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Will durability be a characteristic of future cars?

Nieuwenhuis P.[(a)(b)]

a) Centre for Automotive Industry Research, Cardiff Business School, Cardiff University, Cardiff, Wales, UK
b) Sustainable Places Research Institute, Cardiff University, Cardiff, Wales, UK

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Abstract

The car industry believes it has already done a lot to meet the sustainability agenda. While there has been considerable progress in terms of reductions in toxic emissions, as well as greenhouse gas emissions, they are still very far from being sustainable either as an industry or in terms of the products they make. This point was made by Stuart Hart in 1997 (Hart, 1997), and despite progress since then, the same still holds today. Progress so far has been along an 'eco-efficiency' trajectory – i.e. doing the same thing we have been doing, but more efficiently. In reality, we need to stop doing what we have been doing and work out an alternative means of achieving what we are actually trying to achieve – motorised personal mobility with optimum enjoyment, comfort and safety levels. We need to do things differently, in other words.

It is clear that we are at the start of a technological transition from IC to EV powertrain technology in cars and light commercial vehicles. This brings with it a shift in the lifetime carbon impact of the vehicle from the use to the manufacturing and recycling phase (Ricardo 2011; Hawkins et al. 2012). This would suggest a longer product lifespan would be desirable for EVs. It has also been suggested that the current or imminent transition in the personal transport system involves not only a technological transition from IC to EV, but also a transition in ownership patterns from private ownership of cars to various types of PSS, such as car clubs, leasing models, etc. (Marletto 2014). Does this mean that we will witness a further alienation of the user from the product? If so, would this result in an even lower value being placed on the product by the user than we have already seen so far? Alternatively, would such a move instead create an incentive on the part of the new owner, i.e. the provider of the PSS, to regard the vehicle as an asset that needs to be valued for its ability to enable the business to operate, the 'P' in the PSS.

Introduction

Industry's response to legislation

There has been considerable progress in terms of reductions in toxic emissions, as well as greenhouse gas emissions from cars. However, they are still very far from being sustainable. More significantly, the inevitable shift to increasingly electric rather than internal combustion powertrain brings with it a shift in the lifetime carbon impact of the vehicle from the use to the manufacturing and recycling phase (Ricardo 2011; Hawkins et al. 2012), as summarised in Figure.1.

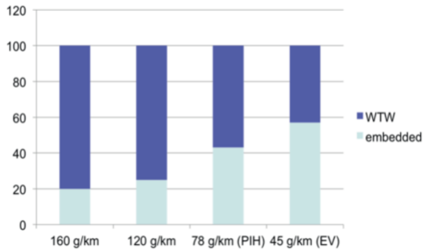

Figure 1. Embedded emissions increase with electrification.

In this respect then, its continued use is to be valued, as its replacement would constitute a cost to the business that is best avoided, or at least postponed for as long as technically feasible. This would then create a new (to personal motorised mobility at least) incentive towards more durable cars. This dynamic towards more durable cars will be explored in this contribution.

What are Cars for?

The key issue is really what do we need from our cars? What kind of functionality do we require and how is that best satisfied, in the most sustainable manner? We have a long way to go in this, but first let us assess where we are now, because even cars with similar functionality can have very different environmental impacts. Power, weight and fuel efficiency are key performance parameters. However, to the customer, there are other factors, such as top speed and acceleration, image, status. All of these are part of a car's functionality, not just transport. Acceleration conveys the sensation of power, although more due to power to weight ratio than to outright power. In simple terms, the functionality of the vehicle can be expressed as the number of people the vehicle can safely accommodate. CO2 emissions and weight do provide a rough indication of overall environmental impact in terms of production (Nieuwenhuis and Wells, 1998; Wells and Nieuwenhuis, 1999).

Using the above parameters to map onto a 'radar' or 'spider' graph, we can create virtual footprints for different car models; the smaller the footprint, the better. It is clear from these diagrams how performance parameters, notably power, acceleration and weight are interrelated and linked with CO2 emissions. In this way, of the vehicles presented in Figure 2 , the Range Rover has the largest footprint, resulting from a combination of weight, power and acceleration. In terms of functionality one could argue it has off-road capability, unlike the other two; a parameter I have not included, but which could be added to the functionality calculation. The Smart comes out best, although its functionality is more limited by the fact that it seats only two. The vehicles compared here are 2013 model year Smart Fortwo 1.0 70 mhd Pulse, Volkswagen Golf 1.2 TSI 85S and Range Rover Vogue 4.4TD V8. These are all typical for their respective model ranges.

