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

McMASTER INSTITUTE FOR
TRANSPORTATION
& LOGISTICS

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The Social Costs and Benefits of Electric Mobility in Canada

Infrastructure

Consumer

Environment

Transit

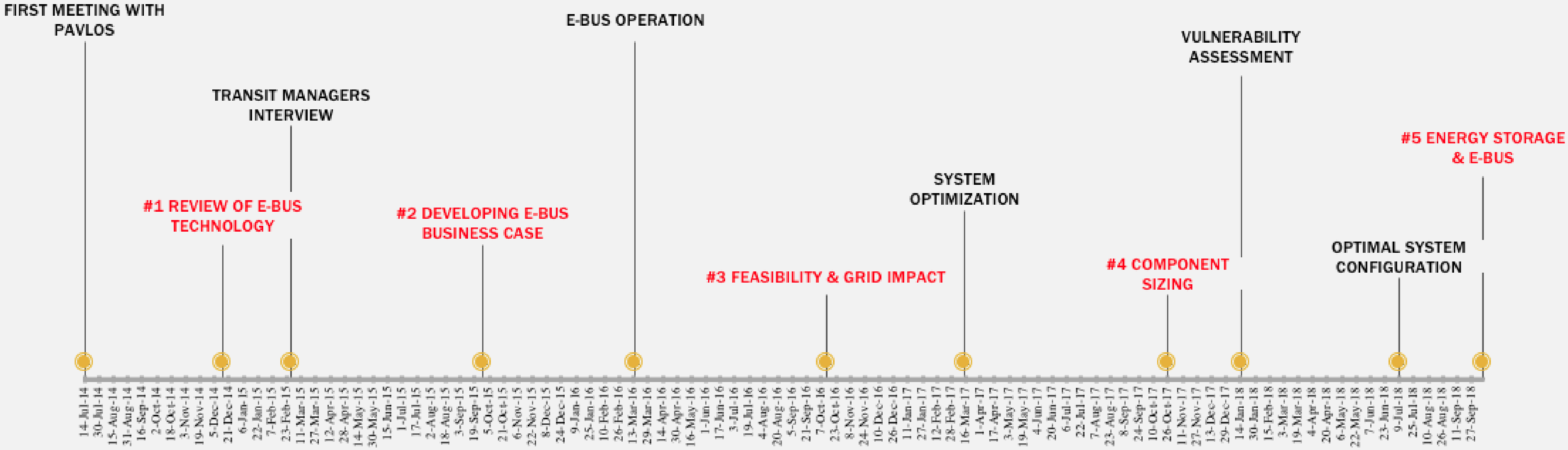
Fleet

Economic

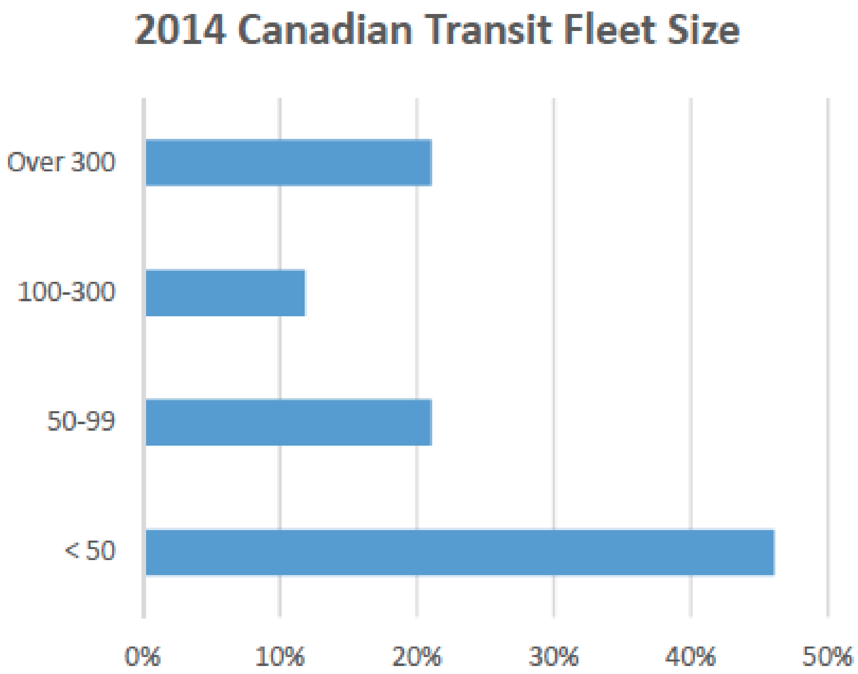
Geographic

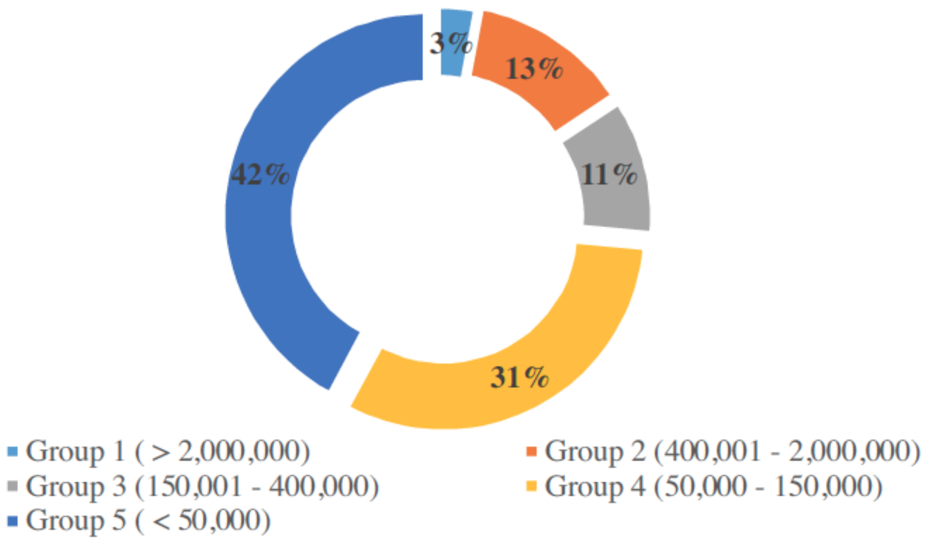
Integration

Timeline


FIRST MEETING WITH PAVLOS
#1 REVIEW OF E-BUS TECHNOLOGY
TRANSIT MANAGERS INTERVIEW
#2 DEVELOPING E-BUS BUSINESS CASE
E-BUS OPERATION
#3 FEASIBILITY & GRID IMPACT
SYSTEM OPTIMIZATION
#4 COMPONENT SIZING
VULNERABILITY ASSESSMENT
OPTIMAL SYSTEM CONFIGURATION
#5 ENERGY STORAGE & E-BUS

