Electrifying the Kyung-Bu highway with OLEV technology

: Economic feasibility of OLEV bus in comparison with BEV and ICE buses

Hongjin Kim, Junghun Jang

College of Business, Korea Advanced Institute of Science of Technology
E-mail: romendacil@business.kaist.ac.kr, bangul58@business.kaist.ac.kr

This paper aims to compare the economic feasibility of transforming the fleet of highway express buses from internal combustion engine buses to electric buses. The electric bus technologies specifically considered are on-line electric vehicle (OLEV) and battery electric vehicle (BEV). Implementation of electric vehicle buses entails three costs: vehicle purchasing, infrastructure installation, and operation cost. Linear programming methods are used to minimize the total costs required for the three technologies. The Kyung-Bu highway is chosen as a test-bed.

Introduction

▶ Objective

Feasibility study of introducing OLEV and BEV bus to the Kyung-Bu highway through comparison between OLEV, BEV, and ICE buses.

▶ Research Question

1. What are the individual **optimal total costs** for OLEV, BEV, and ICE buses?

2. What implications can be taken from comparing the total social costs change when technological progress, economic effects, and political regulations are taken into consideration?

Overview

▶ OLEV

OLEV(On-Line Electric Vehicle) is an electric vehicle using magnetic induction to either power the vehicle motor or to charge battery.

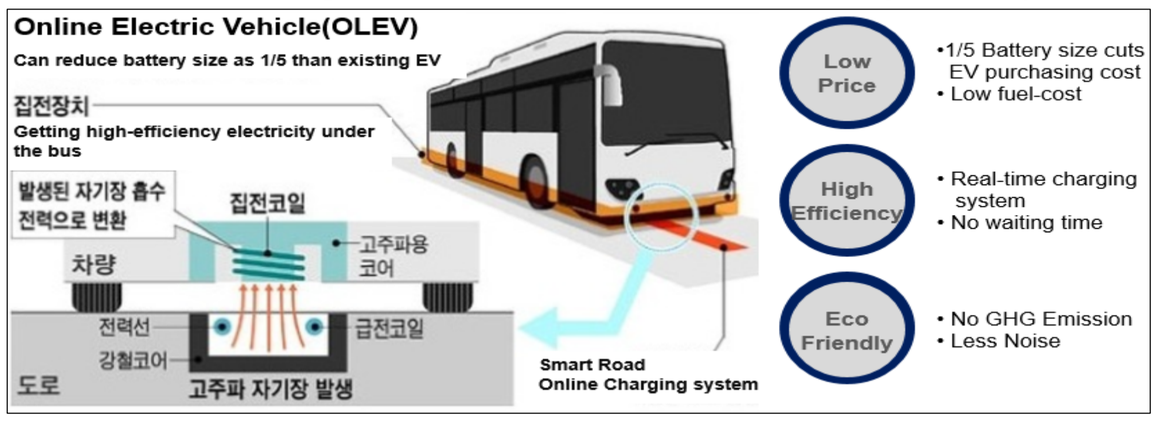

Figure 1. Concept and Feature of OLEV Technology

▶ BEV (Battery Swapping Electric Bus)

- The Automatic Battery Swapping Electric Bus attaches battery packs on top of the vehicle. When batteries deplete, the automatic swapping system replaces them with fully charged batteries.
- Latest battery switching technology can replace a 50kWh battery with a new one in less than a minute. Continuous movement made available though battery swapping.