It is also clear from comparing the Golf and the Range Rover, how with a similar functionality, weight and performance do impact on CO2 emissions.

The weight of the average European car grew from around 900 kg to around 1120 kg in the 30 years up to 2003 (Jochem et al. 2004). Similarly, the range of weights for popular EU cars rose from 680-900 kg in 1970 to 1150-1250 kg by 2002 (WBCSD 2005), although it has stabilised since in the pursuit of lower CO2 emissions. A heavier car takes more energy to accelerate to a given speed than a lighter car. For this reason, the power also increased, while for other, more market-driven reasons, acceleration has increased.

This effect is illustrated in Figure 3 which shows a comparison between a 2013 VW Golf 1.6 TDI and its 1970s equivalent, the 1976 Golf 1.6 S – typical popular variants from the middle of their respected ranges. The graph also shows the CO2 advantage derived from the shift to diesel. According to Eberle and Franze (1998) reducing vehicle weight by 100kg translates into a saving of between 0.34 and 0.48 litres per 100 km. The industry has attempted to compensate by adding lighter materials. Thus, in 1975 the average car contained 75% steel, but by 2000 this had come down to 59%. Instead, aluminium content had risen from 3% to 8%, plastics from 6% to 14% and elastomers from 12% to 14% (Jochem et al. 2004). This has implications for end-of-life processing.

With the move to EVs, the picture changes, as illustrated in Figure 4. The BMW i3, Nissan Leaf 24kWh and Tesla Model S P90D are representative of the range of EVs currently available. These are all notionally zero emissions, as the NEDC assumes this to be the case. In reality, EV emissions depend on the generating mix used to charge

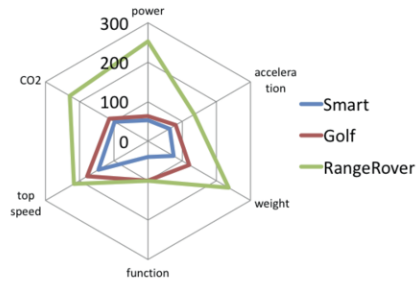

Figure 2. Ecofootprint comparison Smart, Golf, Range Rover

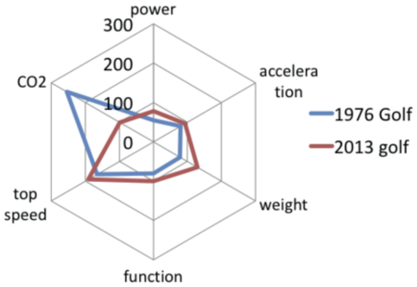

Figure 3. Comparison VW Golf 1976 v 2013.

them and this is too variable to include here. Hence the CO2 parameter is somewhat redundant, although here too, a heavier vehicle, such as the Tesla, will inevitably need more energy to accelerate, than a lighter one, while it will also contain more embedded carbon in the form of a range of new and conventional materials. The Nissan uses mainly conventional steel for its basic structure, while the Tesla uses aluminium and the BMW an aluminium chassis with carbon-fibre body (BMW AG, 2015; Nissan, 2017; Car and Driver, 2016).

Once we move into more esoteric materials and technologies, therefore, both in terms of body construction and powertrain, we can move towards a situation whereby we both have zero emissions at point of use and the functionality we need, want or crave.

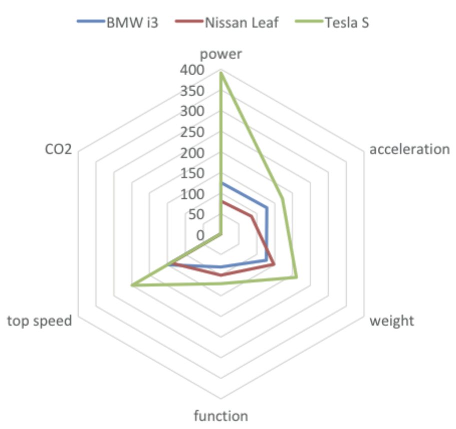

Figure 4. Footprint comparison EVs.

