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Electric Vehicle Adoption in Singapore- A Feasibility Analysis

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Abstract

Sustainable last-mile deliveries are pivotal in addressing environmental challenges. This research paper analyses and compares the cost and environmental impact of ICE on EVs in Singapore's context. In this research, the lifecycle costs of EVs and ICE vehicles that have a significant environmental impact were considered. An assessment from a Well-to-Wheel perspective using data collected from a leading logistics service provider was applied to analyze energy consumption and carbon emissions. Furthermore, a survey was conducted to comprehend the awareness of EVs and the adoption feasibility among logistics personnel and individuals across various industries while the world transitions to more sustainable logistics planning and manufacturing. It gives an overview of public acceptance in moving towards lesser carbon emission delivery options for last-mile deliveries. The key findings revealed that firstly the availability of adequate charging infrastructures is essential in the EV adoption discussion; however, this can be overcome by the current URA-LTA tender, which is set to accomplish at least 60,000 charging points by 2030 (URA, 2020). Secondly, switching from combustion vehicles to electric vehicles was cost-efficient with the least environmental impact. The LCC results further validate that financial incentives and exemptions positively impact the adoption of EVs.

Keywords
Carbon emissions, EVs, Fuel-based vehicles, lifecycle costs, sustainable last-mile delivery.

1. Introduction
Demand for last-mile deliveries increases considerable carbon emissions. (Kromer et al. 2022). They frequently involve vehicles that run on non-renewable fuels, causing air pollution and CO_2 emissions that are detrimental to people and ecosystems. Emissions and fuel consumption is soaring due to delays, and traffic congestion. Fossil fuel consumption and deforestation are driving this trend to speed up climate change and increase greenhouse gas levels.

Speed is prioritized in last-mile delivery procedures now, which raises carbon emissions. (Villena & Gioia 2020). As a result, implementing sustainable supply chain practices is essential, with an emphasis on achieving Environmental, Social, and Governance (ESG) goals. Implementing reductions in mileage and delivery vehicle deployments are possible remedies. Solutions to encounter the impacts and challenges of last-mile deliveries should include the adoption of electrical vehicles, including carbon emission tracking tools to measure carbon footprint emissions.

(FedEx Environmental & Social 2023). The purpose of this research study is twofold. Attention will be paid to EV adoption in Singapore and how it can be optimized to counter CO_2 emissions. This research will analyze whether the transition from combustion vehicles to electric vehicles will influence the daily last-mile operations for a leading logistics service provider, Company S.

1.1 Objectives

What are the expected costs and externalities that could arise from EV adoption in Singapore?
Research Objective - To conduct an LCA between electric LGVs and ICE commercial vehicles.
How will adopting electric vehicles (EVs) allow Company S to practice sustainable last-mile objectives?
Research Objective – To offer Company S's perceptions on the carbon footprint using an emissions calculator from the database of Company S and tailpipe emissions based on the Well to Wheel (WTW) approach.

How will the adoption of electric LGVs operationally affect or benefit Company S?
Research Objective – to employ a qualitative and quantitative methodology that allows the analysis of data to obtain results to derive a constructive conclusion.

2. Literature Review

János Juhász and Tamás Bányai (2018) investigated how companies use Industry 4.0 technologies to enhance procedures. The supply chain faces difficulties with last-mile delivery, such as integrating technology sustainably, controlling shifting customer preferences, and adjusting to new environmental regulations. These issues must be resolved for effective commodities movement. Dedicated house deliveries have been noted by Juhász and Bányai (2018) as a significant last-mile issue that raises expenses and contributes to pollution.
(Juhász & Bányai 2018).

Table 1. Factors and Cost in Logistics (Juhász & Bányai 2018)

Table 1. Factors and costs in logistic

Internal	External	Performance	System structure	Technology integration	Other expenses
Customer satisfac-tion	Technology	**Productivity development**	Better relationship	**Information systems**	Transportation cost
Quality	Globalization	Quality	Supply chain	Intelligent systems	Holding cost
Networks	Working force	**Good service**	Communications	**Smart technology**	Inventory cost
SCM	Environmental	**Modify response needs**	Organization care	**Smart grid**	Order processing cost

Industry 4.0 uses new technologies to improve supply chains, saving resources and boosting productivity. Crowdsourcing logistics and consumer self-collection for last-mile delivery are two solutions (Castillo, et al., 2018). R. de Souza (2014) brought attention to Singapore's supply chain problems, pointing out that while last-mile deliveries were well coordinated, the outcome was inefficient truckload usage, greater expenses, and decreased productivity. Better freight management can lower expenses and increase environmental friendliness, as Table 1 illustrates. Given Singapore's adoption of cutting-edge technology and robust public-private collaborations, this strategy is workable. (Souza et al. 2014).