Bus Transit In Canada

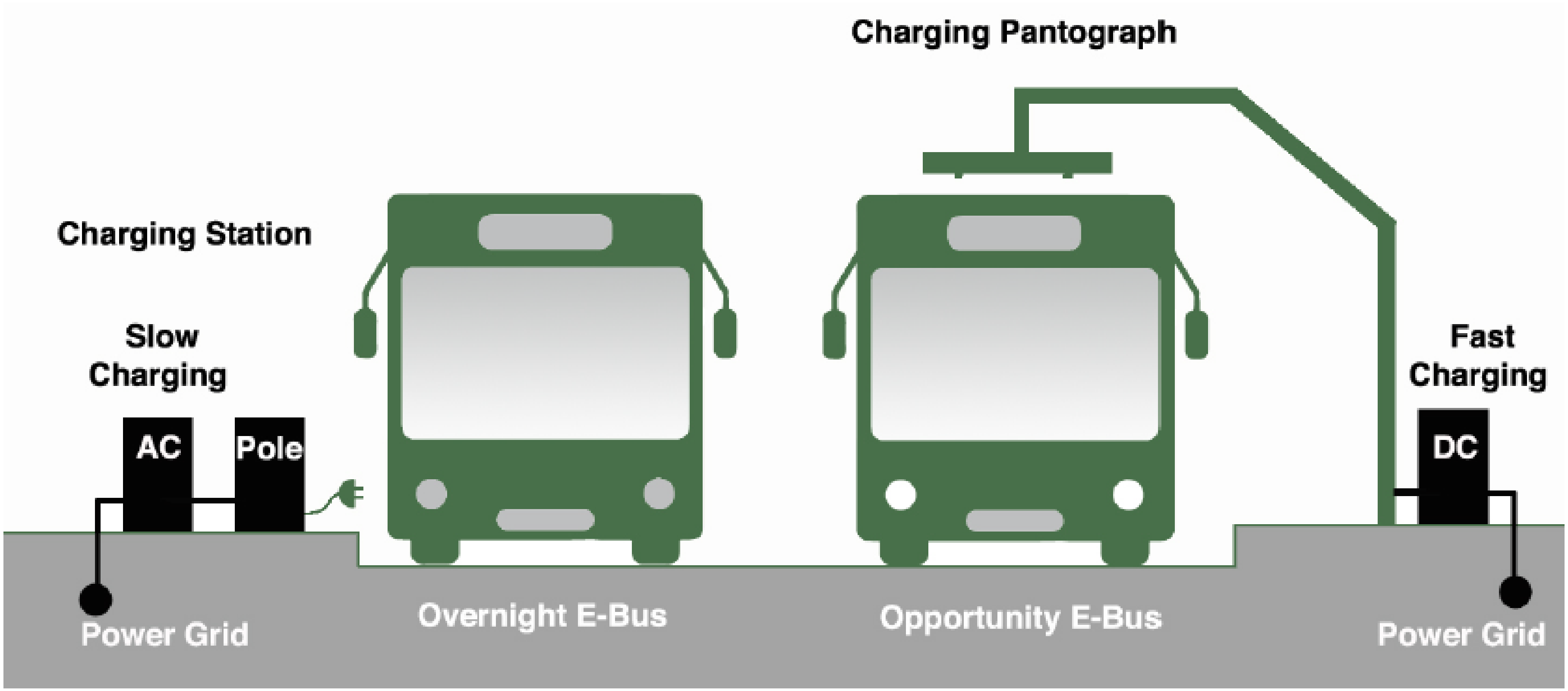




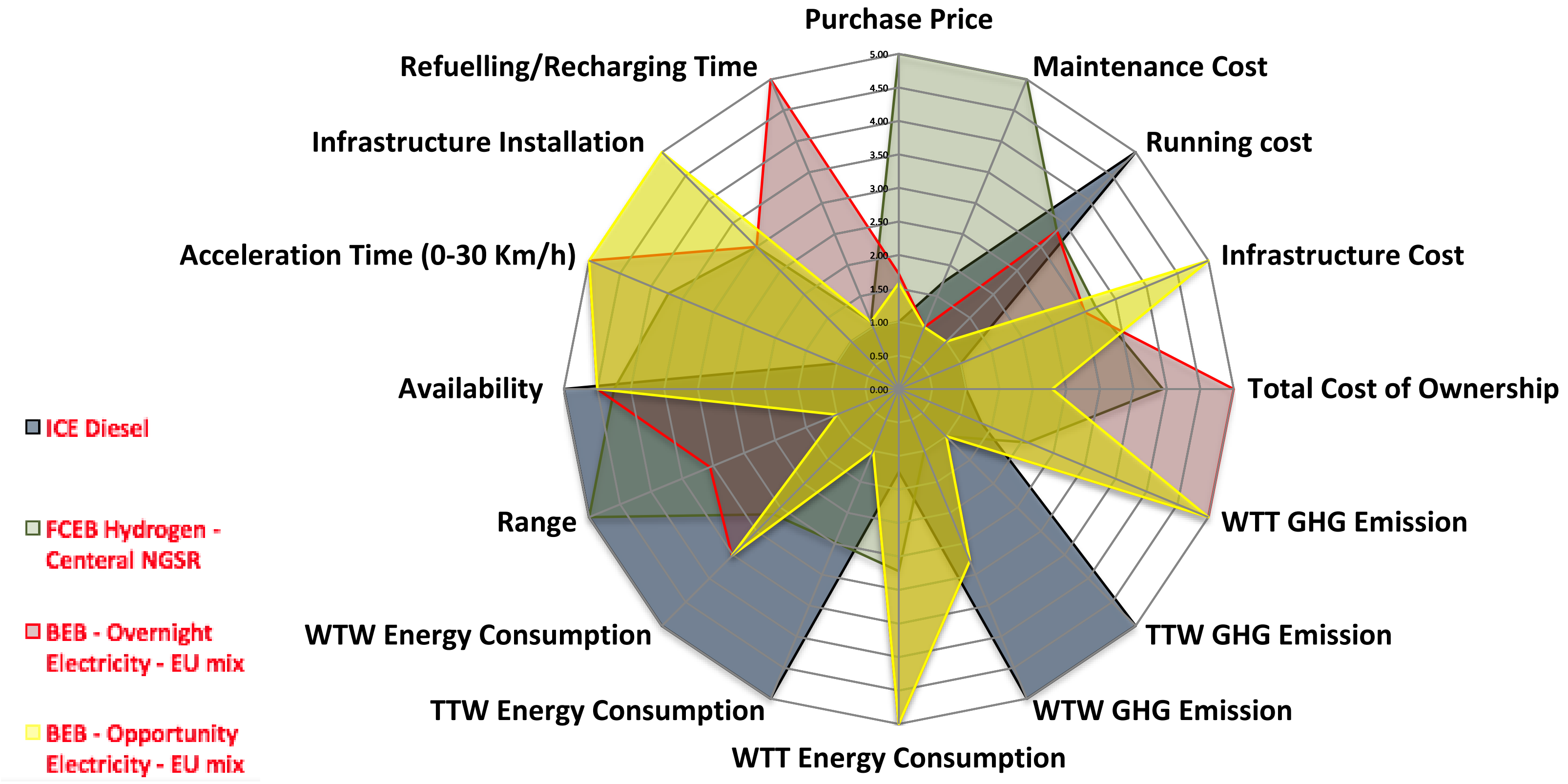
Research Focus 1

Review of Alternative Powertrains

Review e-Bus Technology



Mapping e-Bus Technology



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

Transit Provider	City, Province	Population Served	% of National Ridership	Fleet Size
TTC	Toronto, ON	2,808,503	26.40%	1,869
HSR	Hamilton, ON	490,000	1.10%	221
Windsor Transit	Windsor, ON	210,891	0.31%	112
GRT	Region of Waterloo, ON	434,437	1.07%	235
Metro Transit	Halifax, NS	308,084	0.95%	312
Kings Transit	Kentville, NS	42,500	0.02%	14
Fredericton Transit	Fredericton, NB	50,000	0.08%	27
Winnipeg Transit	Winnipeg, MB	675,300	2.46%	583
Calgary Transit	Calgary, AB	1,195,194	5.44%	1,053
OC Transpo	Ottawa, ON	857,890	4.79%	936
STM	Montreal, QC	1,959,987	20.56%	1,729

Attitude Towards the e-Bus

The "Guinea Pig" Syndrome

Technology Anxiety