Embedded Carbon

The notion of product durability has long been on the margins of environmental concern, yet key events in the early development of the SCP concept consistently mention product durability (OECD-MIT 1994, UN 1997). Nevertheless, work in this area is still sporadic at best (Cooper, 2005), although some durability work has focused specifically on the car (Porsche 1976, Stahel and Reday-Mulvey 1981, Nieuwenhuis 1994, 2008; de Groot and McCrossan Maire 1998). This issue of a car's life expectancy has come to the fore once again due to work on embedded (or 'embodied') carbon in cars (Ricardo/ Carbon Trust, 2011; Hawkins et al., 2012). It is clear from this that as we move towards greater electrification of the powertrain from hybrid, through plug-in hybrid, to battery EV, the proportion of embedded carbon increases in relation to carbon emissions in the use phase (Figure 1). Embedded carbon refers to the carbon emitted as a result of producing something, rather than from its use. In the case of a car this includes the mining of raw materials, their transport, production of components, as well as the production of the car itself. In the context of the EVs presented in Figure 4, we could point out that steel typically contains around 20 GJ/t of embedded energy, compared with around 80 GJ/t for plastics and around 155 GJ/t for aluminium (Allwood and Cullen, 2012), so the differences are considerable as we move from IC to EV, even in the materials used for their structures. Once we have invested carbon or energy or other resources in a product, we should not really waste them.

The Ricardo study shows that even with conventional technology, the car body contains the largest proportion of embedded carbon (30%), followed by the engine (20%). The study shows that by optimizing existing technologies, this could be reduced by around 50%, however, there is also an increasingly strong case to be made for extending the useful life of the car itself. The analysis by Hawkins et al. (2012) focuses specifically on the difference between 'conventional' and electric vehicles. They calculate that the global warming potential benefit of EVs, as a result of this, amounts to 10-24% with the European electricity generating mix, assuming a lifespan of 150,000km. Increasing the lifespan to 200,000km increases this benefit to 27-29% relative to petrol cars and 17-20% relative to diesel. However, decreasing the lifespan to 100,000km reduces the benefit to 9-14% against petrol, and no discernable difference with diesel. They suggest reducing the impact along the supply chain while also reducing in-use emissions through lower carbon energy generation. Whilst neither study specifically advocates a longer lifespan, this seems a logical implication. Van Wee et al. (2011) agree; they argue that the more embedded energy there is in a car, the older the car should be before it is scrapped. Experience with older EVs indicates that EVs already are likely to last longer than IC engined vehicles, however, will consumers be able to adjust to keeping cars for longer? And, will the industry be able to handle such a development?

The precise impact of an EV in use will depend on the electricity generating mix from which it is charged, and this can vary considerably, from high carbon coal, to zero carbon renewables such as solar or wind. Another area of potential concern is the battery technology currently used for EVs. Ellingsen et al. (2013) calculate that production of a 26.6 kWh, 253kg battery pack contributes 4.6 t of CO2e. This size of battery pack is similar to what is used in a Nissan Leaf. To put this 4.6t for the battery pack into perspective, the authors compare this with the 6.1 t of CO2e needed to make an entire Mercedes A180 compact car (Ellingsen et al., 2013; Daimler AG 2012).

In addition, there are still issues around the recyclability of traction batteries and their expected lifespan. Although EV batteries in use are lasting longer than expected, their maximum useful life is still unclear. Alternative uses for batteries that have reached the end of the road in a car for energy storage from e.g. solar or wind generation has been suggested, implying some residual value for used EV batteries, easing the pain of replacement if the vehicle structure and powertrain are otherwise still usable – an increasingly likely scenario (Richardson, 2016). However, Tesla CTO Straubel argues that recycling batteries makes more sense. Tesla foresees a useful life of at least 10-15 years for its batteries, which – due to their high capacity and range – need fewer charging cycles than most and it is these that age a battery pack (Shahan, 2016).

