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Green Financial Model for Heavy-Duty Commercial Vehicle

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Abstract
Environmental-friendly Transportation is the latest evolution in managing operation and combating climate crises. In the automotive industry, this concept introduces a new feasibility study to the post usage stage of the transitioning green heavy-duty vehicle specifically in municipal operations. This financial model research investigates the environmental, social and economics, focusing overloading problems for improvement needs. To achieve this, factors of vehicles for Total Cost of Ownership (TCO) is considered. Then, each factor is individually modelled to accurately represent its respective environmental, economic, and societal needs. A mathematical financial model, derived based on the modelled relationship, was later constructed, and later converted into a computer model. Furthermore, the result of each model will be able to assist the Malaysian Government, automotive manufacturers, and hired waste management contractors to formulate policies and strategies that would lead towards positive financial performance with related to environmental issues to be quantified. Hence, this paper examines the adoption of environmentally friendly technologies in Malaysia, focusing on the challenge of assessing the minimum Total Cost of Ownership (TCO) for GHDV fleets. This paper highlights the need for comprehensive TCO analysis, considering environmental impacts, and integrating LCC principles for effective implementation and management of cost-efficient HDV fleets.
Keywords: TCO, Green Vehicle, Financial Model, Life Cycle Cost (LCC), Commercial Vehicle

Introduction

Transportation plays a pivotal role in modern societies, however, the transportation industry's significant contribution to global greenhouse gas emissions and air pollution has raised environmental concerns. While many researchers agree that conventional Internal Combustion Engines (ICE) can be further improve, it will still not be enough to meet the GHG reduction target. Therefore, there is a growing need for alternative technologies such as Battery Electric Vehicles (BEVs), Hybrid Electric Vehicles (HEVs), Plug-in Hybrid Electric Vehicles (PHEVs), and Hydrogen Fuel Cell Vehicles (FCVs). Despite being commercially available and their relative environmental benefits, these alternative technologies are greatly influenced by consumer usage. For instance, fleet managers base their decisions on seven key obstacles to electrification (Sugihara & Hardman, 2022). Apart from that, budgeting is also a key challenge where even large firms find it hard to manage fleet costs (Kotze et al., 2021); and, smaller organisations chose to be a follower even when managing budgets for fleet fixed replacement schedules (Saadatlu et al., 2022). Even then, annual replacement budget would be made available not for all vehicles in the schedule but based on priority to replace. With ESG looming and sustainability a key issue, organisations must prioritize its new fleet Total Cost of Ownership (TCO) based on vehicle life environmental impacts, thus integration of Life Cycle Costing (LCC) principles is important to identify valuable insights.

Hence, this paper aims to formulate the adoption of environmentally friendly technologies, particularly during the use stage and assessing the minimum Total Cost of Ownership (TCO) for factors such as acquisition costs, operational expenses, and maintenance requirements. By conducting a comprehensive TCO analysis, including the consideration of environmental impacts and the integration of LCC principles, it is important to clearly view the valuable insights and recommendations to effectively implement and managing cost-efficient and environmentally friendly HDV fleets.

