GOING ELECTRIC

Comparing Operational Performance of Electric, Hybrid, and Diesel Buses in Portland, OR, USA

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INTRODUCTION

- Electrification of public transport has the potential to decrease the amount of greenhouse gas (GHG) emissions from the sector.
- Electric buses are considered to be less flexible when compared to diesel counterparts due to their limited range and relatively long charging periods.
- Is there a difference in running time between electric, hybrid, and diesel buses, and what are the operational factors that influence the distance an electric bus can travel after regular maintenance before a breakdown takes place?

METHODS

- Used a linear regression for the running time model.
- Estimated a multilevel regression for the distance traveled until breakdown after a regular maintenance model.
- Data:
  - Automatic vehicle location (AVL) and automatic passenger counts (APC) data from TriMet – a regional transit provider in Portland, OR, covering the period from September 5th, 2021, to June 6th, 2022;
  - Historical information on the failures graded as road calls per the National Transit Database from TriMet's vehicle failure records.
- The analysis focused on the 4 TriMet Routes in the region – 6, 8, 20, and 62 that operated electric buses.

Running Time Model Dependent Variable

Time between the departure from the first stop until the arrival at the last stop on the same route (seconds)

Distance Traveled Until Breakdown Model Dependent Variable

The distance a bus traveled after a regular maintenance until breakdown (miles)

ANALYSIS/RESULTS

Study Area

Geography of the studied region and the routes with electric buses

Running Time Model

Variable	Estimate	99% CI	t-stat
Constant	5055***	5022.73, 5087.15	404.19
Stops per trip	29.16***	28.19, 30.13	77.54
Average load	-59.61***	-64.06, -55.15	-34.44
Average load ^ 2	1.51***	1.27, 1.76	15.77
Ons+Offs	9.23***	8.66, 9.81	41.42
Ons+Offs ^ 2	-0.02***	-0.03, -0.02	-24.87
Inbound	-102.2***	-108.6, -95.72	-40.86
Operator experience (y)	-1.83***	-3.54, -0.11	-2.75
Operator experience ^ 2 (y)	0.07***	0.01, 0.1	2.86
Ramp deployed	23.23***	20.37, 26.08	20.97
Week schedule	-47.65***	-55.42, -39.88	-15.8
6:30pm-3:00am	Reference		
3:00am-6:30am	-237.5***	-251.53	-43.67
6:30am-9:30am	14.51***	3.86, 25.16	3.51
9:30am-3:00pm	399.8***	389.89, 409.64	104.25
3:00pm-6:30pm	410.4***	399.32, 421.41	95.7

Variable	Estimate	99% CI	t-stat
Route 20	Reference		
Route 6	-2532***	-2548.29, -2515.65	-399.59
Route 8	-2594***	-2611.27, -2577.08	-390.94
Route 62	-2512***	-2534.25, -2489.96	-292.23
Precipitation (inches)	36.33***	24.91, 47.75	8.19
Avg. temperature (°F)	-3.34***	-3.71, -2.96	-23.18
Electric bus	-92.84***	-174.77, -10.91	-2.92
Average temperature*Electric bus	2.62***	1.09, 4.15	4.42
N			115,669
R2/ Adjusted R2			0.94/0.94
F-statistic (21, 115647)/ F signif. (Prob > F)			8 1,540/ 0.00

Note: *p<0.1; **p<0.05; ***p<0.01

Electric buses are running by a minute and a half faster than diesel ones, ceteris paribus

Distance Traveled Until Breakdown Summary

d_{nj} stands for the distance in miles a bus j was planned to travel during the time period n before it broke down and went back to the garage for maintenance.

Variables	All buses		Diesel		Electric		Hybrid	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Distance traveled (miles)	4,590	4,600	4,630	4,618	2,124	2,196	3,512	3,625
Previous breakdowns	2.5	2.4	2.4	2.4	3.1	2.4	3.4	2.7
Maintenance instances	8.7	8.7	8.8	8.7	3.6	3.4	5.7	5.8
Average load	5.5	0.9	5.5	0.9	6	0.8	6.9	0.9
Stops per trip (00s)	57	58.4	57.5	58.7	24.9	25.1	50.4	50.9
Ramp used per 100 stops	2.1	1.2	2.1	1.2	2.1	0.9	2.1	0.5
Average temperature (°F)	49.8	8.4	49.8	8.5	47.6	6.5	48.3	9.3
Number of buses	618		609		7		2	
Breakdowns/Bus	4		4		5.6		7	

Summary statistics for the distance traveled until breakdown after a regular maintenance model

Distance Traveled Until Breakdown Model

Electric buses traveled almost 464 more miles before the breakdown when compared to diesel models. Moreover, every stop made before a breakdown added almost 6 miles to that range of an electric bus, potentially due to the charging during breaks.

Variable	Estimate	99% CI	t-stat
Constant	1,082***	909.16; 1,254.07	10.32
Previous breakdowns	-15.65***	-25.05; -6.24	-2.74
Maintenance instances	49.40***	43.31; 55.48	13.4
Average load	-126***	-151.05; -101.03	-8.29
Stops per trip (00s)	74.88***	73.58; 76.18	95.25
Stops per trip ^ 2 (00s)	-0.02***	-0.02; -0.01	-6.36
Ramp used per 100 stops	-0.02	-11.81; 23.84	0.56
Average temperature (°F)	-7.92***	-10.44; -5.4	-5.19
Hybrid bus	-1,623*	-3,118; -127.68	-1.79
Average temp.* Hybrid bus	31.07*	2.18; 59.93	1.77
Electric bus	463.5*	70.33; 856.19	1.94
Stops per trip*Electric bus	5.88*	0.09; 11.68	1.67
Ramp/Stops*Electric bus	-204.6**	-361.52; -48.09	-2.15

Model Fit	
N	2,453
AIC/BIC/ Log-likelihood	38,661.7/38,760.3/ -19,313.8
Marginal R2/ Conditional R2	0.98/0.99
Random effects (Bus ID): Constant	Variance: 225,347; SD: 474.7
Random effects (Bus ID): Electric Bus	Variance: 225,356; SD: 474.7
Random effects: Residual	Variance: 291,962; SD: 540.3

Note: *p<0.1; **p<0.05; ***p<0.01

Distance traveled until breakdown after a regular maintenance model

CONCLUSION

- Electric buses should be used on short routes with many stops (e.g. feeder toutes, on-demand transit). This deployment employs a positive confluence of two different factors of electric bus operations – short running time will allow fewer vehicles to serve the area, while frequent stops will extend the range of the bus battery.
- Electric buses underwent fewer instances of maintenance which follows the trend observed in previous studies. While this indicates their lower running costs compared to diesel buses, it is evident that electric buses could benefit from more preventive maintenance.
- Transit providers should consider deploying electric buses on routes known to have fewer requests for the deployment of ramps. This can be a temporary solution until the ramp impacts are studied in more depth with mechanical engineers. Alternatively, capital projects at known locations with frequent ramp deployment can be designed for near-level or level boarding in the future.
- Hybrid buses offer a service range similar to diesel ones, but have lower emission levels and are not constrained by the service range as electric buses are. It is recommended that agencies prioritize the use of hybrid buses on long routes, while battery-operated technology increases its capacity.
- It is possible that more frequent preventive maintenance can increase the range before a breakdown for hybrid buses as well.

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