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Frans Bal
HU University of Applied Sciences Utrecht
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Insights into the merits of the total cost of ownership and some financial indications regarding Dutch e-bus investments and operations

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1. Introduction

Opposite to buying consumable goods, an investment in durable goods is meant for use for a longer period and is accompanied by a serious level of risk. An investment in the less optimal or wrong product may result in lower revenues and/or additional costs for a longer period. Hence, deriving insights into the optimal product to acquire commonly initiates some type of in-depth study. The higher the risk, the more rigorous the study will be.

A Dutch concession holder[1] receives a reimbursement per hour of bus service in addition to passenger revenues. The margin between cost and revenue per kilometre may be marginal. At the same time, due to COVID-19 the demand for the public, and thus the passenger revenues, decreased suddenly and may be changed significantly in the upcoming years. So, currently, it is difficult to predict whether and when the volumes will reach their pre-COVID-19 levels again and how the business case will be in the near future, adding to the overall uncertainty about the future and the level of risk that accompanies investments.

In the business environment, the Total Cost of Ownership (TCO) is a method that is commonly used to contribute to a more rigorous underpinning of investments. It is a way of assessing all the costs induced over an entire lifespan of an asset. In the Netherlands just recently the application of the Total Cost of Ownership method is gaining ground in assessing public transport (PT) investments. These days a concession holder faces many aspects in the search for the optimal choice regarding asset investments, including buses. Environmental layout, route characteristics, governmental regulations, and financial aspects are among the most prominent ones. New ZE buses require an advanced electric infrastructure compared to the common diesel versions. Besides the purchase of the ZE-buses also an investment in additional infrastructure (e.g., sophisticated maintenance tools, chargers, additional safety measures) is compulsory, adding new elements to the decision-making process and extra financial aspects to the business case. Hence, depicting the most suitable type of bus in service for the next 10 years is not straightforward anymore.

[1] A concession holder is the public transport operator that provides mobility services in compliance with the issued concession.

2. A TCO Study: The Basic Idea Behind the Method

Clearly, the replacement of the fleet of diesel buses with more sustainable ones is more complicated. With the transition towards ZE-variants, new elements are to be considered in the common business case studies (e.g., the cost due to the charging infrastructure). A TCO is a method of study (often applied as a spreadsheet tool) to help potential buyers estimate with higher precision how much money they will pay to operate an asset[2]. It is primarily relevant for investments that are accompanied by a complex decision-making process under uncertainty.

Besides the actual purchase of the asset itself, additional elements are to be considered to 'get the whole picture'. These elements may induce significant costs, such as maintenance costs, the needed software updates and/or upgrades, auxiliary machinery, tools, and supplemental services. A TCO study enables to identify the direct and indirect costs[3] incurred by the purchase of an asset. Its objective is to avoid unexpected expenses and calculate profits and losses. According to FORCAM (2022), "… *it goes beyond the purchase price and takes into account the total financial obligations associated with an investment. In this way, companies can better manage costs, allocate resources efficiently and identify cost drivers early on.*"

3. TCO versus LCC: What's the Difference?

The common form of TCO is concerned with identifying the relevant monetary variables to present a financial overview to support the managerial decision-making process. This is not different from Life Cycle Cost (LCC). The main difference between TCO and LCC is that the latter method is referring to products and services in the category of so-called public goods. These goods are provided by governments and lack a price-setting mechanism in the (commercial) market(s). National security by the nations armed may serve as an example. In general, costs emerge, but no turnover or revenue can be determined. In addition, with a TCO the economical life span is commonly considered, whereas with an LCC the total time of the commission of the asset is often applied. This may be up till its technical life, which may exceed the economical life span. Useful background information to undertake a proper rigorous LCC study is provided by Smit (2012).

4. TCO: The Sum of the Parts

In general, a TCO calculation aims to provide *ex-ante* the full spectrum of the financial implications of a potential investment. In practice, a TCO (and LCC) aims to derive insights into the 'submerged' part of the iceberg of costs that lies awaiting when the investment is initiated. This idea is visualized in Figure 1.

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[2] Or buy-in of a service, not considered here.

[3] Besides costs, this may also include additional (in)direct income and/or cost reduction that arises as a result of the purchase of the product or service.