Literature Review

Road Transportation trucks come in a variety of shapes, sizes, weights, and engine powers to suit the needs they serve (Alonso-Villar *et al.*, 2022). The terminology of HDV is also categorized accordingly to gross vehicle weight (GVW), chassis configuration and axle type in European countries (Rodriguez, 2018). GVWR is the maximum loaded weight of the vehicle, or its weight plus its payload. On the other hand, Malaysia dimensions in terms of their weight, length, and axles number are regulated under the Weight Restrictions (Federal Roads) (Amendment) Order 2003 - P.U. (A) 275) (Ministry of Transport Malaysia, 2021). Generally, the powertrain of conventional HDVs is the engine, clutch, and gearbox make up a condensed configuration of a normal diesel consumption. The engine which primarily functioning on compression ignition (CI) to produce rotation and engine's torque and will be transformed by the gearbox into revolutions of the axles (Demeulenaere, 2019). Contrary to conventional fossil-based fuels like petrol and diesel, alternative fuels are described as fuels obtained from sources other than petroleum. Commercially available alternative fuel HDV powertrain technologies include hybrid powertrains compressed natural gas (CNG), liquefied natural gas (LNG) and biodiesel (Alonso-Villar et al., 2022; Department of Energy and Climate Change, 2023). After that, Hydrogen fuels as motive fuel combined with electric motor is defined as fuel cell electric vehicles (FCEVs) which produced tail-pipe warm air and harmless water vapour (Department of Energy and Climate Change, 2023). Additionally, the BEV HDV is defined as a vehicle that can be propelled by an electric motor that draws power from a battery and can be charged externally is referred to as an EV. Both an all-electric vehicle and a plug-in hybrid electric vehicle are considered electric vehicles (BEV). The system is much simple and more efficient than conventional with DC-AC converter that control the input signal of battery pack power required and inverter and battery pack (Endiz, 2023). All-electric vehicles can only be powered by an electric motor that draws electricity from a battery. Plug-in hybrid electric vehicles (PHEV) or hybrid (HEV) can also be powered by an internal combustion engine (Department of Energy and Climate Change, 2023).

Feasibility Model using LCC Method

The overall expenses of owning, running, and maintaining an asset over the course of its full life cycle are determined by a financial indicator called total cost of ownership (TCO) whilst the term "life cycle assessment" (LCA) refers to a broad methodology framework used to assess the environmental effects of a system, process, or product throughout the course of its full life cycle. It considers the procurement of raw resources, quantifies environmental elements like energy use, carbon emissions, water use, and waste production throughout the stages of manufacture, use, and end-of-life. A financial analysis known as life cycle cost (LCC) considers the costs incurred over the course of a system, asset, or product's life. It includes expenses incurred throughout several phases, such as pre-, during-, and after-manufacturing. Production costs, operating costs, maintenance costs, and disposal costs are all included in LCC. The use of analytical methods and procedures to assess the life cycle costs of a system or product is known as life cycle cost analysis (LCCA). It entails evaluating the costs to the economy and the effects on the environment at every step of the life cycle. To give a thorough analysis of the costs and benefits connected with a particular project or technology, LCCA includes aspects from TCO, LCA, and other pertinent factors. While LCC analyses the financial costs throughout the life cycle, LCA assesses the environmental implications. All these components work together in LCCA to provide a thorough study of both financial and environmental factors, enabling informed decision-making and comparison of various options. According to table 2, more research related to the use-stage recently compared to manufacturing and pre-manufacturing phase. The ELV phase is considered in waste management area of research interest making the network directly encountered to GHDV are less found. The research are as follows:

Table 1
EV LCC Elements in Life Cycle Stages

Life Cycle Stage	Related Author	Related Keywords
Pre-Manufacturing	(Salvi et al., 2013), (Yaïci and Longo, 2022), (Gunawan and Monaghan, 2022), (Lui et al., 2022),(Alonso-Villar et al., 2022; Cunanan, 2021; Kotze et al., 2021) (H. Stancin, 2020; Jovan and Dolanc, 2020) (Todorovic and Simic, 2019) (Muzammil Idris et al., 2019)	LCC, power grid, LCC planning
Manufacturing	(Qinyu Qiao, 2020), (H. Stancin, 2020; Qiao et al., 2022; Todorovic and Simic, 2019; Tyson, 2019) (Muzammil Idris et al., 2019)	LCC batteries, Power Grid, Green Vehicle Manufacturing,
Use	(Cameron Rout, 2022), (Osman Alp, 2022), (Hsieh and Green, 2020), (Vijayagopal and Rousseau, 2021), (Diego Troncon, 2019) (Guo et al., 2023) (Verma et al., 2022) (Alonso-Villar et al., 2022) (Stephen Comello, 2021) (Qinyu Qiao, 2020) (Siti Indati Mustapa, 2020) (Kara et al., 2017) (Junjie Li, 2020), (Bae et al., 2022), (Bhardwaj and Mostofi, 2022; Cunanan, 2021)	TCO, LCC, maintenance,
Post-Use (ELV)	(Petrauskienė et al., 2022), (Zhang et al., 2022), (Ene and Ozturk, 2015)	ELV Green Vehicle, Batteries disposal cost

