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Driving in the wrong lane: towards a longer life-span of cars

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Abstract: Within the context of product longevity, one especially impactful and ubiquitous product demands further research: the car. Car longevity has been addressed in the context of product life extension and product lifetime optimisation but there have been a few studies on car longevity in the context of business and none specifically from an industrial design context. This paper presents initial findings from preliminary interviews with key industry representatives such as car designers and engineers. It discusses the barriers to and opportunities for designing a car with a longer life-span. This and further data will later be analysed in order to produce a design framework to inform car designers on life-span and usage optimization through design. Strategies such as increased longevity or use-intensity can potentially reduce the throughput - and thereafter the consumption - of cars. Such a shift in the automotive sector would support the transition from a linear economy to a more sustainable one. The initial findings, however, suggest that a longer life car is not an uncompromised solution and important concessions would have to be made in order to make this an acceptable product.

Introduction

Increasing the life-span of cars as a way of diverting products from being scrapped has been highlighted in a report by the O.E.C.D. (1982), and also discussed by Ware (1982), who envisages a maintenance plan to keep used cars running for longer. More generally, Cooper (1994) proposed going beyond recycling consumer durables such as cars in order to reduce environmental impacts.

Nieuwenhuis (1994) has noted that doubling the life-span of cars from 10 years to 20 years would potentially reduce the volume of vehicles produced and dismantled, and thus associated environmental impacts. Allwood and Cullen (2012) similarly suggest that vehicles can last up to 20 years, potentially reducing material and energy demands. However data shows that vehicles in the UK are lasting, on average, around 13 years (Oguchi and Fuse 2014). In order to enable longer life products Stahel (2010) identifies three conditions that need to be in place to make this possible: durability, function and performance. These, he argues, are a prerequisite for product longevity, leading to design for ease of repair, maintenance and technological upgrade.

Other authors argue that for energy-using products such as passenger cars, with environmental impacts during use phase, designing a user-intensive solution might be the preferred option, even though this may imply earlier product replacement (Van Nes and Cramer 2006; Vezzoli and Manzini 2008).

Whether or not increasing vehicle life-spans has environmental benefits (Kagawa, Tasaki *et al.* 2006), vehicle manufacturers currently engaged in longer product life-span activities such as remanufacturing are motivated by spare parts security, warranty issues, market share, brand protection and customer orientation (Seitz 2007).

Methodology

This paper is based on a preliminary analysis from seven in-depth semi-structured interviews with automotive designers and engineers. Subjects came from a variety of different automotive companies and countries ranging from mass-market, premium and high premium manufacturers, a large multi-national tier-one supplier and a vehicle testing consultancy, reflecting different company cultures and approaches to vehicle design in order to avoid bias. For confidentiality reasons they will be named D1 (Designer 1) E1, (Engineer 1) and so on (Appendix 1). A balance between car designers and engineers was achieved in order to provide a suitable breadth of opinions. The interviews were made on location, where possible, or via video-call. The duration of the interviews ranged between forty minutes to one hour. An open question approach was used (Robson 2002) in order to explore impacts of designing for longevity. All interviews were voice-recorded and transcribed. The analysis was made by clustering answers against codes identified in the interviews (Bryman 2008); these clusters were then classified into barriers and opportunities.

The questionnaire focused on the adoption of longer life-spans for passenger cars in the design process. It was divided into four indicative questions to explore the barriers and opportunities of designing cars with longer life-spans. Barriers and opportunities described here are not exhaustive but were considered significant.

The first question related to the currently accepted process of vehicle design and whether designing for longevity would impact this process. The next question related to the vehicle itself, especially features such as modularity, ease of repair, easy disassembly and upgrading (Gehin, Zwolinski *et al.*. 2008; Stahel 2010 and Go, Wahab *et al.*. 2011). A third question focused on a 20 year life-span car (Nieuwehuis 1994, Allwood and Cullen 2012) and the designer/engineer approach to its design. The final question asked how interviewees would design an optimal life-span car with less material; this was intended to summarise the interviewee's views on vehicle longevity.

Barriers and Opportunities

A range of barriers to and opportunities for longer lasting cars were identified during the interviews. Some of the clusters identified relate to one or more codes, making the separation between barriers and opportunities rather challenging (Appendix 2). However, initial research findings show that to achieve a longer life-span car, important compromises have to be made by consumers and industry.

Duty cycle

Three interviewees argued that for longer life-span cars, reinforced structures are needed to deal with extra years in service. To achieve this, engineering interviewees affirmed that car structures and vehicle systems would have to be strengthened, adding more material in order to manage the extra life-span. This would have rebound effects on energy spent in manufacturing and usage. Interviewees D1 and E3 stressed that heavier vehicles may not meet emissions targets set by the EU. E4 confirmed evidence from literature that car structures nowadays can easily last more than 20 years. E1 suggested that vehicle manufacturers have data on longevity from taxis suggesting that in some cases taxis clock-up one million miles.