Figure 2. Concept of the Battery Swapping Bus

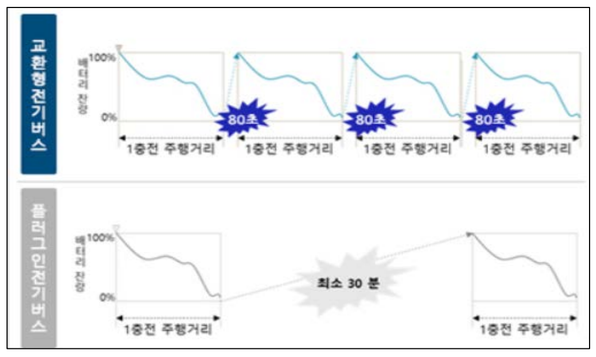

Figure 3. Efficiency Securement

Methodology

- Using linear programming model to minimize total cost required for transforming the Kyung-Bu highway for OLEV and BEV buses.
- For BEV and OLEV, fleet cost and infrastructure cost are calculated. For all three vehicles, operational costs are calculated.
- For OLEV, find the optimal total power transmitter distance and For BEV, find the optimal total number of chargers required to meet the demand of buses that travels the Kyung-Bu highway.
- Assumption

1. Fleet and infrastructure costs associated with ICE buses are measured for current operating buses.
2. Number of buses OLEV/BEV purchased is the same as the number of ICE buses currently operating in the Kyung-Bu highway.
3. Yearly number of trips per bus is equal for OLEV, BEV, and ICE
4. Electricity cost same for both OLEV and BEV buses.

Result

▶ Total Cost

OLEV outperforms BEV and ICE in operational costs. OLEV also outperforms BEV in infrastructure and operational costs.

	BEV(Battery Swap)	OLEV	ICE
Fleet	$229M	$429M	$71M
	Per vehicle cost is lower than OLEV vehicle cost	Compared to BEV, OLEV has disadvantage in vehicle cost	Compared to BEV and OLEV, ICE fleet cost is extremely competitive
Infrastructure	$171	$36M	$105M
	Battery inventory contributes to high infrastructure cost	Optimized power transmitter installation cost is lower than BEV / ICE infrastructure costs	Infrastructure cost in between OLEV and BEV infrastructure costs
Operational Cost (9 years)	$355M	$120M	$432M
	Charging large amount of battery results in high cost	Electricity costs less using OLEV power transmitters	Gasoline cost is considerably higher than EV electricity costs
	$755M	$585M	$608M

Figure 4. Estimated Cost of Three Vehicle

▶ Optimization

- OLEV
  Minimum total distance of power transmitter is 181.37km that is 46% of total distance from Seoul to Busan.
- BEV
  Minimum total number of charging machines at station 1 is 53 and number of charging station is 7.