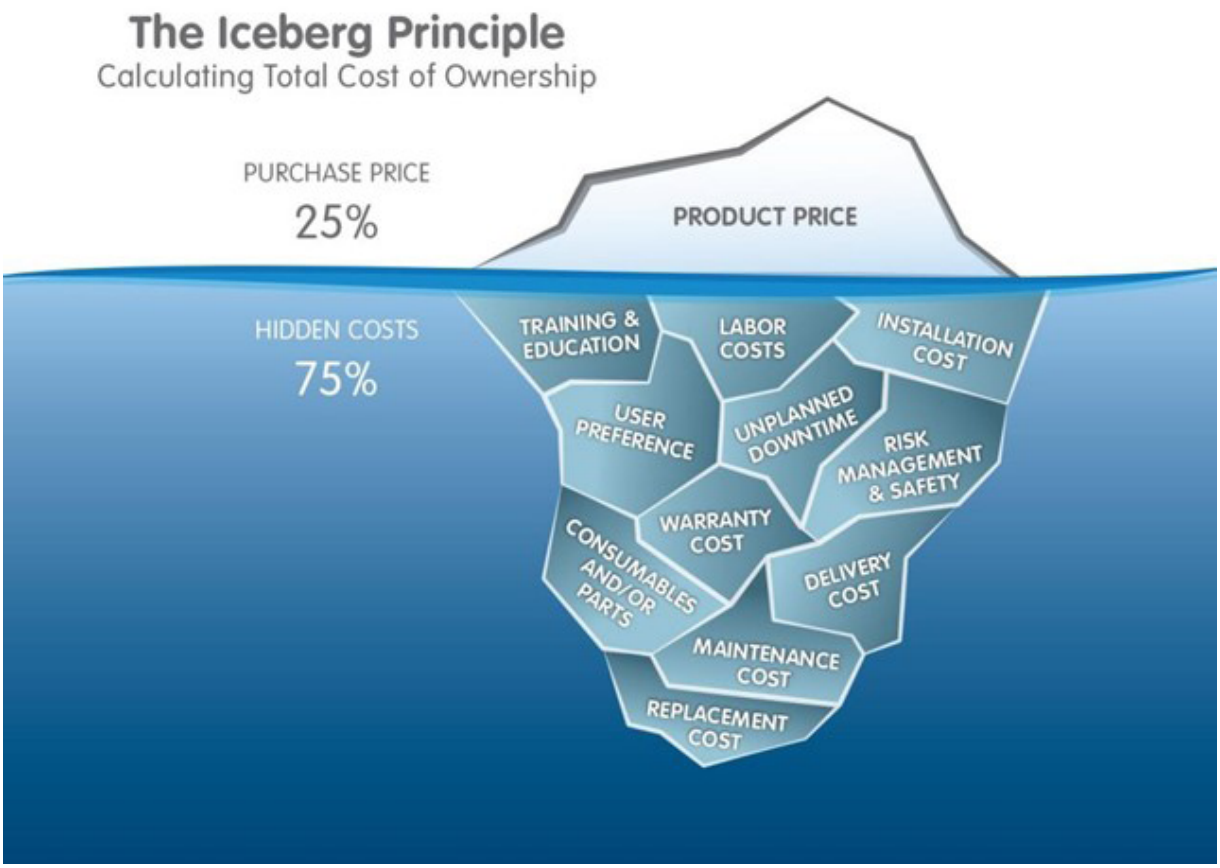

Figure 1. Visualization of disclosing the costs incurred by buying an asset by a TCO-study
Source: https://blog.buyq.org/wp-content/uploads/2017/06/unnamed-1024x768.jpg

In the literature and on the internet, various interpretations and visualizations of the TCO model can be found. depending on the (business) case at hand. See, for instance, Figure 2. Although sometimes labelled and arranged slightly differently, in the literature, there is consensus that a TCO study consists of several categories of cost drivers, viz:

- Acquisition costs (including the (TCO) study process costs, decision-making and planning costs, costs to train personnel, etc.)
- The purchase price (including the purchase of the necessary maintenance equipment, buying or modifying buildings to store the newly obtained product(s), etc.)
- Operational cost (e.g., energy costs, costs due to wear-and-tear, purchase of lubricants and spare parts, etc.)
- End of service life costs (decommission costs, such as refurbish to re-sell costs, scraping costs, recycling costs, etc.)