Research Methodology

Based on the above literature reviews, it is notable that there are many researchers interested in studying vehicles related to LCC at use-stage. In this context, recent research is reviewed on finding study approaches amongst in LCC method green vehicles and environmental impacts. To review the LCC methods, GHDV LCC element at use-stage, a comprehensive literature review was carried out by analyzing authors provided keywords (Green Fleet Management; Heavy Vehicle; Life Cycle Cost; LCC green heavy vehicle; TCO green heavy vehicle; LCC alternative fuels vehicle; Green LCC; Life-Cycle Cost; Life cycle carbon emission; TCO carbon emission; electric vehicle; life cycle cost assessment) using text mining on web journals. This research was carried out using the main scientific databases, journal articles, conference papers, books, and other relevant documentation. The articles found are then reviewed and transformed into author and related vehicle factors in LCC as in Table 3 with 17 most recent and related articles or journals articles to LCC necessity.

Table 2
LCC Elements Found in Literature Reviews (Own Table)

Author	Purchase Cost	Purchase tax	Operation and maintenance cost	Disposal cost	Environment cost	Duty Concern	Fuel Cost	Insurance and Tax	Depreciation Cost	Incentive Benefit
(Guo et al., 2023)	x	x	x		x					
(Cameron Rout, 2022)	x		x	x			x	x	x	x
(Shantanu Pardhi, 2022)							x			
(Verma et al., 2022)	x		x	x					x	
(Alonso-Villar et al., 2022)	x		x		x		x	x	x	
(Osman Alp, 2022)	x		x	x	x		x	x	x	x
(Petrauskienė et al., 2022)	x	x	x	x		x	x	x	x	
(Stephen Comello, 2021)	x						x			
(Krzysztof Zamasz, 2021)	x		x		x	x	x			
(Vijayagopal and Rousseau, 2021)	x					x	x			
(Hsieh and Green, 2020)	x	x	x				x	x		x
(Qinyu Qiao, 2020)	x		x				x			
(Siti Indati Mustapa, 2020)	x		x	x				x		
(Junjie Li, 2020)	x	x	x	x	x					
(Diego Troncon, 2019)			x			x	x			
(Kara et al., 2017)	x		x	x						
(Lambros K. Mitropoulos, 2017)							x			