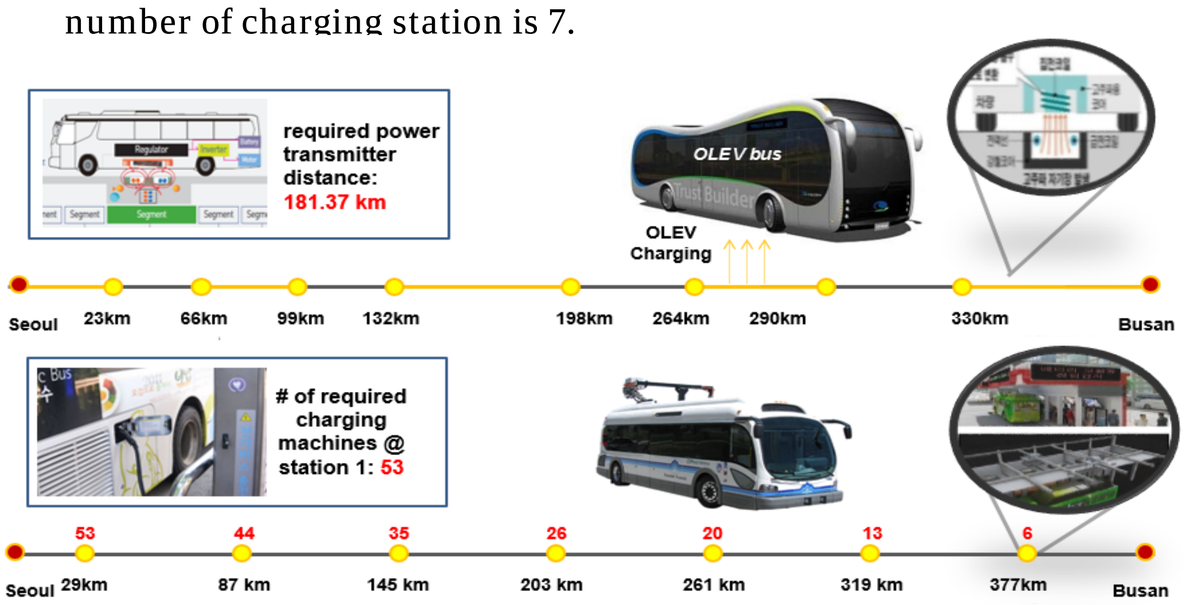

Figure 5. Optimization Result of OLEV (required power transmitter distance) and BEV (# of required charging machines at station 1)

Conclusion

- In the short run, OLEV's high fixed costs make it uneconomical vehicle. However, it has potential for total cost reduction in operating cost.
- With current technological specifications, break-even point between OLEV and ICE occurs after at least 8 years. Break-even point between OLEV and BEV occurs after 2.5 years.
- There is room for shortening the BEP for OLEV and BEV given that there are significant improvements in EV technologies.

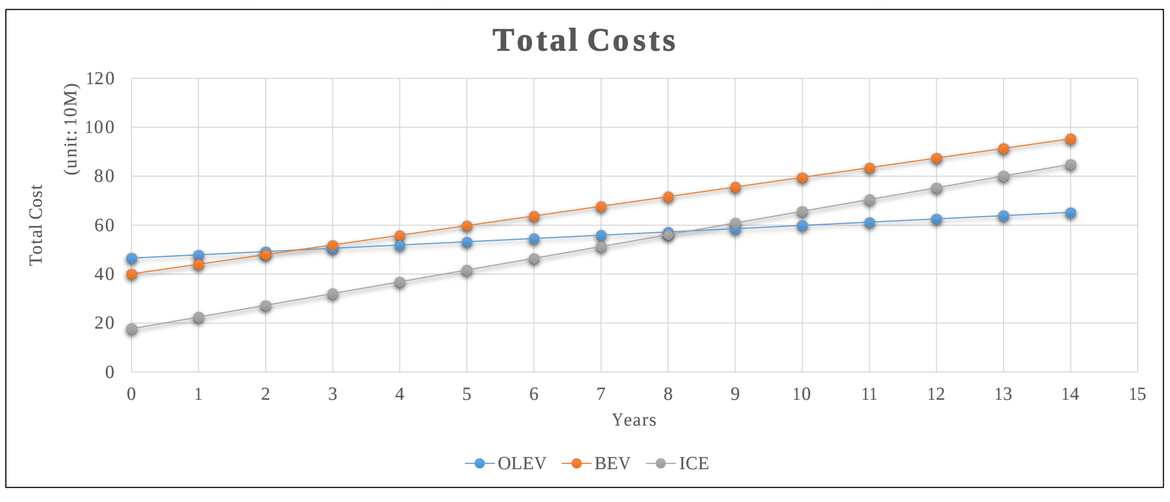

Figure 6. Total Cost of Three Vehicles for 14 Years and Break-Even Point of OLEV

References

[1] Ko, Young Dae, and Young Jae Jang. "Optimal Design of On-Line Electric Vehicle."
[2] 변상흠. "배터리 교환형 전기버스 인프라 규모 산정 및 평가기법 개발".(2014)
[3] OLEV Development Plan - KAIST Green Car TFT 2009
[4] Suh, N. P., D. H. Cho, and C. T. Rim. "Design of on-line electric vehicle (OLEV)." *Global Product Development*. Springer Berlin Heidelberg, 2011. 3-8.