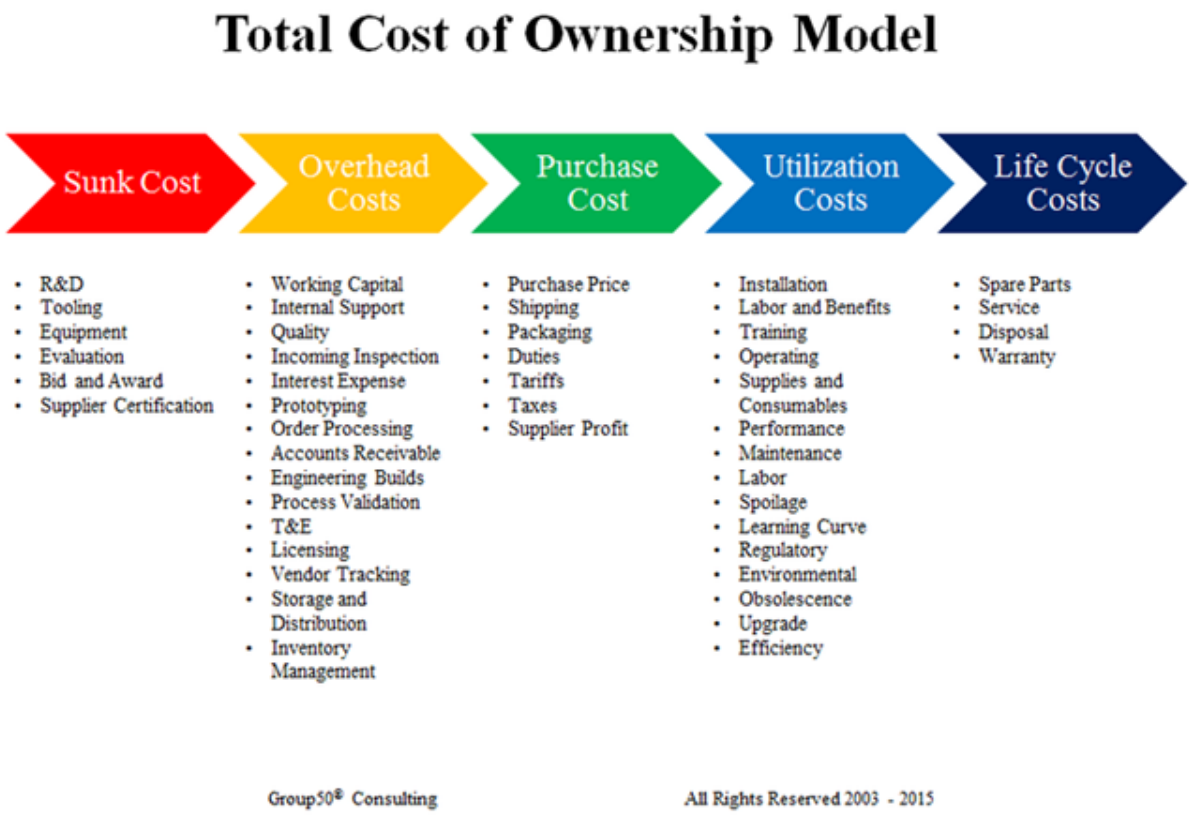

Figure 2. An example of a TCO model and common relevant cost drivers
Source: https://www.group50.com/total-cost-of-ownership-tco-process/

Various types of costs can be distinguished, viz:

- Direct cost
- Indirect cost

Opposite to direct costs, indirect costs cannot be related to a single cost objective but are needed to operate the organization as a whole. In different words, it can be cost related to two or more specific cost objectives. In practice, indirect costs incur due to administrative overhead. Having a Legal and/or Marketing department may serve as an example. Hence, the analysis of the individual components and TCO estimation reveals the (also hidden) direct and indirect costs, helping to identify cost drivers subject to the (potential) investment at an early stage. Essential is to expose costs that are hidden in the entire organization.

5. A TCO-study: Insights in the Financial Aspects from 'Scratch to Scrap' or 'Cradle to Grave'

As the figure on the next page shows, several phases can be distinguished regarding the lifespan of an asset. Its connection with TCO is elaborated in Figure 4. Ideally, the managerial decision-makers should evaluate the TCO study afterwards via a PDCA cycle to derive additional insights and to further improve the TCO process for the next one.