Despite this, structural safety evolution is reaching a plateau. Safety and crash rates are being driven by electronic systems such as pedestrian protection or collision-avoidance systems. E4 pointed out that if such devices can successfully avoid collisions at low speed, sacrificial low speed crash structures such as bumper structures can be eliminated, reducing material and weight.

Vehicle weight

Excessive material in cars has implications for weight, and thus energy use. Carrying excessive weight for 20 years or more is wasteful and creates a vicious cycle of more power to carry more weight, leading to bigger brakes, bigger cooling systems and so on (D1). However, interviewee E4 pointed out that steel operating in an infinite fatigue region - i.e. an over-engineered structure able to support "the amplitude (or range) of cyclic stress that can be applied to the material without causing fatigue failure" (Beer, Johnston *et al.* 2004) - will be able to have a prolonged life. This suggests that a very simple yet robust structure would be desirable.

Asked about lightweight materials as alternatives to steel, D1 suggested that aluminium and carbon-fibre are energy-intensive to produce, potentially offsetting the benefits of a longer life-span with more energy usage during production.

Material usage

Material and embodied energy are closely associated (Allwood and Cullen 2012). Steel was identified as the most energy efficient and cost effective material for structural purposes (D1). Carbon-fibre and (virgin) aluminium may push the demand for energy upwards if widely used.

E4 stressed that conventional materials, such as steel, and technology used, ~~such~~ as in internal combustion engines, are often underestimated and sometimes possess potential to be improved. High-tensile strength steel has seen an uptake in recent years especially in car structures (Heuss, Muller *et al.*. 2012). Recycled aluminium is also finding its way into lightweight structures (Jaguar Land Rover Corporate 2013).

Vehicle packaging size was considered an area with potential for optimisation by D1, E2 and E4. Smaller cars were identified as better packaged than larger ones; if small vehicle packaging is pushed further, gains in material reduction can be reaped effectively (E4). D3 and E3 identified corrosion protection for steel, currently guaranteed for 12 years against perforation, as suggesting that extending the life-span of cars can stimulate the development of better corrosion protection systems.

Design and development

Design has been identified as a key enabler for longer life products, capable of standing the test of time and overcoming fashion (Cooper 2005, 2010). Interviewees indicated that opportunities for designs that are visually simple (D1), providing basic equipment with options for personalisation, can potentially create greater attachment and more user-machine interfaces (D2). Designers could be constantly involved in one ongoing project, especially if there is better interaction between them and the customer due to modularisation and upgradability (D2).

3D printing was identified as an opportunity for personalisation, although only for non-structural interior parts (D2). Another opportunity identified was design for disassembly of parts (D1), although this could also act as a barrier by making visible, in order to facilitate access, unattractive components that are conventionally away from sight (D1 and E4), penalising overall styling. D1 suggested that this kind of a longer life-span vehicle would be suited for developing countries, perhaps built locally, but would not be attractive to the automotive industry in industrialised countries.

Upgradability and modularity

Upgradability and associated modularity are often features of durable products. Upgrading opportunities were seen as limited by several interviewees. The barriers to upgradability and the necessary modularity were said to concern technology and legislation anticipation (D1, E1, E4) and technical obstacles (D1, E1, E2, E4). For example, the ever-changing criteria in legislation meant that from one product generation to another, currently around eight years, upgrades can only be achieved for validation with new structural architectures (E3) as, otherwise, the whole vehicle structure is seriously compromised in its integrity, performance and safety protection. Powertrain upgradability was also seen as a barrier; fuel cells require more cooling capacity than internal combustion engines, hindering aerodynamics (E4). One opportunity identified was component upgradability. These could be designed to have limited life-spans, as in the aerospace industry, and replaced when scheduled (E4).

D3 exemplified barriers to modularity in dashboards; for comprehensive modularity, hidden subsystems such as passenger air-bags would have to be separated from the dashboard structure and become more visible. D1 remarked that cars are designed with a certain style and components would have to fit structures with some degree of compromise. In order to become modular, car styling would be compromised and the interviewee was sceptical about the market accepting this.

Service, maintenance and disassembly

Repair and maintenance is an important element in strategies for longer product life-spans (Cooper 2005, Bakker, Wang *et al.* 2014).