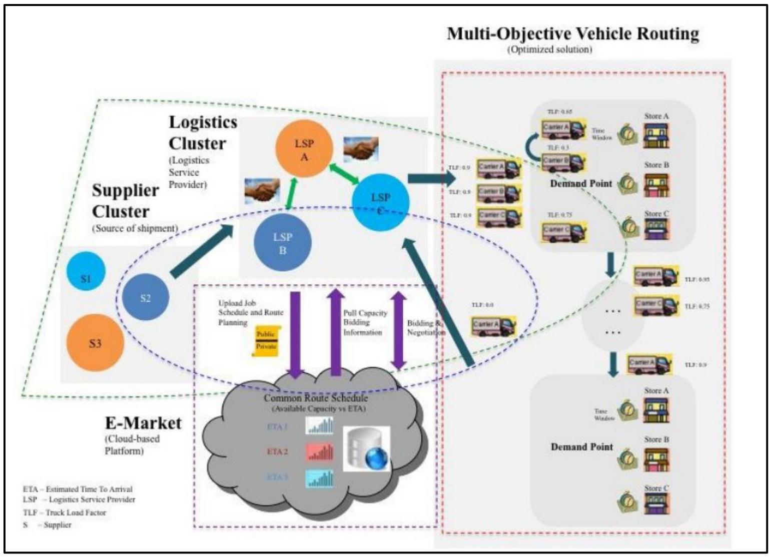

Figure 1. Collaborative urban logistics concept. (Souza, et al., 2014)

Sergio Maria Patella analyzed the use of electric commercial vehicles in urban goods transport, focusing on e-commerce and sustainability. The study underlines concerns such as congestion, pollution, and increases in costs due to delivery trucks, thus reducing the quality of life and causing CO_2 emissions and economic efficiencies. Patella recommends EV adoption in logistics, especially for e-commerce (Patella et al.2020). Idris and Koestoer investigated EVs' role in life cycle assessment (LCA), observing that while EVs can reduce emissions, their environmental impact during production and battery disposal is crucial. They stressed that EV usage is heavily dependent on energy consumption throughout its operational period, and the environmental impacts must be gauged through LCA (Idris & Koestoer 2023). To evaluate the operating costs of internal combustion engine vehicles (ICEVs) and electric vehicles (EVs) in Singapore, Y.S. Wong examined the life cycle cost (LCC) model. The LCC model aids in estimating acquisition, operating, and external costs associated with EV adoption because automobile manufacturing is non-existent in Singapore. Operational expenses include usage taxes, whereas acquisition costs consist of purchase prices, taxes, and rebates. The emissions from these cars are referred to as externalities. (Wong et al. 2010).

3. Methods

This research utilizes a dual-phase approach, with a collaboration of quantitative and qualitative data collection. It focuses on transitioning to EVs as sustainable practices within Company S. Carbon emission calculations will be obtained from the annual carbon audit conducted by Company S to track its carbon footprint. These data will provide insights into specific emission figures based on ICE and EV vehicles. Life Cycle Cost analysis will be carried out across several variables. The favorable analysis results in less congestion, lesser delivery costs, a yield in last-mile deliveries, productivity efficiency, and positive environmental impacts. The compilation of qualitative data will be a web-based survey via the Survey Sparrow portal. The survey will assist us in obtaining necessary information on the current last-mile delivery methods, benefits, and challenges arising from the adoption of electric vehicles. It can determine ways to improve sustainability in Company S's operations.

4. Data Collection

1.1 Ownership Cost Analysis

Life Cycle Cost Model - The LCC model in the following discussion is aimed towards the evaluation of ownership, operational, environmental, and miscellaneous costs of vehicles in Singapore.

Ownership Costs – also known as upfront costs of a commercial vehicle comprises the open market value (OMV), certificate of entitlement (COE) customs value, registration fees, and additional registration fees (ARF), as well as subsidies and taxes. A vehicle with an OMV of S$10,000.00 can generally cost a buyer more than S$90,000.