Figure 3. Several phases of the lifespan of an asset
Source: https://www.appa.org/wp-content/uploads/2019/10/APPA-TCO-cover.jpg

To meet the objective all costs are to be disclosed and incorporated into the calculation. In practice, often a TCO study starts at the moment of the actual acquisition of a durable good. However, the more expensive the good, the higher the risk that accompanies the investment, and the more extensive the pre-acquisition study, planning, and enrollment into service will be. This 'pre-acquisition' period might be an extensive study period, that may cover several years, resulting in significant costs. Therefore, the cost due to this pre-acquisition period should be included in a TCO study. This results in a type of study that aligns with the principle of from scratch-to-scrap or cradle-to-grave, covering the entire lifespan of the asset purchased.

Figure 4 shows an approach in which cost drivers are grouped into three main categories. It must be kept in mind that negative costs (benefits) may occur. For instance, due to subsidies, (re-)sell of goods, benefits incurred by recycling, etc.

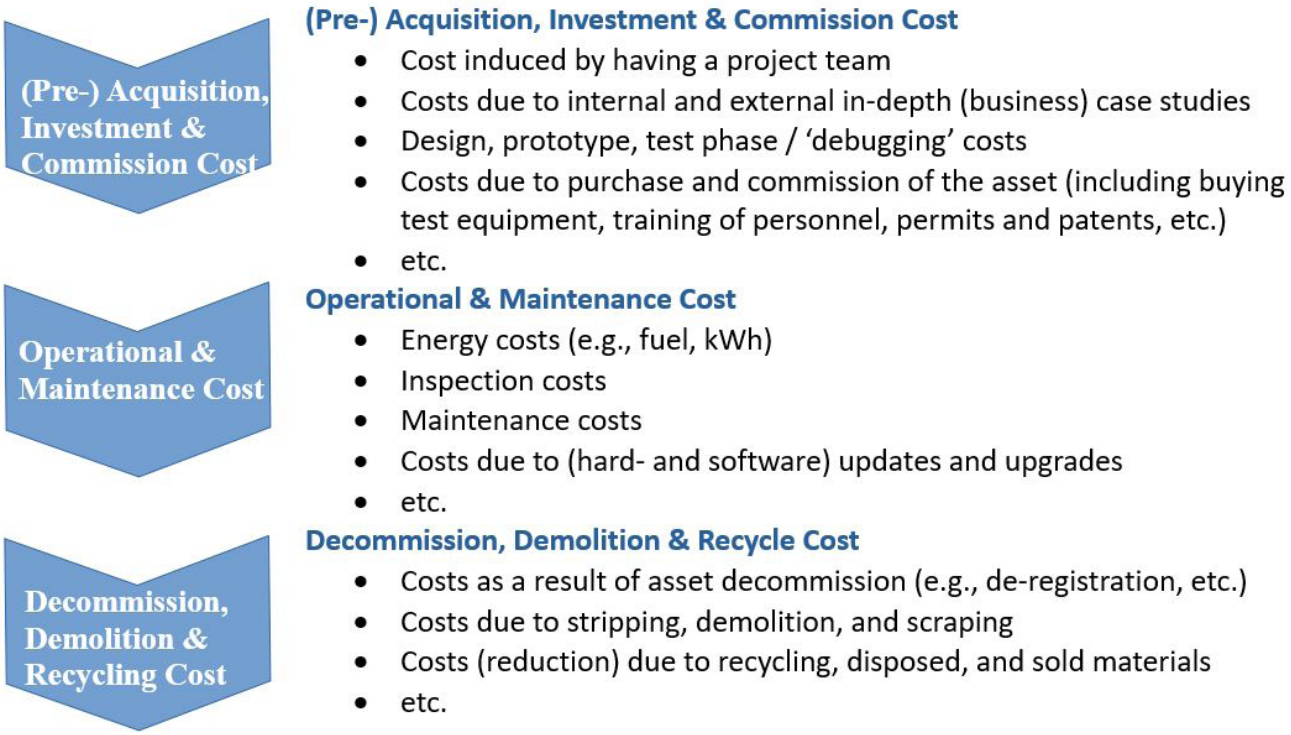

Figure 4. A TCO structure based on the life cycle of the asset

6. An Example of an Application on a Dutch Bus(iness) Case

Important Dutch Market Characteristics

In general, in the Netherlands, a concession holder receives a reimbursement per hour of bus service, in addition to the passenger revenues. As long as the costs due to the service prescribed in the concession are less than this reimbursement plus the passenger revenues the concession holder achieves a positive margin (i.e., the concession holders achieve a profit).