"*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.

Risk & Safety Concerns

Lack of Canadian operational data

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."

Operational Feasibility

Availability

Total Cost of Ownership

Human Resources

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.

Network Optimization

Technology Choice

Standardization

Decision-Making & Fleet Management

Risk Averse DM

The U.S Market Influence

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

Replacement First

Procurement Process

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

Top-down Approach

Canadian Full-network databank

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.

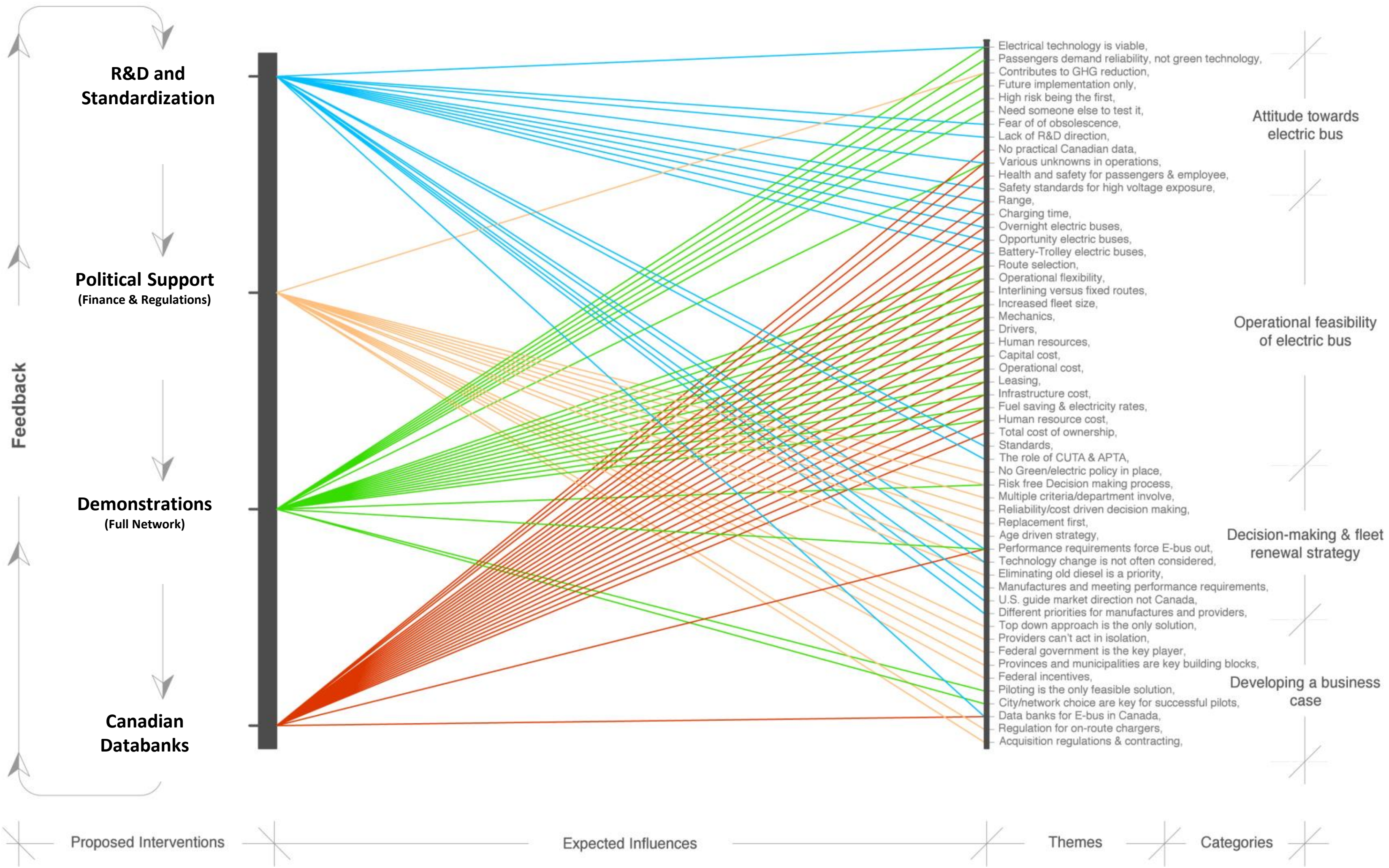
Political Intervention

Regulatory Environment

Service Providers Perspective

	Attitude towards E-bus	Operational Feasibility	Decision making process
Risk			
Oper.			
Cost			