In the case of cars, opportunities were said to lie with replaceable and easier to access panels, flaps and trapdoors for parts that are currently difficult to access. One interviewee suggested that a ‘back-to-basics’ vehicle would be easier to repair with fewer tools and with very basic repair skills (D1), helping also to reduce costs. He gave the example of the original Land-Rover as a vehicle which is simple to repair in any part of the world. He also stressed that safety and market acceptance may be challenging; attachment points such as bolts and screws would need to be visible for easy access and repair. Such a vehicle would also make few concessions to styling. E4 argued that compromises in areas such as reparability have to be made for the benefit of safety and/or regulation.

Increasing preventive maintenance was mentioned as an opportunity (E2). Another would be a change in the image and acceptance of the 'old'; for example, fringes of the classic car market value the patina or discolouration in leather seats (D2).

Production

Changes in design and development would also impact upon production. Vehicle modularity would raise challenges, such as increasing job times per part and manufacturing footprint (E3) and complexity of assembling fasteners, hinges and extra parts for easier access to repair, disassembly and upgrade (D3, E4). These changes in production would in turn increase risk and costs (D3).

On the other hand, extending vehicle life-span and product lifecycle offers potential benefits such as lowering the frequency of tooling investment in production. However, any savings in production would need to offset investment and risk costs, such as loss of market share due to longer product lifecycles (E3). D1 proposed that such vehicles would have to be produced on a more localised scale, meet local needs, and be flexible enough to be changed according to market requirements.

Regulation

Regulation was pointed out as a key barrier to longer life cars by all interviewees except one.

Future changes in regulation affecting a car intended to last at least 20 years are difficult to foresee (E4). E2 noted that emission targets are ever-changing.

E4 identified changes in design requirements due to regulation (e.g. pedestrian protection), which imply that structures may need to change. This might suggest that longer life-span cars may be considered not fit for purpose after a certain period of time. In addition, legislation is less predictable in terms of the driveline/powertrain than a few years ago.

D3 suggested that regulation is an obstacle to differentiation in vehicles and that a different concept would have to be considered in the light of ever-tightening regulation, implying greater conformity.

Discussion

The research findings suggest that concessions may have to be made in several key areas in order to design a longer life-span car. They also confirm that further research is needed to understand consumer acceptance of such vehicles.

Increasing material in cars impacts on production and job times to weld and assemble. Developments in electronics for safety may enable the elimination of some structural parts and components, although reliance on electronics to control safety systems may have adverse effects if accidents occur due to system failure.

There is a lack of comparative data between traditional and light-weight materials for longer life-span cars. Light-weighting materials are desirable, to overcome structural reinforcement barriers, but are more energy-intensive to produce. Steel is more energy efficient in production but there are obvious weight disadvantages that impact on overall emissions over the longer term. In order to understand whether using steel or lightweight materials would be more appropriate ~~in order~~ to achieve longer car life-spans, a life cycle assessment would be needed to compare the environmental effects. If steel was found preferable, then corrosion protection systems would have to be guaranteed for longer than at present.

Disruptive technology is a considerable obstacle to the designed interface and hardware. Longer life-span cars would not be able to integrate all disruptive technology, especially if it made cars more energy efficient.

The industry also faces uncertainty with powertrain technology. Technology road maps point to hybrids with an electrical powertrain having a predominant role and electric vehicles, still limited in their range performance, being outmoded by fuel cells (Automotive Council 2013). However, electric vehicle batteries are evolving to be smaller and lighter. If battery interfaces remain the same, then weight reduction advantages will come forward, potentially enabling product life extension. The challenge to accommodate, in one architecture, all powertrain technologies and upgrading them throughout the life-span of the car remains very difficult for the industry. Performance can be affected by system incompatibility. Upgradability would therefore have to be limited to a few selected components, such as non-structural panels or software.

Interviewees were generally unfavourable towards structural modularity. Making a structure as effective as possible and trying to optimise each component would reduce its performance. Reversible fixing points such as bolts, screws and fasteners would be needed, together with reinforcement materials, adding weight and compromising safety, comfort and emissions. Increasing the number of parts for access would add complexity, longer assembly times and threaten earlier failure. Limited-life components could potentially be made with less energy intensive materials, offsetting increases in structural robustness.

Such barriers to production can potentially lower profits, contributing to industry transition failure (Wells and Nieuwenhuis 2012). New approaches to vehicle design and production would need to accommodate these changes without compromising the product and company profits, which may only be possible in lower volumes and with simpler technology (Wells 2001). If such a car was to be made of lightweight materials such as aluminium or carbon-fibre, power generation could be provided by renewable energy to manage the higher energy demand.

Further research on maintenance is needed. Interviewees suggested that frequent maintenance prevents earlier component failure. However, higher frequency of servicing, material and energy usage needs to be carefully analysed to understand any environmental disadvantages. It is not clear if it these would be offset by longer car life-spans. Records of longer lasting cars (e.g. taxis) which have regular maintenance schemes could be analysed.