A Proposed Conceptual Model/Framework

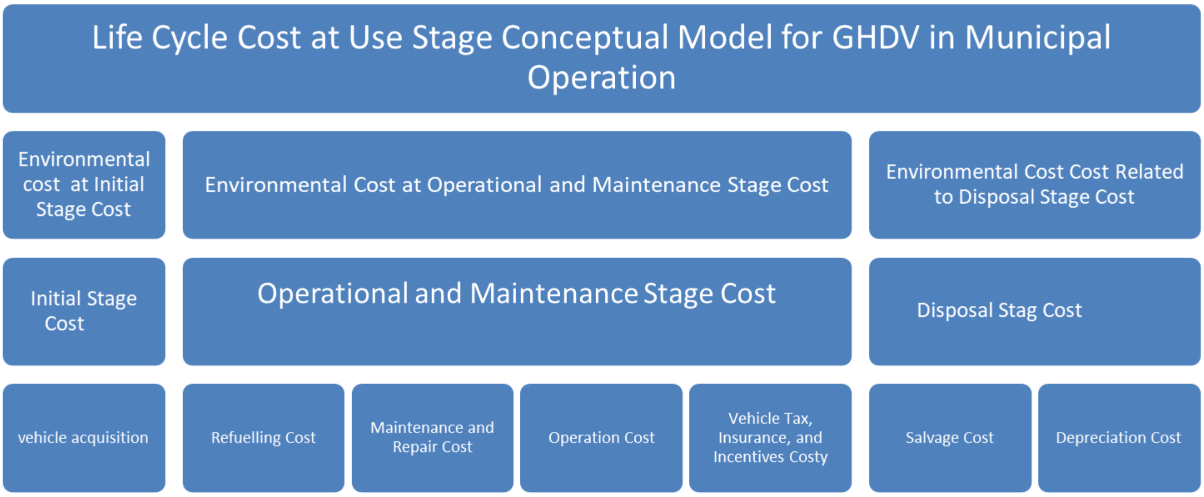

Figure 1. The GHDV Financial Conceptual Model

Results and Discussions

Primarily, this study will start with defining the key inputs including the initial costs, operating costs, and disposal costs accordingly to the factors mentioned above. Then, the following mathematical modelling are developed as follows.

$$\mathrm{LCC_{UP}} = \mathrm{C_I} + \mathrm{C_{OM}} + \mathrm{C_D} \quad (1)$$

$$\mathrm{LCC_{HDV}} = \frac{\mathrm{LCC_{UP}}}{\mathrm{t}} \quad (2)$$

Where LCC_{UP} is the life cycle cost at use-stage, LCC_{HDV} is the specific HDV life cycle cost, C_I is the initial cost stage, C_{OM} is the operational and maintenance cost stage, and C_D is the disposal cost. The model equation for C_I presented as follows as follows:

$$C_I = C_p + C_{gst} \quad (3)$$

Where C_p is the purchase cost of vehicle Chassis, and C_{gst} is the cost of Government Sales Tax. The Operational and Maintenance cost where C_O is the operation cost and C_M is the maintenance cost will be as below

$$C_{OM} = C_O + C_M \quad (4)$$

$$C_O = C_{RF} + C_{OF} + C_{TR} + C_{BT} + \mathrm{C_{DW}} + \mathrm{C_{TL}} + C_{IRY} + C_E \quad (5)$$

Where C_{RF} is the refueling cost, C_{OF} is the oil and operating lubricants, C_{TR} is the tire cost, C_{BT} is the battery cost, C_{DW} is the cost of driver wages, C_{TL} is the tolls cost, C_{IRY} is the cost of annual insurance, tax, and vehicle inspection by law and C_E is the environmental cost. C_{PM} is the prevention maintenance cost and C_{CM} is the corrective maintenance cost as follows

$$C_M = C_{PM} + C_{CM} \quad (6)$$

Thus, the C_{OM} formulation will be elaborated as follows

$$C_{OM} = C_{RF} + C_{OF} + C_{TR} + C_{BT} + \mathrm{C_{DW}} + \mathrm{C_{TL}} + C_{IRY} + C_E + C_{PM} + C_{CM} \tag{7}$$

Then, the $\mathrm{C_D}$ is presented as follows

$$\mathrm{C_D} = \mathrm{C_d} + \mathrm{C_r} \tag{8}$$

Where C_d is the depreciation cost and C_r is the residual value of vehicle

After that, the operational and maintenance cost based on formula (7), Refuelling cost is the average of consumption of a given type of propulsion vehicle. Then, C_{RF} can be expressed by the equation. DT is the distance travelled while FE_{rf} is the fuel economy or fuel efficiency (distance travelled/litre), $\mathrm{P_{rf}}$ is the refueling price (MYR/liter), and V_l is the vehicle service life (km).

$$\mathrm{C_{RF}} = \frac{DT}{FE_{rf}} P_{rf} V_l \tag{9}$$

Since the oil and lubricant, trye and battery are serviced within time interval, and it is important to quantify in formulation out from preventive maintenance formulation. Thus, based on the equation of (7), the formula is as follows

$$C_{OF} = \frac{DT}{FC_{of}} P_{of} V_l \tag{10}$$

where, the DT is the distance travelled, FC_{of} is the oil consumption (km/liter), P_{of} is the oil, fluid, and lubricant cost (MYR). Then, the cost of tyre, C_{TR} are as follows

$$C_{TR} = \frac{V_l}{T_{al}} \eta_T P_T \tag{11}$$

Where T_{al} is the Tire average life (km), η_T is the number of tires required in a HDV (pieces), and P_T is the price of tire (MYR).