A Framework for Bus Transit Electrification



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

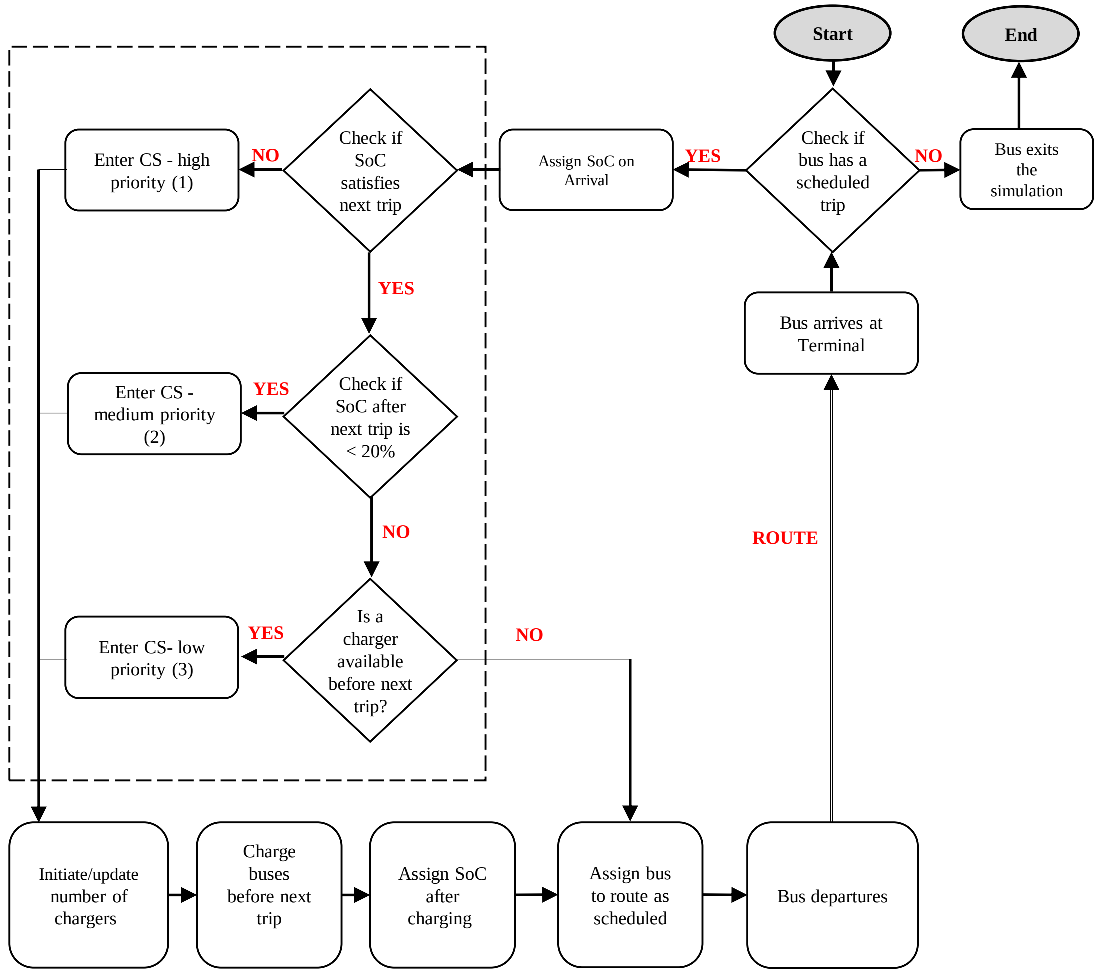
Research Focus 3

Operational Feasibility and Utility Impact

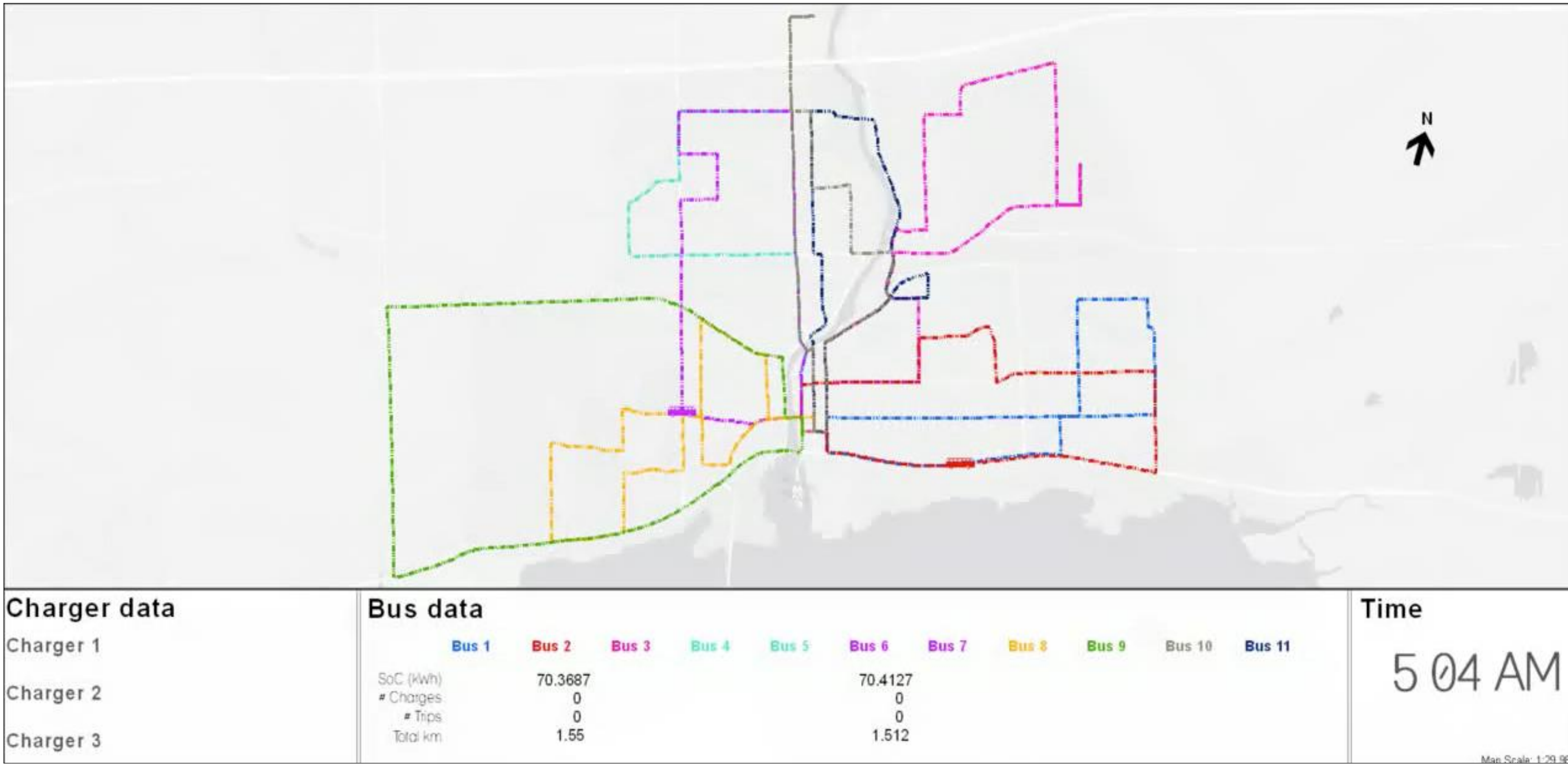
Simulation Model

Operation Constraints

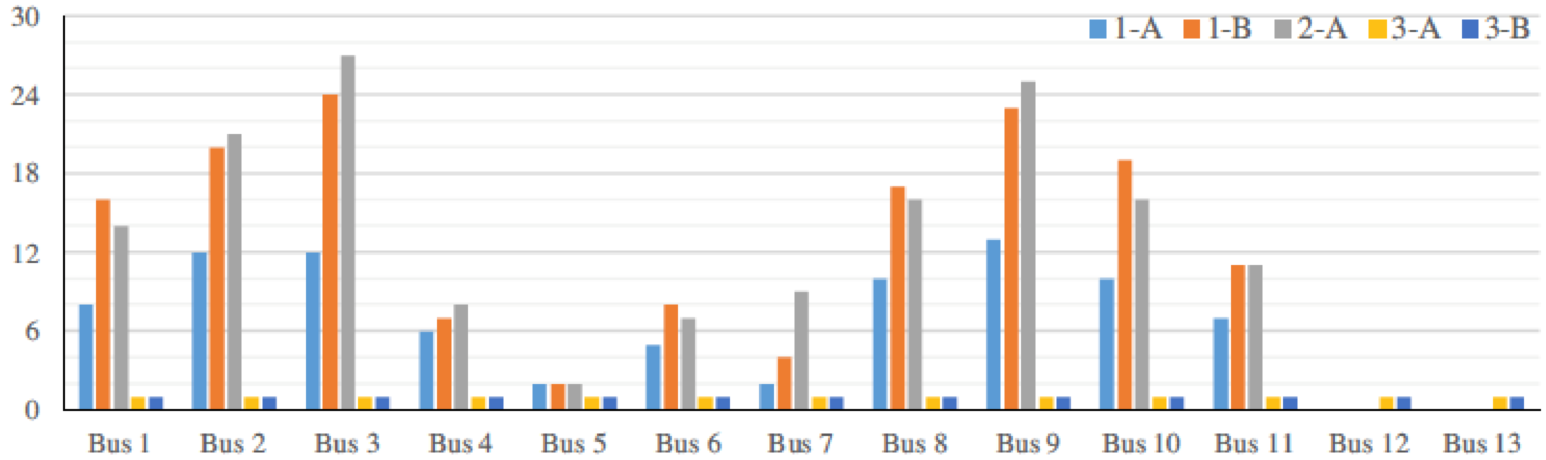
- Fixed fleet size
- Satisfy timetable
- Minimum number of chargers
- Using currently available technology

