-bus
- Operational Feasibility
- Decision making process

Risk

Oper.

Cost
A Framework for Bus Transit Electrification

R&D and Standardization

Political Support (Finance & Regulations)

Demonstrations (Full Network)

Canadian Databanks

Proposed Interventions

Expected Influences

Themes

Categories

McMaster University
Civil Engineering

Transportation & Logistics
So what?
APPLIED RESEARCH
Optimize and Predict Everything

- Feasibility Analysis
- Optimization & Sizing
- Prediction Models
  - Operational Feasibility + Utility Impact Analysis
  - System Optimization + Component Sizing
  - Prediction Toolkits
RESEARCH FOCUS 3

OPERATIONAL FEASIBILITY AND UTILITY IMPACT
Simulation Model

Operation Constraints

• Fixed fleet size
• Satisfy timetable
• Minimum number of chargers
• Using currently available technology
Simulation of Belleville Transit
Charging Profile
e-Bus Energy Demand

Scenario 1-B: Flash Electric (5*250kw) chargers

Scenario 1-A: Flash Electric (3*500kw) chargers

Scenario 2-A: Opportunity Electric (5*250kw) chargers

Scenario 3-A: Overnight Electric (3*80kw) chargers

Scenario 3-B: Overnight Electric (2*200kw) chargers
e-Bus Utility Impacts

1-A: Flash Electric (3*500kw) chargers

2-A: Opportunity Electric (5*250kw) chargers

3-B: Overnight Electric (2*200kw) chargers
Research Findings

• Predominantly, energy demand and the charging behavior of each BEB configuration were very distinct.

• Overall, flash electric bus coupled with fast-charging technology is shown to offer superior operation compared to other configurations.

• From utility perspective, operating flash and opportunity electric buses require a service transformer of a size 5–6 times that required from overnight operation.

• **Taken together, operational feasibility simulation and grid impact models generate contradictory recommendations.**

• This outcome in itself is significant, as it highlights the need to consider both operational constraints and grid impacts simultaneously
RESEARCH FOCUS 4
OPTIMAL SIZING AND SYSTEM CONFIGURATION
Optimization of e-Bus System Configuration
Sizing e-Bus Components

![diagram showing e-buses charging profile and regular load profile. The graph compares the power (MV/A) across daily hours (h). The lower graph illustrates the battery size (kWh) in relation to charger size (kW) for different values of Nch: Nch=3, Nch=4, Nch=5, and Nch ≥ 6. The maximum available size in the market is marked, as well as the minimum available size in the market.]

McMaster University
Civil Engineering

McMaster Institute for Transportation & Logistics
The Impact of Route Topology

(a) Battery Capacity (kWh) vs. Charger Size (kW)

(b) Battery Capacity (kWh) vs. Charger Size (kW)
CLOSING REMARKS!
What we have learned?

• A mix of overnight and on-route e-Buses is required, yet it might hinder the operational flexibility.

• e-Bus operation is very sensitive to context; different operational approaches are recommended for fixed-route vs interlining operation.

• Bus barn upgrade is expected especially for the overnight e-Bus due to its weight.

• The guinea pig syndrome is a significant hurdle, incentives should be offered to mitigate this syndrome.
What we have learned? Utility Vs. Operation

• Predominantly, energy demand and the charging behavior of each e-Bus configuration are very distinct.

• Overall, the on-route electric bus coupled with fast-charging technology is shown to offer superior operation compared to other configurations.
What we have learned? Utility Vs. Operation

• From a utility perspective, operating on-route e-buses require a service transformer of a size 5–6 times that required from the overnight operation.

• Taken together, operational feasibility simulation and grid impact models generate contradictory recommendations.

• This outcome in itself is significant, as it highlights the need to consider both operational constraints and utility impact simultaneously.
Thank You!

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