Life Cycle Cost Analysis of Electrical Vehicles in Australia

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Abstract
Electric vehicles (EV) have tremendous potential due to their ‘zero tail-pipe emission’ and low maintenance costs. However, a higher upfront cost comparing to internal combustion engine vehicles (ICEVs) threatens the popularity of EVs in Australia. Moreover, the uncertainties of the new technology are often responsible for unanticipated costs over the vehicle life cycle. Hence, this paper aims to investigate the economic feasibility of EVs in Australia. A Life Cycle Cost (LCC) analysis was conducted on the 2011 Nissan Leaf in order to estimate the total economic impact over its life cycle under Australian conditions.

1. Introduction

Australia, as a developed country, is not immune from a high level of car use across the globe. In fact, the transport sector contributes to approximately 14% of Greenhouse Gas Emissions in Australia and it is also the second fastest source of emissions growth. Road travel, at 89%, is the main contributor to the 14% of greenhouse gas emissions attributable to the transport sector [1]. Recently, there is a total of 17.63 million vehicles registered across Australia with an annual growth of 2.5% from 2009 to 2014. Petrol powered vehicles compose 78.8% of the total vehicle fleet whilst diesel-powered vehicles account for another 18.5% [2]. This larger proportion of Internal Combustion Engine Vehicles (ICEVs) currently in Australia, combined with a decrease in traditional automobile pricing [3], has the potential to significantly worsen Australia’s road pollution problem. It is therefore of prime importance to assess the capacity of alternative fuel vehicles to mitigate associated issues including health problems, global warming and fossil fuel dependence.

Electric vehicles (EV) are being increasingly seen as a form of sustainable personal transport in the future. This idea has been reinforced through government policies across the world that aims to reduce greenhouse emissions and improve energy security. For example, the European Union has aimed to substitute 10% of the conventional fuels used in the road transport sector prior to 2020 [4]. If all the potential benefits of EVs can be realised upon widespread utilisation, greenhouse gas emissions, ambient air pollution and foreign oil dependency can all be significantly reduced.

However, the operating cost savings, brought about by the lower electricity price in comparison to liquid fuels, are deemed to be not a sufficient incentive for adoption [1]. Moreover, the added uncertainties of the new technology are often responsible for unanticipated costs over the vehicle lifecycle. Since the modern society has become progressively cost and risk averse, an unclear net benefit of adopting EVs would further hinder its popularity.

In order to quantify both the cost savings and extra cost attributed to EVs, a life cycle cost (LCC) analysis must be conducted. This allows for the identification of the key input parameters that make the EVs less competitive in relation to conventional ICEVs. This can then be used to focus future research efforts in an attempt to enhance the efficiency of these crucial components as well as determine the extent of the necessary government interventions to enable EV
feasibility. In this paper, the LCC framework is applied to quantify the economic impact of a 2011 Nissan Leaf under Australian conditions and provide a comparison with an equivalent ICEV, the Toyota Corolla.

2. Background

The lifecycle cost is often referred to as the sum of all costs incurred during an asset’s useful life and allows for a more appropriate cost-benefit analysis. The ‘realistic appraisal’ conducted through LCC analysis is further reinforced by considering the time value of money. This method assists in the reduction of the total cost of a product, identification of high-cost components in a product’s lifecycle, and comparison of competing products. The LCC procedure used in this analysis is based on the AS/NZS 4536:1999 Standard, which follows 6 steps including analysis plan, model development, model analysis, analysis documentation, review of results, and implementation & update [5].

For a typical automobile, the LCC can be defined as [6]:

\[
\text{Total LCC} = \text{Acquisition Cost} + \sum_{i=1}^{n} \left( \text{Operating Cost for a Given Year} + \text{Scheduled Maintenance Cost}_i + \text{Unscheduled Maintenance Cost}_i \right) + \text{Car Disposal Cost}
\]

These cost elements have been successfully utilised by [7-8], for automobile lifecycle studies in Singapore and the United States respectively. However, many other studies, including that conducted by [9] have omitted the “Unscheduled Maintenance Cost” category due to limited first-hand data availability which limits the accuracy of time and cost prediction. As a result, this paper also excludes the unscheduled maintenance aspects of vehicle ownership.