End-of-life issues

Around two million vehicles are scrapped in the UK alone in a typical year, yielding waste amounting to nearly two million tonnes a year, while around 17% are scrapped prematurely as a result of being 'written off' by insurers (Kollamthodi et al., 2003). Few studies have investigated the reasons why final owners dispose of their vehicles, although Hamilton and Macauley (1998) find a correlation between lower maintenance costs and longer useful vehicle life, making maintenance and repair cost a key element, while replacement cost is always a key issue (Nieuwenhuis 1994). Assuming that premature scrapping is wasteful, or indeed even morally questionable, as Kohak (1985) argues, is it possible to make consumers more attached to their cars and thereby reduce this waste burden? The longer a product lasts, the less often it needs to be replaced and therefore the less often it needs to be produced, thus reducing overall production and resource use. At the same time, durable products significantly change patterns of consumption (Nieuwenhuis, 1994). The mass car industry has long resisted the move towards more durable products, with some exceptions (de Groot and McCrossan Maire, 1998), although many specialists, such as Rolls-Royce, have prided themselves on their products' long life expectancy. That mainstream cars now last longer and are capable of much higher mileages has been due to the pressure to improve product quality.

Porsche (1976), Stahel and Reday-Mulvey (1981), and Deutsch (1994) made it clear that cars can be made to last 20-30 years without significant additional cost. The

Porsche work by its research arm in Weissach was also used internally by the car division, which began to specify the galvanization of bodies for its cars. Some Porsche models were made by Audi at this time, which then introduced this process on its own cars from the 1986 Audi 80 onwards, as well as taking another idea from the Porsche (1976) study on board, namely the use of aluminium bodies. This led to the Audi A8 with its aluminium spaceframe technology, developed in conjunction with Alcoa. Other firms, such as Volvo, already had a durability ethos, making long-life cars (LLC) that linked up with their quality image.

Changes in car use

Marletto (2014, 174) points out that the imminent transition is not only technological, but involves the broader business model as it will "…simultaneously weaken the dominant position of the 'individual car' system and support alternative transition pathways." In this context we could highlight the move towards various forms of car sharing, as well as moves towards more connected and autonomous cars. The move towards sharing takes a number of forms, such as peer-to-peer sharing schemes whereby a privately owned car is rented out to other people while its owner does not need it. More popular are car 'clubs' whereby members own the cars collectively and can access them for specific journeys. While initially these were indeed clubs, more and more this model is taken on by commercial organisations such as the Enterprise City Car Club and Autolib, the Paris-based EV car sharing scheme. In such cases, the car becomes part of the business model in that it is the tool that allows the business to operate (Deutsch, 1994). As such, the pressure to retain it in use is much greater, as its replacement constitutes a cost to the business. In this context, then, such business models could lead to longer product lifespans.

Conversely, the more intensive use that some promoters of such schemes advocate as a key advantage, could also reduce lifespans through more intensive – and possibly less sympathetic – use than is typical for individually owned private cars. In practice, the very fact that vehicles have to be available when a user requires their use, means that many shared cars will spend much of their time waiting to be picked up, so the net benefit in terms of use intensity may be limited.

Conclusions

This contribution has shown, then, that with the move towards greater electrification, the traditional balance between in use and embedded energy, carbon and resources will shift from the use phase to the production phase. This should prompt a dramatic change in how product lifespans of future cars are perceived. Given that both producing new cars and recycling their materials at end-of-life will represent a rapidly increasing environmental burden, the pressure to move towards significantly longer lifespans seems inevitable. Clearly this requires a significant rethink in terms of the automobility system; existing 'fire and forget' business models are no longer adequate and some form of product stewardship, material leasing system, combined with a much longer in-use phase would seem inevitable. New business models would need to consider managing people's emotional attachment to private cars over longer lifespans (Nieuwenhuis 2008, 2014), although where cars are shared, business thinking will increasingly see the car as an asset to be 'sweated' as its replacement means a cost to the business. EV business models would need to accommodate scenarios whereby the vehicle structure, motor, inverter and controllers outlast the battery, such that easing battery ownership and replacement would need to be part of the model. With the steady acceleration in the shift from IC to EV the time to consider such alternative business models is now.

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