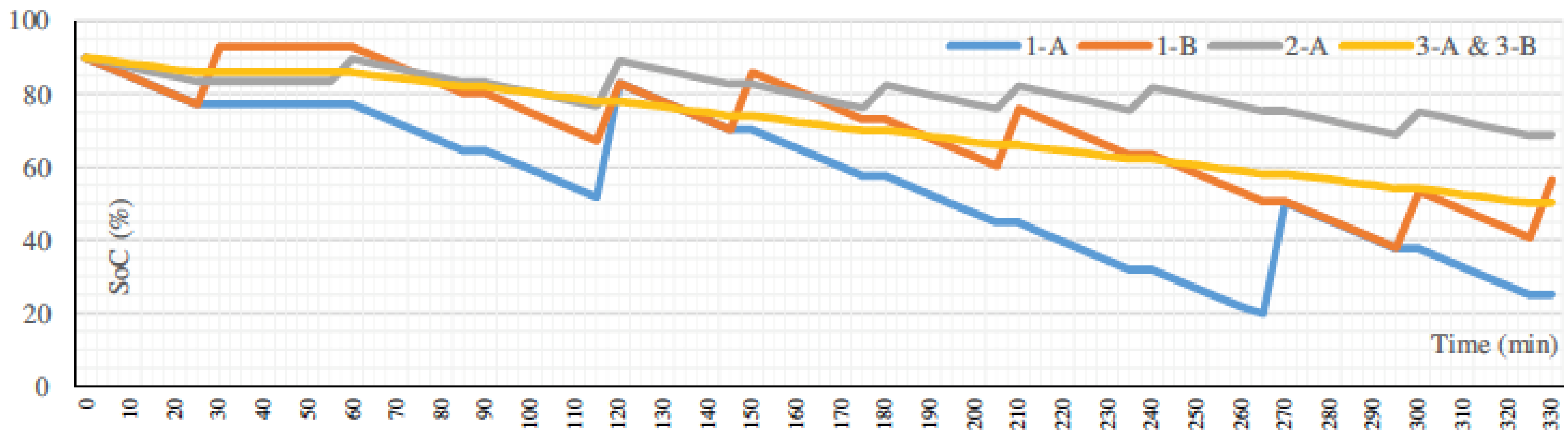


Simulation of Belleville Transit

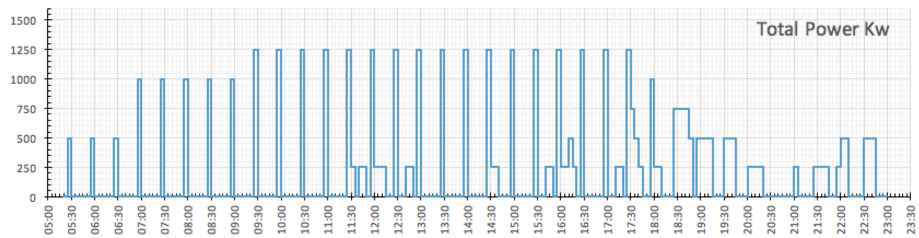


Charging Profile

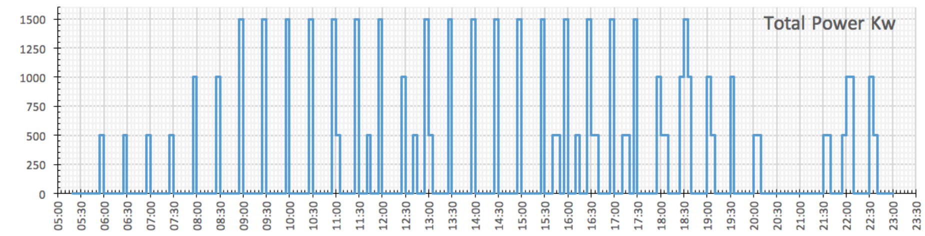




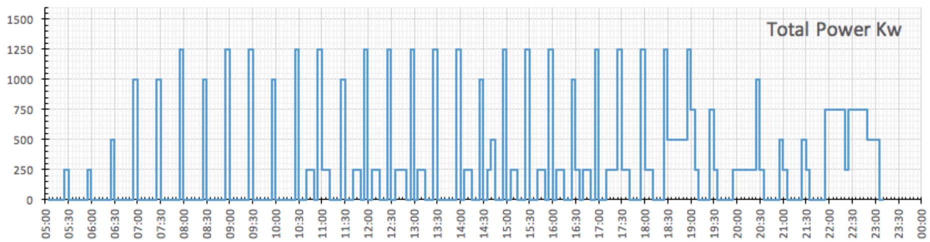
e-Bus Energy Demand



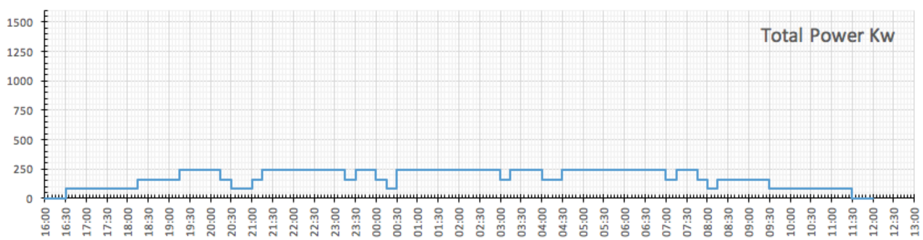
*Scenario 1-B: Flash Electric (5*250kw) chargers*



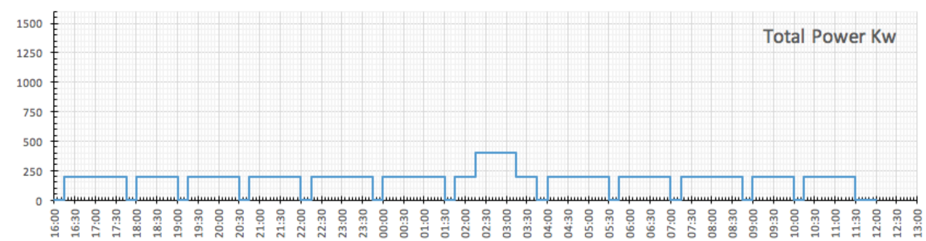
*Scenario 1-A: Flash Electric (3*500kw) chargers*



