Calgary Electric Bus Pilot Project

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Introduction and Background

Calgary Transit is launching a pilot project in Fall 2022 to implement the usage of 14 electric shuttle buses around the City of Calgary. These electric shuttle buses will be based out of Spring Gardens garage located at 928 32 Ave NE. The design of our project was focused on developing block schedules for these 14 electric shuttle buses while also minimizing cost and GHG emissions.

[1]

[2]

The focus on GHG emissions was based on the City of Calgary's interest in exploring opportunities to reduce greenhouse gas emissions as part of the green fleet initiative. Cost is always a concern for public projects such as this. The second piece of criteria our group selected for our design was minimizing costs, addressing this concern of stakeholders.

REFERENCES

[1] http://www.busdrawings.com/Transit/alberta/calgary/shuttle/arboc/1835-1844/index.htm

[2] https://vicinitymotorcorp.com/modelsm/vicinity-lightning-ev.html

Design Criteria Options

Our group choose between 3 design options in the fall using the following decision matrix. All design options sought to minimize GHG emission as well as minimize costs (Design 1), maximize ridership (Design 2), and target specific demographics (Design 3)

Factor	Weight	Design #1	Design #2	Design #3
Group Interest (Ease of analysis, Data required)	2	3	2	1
Importance to Stakeholders (Sustainability)	3	3	1	2
Uncertainty	1	2	1	3
Innovation	2	1	2	3
Overall Ranking		19	12	17

Design Considerations

- Comparison of electric shuttle buses to gasoline shuttle buses
- Buses departing from and returning to spring gardens
- Buses cannot charge en route
- Electric heaters
- Range of buses is considerably different in summer vs. winter

GHG Summary Table

The total % change in GHG emissions was -28.79%

Block Name	Electricity Used Per km by One Bus (kWh/km)	Emissions Intensity of bus (kg CO2 eq/km)	Percent Change in GHG Emissions
Summer Saturday	0.9438	0.5191	-51.24%
Summer Sunday	0.9828	0.5405	-49.22%
Summer Weekday	1.0186	0.5602	-72.87%
Winter Saturday	3.1046	1.7076	60.41%
Winter Sunday	2.8905	1.5898	49.34%
Winter Weekday	3.2376	1.7807	67.27%

RESULTS/ANALYSIS

Cost Model

Our final design minimized the cost of implementing the new buses. Cost comparison formulas to compare the cost electric and gasoline shuttle buses were developed.

Gasoline Shuttle Bus

Cost = Operational Cost + Capital Cost

$$Cost = \frac{\$75}{hr}(x) + \frac{\$4.52}{hr}(x)$$

Electric Shuttle Bus

Cost = Labor and BOH support + Maintenance + Fuel + Cleaning and Storage + Capital Cost

Summer

$$Cost = 0.7x\left(\frac{\$75}{hr}\right) + 0.6y\left(\frac{\$0.30}{km}\right) + \left(\frac{\$11}{kWh}\right)\left(\frac{0.86kWh}{km}\right)y + 0.04x\left(\frac{\$75}{hr}\right) + \left(\frac{\$15.9}{hr}\right)x$$

Winter

$$Cost = 0.7x\left(\frac{\$75}{hr}\right) + 0.6y\left(\frac{\$0.30}{km}\right) + \left(\frac{\$11}{kWh}\right)\left(\frac{2.76kWh}{km}\right)y + 0.04x\left(\frac{\$75}{hr}\right) + \left(\frac{\$35.8}{hr}\right)x$$

Where: x= duration of block (hr), y= distance of block (km)

Range Validation

Overestimation of the range of electric vehicles is a common problem. To address this, we created a range model to validate the bus range in both summer and winter.

	Ambient Temperature (°C)						
Speed (km/hr)	-12	-7	-1	4	10	16	21
20	95.29	102.26	110.78	116.98	126.27	306.25	306.25
30	84.17	90.33	97.86	103.34	111.55	233.33	233.33
40	77.17	82.82	89.72	94.74	102.27	196.88	196.88
50	72.36	77.66	84.13	88.83	95.89	175.00	175.00
60	68.85	73.88	80.04	84.52	91.24	160.42	160.42
70	66.17	71.01	76.93	81.23	87.69	150.00	150.00
80	64.06	68.75	74.48	78.64	84.89	142.19	142.19
90	62.36	66.92	72.50	76.55	82.64	136.11	136.11
100	60.95	65.41	70.87	74.83	80.78	131.25	131.25

GHG Analysis

Public transportation use is one of the most effective actions individuals can take to reduce their GHG emissions footprint. A sensitivity analysis was conducted based on the projected GHG intensity of Alberta's electric grid.

		Gasoline Shuttle			Electric Shuttle				
Year	km/year	L/100 km	kg CO2 eq/L	kg CO2 eq/year	kWh/km	kWh	kg CO2 eq/kWh	kg CO2 eq/year	% GHG Reduction
2021	49,950	45	2.365	53,173	1.05	52,447.5	0.63	32,990	37.96%
2022	49,950	45	2.365	53,173	1.05	52,447.5	0.55	28,818	45.80%
2023	49,950	45	2.365	53,173	1.05	52,447.5	0.51	26,905	49.40%
2024	49,950	45	2.365	53,173	1.05	52,447.5	0.47	24,898	53.18%
...	...	...	...	...	...	...	...	...	...
2035	49,950	45	2.3656	53,173	1.05	52,447.5	0.27	14,048	73.58%

Final Block Schedule

Seen below is an example of one block schedule designed by our group (Summer – Sunday). It shows when the buses run, the routes taken, and the distance travelled for each bus in a day.

Bus #	Block	Route	Distance (Km)	Start	End
1	17 - 91	17	194.336	6:25	19:03
2	17 - 92	17	194.336	7:10	19:48
3	30 - 91	30	224.948	7:17	19:02
4	40 - 93	40	236.396	7:55	19:02
5	404 - 91	404	202.003	6:40	18:48
6	411 - 91	411	177.731	8:47	18:57
7	414 - 91	414	200.96	8:39	19:25
8	502 - 91	502	187.714	7:42	19:02
9	302 - 92 A	302	228.444	5:07	14:18
10	302 - 92 B	302	226.05	13:51	22:58
11	114 - 91 A	86, 114	229.66	5:05	14:57
12	114 - 91 B	86, 114	232.412	14:20	0:28
13	114 - 92 A	86, 114	222.965	5:17	14:58
14	114 - 92 B	86, 114	233.603	14:25	0:40

Cost Summary Table

Block Name	Days	Cost Difference/Day	Cost Difference
Summer Weekday	141	$(276.32)	$(38,960.91)
Summer Saturday	29	$52.41	$1,519.91
Summer Sunday	28	$(258.16)	$(7,228.45)
Winter Weekday	119	$1,403.80	$167,051.83
Winter Saturday	24	$1,787.65	$42,903.62
Winter Sunday	24	$1,655.73	$39,737.42
Yearly Total	365		**$205,023.42**

Recommendations and Conclusion

We have developed block schedules for both winter and summer. Weekdays and weekends each have their own feasible block schedule based on seasonal ranges, minimizing GHG emissions and cost. We have developed 6 block schedules (3 for winter, 3 for summer). Our primary recommendation would be to not use electric heaters since they considerately reduced the range of the electric buses.