Market barriers were also addressed. The industry is sceptical about consumers accepting a long life-span car, noting that data shows an increase in car production worldwide (OICA 2015). The market offer of short leasing schemes of two to three years can be a barrier together with the culture of fast consumption of consumer goods. The challenge may lie in the vehicle owner's perception of wear and 'old'.

Longer term regulation changes ~~were~~ cannot be foreseen. Predicting its direction in the short term is not so difficult, but forecasting for two decades ahead is challenging. Ever-shifting parameters in standards for design, safety and emissions make it a barrier to change. In theory modularity could overcome this problem, but technical barriers may make modularity (and upgradability) problematic.

Conclusions

It was evident from an initial analysis of these interviews that longer life-span cars are far from being uncompromised, and concessions in styling, size or basic system technologies may need to be accepted by consumers and industry in order to make them feasible. However, despite the barriers encountered, opportunities were found. The challenges posed by a longer lasting vehicle could potentially stimulate companies to find new solutions for weight and complexity.

Further research needs were identified: comparative LCAs of light-weight materials in longer life-span cars; a policy framework suitable for autonomous safety systems which would enable elimination of some safety structures and reduce weight; impacts of limited-life components on cost and remanufacturing; consumer perceptions of wear and 'old' in cars; market research for the uptake of longer life-span cars; explaining the disconnect between industry capability of producing cars made to last over 20 years and current practice of cars being scrapped by consumers in the UK at an average age of 13 years.

This research project is ongoing and alternative solutions for excessive waste from discarded vehicles, such as user-intensive cars, are also to be addressed.

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Appendix 1. List of interviewees.

Reference	Job Title	Type of Company
Designer 1 (D1)	Head of Concepts	High-Premium Manufacturer
Designer 2 (D2)	Vehicle Interior Designer	High-Premium Manufacturer
Designer 3 (D3)	Senior Interior Designer	Generalist Manufacturer
Engineer 1 (E1)	Senior Manager Corporate Engineer & RD	Tier 1 Multinational Supplier
Engineer 2 (E2)	Principal Materials Engineer	Premium Sports Car Manufacturer
Engineer 3 (E3)	Chief Engineer Body Complete	Premium Manufacturer
Engineer 4 (E4)	Global Business Director - Former Technical Director	Vehicle Testing Consultancy

Appendix 2. Barriers to and Opportunities for Longer Life-span Cars

	Codes	Barriers	Opportunities
Longer Life Vehicle	**Duty Cycle**	- Heavier structural reinforcements - More energy spent in production	-
	Weight	- Inefficient transportation of excessive mass - Heavier systems and subsystems (e.g. brakes)	- Simpler but more robust structure - Infinite fatigue region operating materials - LCA of lightweight materials in longer life-spans
	Lightweight materials/ Material usage	- Lightweight materials more energy intensive to produce	- Structural recycled aluminium - Conventional materials potential often underestimated - Smaller vehicle packaging - Stimulus for longer-life corrosion protection systems (currently 12 years)
	Design and development	- Easier disassembly will bring to the fore "invisible" components… … hindering aesthetics	- Visually simpler solutions - Basic equipment... - ...providing scope for personalisation…. - … enabling attachment - More user interfaces - 3D printing - Easier disassembly of parts - Greater degree of interaction between designer and consumer - Ongoing project
	Ownership/ usage	- Consumers will not necessarily keep their cars for longer	- Personalisation - Direct feedback to designers
	Upgradability/ Modularity	- Frequent changes in regulations/standards - Cost - Structural modularity - Foreseeing effects of disruptive technologies	- Upgradability of non-structural parts (wings, door panels) - Quicker response to customer demand - Limited lifetime parts built with less energy.
	Service/ maintenance/ disassembly	- Increase of access to parts adds complexity (e.g. flaps, hatches, etc.) - Longer life may increase failure rates - Compromises in reparability favouring safety	- Back to basics cars easier to repair - Increase in preventive maintenance - Redefine the image of old and used
	Production	- Increase in job times due to complexity of built-in accessibility - Risk costs in changing production processes - Energy demand in lightweight materials	- Less tooling costs if vehicle is in production for longer. - New approach to vehicle design - Local/more flexible production
	Market	- Market acceptance of aesthetics compromise - Risk of losing market to competitors - 20 yr Market trends forecasting	-
	Regulatory	- Foreseeing regulatory evolution in a 20 yr window	-
	Business	- No interest from the mainstream manufacturers in changing the established business model - Panel upgrading has been tried before unsuccessfully	-