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

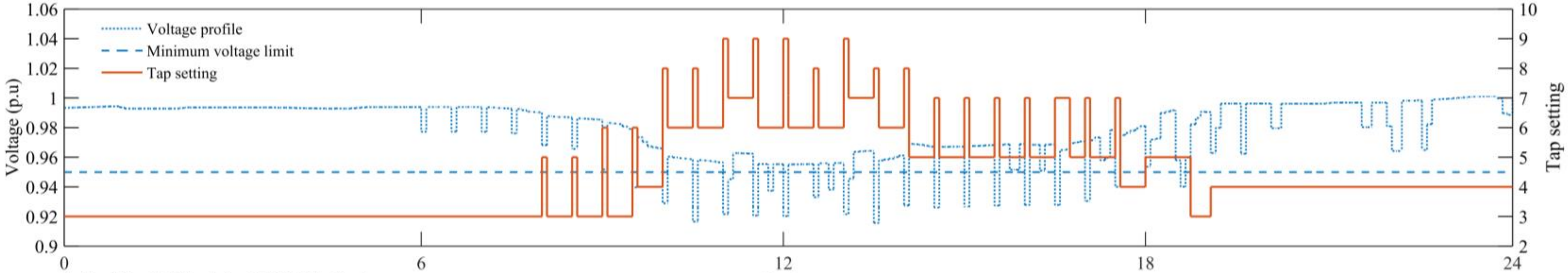


*Scenario 3-A: Overnight Electric (3*80kw) chargers*

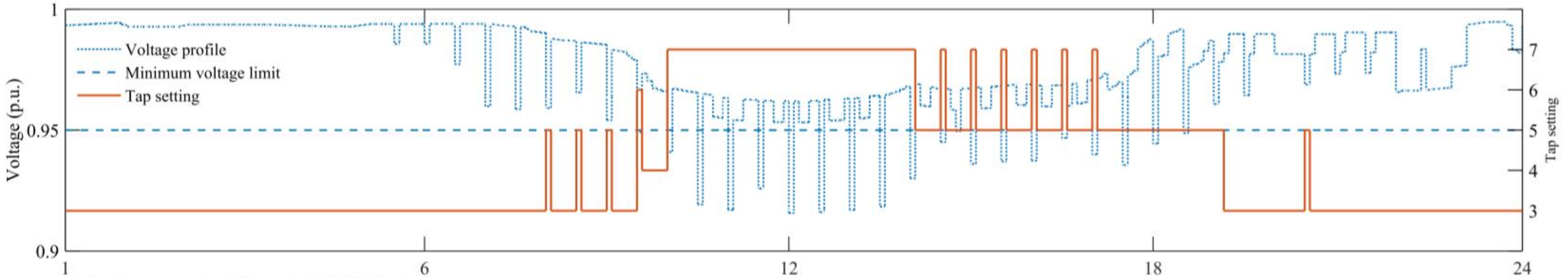


*Scenario 3-B: Overnight Electric (2*200kw) chargers*

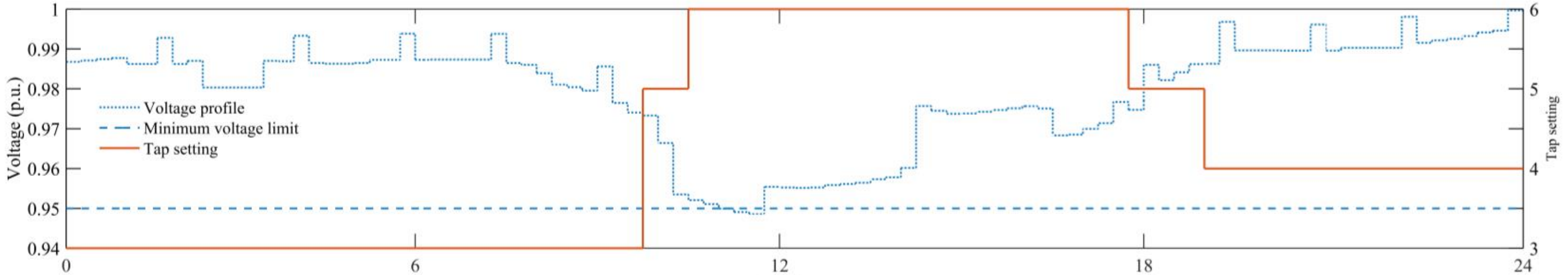
e-Bus Utility Impacts



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



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