$$C_{BT} = \frac{V_l}{B_{al}} \eta_B P_{TB} \tag{12}$$

Where B_{al} is the battery average life (km), η_B is the number of batteries required in a HDV (pieces), and P_B is the price of battery (MYR). After that, the operational cost is continued with driver wages, tolls, insurance, tax, and inspection related. The formula is as follows:

$$\mathrm{C_{DW}} = (c_{\mathrm{ms}}) V_{la} \tag{13}$$

$$\mathrm{C_{TL}} = (c_{\mathrm{tl}}) V_{la} \tag{14}$$

where c_{ms} is the average cost monthly driver wages (MYR) and c_{tl} is the average monthly cost of toll (MYR) while V_{la} is the years of vehicle life until decommissioning (years). The $\mathrm{C_{IRY}}$ is formulated as follows with $\mathrm{C_{ins}}$ as the insurance cost, $\mathrm{C_{rtx}}$ is the yearly road tax cost and $\mathrm{C_{yi}}$ is the cost per inspection that makes it biannual. The formulation are as follows

$$\mathrm{C_{IRY}} = (\mathrm{C_{ins}} + \mathrm{C_{rtx}} + 2\mathrm{C_{yi}}) V_{la}$$

(15)

The cost of yearly inspection is calculated based on the biannual basis and its mandatory for commercial classes. C_{ei} is the carbon emission inspection (MYR), C_{ti} is the technical inspection (MYR), V_n is the number of years the emission measurement and technical condition should be inspected by law (years). The formula are as follows

$$C_{yi} = (C_{ei} + C_{ti}) \frac{V_n}{V_{la}}$$

(16)

Cost of preventive maintenance, C_{PM} and corrective maintenance, C_{CM} as mentioned in formula (7), $\mathrm{C_{pmp}}$ is parts for preventive maintenance, $\mathrm{C_{pml}}$ is the labour cost for preventive maintenance, $\mathrm{C_{pme}}$ is the equipment cost for preventive maintenance, $\mathrm{C_{pcp}}$ is the cost of corrective maintenance parts, $\mathrm{C_{pcl}}$ is the cost of corrective maintenance labour cost and $\mathrm{C_{pce}}$ is the cost of equipment for corrective maintenance.

$$\mathrm{C_M} = (\mathrm{C_{pmp}} + \mathrm{C_{pml}} + \mathrm{C_{pme}}) + (\mathrm{C_{pcp}} + \mathrm{C_{pcl}} + \mathrm{C_{pce}})$$

(17)

Preventive maintenance is performed based on scheduled distance travelled while corrective maintenance is measured by interval of vehicle use until failure happened. Thus, the parts, downtime spent, workshop equipment cost, and training of mechanics are considered in both maintenance activities. In this formula, the mean time between maintenance and failure is differentiate of $\mathrm{C_{PM}}$ and $\mathrm{C_{CM}}$. the formulas are both as follows

$$\mathrm{C_{PM}} = \frac{\mathrm{T}_p}{\mathrm{MOTP}} (\mu c_{\mathrm{sp}} + (\mu c_{\mathrm{le}} \mu T_{\mathrm{lp}})$$

(18)

Where T_p is the operating time before failure, MOTF is the mean operating time before failures, μc_{sp} is the costs of parts used for corrective maintenance (MYR), μc_{le} is the cost of labour and equipment used hourly (MYR/hour) and μT_{lp} is the labour total hours need to complete preventive maintenance (hours). On the other hand, the corrective maintenance formulation are as follows

$$\mathrm{C_{CM}} = \frac{\mathrm{T_f}}{\mathrm{MOTF}} (\mu c_{\mathrm{sp}} + (\mu c_{\mathrm{le}} \mu T_{\mathrm{lf}}))$$

(19)