- **Open Market Value** - The price includes purchase price, insurance, freight for transporting the vehicle to Singapore and all other secondary costs incurred from the sale and delivery of the vehicles.
- **Goods and Services Tax** – GST of 8% is applicable once the vehicles are imported into Singapore.
- **Excise Duties** – Vehicles are subject to Singapore Customs duties, which are computed as 20% of the customs value of the vehicle.
- **Certificate of Entitlement Fee** – COE was initiated by the Singapore Government in 1990 as a program to curb the number of vehicle ownership as well as the number of vehicles on Singapore roads. The illustration below indicates five categories of COE as of October 2023. (Motorist N 2023).

Table 2. Certificate of Entitlement Fee (MotoristM2023)

October 2023
1st Bidding
2023 | Oct, 1st Bidding | Filter

COE Category	CAT A CARS ≤ 1600cc & 130bhp, or 110kW	CAT B CARS > 1,600cc or 130bhp, or 110kW	CAT C GOODS VEHICLE & BUS	CAT D MOTORCYCLE
Quota Premium	$104,000 ▼ $1,000	$146,002 ▲ $5,113	$85,900 ▲ $2,099	$10,856 ▲ $156

- **Registration and Additional Registration Fees (RF & ARF)** – A vehicle's registration fees are computed based on a percentage of the vehicle's open market value. With effect from January 2022 to December 2023, the minimum ARF for all-electric vehicles has been set to SGD 0.00. The waiver is expected to propel the purchase of EVs in Singapore. Following is the tax structure applicable for registrations of LGVs in Singapore.

Table 3. Tax Structure of LGVs (Motoring 2023)

Tax structure for registering a Light Goods Vehicle	
Registration Fee (RF)	$350
Additional Registration Fee (ARF)	5% of Open Market Value (OMV)
Certificate of Entitlement (COE) Category	C or E

<u>**Rebates on Taxes from the Adoption of EVs**</u>

- "EV early adoption incentive" was introduced in 2021. ARF for electric commercial vehicles will enjoy a 45 percent rebate off their purchase, which is capped at a maximum amount of SGD 20,000.00.
- Early Turnover Scheme (ETS) was initiated in April 2013. The scheme was to propel organizations to replace their diesel-powered commercial vehicles with electric vehicles.
- Commercial Vehicle Emissions Scheme (CVES) offers rebates between S$15,000 to S$25,000. CVES is fundamentally a rebate strategy aimed at monitoring emission levels for all types of vehicles. (Higer, 2023) Based on the CVES, there are three bands: A, B, and C classifications for LGVs. These comparisons are split into pollutant indexes such as hydrocarbons (HC), carbon monoxide (CO), carbon dioxide (CO_2), nitrogen dioxide (NOx), and particulate matter (PM). The illustrations below are an outline of the 3 CVES bands and their emission limit values applicable for LGVs and HGVs:

Table 4. CVES Bands and Emission (NEA, 2023)

Band	Incentive / (Surcharge)	CO_2 g/km	HC g/km	CO g/km	NOx g/km	PM mg/km
A	$15,000	≤123	=0.0	=0.0	=0.0	=0.0
B	$5,000	≤216	≤0.025	≤0.27	≤0.015	≤0.85
C	($15,000)	>216	>0.025	>0.27	>0.015	>0.85

Table 5. Early Turnover Incentives (NEA, 2023)

Existing Vehicle and Emission Standard		Replacement Vehicle (Euro VI or equivalent)	Incentive(COE Bonus)
LCVs	Euro II, III	Band A under CVES	40%[2]
		Band B under CVES	20%
	Euro IV	Band A under CVES	20%[2]
		Band B under CVES	10%
HCVs	Euro II, III	Vehicle without tailpipe emissions [1]	90%[3]
		Vehicle with tailpipe emissions [1]	60%[4]
	Euro IV	Vehicle without tailpipe emissions [1]	70%[3]
		Vehicle with tailpipe emissions [1]	25%[4]

Operational Costs

Operational Costs comprise road tax (RT), insurance costs, parking costs, maintenance charges, and infrastructure charging and refuelling costs. In Singapore, LGVs are based on their maximum laden weight (MLW), which is then used to allocate the payable road tax. The table below indicates that six-monthly RT payable by diesel-powered vehicles is higher compared to electric powered vehicles.

Table 6. Road Tax – Six Monthly (Motoring, 2023)

Vehicle type	Road tax (six-monthly
Diesel and diesel hybrid	S$213
Petrol and petrol hybrid	S$170
Electric	S$170

The insurance charge is conditional upon the type of vehicle, the insurance guarantee and coverage and the engine of the LGV. An LGV specifically purchased for delivery purposes will incur an insurance cost of approximately S$1,500 to S$3,500 per annum. (Motoring 2023)

Following is a ballpark estimation of season parking charges per month, which may be applicable for LGVs based on the unladen weight of the vehicle, and the type of car park.