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

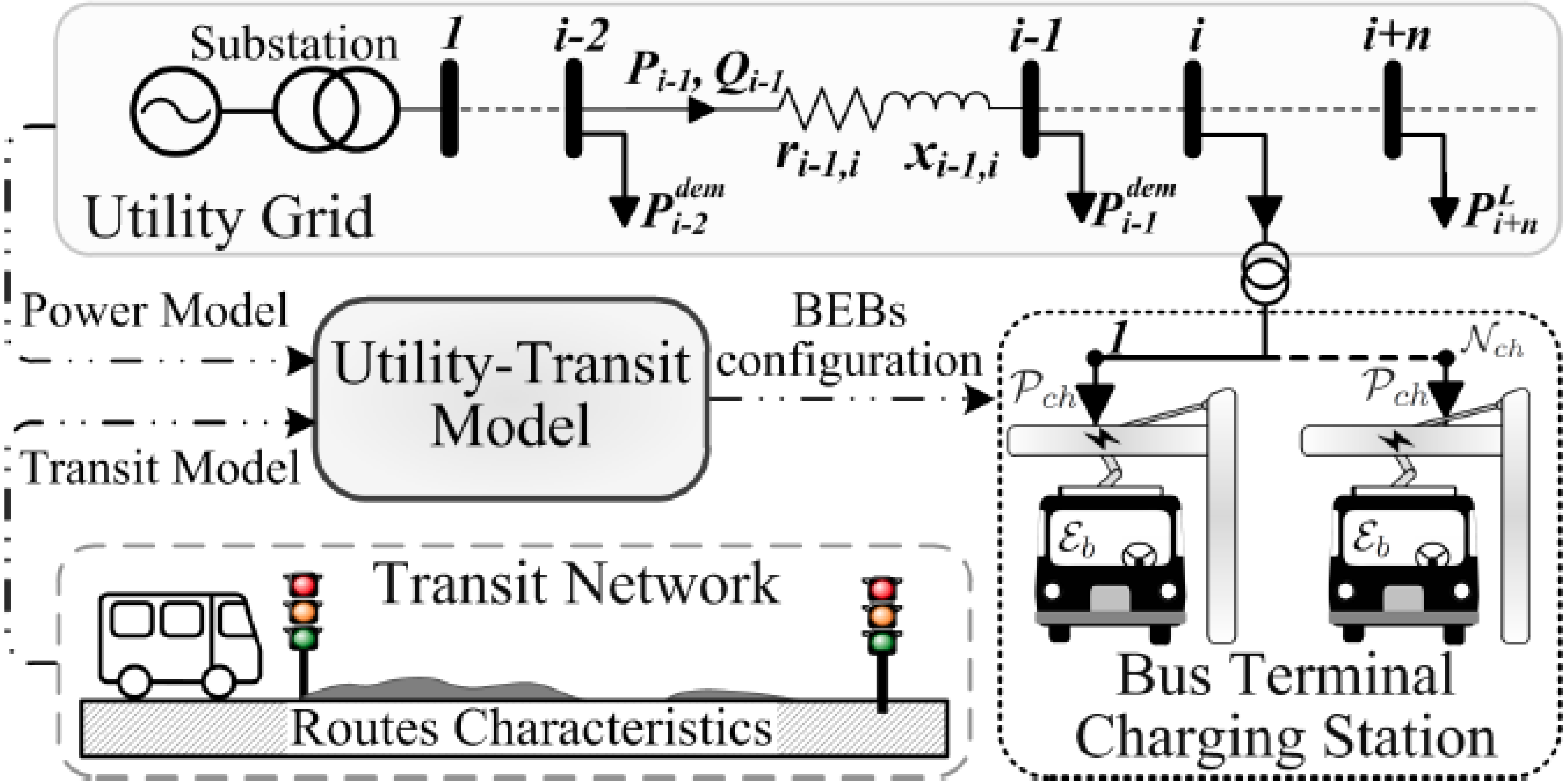
Research Findings

- 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

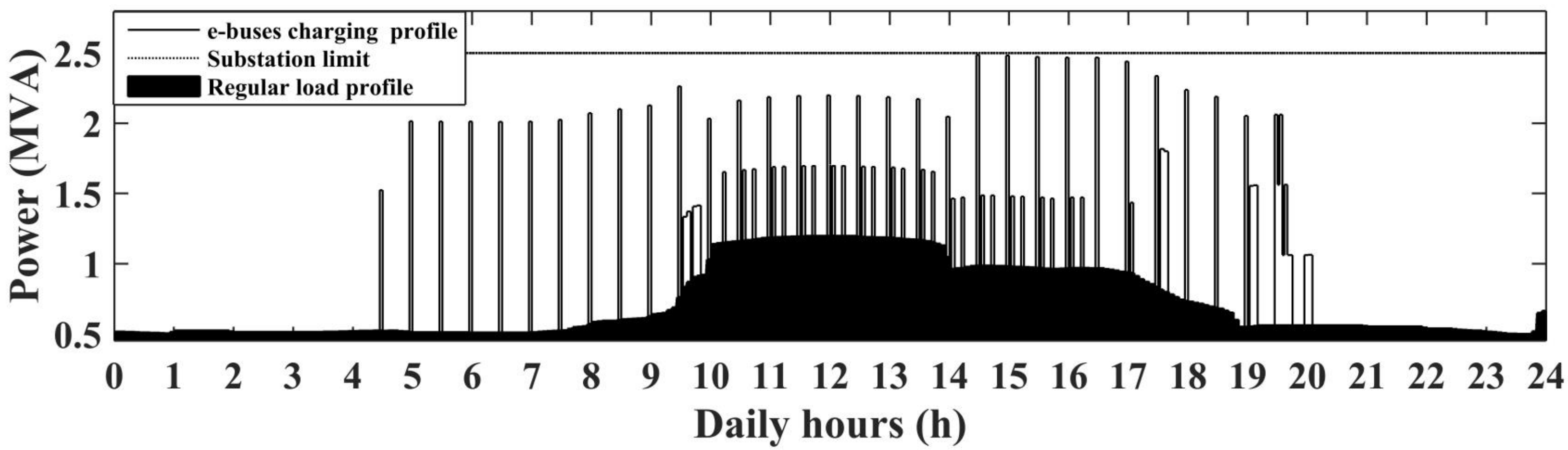
Research Focus 4

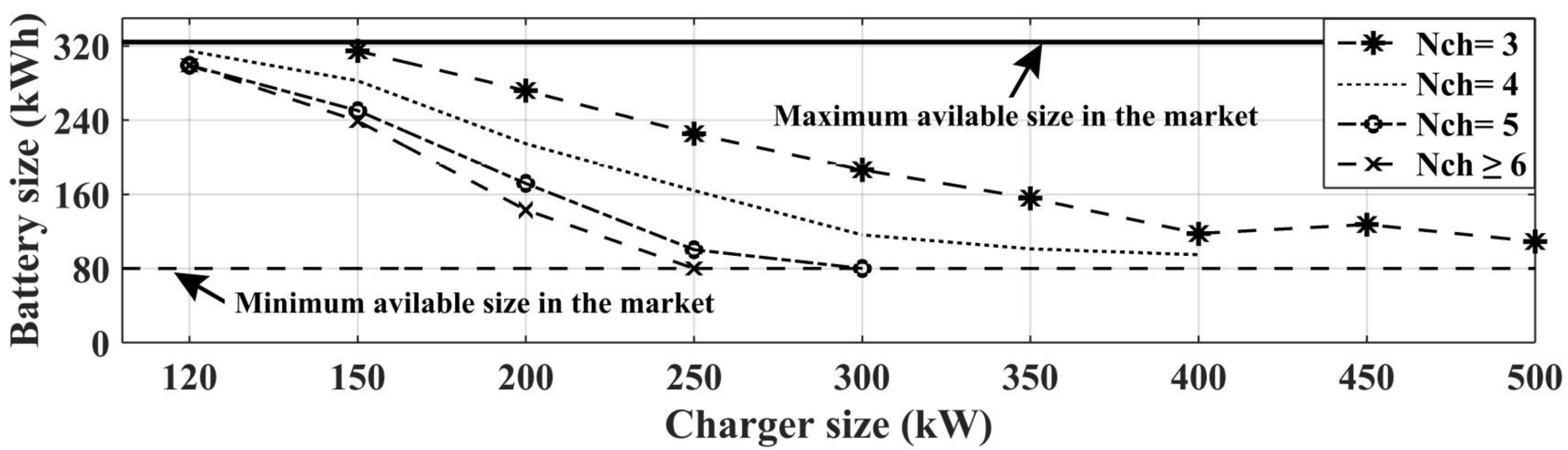
Optimal Sizing and System Configuration

Optimization of e-Bus System Configuration



Sizing e-Bus Components