Where T_f is the operating time before failure, MOTF is the mean operating time before failures, μc_{sp} is the costs of parts used for corrective maintenance (MYR), μc_{le} is the cost of labour and equipment used hourly (MYR/hour) and μT_{lf} is the labour total hours need to complete corrective maintenance (hours). On top of that, the calculation for environmental cost, C_E will be formulated on each stage.

$$C_E = \mathrm{VEF} \frac{DT}{EF}$$

(20)

Where VEF is the vehicle emission factor, DT is the vehicle distance travelled while EF is the vehicle fuel efficiency. Then, the disposal formula from formula (5), the elaboration formula to calculate the depreciation formula and residual formula is as below

$$\mathrm{C_d} = \mathrm{C_p}(1 - \mathrm{r})^{\mathrm{n}} \tag{21}$$

$$\mathrm{C_r} = \mathrm{C_r}(1 - \mathrm{r})^{\mathrm{n}} \tag{22}$$

Where the r is the rate of depreciation and n is the time (in year). Hence, based on formula, the LCC cost has the following form.

$$\mathrm{LCC_{UPHDV}} = \mathrm{C_I} + \mathrm{C_{OM}} + \mathrm{C_D} \tag{23}$$

$$\begin{aligned} LCC_{UP} = {} & C_p + C_{gst} + \mathrm{VEF}\frac{DT}{EF} + \frac{DT}{FE_{rf}} P_{rf} V_l + \frac{DT}{FC_{of}} P_{of} V_l + \frac{V_l}{T_{al}}\eta_T P_T + \frac{V_l}{B_{al}}\eta_B P_{TB} \\ & + (c_{\mathrm{ms}})V_{la} + (c_{\mathrm{tl}})V_{la} + (\mathrm{C_{ins}} + \mathrm{C_{rtx}} + 2(C_{ei} + C_{ti})\frac{V_n}{V_{la}})V_{la} + \frac{\mathrm{T}_p}{\mathrm{MOTP}}(\mu c_{\mathrm{sp}} \\ & + (\mu c_{\mathrm{le}} \mu T_{\mathrm{lp}})) + \frac{\mathrm{T_f}}{\mathrm{MOTF}}(\mu c_{\mathrm{sp}} + (\mu c_{\mathrm{le}} \mu T_{\mathrm{lf}})) + \mathrm{VEF}\frac{DT}{EF} + \mathrm{C_d} + \mathrm{C_p}(1 - \mathrm{r})^{\mathrm{n}} \\ & + \mathrm{C_r}(1 - \mathrm{r})^{\mathrm{n}} + \mathrm{VEF}\frac{DT}{EF} \end{aligned} \tag{24}$$

$$LCC_{UPHDV} = \frac{LCC_{UP}}{V_l} \tag{25}$$

Based on the studies made, the initial cost is an important factor in understanding the financial impact of acquiring green commercial vehicles. Equation (3) captures this cost by summing the purchase cost of the vehicle chassis and the government sales tax. This is added to the value of emission cost at the initial cost of the vehicle at equation (24). This study would answer the following limitation of research gap in Malaysia case different taxation method which Petrauskienė et al (2021); Zamasz (2021) specifically mentioned about studying green vehicle in context of their own countries of Lithuania and Poland environment.

Besides that, maintenance and operational state has also elaborated to filled the gap of the classification of HDV and maintenance cost limits its LCC comprehensiveness at use-stage technically (Zamasz, 2021; Pardhi, 2022) proposing different type of analysis LCC comparing ICEV with HVO powertrain, specifically in Netherland scenario. Moreover, many researchers conclude that BEV will still become competitive only if conventional fuel cost reach certain limit based on their sensitivity analysis (Guo et al., 2023). However, Zamasz (2021) argue that BEV still the best when fuel cost focuses on carbon emission at tailpipe on BEV in additional to maintenance cost reduction on BEV for fleet management. The same result for GHDV, HEV remains the best for long-range travel in GHDV options and this makes BEV competitive only with the help of government subsidies (Rout, 2022). The statement on GHDV is supported by (Alonso-Villar et al., 2022; Comello, 2021) when focusing on trucks duty concern on delivery and long-haul trucks while positively mentioned about the positive future of FCEV.