The margin between cost and revenue per bus hour may be marginal. Due to COVID-19, the demand for public transport decreased suddenly and, possibly significantly in the upcoming years. So, currently, it is difficult to predict whether and when the volumes will reach their pre-COVID-19 levels again and how the business case will be in the near future. This results in a significant level of uncertainty in the decision-making process. Hence, deriving in-depth financial insights into the cost and revenues accompanying the potential investment will provide the concession holder with valuable information for a more rigorous selection between e-bus alternatives, in general, and within the specific bus categories in particular.

The Dutch reimbursement model is the heart of the decision-making process, previously initiating a rather rudimentary calculation process for the business case. Therefore, it should be considered by the concession holder to incorporate a more elaborate financial study regarding new investments. Especially, as indicated later in this

article, the composition of the cost per kilometre of e-buses is significantly different compared to their well-known diesel equivalents. In this manner, the decision-makers – and governing concession provider, the province – derive better insights into the various components and individual cost levels that determine the cost per bus kilometre.

Investment into new buses or the replacement of the existing rolling stock by e-buses is not only a matter of deriving insights into the technical specifications to meet the concession requirements. In general, it is a long-term investment, that may span a decade of public transport service . A mismatch may imply unforeseen costs, reduced income, claims, etc. for a long period. In fact, this investment process of acquiring buses is accompanied by uncertainty. Especially, while the new e-buses require an advanced electric infrastructure compared to the common diesel versions. Hence, this means an investment in additional infrastructure (e.g., sophisticated maintenance tools, chargers, additional safety measures) results in new elements in the decision-making process, adding extra financial aspects to the business case.

It is not enough to consider new investments in e-buses, but also to look at the business opportunities. As a result of granted concessions of limited time, the buses and even the bus depot (and its e-infrastructure) may be transferred to another concession holder later in time. Practically, the financial implications of the earlier investment decisions may be useful information to include in the dossier and negotiations in case the concession is granted to another concession holder.

En route to a proper TCO Calculation

In its basic form, it is limited in terms of variables considered and the number of study stages. In search of sound financial decision-making under uncertainty, an elaborated process is needed to be a useful tool for the concession holders' decision makers to

get a better insight into the business case. The presentation at the Utrecht Interreg Interregional Learning Event webinar on 16 September 2021, shows that an ex-ante iterative three-step scenario TCO-study with sensitivity analysis is a study approach enabling to obtain in-depth insights into the financial implications of e-bus investments. This roughly consists of three phases, viz.:

I. the inventory of parameter cost values of selected lines
► Preliminary TCO per specific line
► The match of the initial idea of the budget needed and decide which type of lines & types of buses require further investigation.

II. a market research of buses & infrastructure components
► Scenario computations that include optimizing the e-bus deployment schedules versus their battery size.

III. Adding financial constraints and possible cost reductions (e.g., due to third-party loans and other favourable financial agreements, considering various depreciation time possibilities) in the scenario analysis.

In the end, an array of detailed estimates are obtained, which includes the required budget and the number and types of buses that fit the concessions holder's objective [6]. So, the use of the TCO model in this manner yields a high added value by providing the rigorous decision framework for the evaluation and accountability of the concession holders' ambition level, logistical possibilities, and available budget.

Jump-starting a TCO-model Calculation

In the Netherlands, a TCO model for ZE buses is provided via CROW (see: www.tco-zeb.nl), free of charge, for all contributing to the introduction of ZE bus services. They host the needed tooling (computer simulation program), help-desk facilities and provide expertise, including special demonstration sessions about the TCO model for users and via a special LinkedIn group.

A Near-future Scenario

Due to both
• the technical issues as a result of introducing new advanced technologies and
• the limited range of early series, on the one hand and being commissioned on routes and in timetable-schedules of diesel buses, on the other,
e-buses are currently not so effective and efficient as their diesel counterparts. In practice, more e-buses are needed to fulfil the daily bus service operations [7]. Having slack equipment and extra personnel generates extra costs.