Table 7. Season Parking Charges (HDB, 2023)

Unladen Weight of the Commercial Vehicle*	Season Parking Charges			
	Multi-Storey Car Park		Surface Car Park	
	Tier 1	Tier 2	Tier 1	Tier 2
≤ 1,800 kg^	$110	$120	$80	$90
> 1,800 kg	$185		$185	

Employment & Skilled Workforce: The move from ICE to EVs will have impacts on recruitment in the ICE vehicle industry, such as at service stations and mechanics. The succession of EVs may cause a potential gap in required skills. With the increase in EVs on the roads, a skilled workforce with adequate skills and knowledge to maintain or repair will be required. EVs may reach high voltages when in operation, and therefore, it is crucial for technicians to have the proper knowledge of handling high-voltage vehicles. The NTUC Learning Hub is extending an electric vehicle course for technicians to offer learners essential expertise on the maintenance and reparation of electric vehicles. There are further concessions to the prices for the courses based on SkillsFuture credits and company sponsorships.

Table 8. Course Fee (NTUC 2023)

Course Fee and Government Subsidies				
	Individual Sponsored Trainee		Company Sponsored Trainee	
	before GST	with GST	before GST	with GST
Full Course Fee	$1177.00	$1271.16	$1177.00	$1271.16

5. Results and Discussion

5.1 Numerical Results

EVs transform 77 percent of energy from the electricity grid, whereas the most efficient of fuel-powered commercial vehicles use 12 to 30 percent of energy stored in the fuel. (Tan 2021)The following analysis was made for three comparable electric LGVs and their diesel and petrol counterparts. The initial ownership costs are higher than their fuel counterparts; however, based on the illustrations below, the incentive schemes initiated by the governing bodies in Singapore lessen the upfront costs of purchasing electric LGVs.

Table 9. Price Analysis between Electric and Diesel-Powered Commercial Vehicles - Total Upfront Costs

Models of Electric Light Good Vehicles	Opel Vivaro-E (ELECTRIC)	Opel Vivaro (DIESEL)	Renault Kangoo ZE (ELECTRIC)	Renault Kangoo (DIESEL)	Toyota Pro-Ace (ELECTRIC)	Toyota Hi Ace (PETROL)
CVES Banding	A	C	A	C	A	B
Energy / Fuel Consumption	16.7KwH / 100km	5.4L / 100km	18.75kWh / 100km	5.2L / 100km	15.3kWh / 100km	7.8L / 100km
Open Market Value	S$49,500.00	S$40,800.00	S$58,411.00	S$56,400.00	S$58,088.00	S$52,800.00
Certificate of Entitlement (CAT C) (October 2023)	S$85,900.00	S$85,900.00	S$85,900.00	S$85,900.00	S$85,900.00	S$85,900.00
Goods and Services Tax (8%)	S$3,960.00	S$3,264.00	S$4,672.88	S$4,512.00	S$4,647.04	S$4,224.00
Excise duty (20%)	Exempted	Exempted	Exempted	Exempted	Exempted	Exempted
Registration Fees	S$350.00	S$350.00	S$350.00	S$350.00	S$350.00	S$350.00
Additional Registration Fees (5% of	0.00	0.00	0.00	0.00	0.00	0.00
Commercial Vehicles Emission Scheme (CVES)	S$-15,000.00	S$15,000.00	S$-15,000.00	S$15,000.00	S$-15,000.00	S$-5,000.00
Total Upfront Costs (Singapore Dollars)	S$124,710.00	S$145,314.00	S$134,333.88	S$162,162.00	S$133,985.04	S$138,274.00

With an increase in the number of electrified LGVs, there needs to be sufficient spare parts and batteries available. In May 2022, LTA announced that there will be initiatives taken to offer certifications to technicians in the maintenance and servicing of electric vehicles. Maintaining and operating a fleet of electric LGVs will be distinctly lower than for a fleet of diesel and petrol alternatives. (VIVOPOWER, 2021) Next, we will investigate the infrastructure costs for electrified LGVs. There are three EV charging providers in Singapore. They are Total Energies, SP Power, and Shell's