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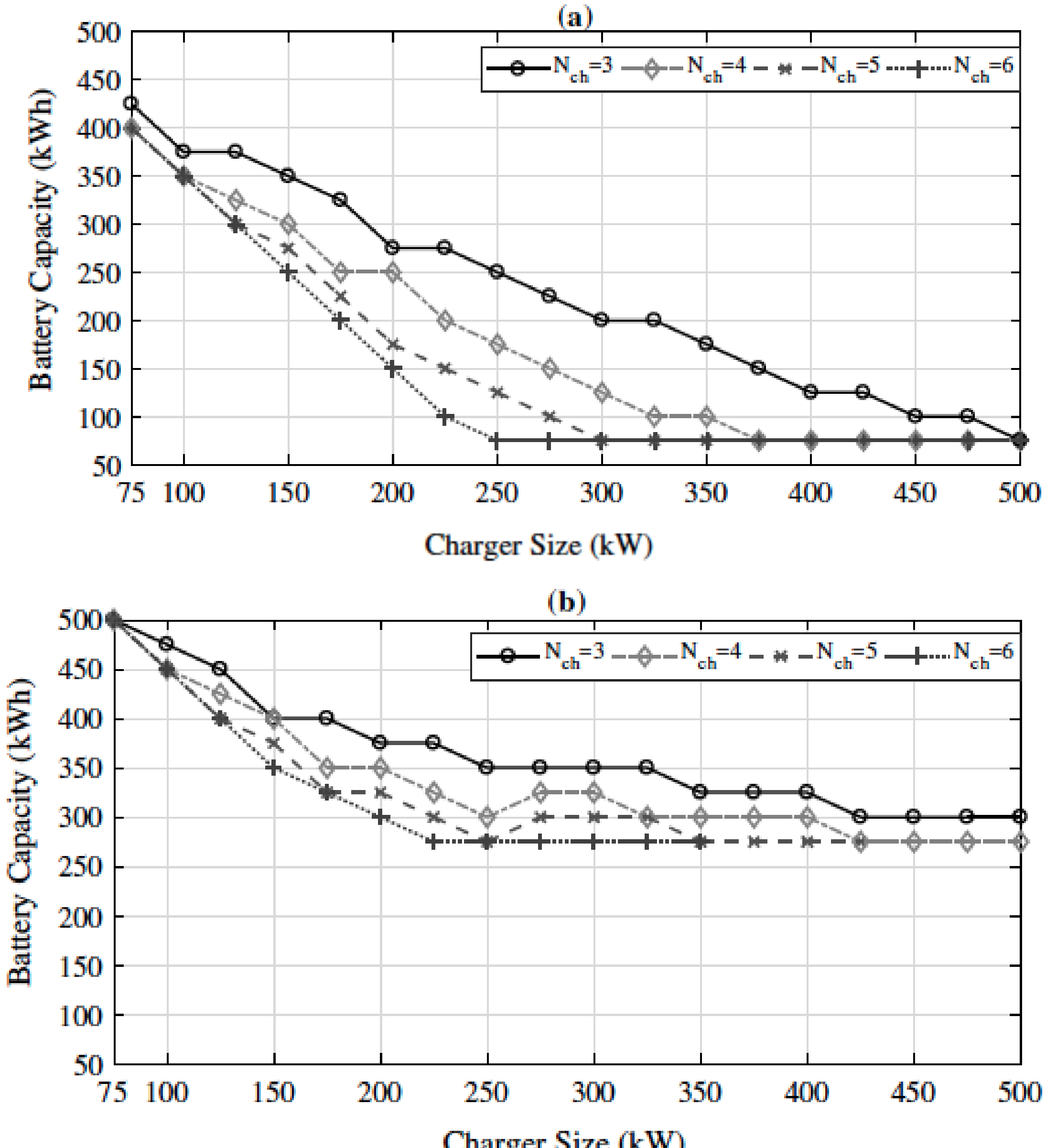
Research Focus 5

Uncertainty Analysis

The Impact of Route Topology



Closing Remarks!

What we have learned?

- A **<u>mix</u>** of overnight and on-route e-Buses **<u>is required</u>**, 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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