According to the study by CROW (2020a), when e-buses have a range of 5,00 kilometres or more, they can replace 93% of the combustion engine (e.g., diesel, CNG/

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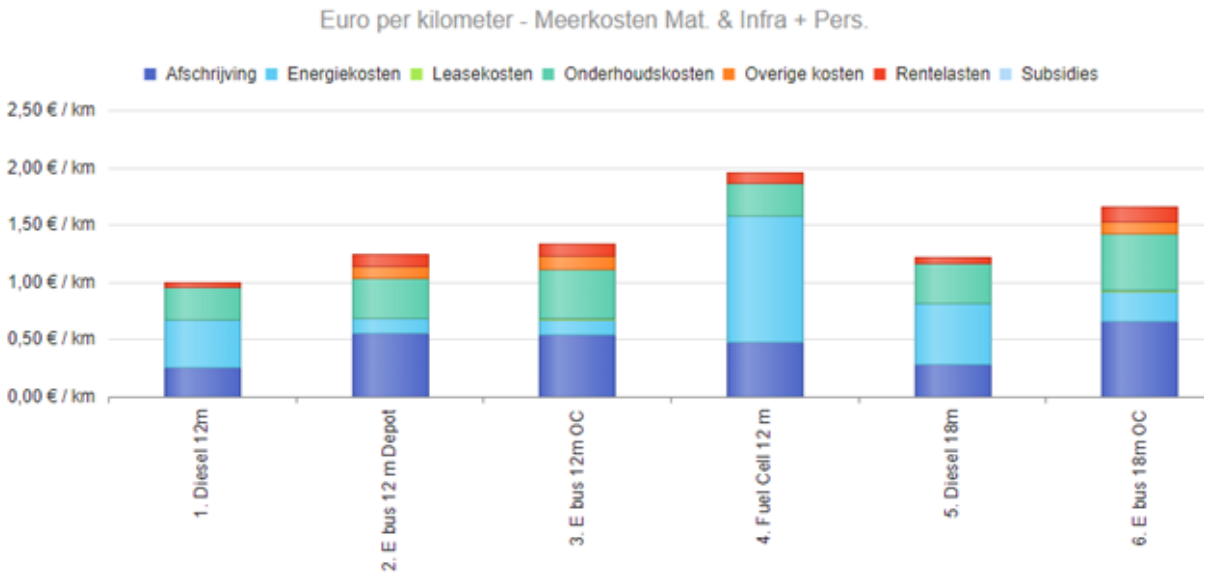
[6] This will depend on the concession holders' preferences (e.g. preferred service level, the accepted downtime levels, etc.) within the degree of freedom of the concession.
[7] This situation emerges especially when charging during the daytime is needed.

LNG) buses. With new types of e-buses currently entering the market (e.g., Ebusco 3.0, VDL Citea) their influx in the daily bus service operations will be substantial because of the aim of many newly issued concessions to achieve the objective of emission-free public transport mobility at the end of this decade (e.g., Platform Duurzaam OV en Spoor, 2021).

In light of this scenario of a 93% replacement of diesel buses by e-buses, CROW (2020b) estimated the cost per kilometre for various types of buses. The next figure shows that, overall, the cost per kilometre of ZE-buses is significantly higher than that of diesel buses. In more detail, the depreciation cost and the level of interest of ZE-buses is higher compared to diesel buses. This is, for instance, the result of the more expensive e-bus and the necessary acquisition of sophisticated electrical equipment. Also, the maintenance cost is higher. However, due to the lower energy cost, these extra costs are largely compensated, resulting in a modest higher cost per kilometre.



Dutch	English Translation
Afschrijving	Costs of depreciation
Energiekosten	Energy costs
Leasekosten	Lease costs
Onderhoudskosten	Maintenance costs
OC	Opportunity charging
Overige Kosten	Other costs
Rentelasten	Interest costs
Subsidies	Subsidies
12m/18m	12 meter/18 meter in length

Figure 5. An overview of the cost composition per bus type.
Source: CROW (2020b), pp. 9. Note: The calculations are based on an operational replacement of 10 diesel buses. Additional costs emerge due to 10% extra e-buses and the needed extra utilization of the e-infrastructure and personnel. The depreciation period of the charging infrastructure is considered to be 15 years.