Greenlots. We will base our analysis on SP Group charging capacities. SP's charging stations are located at most warehouses, malls, and commercial buildings, which proves to be mostly accessible to LGVs. SP's charging standards are AC: IEC Type 2 7.4kW, 11 kW, 22kW and 40kW, all costing $0.59 per kWh as of September 2023. The current diesel price as of September 2023 is S$2.71/ litre and the petrol price LEVO (95) as of October 2023 is S$2.88. The illustration below reflects the cost of charging an electric LGV versus a diesel and petrol LGV. The capacity of the electric LGV is indicated in kilowatt hours (kWh), which is 75kWh. Based on the formula below, we can establish the cost of charging an Opel Vivaro-E. **Formula**: Battery size (kWh) x Electricity cost of your SP Power (cents per kilowatt hour) = Cost to charge the selected LGV from empty to full. A comparison can then be done with petrol/diesel alternatives. (KIA, 2023)

Table 10. Cost per Full Charge/ Full Tank

Models of Electric Light Good Vehicles	Opel Vivaro-E (ELECTRIC)	Opel Vivaro (DIESEL)	Renault Kangoo ZE (ELECTRIC)	Renault Kangoo (DIESEL)	Toyota Pro-Ace (ELECTRIC)	Toyota Hi Ace (PETROL)
Size of Battery Pack / Fuel Tank Capacity	75kWh	60L	48kWh	54L	50kWh	70L
Battery Charging / per KwH (2023) basis SP Group car charging stations	S$0.59 / Kwh	NA	S$0.59 / Kwh	NA	S$0.59 / Kwh	NA
Diesel / Petrol basis Fuel Prices as at 7th October 2023	NA	S$2.71 / litre	NA	S$2.71 / litre	NA	S$2.88 / litre
Cost per Full Charge/ Full Tank (Singapore Dollars)	S$44.25	S$162.6	S$28.32	S$146.34	S$29.50	S$201.60

With the above representations, the price differences in costs between EV charging and filling up on diesel/ petrol. In the following illustration, we will be able to establish the utility/propulsions costs between an electric LGV and a petrol/diesel LGV. Calculations are based on the current preceding electricity and fuel costs. The tabulations outline that the annual propulsion costs for operating an electrified LGV are lesser than its diesel/ petrol substitutes.

Table 11. Annual Propulsion Cost for Last Mile Deliveries

Models of Electric Light Good Vehicles	Opel Vivaro-E (ELECTRIC)	Opel Vivaro (DIESEL)	Renault Kangoo ZE (ELECTRIC)	Renault Kangoo (DIESEL)	Toyota Pro-Ace (ELECTRIC)	Toyota Hi Ace (PETROL)
Size of Battery Pack / Fuel Tank Capacity	75kWh	60L	48kWh	54L	50kWh	70L
Battery Charging / per KwH (2023) basis SP Group car charging stations	S$0.59 / Kwh	NA	S$0.59 / Kwh	NA	S$0.59 / Kwh	NA
Diesel / Petrol basis Fuel Prices as at 7th October 2023	NA	S$2.71 / litre	NA	S$2.71 / litre	NA	S$2.88 / litre
Cost per Full Charge/ Full Tank (Singapore Dollars)	S$44.25	S$162.6	S$28.32	S$146.34	S$29.50	S$201.60
Average Daily Mileage (km) basis Last Mile Deliveries in Singapore	100km	100km	100km	100km	100km	100km
Fuel / Energy Consumption per 100km	29.5kWh	6.5L	18.75kWh	4.8L	43.1kWh	12.4L
Fuel / Energy Consumption per Annum basis 30,000km	8,850kWh	1,950L	5,625kWh	1,440L	12,930Kwh	3,720L
Annual Propulsion Cost for Last Mile Deliveries (Singapore Dollars)	S$5,221.50	S$5,284.50	S$3,318.75	S$3,902.40	S$7,628.70	S$10.713.60

We will now focus on the total tabulations for all operational costs over ten years. The calculations indicate that the operating costs for electric LGVs over ten years are lower than combustion engine LGVs.