The majority of previous EV life cycle costing studies highlight battery cost as the most contributing factor to the current high price of EVs. The retail cost of a typical EV Lithium-Ion battery is estimated at 300A$/kWh. For the Nissan Leaf’s 24kWh battery, this amounts to A$7,200, which is a significant cost premium [10]. The battery production costs are however decreasing at present in conjunction with the rise of the specific energy of the batteries. It is hoped that as EVs become increasingly popular due to rising environmental and energy concerns, the high volume of battery production will further decrease the costs per unit in line with the experience curve.

It is nonetheless important to note, that the total life cycle cost results for an EV are heavily dependent on the assumptions within each model as well as the scope of the study. Whilst some of the previous analyses depict EVs as uneconomical in the near future, others demonstrate the significant cost savings that may be realised. For example, a study conducted by [11], reveals such positive cost savings in a scenario that assumes EV home recharging and no replacement/repair costs. The availability of a replacement ICEV, for travel on days when the EV range was exceeded, had been assumed. However, pollution and public charging infrastructure costs were not incorporated. A study conducted by [12] has evaluated the reductions in air pollution that are viable with EV vehicle introduction in Australia if the social costs of pollution are incorporated into the LCC of an EV.

The 2011 Nissan Leaf represents the most successful fully electric vehicle on the market today and as such is deemed to be the most appropriate for representing a small to medium passenger electric vehicle in this study. The key specifications are listed in table 1.

Table 1. 2011 Nissan Leaf Specifications

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Country of Origin</strong></td>
<td>Japan</td>
</tr>
<tr>
<td><strong>Motor</strong></td>
<td>80kW AC Synchronous</td>
</tr>
<tr>
<td><strong>Battery</strong></td>
<td>24kWh Lithium Ion</td>
</tr>
<tr>
<td><strong>Battery Weight</strong></td>
<td>294kg</td>
</tr>
<tr>
<td><strong>On Board Charger</strong></td>
<td>3.3kW</td>
</tr>
<tr>
<td><strong>Kerb Weight (Max)</strong></td>
<td>1541kg</td>
</tr>
<tr>
<td><strong>Max Pay Load</strong></td>
<td>395kg</td>
</tr>
<tr>
<td><strong>Overall Dimensions (L x W x H)</strong></td>
<td>4445mm x 1770mm x 1550mm</td>
</tr>
<tr>
<td><strong>Rated Range per Charge</strong></td>
<td>175km</td>
</tr>
<tr>
<td><strong>Electricity Consumption</strong></td>
<td>289Wh/mile [11]</td>
</tr>
<tr>
<td><strong>108-240Wh/km [15]</strong></td>
<td></td>
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</tbody>
</table>

3. LCC model development

In this analysis, the functional unit is 1 km driven by the 2011 Nissan Leaf in NSW metropolitan region, Australia. This analysis uses a “cradle-to-grave” approach that all costs associated with the purchase, operation and disposal of the vehicle will be incorporated.

The useful life of 2011 Nissan Leaf is assumed to be 200,000km, or more specifically 20 years with an annual mileage of 10,000km. This assumption is based on Australian statistics that an average registered vehicle has an age of 10 years and annual mileage of 14,000km [16]. The adjustment is made because EVs are expected to outlast their ICEV counterparts due to lower range availability and below average annual mileage of 10,000km combined with adequate maintenance. At a replacement cost of approximately A$7,300 [17], it is assumed that battery replacement would be economically feasible for selected vehicle owners. Since the vehicle was purchased in 2014, all prices have been quoted in 2014 Australian Dollars. Based on the guidance of the NSW Department of Treasury and Finance, an interest rate of 7% has been implemented in this study [18].

Although the electricity consumption of driving EVs is heavily dependent on regional factors [15], this study assumes the energy consumption during the operation phase is 0.137kWh/km due to simplicity. In addition, the efficiency of the level 2 charging process has been taken into account that additional 20% energy is required due to the losses associated with the assumed sole charging method [19].

3.1. Consumer LCC Model

Based on above scope and assumptions, Fig. 1 illustrates the framework of the base case consumer LCC model for this study.
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