There are researchers neglecting the disposal cost such as (Alonso-Villar et al., 2022; Li, 2020; Zamasz, 2021; Petrauskienė et al., 2021; Comello, 2021) whom focuses on fuel consumption to established comparison to environment cost (Pardhi et al., 2022; Pardhi, 2022). The limitation on external costs together with disposal cost makes the LCC not comprehensively evaluated in such Guo et al (2023) mentioned reduction of 47% in lifecycle cost on carbon at use-stage still cannot compensate for initial purchase cost. This is worsened with reduction of government support to enhance GHDV implementation. Thus, equations 8, 21, and 22 calculate depreciation and residual value while considering variables like the rate of depreciation and the lifespan of the vehicle. Understanding how the vehicle's value changes over time and how it affects the LCC calculation is made possible by using these equations.

Furthermore, in the aspect of environmental concern as Equation 20, it is based on many studies that the vehicle emission factors of duty concern, distance traveled and fuel efficiency as to established comparison to environment cost (Pardhi et al., 2022; Shantanu Pardhi, 2022). With China leading the LCC modelling with environmentally consequences in studies related (Guo et al., 2023; Li, 2020; Mitropoulos, 2017; Qiao et al., 2022; Qiao, 2020), but many research does not include the environment cost (Rout, 2022; Mitropoulos, 2017). Hence, the financial modelling established insights in developing a comprehensive LCC at use-stage for commercial vehicles.

In summary, it is important for Malaysia to study the financial modelling for commercial vehicles as the study in Malaysia Mustapa (2020) and Australia Kara et al (2017) focus generally on passengers vehicle concerning options of green vehicle availability and its high LCC on cost per distance and fuel consumption. The result limited to only passenger vehicles has been supported by Troncon (2019); Hsieh & Green (2020); Mitropoulos (2017); Vijayagopal & Rousseau (2021) when researchers preferred PHEV and HEV more than BEV while optioning out ICEV. The travel distance and fuel cost are the most important element of comparison. However, these researchers neglected the importance of environmental cost and social impact, resulting in quantifying operational cost concerns.

Conclusions

Environmental cost in definition for GHDV is the value of environmental affected by emissions are translated into uniform comparable values. The proposed Financial Modelling is built on life cycle cost (LCC) analyses and life cycle emissions projections for several types of HDV in transportation. Alternative vehicle technologies are studied including engine and fuel possibilities considering fuel consumption at use-stage. As for the environmental cost, the calculation need to be further narrowed down to ensure correct unit price of the equivalent value which is then transformed into the carbon equivalent value (Li, 2020). Besides that, as many researchers neglected the importance of environmental cost and social impact, resulting in quantifying operational cost concerns, these green financial model should fill the gap of external costs and disposal cost as mentioned by (Guo et al., 2023; Cameron Rout, 2022; Lambros Mitropoulos, 2017). This is important to enhance the relativity for LCC with GHG emissions which have attracted many researchers considering the environmental consequences to enhance the LCC modelling in many countries recently with China leading the research (Guo et al., 2023; Junjie Li, 2020; Mitropoulos, 2017; Qiao et al., 2022; Qinyu Qiao, 2020).

In conclusion, this study provides insights into the viability and advantages of transitioning Malaysia's fleets to green vehicles, particularly GHDV. It helps decision-makers build sustainable transportation policies by examining the relationship between carbon emissions, upfront costs, and ongoing operating costs between ICE and GHDV. The research develops an important tool to assess the costs and benefits of transitioning to greener and cleaner transportation options. The environmental concern that led to environmental cost in LCC is undeniable. As a result, economic benefits such as reduced fuel costs and reduced dependence on fossil fuels, the GHDV also reduces the impact of transportation on the environment and the dependence on non-renewable resources. It is important to consider all these factors when evaluating the potential benefits and drawbacks of green heavy vehicles and when developing policies and programs to promote their use. Hence, this factor should be an important factor to be quantified to be presented the benefit not only quantifying direct from initial cost.

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