Table 12. Total Operating Costs – 10 years

Models of Electric Light Good Vehicles	Opel Vivaro-E (ELECTRIC)	Opel Vivaro (DIESEL)	Renault Kangoo ZE (ELECTRIC)	Renault Kangoo (DIESEL)	Toyota Pro-Ace (ELECTRIC)	Toyota Hi Ace (PETROL)
Road Tax Per Annum	S$340.00	S$426.00	S$340.00	S$426.00	S$340.00	S$340.00
Insurance Per Annum	S$1,500.00	S$1,500.00	S$1,500.00	S$1,500.00	S$1,500.00	S$1,500.00
Parking Costs Per Annum	S$2,220.00	S$2,220.00	S$2,220.00	S$2,220.00	S$2,220.00	S$2,220.00
Annual Propulsion Cost for Last Mile Deliveries (Singapore Dollars)	S$5,221.50	S$5,284.50	S$3,318.75	S$3,902.40	S$7,628.70	S$10.713.60
Total Operating Costs Per Annum	S$9,281.50	S$9,430.50	S$7,378.75	S$8,048.40	S$11,688.70	S$14,773.60
Total Operating Costs for a period of 10 Years (Singapore Dollars)	S$92,815.00	S$94,305.00	S$73,787.50	S$80,484.00	S$116,887.00	S$147,736.00

The final Life Cycle Cost Analysis is based on a combination of ownership and operational costs.
Upfront costs were determined based on the following factors: Open Market Value + Certificate of Entitlement (COE) + Goods & Services Tax (8%) + Registration Fees (RF) – Commercial Vehicles Emission Scheme = Total Upfront Costs. Operating costs were determined based on the following factors: Road Tax (Per Annum) + Insurance (Per Annum) + Parking Costs (Per Annum) + Propulsion Costs (Per Annum) = Total Operating Costs Per Annum. The analysis below allows us to conclude that lifetime costs incurred for electric LGVs, indicating an average amount of S$225,000 for ten years, whilst the ICE LGVs amount to S$256,019.

Table 13. Lifetime Costs Analysis – Part 1

Models of Electric Light Good Vehicles	Opel Vivaro-E (ELECTRIC)	Opel Vivaro (DIESEL)	Renault Kangoo ZE (ELECTRIC)	Renault Kangoo (DIESEL)	Toyota Pro-Ace (ELECTRIC)	Toyota Hi Ace (PETROL)
CVES Banding	A	C	A	C	A	B
Energy / Fuel Consumption	16.7KwH / 100km	5.4L / 100km	18.75kWh / 100km	5.2L / 100km	15.3kWh / 100km	7.8L / 100km
Open Market Value	S$49,500.00	S$40,800.00	S$58,411.00	S$56,400.00	S$58,088.00	S$52,800.00
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Goods and Services Tax (8%)	S$3,960.00	S$3,264.00	S$4,672.88	S$4,512.00	S$4,647.04	S$4,224.00
Excise duty (20%)	Exempted	Exempted	Exempted	Exempted	Exempted	Exempted
Registration Fees	S$350.00	S$350.00	S$350.00	S$350.00	S$350.00	S$350.00
Additional Registration Fees (5% of	0.00	0.00	0.00	0.00	0.00	0.00
Commercial Vehicles Emission Scheme (CVES)	S$-15,000.00	S$15,000.00	S$-15,000.00	S$15,000.00	S$-15,000.00	S$-5,000.00
Total Upfront Costs (Singapore Dollars)	S$124,710.00	S$145,314.00	S$134,333.88	S$162,162.00	S$133,985.04	S$138,274.00

Table 14. Lifetime Costs Analysis – Part 2

Models of Electric Light Good Vehicles	Opel Vivaro-E (ELECTRIC)	Opel Vivaro (DIESEL)	Renault Kangoo ZE (ELECTRIC)	Renault Kangoo (DIESEL)	Toyota Pro-Ace (ELECTRIC)	Toyota Hi Ace (PETROL)
Road Tax Per Annum	S$340.00	S$426.00	S$340.00	S$426.00	S$340.00	S$340.00
Insurance Per Annum	S$1,500.00	S$1,500.00	S$1,500.00	S$1,500.00	S$1,500.00	S$1,500.00
Parking Costs Per Annum	S$2,220.00	S$2,220.00	S$2,220.00	S$2,220.00	S$2,220.00	S$2,220.00
Annual Propulsion Cost for Last Mile Deliveries (Singapore Dollars)	S$5,221.50	S$5,284.50	S$3,318.75	S$3,902.40	S$7,628.70	S$10.713.60
Total Operating Costs Per Annum	S$9,281.50	S$9,430.50	S$7,378.75	S$8,048.40	S$11,688.70	S$14,773.60
Total Operating Costs for a period of 10 Years (Singapore Dollars)	S$92,815.00	S$94,305.00	S$73,787.50	S$80,484.00	S$116,887.00	S$147,736.00
Total Costs (Singapore Dollars)	S$217,525.00	S$239,619.00	S$208,121.38	S$242,646.00	S$250,874.04	$286,010.00

Research Objective 1

The life cost analysis was done to ascertain a comparison of ownership and operational costs on an annual basis and thereafter over a lifetime period of 10 years. The analysis used actual costs for six commercial vehicles sold in Singapore. The commercial vehicles considered were battery-electric vehicles and diesel or petrol-powered vehicles. Ownership costs for the electric LGVs were substantially on the higher curve. However, the implementation of the CVES Rebate scheme resulted in lessening the total amount of ownership costs.
The charging costs for an electric LGV ranged between S$28.00 to S$45.00, whereas a full tank of petrol or diesel ranged between S$145.00 to S$200.00.