An overview of the CROW (2020b) estimates of the additional cost of the commission of e-buses in various scenarios is presented in the next table.

Scenario / bus length+charge type	**12m depot charge**	**12m OC**	**18m OC**
	Additional costs per bus per annum		
+ 20% extra e-buses	€35.000	€44.000	€53.000
+ 10%: the benchmark (discussed case)	€24.000	€32.000	€40.000
1-to-1 operational replacement (no extra e-buses)	€6.000	€15.000	€24.000

Figure 6. An overview of several scenarios of diesel bus replacement and the costs incurred.

According to CROW (2020b), only in the case of the most optimistic – but unrealistic - scenario of a 100% (1-by-1) replacement of diesel buses by e-bus equivalent results in a lower cost per bus per annum for all scenarios.

7. Favourable Loans

As Figure 5 indicated, the interest costs of e-buses are higher compared to diesel buses. This is the result of higher purchase costs per e-bus and the investment in additional electrical infrastructure (e.g., charging equipment). Financing investments at lower interest rates significantly reduce the interest costs. In the Netherlands, two state-owned public banks (Bank Nederlandse Gemeenten, BNG, and the Nederlandse Waterschapsbank, NWB) issued loans for EUR 400 million to several concession holders (e.g. the GVB, the concession holder in Amsterdam) to enable the replacement of old rolling stock and the purchase of additional vehicles that are more sustainable. Within this financial construction, there is also room for cheap(er) investments in auxiliary equipment such as maintenance and care (bus) wash equipment, IT infrastructure, real estate investments, a.s.o [8]. For example, in the case of the city of Amsterdam, the concession granter compensates for the inflicting interest costs on the side of the concession holder as a result of the investments by the latter.

[8] For more information, see Platform Duurzaam OV en Spoor, [2021].

8. TCO and Dutch e-Bus Mobility: Retrospect and prospects

An ex-ante iterative three-step scenario TCO-study with a sensitivity analysis provides useful financial information for decision-makers and parameter estimates for optimization processes. Especially, it adds to the understanding and calculation of the cost of investments in e-buses and the electric infrastructure and its residual market value when a new concession holder takes over.

Although the estimates are based on a small sample, those involved in the introduction of ZE-buses can obtain for free the needed tooling and support. Paving the way for a more extensive study approach. Clearly, providing the TCO tooling and service in English would extend the range of its application drastically.

The cost per kilometre and addition cost estimates are a snapshot of the actual situation. Clearly, future developments may change the picture. For instance, the low price per kWh is likely to rise significantly when the Dutch government is rising the taxes on electricity to compensate for the decline in taxes on petrol and diesel fuel in the next decade due to the transition to e-vehicles.

Interesting is the impact of favourable loans and other financial agreements on the cost per kilometre. By offering favorable loans, or by offering guarantees to banks that finance the busses, public transport authorities significantly reduce the cost of financing the transition to zero-emission buses, covering the incremental costs compared to diesel buses.

On average, a concession lasts for about 10 years. In practice, in the Netherlands diesel buses are replaced after ± 9 years of service and are often sold afterwards. It is unclear what the lifespan of the e-buses will be and what the residual value will be. Is there a market for secondhand e-buses anyhow? This will have a direct impact on the TCO cost per kilometer estimates.

The competitive cost per kilometre of e-buses is achieved due to the low energy cost and a depreciation period of charging equipment of 15 years. In a market subject to rapidly evolving technology, it is questionable whether the charging equipment is expected to last that long. Technically, maybe, but this may be different from an economic perspective. For instance, when V2G or V2X-systems are becoming favoured (subsidized) by governments or rapid developments change the overall landscape of the energy markets.

The re-sell value and depreciation cost are directly influencing the outcome of a TCO study, the cost per kilometre, and whether a transition to e-buses is not only an ecologically but also an economically viable one. This question is difficult to answer in a developing market being in its early adopter phase consisting of new initiatives and pilots. Clearly, any organization that grants a concession should be aware that the concession period, on the one hand, and the business case period, on the other, may deviate from one another significantly. This may hamper the process of granting in a liberalized public transport market as the Dutch market is. A so-called Overnameregeling (CROW, 2020c) with explicit arrangements about the transfer of vehicles and equipment to the new concession holder may be needed, resulting in an extra step in the already elaborate concession granting process.

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