For the operational phase, 30,000 kilometers per annum delivery runs were analyzed for all six vehicles – Opel, Renault, and Toyota. The annual costs for the ICE commercial vehicles were higher.

Other factors contributing to the operating phase were the road tax per annum, insurance per annum, parking costs, and the annual propulsion costs, considering the vehicles were utilized for last-mile operations. The total operating costs per annum for electric LGVs resulted in lower amounts than ICE LGVs. The total lifecycle cost over ten years presented us with an average of S$ 225,506.81 for electric LGVSs, S$286,010.00 for petrol LGVs and S$241,132.50 for diesel LGVs. Based on the above analysis, Company S can leverage cost reductions ranging from S$15,000.00 to S$60,000.00 over ten years through the transition of EVs.

Carbon Emissions: Air pollution is the main externality that appears in our minds when we discuss the use of EVs.. The below assessment of the energy consumption was established with the use of the life cycle analysis perspective and Company S's carbon emission calculator. The life cycle analysis approach was based on the Well-to-Wheel approach, which comprises the following points Tank-to-Wheel (TTW) energy consumption (MJ/km) and Well-to-Tank (WTT) vehicle CO_2 emissions (g/km).

Table 15. Carbon Emission – WTT, TTW, WTW

Models of Electric Light Good Vehicles	Opel Vivaro-E (ELECTRIC)	Opel Vivaro (DIESEL)	Toyota Hi Ace (PETROL)
Curb Weight (KG)	2,131.00	1,678.00	2,861.00
WTT (MJ/km)	0.66	0.27	0.27
WTT (g/km)	63.00	24.00	25.00
TTW (MJ/km)	0.63	1.67	1.96
TTW (g/km)	**63.00**	**124.00**	**143.00**
WTW (MJ/km)	**1.29**	**1.94**	**2.23**

Based on the above analysis, an electric LGV has a lower TTW has a smaller contribution (0.63 MJ/km). The TTW for a diesel and petrol LGV are 1.67 MJ/km and 1.96 MJ/km, respectively. At the WTT stage, an electric LGV has a higher contribution of 0.66MJ/km, whilst diesel and petrol LGVs had 0.27MJ/km. Generally, the WTW for electric LGV presented lower emissions results with an energy consumption of 1.29 MJ/km. WTW for the diesel and petrol LGV had results of 1.94 and 2.23MJ/km.

Tailpipe Emissions - The following table illustrates the life cycle emissions between electric LGVs and ICE LGVS using tCO_2e. These numbers were obtained from the Company S online emission calculator based on a phase of 10 years with a traveled distance of 300,000 kilometers. The results derived show the production stage for electric LGVs is approximately 40% higher than ICE LGVs, and this can be attributed to the derivation of raw materials for batteries. However, battery life is expected to exceed or equal the vehicle life, and therefore, we can conclude that electric LGVs have the lowest life cycle emissions in comparison to petrol/ diesel LGVS. (FedEx, 2023)

Table 16. Lifecycle Emissions – tCO_2e (FedEx, 2023)

Engine Type	Process	Battery	Petrol	Diesel
Emission from Production (tCO2e)	**Manufacture of Battery**	5	0	0
	Manufacture of Vehicle	9	9	10
Emission from Use Phase (tCO2e)	**Production of Fuel / Electricity**	26	12	13
	Tailpipe Emissions	0	24	32
	Maintenance	1	2	2
Total		**41 tCO2e**	**47 tCO2e**	**57 tCO2e**

Research Objective 2

A Well-to-Wheel approach and carbon emissions calculator from Company S was utilized to compare the GHG / tailpipe emission between electric and ICE LGVs. A well-to-wheel technique deliberates over the entire emission process resulting from the production of batteries, production of fuel, physical processing, handling, and vehicle operating. The well-to-wheel analysis was obtained for Opel Vivaro (electric), Opel Vivaro (diesel) and Toyota Hi-Ace (Petrol). Data was obtained from each specific commercial vehicle brand from the Company S database, whereby the emission factors were documented in megajoules per kilometer.

The results showed that the well-to-wheel process for an Opel Vivaro (electric) had a lower energy consumption in comparison to Opel Vivaro (diesel) and Toyota Hi Ace (Petrol), which had 1.94MJ/KM and 2.23MJ/KM respectively.
The tailpipe and GHG emissions were obtained from Company S emission calculators. Emissions from vehicle and battery productions were considered. The results allowed us to note that an electric LGV had lower greenhouse gas emissions than its petrol and diesel counterparts.

5.2 Graphical Results

The survey conducted had 83 respondents. Based on the survey data collected, the predominant group of respondents were from supply chain industries who had a profound understanding of the industry perspectives. There are other sectors, which can contribute to public awareness of carbon emissions and EVs. 77.11% of respondents expressed that savings from using electricity instead of petrol or diesel was the encouraging factor for them to purchase an electric vehicle.

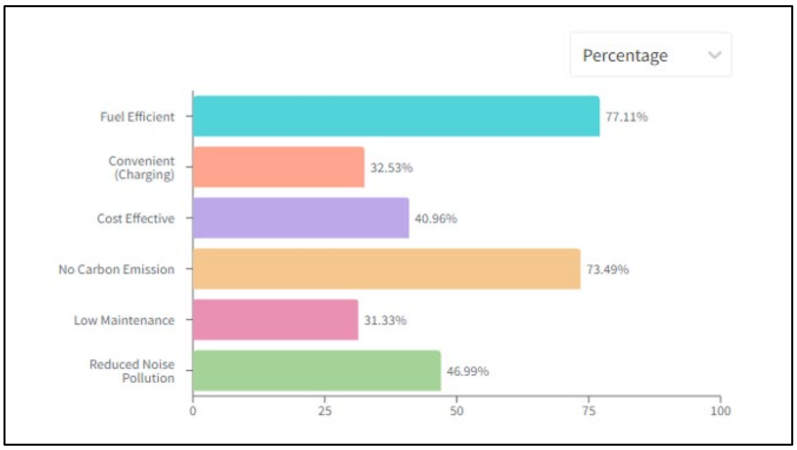

Figure 2. Electric Vehicles Advantages

<u>Research Objective 3</u>

The study conducted a survey to measure consumer beliefs on EV adoption for last-mile deliveries. Survey results revealed a lack of awareness regarding government incentives and charging infrastructures. The LTA-URA tender aims for 60,000 EV charging points by 2030 (URA 2020). The Busways-Shell Consortium initiated fast EV charging since June 28, 2023, addressing infrastructure challenges for commercial fleet owners (Staff Reporter 2023).

5.3 Proposed Improvements

The first logical step for Company S is to obtain a telematic technology to tap into its current fleet to check on the route mileage and idle time each day. Investments in training and resources within the organization and among its stakeholders to be familiar with the advancements in technologies associated with the transitions to EVs.

Finally, Company S could invest in an online tool similar to the EV Fleet Savings calculator that many fleet owners in America have utilised. The online tool enables an organisation to evaluate the costs associated with transitioning the current fleet of commercial vehicles to electric vehicles.

6. Conclusion

The paper has reviewed the adoption of electrified light-duty commercial trucks by analyzing a life cycle cost breakdown and a survey. The life cycle cost breakdown indicated the financial and usage effects, while the survey gave us insight into the public's readiness for electric vehicles. The comprehensive direction of this paper is to examine EV adoption for last-mile deliveries in the supply chain process.

There were three objectives to be analyzed with specific methodologies. Firstly, a life cycle analysis was carried out to achieve the first objective to obtain the expected costs and externalities that may arise from the adoption of electric vehicles in Singapore. The findings proved that transitioning to electric commercial vehicles lead to cost reductions ranging from S$15,000.00 to S$60,000.00 over ten years. Secondly, an emission calculator and Well to Wheel (WTW) approach aided the author in analyzing if the adoption of electric commercial vehicles will promote sustainable last-mile objectives. The results from tailpipe, GHG emissions and analysis from a (WTW) approach allowed the author to note that an electric LGV had lower greenhouse gas emissions than its petrol and diesel counterparts.
Lastly, qualitative and quantitative methodologies were applied to obtain the objective of finding out how the adoption of electric vehicles will either affect or be beneficial to Company S. The findings were crucial in understanding consumers' feelings and behavior if an organization shifted towards EV usage to complete last-mile deliveries.

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