

See discussions, stats, and author profiles for this publication at: <https://www.researchgate.net/publication/233906322>

Future vehicles: An introduction

Article in *International Journal of Vehicle Design* · January 2004

DOI: 10.1504/IJVD.2004.004048

CITATIONS

4

READS

1,387

2 authors:



Damon Honnery

Monash University (Australia)

274 PUBLICATIONS 3,627 CITATIONS

[SEE PROFILE](#)



Patrick Moriarty

Monash University (Australia)

241 PUBLICATIONS 1,957 CITATIONS

[SEE PROFILE](#)

Some of the authors of this publication are also working on these related projects:



Optical and X-ray Diagnostics for Pressurized Metered Dose Inhalers [View project](#)



hydrogen [View project](#)

Future vehicles: an introduction

Damon Honnery

Department of Mechanical Engineering, PO Box 31,
Monash University, Victoria 3800 Australia
E-mail: Damon.honnery@eng.monash.edu.au

Patrick Moriarty

Department of Mechanical Engineering, Monash University,
Caulfield Campus PO Box 197, Caulfield East, Victoria 3145
Australia
E-mail: patrick.moriarty@eng.monash.edu.au

Abstract: Many researchers doubt that the familiar car can continue on the course developed over the past half-century or more. Environmental and resource problems from the manufacture, operation, and disposal of cars will require major changes in vehicle design and manufacturing methods, and in the materials and fuels used. Growing world car ownership is increasing both road congestion and traffic fatalities, and both factors could also influence future car design. At the same time, advances in Information Technology appear to offer new approaches to vehicle design, congestion, and safety. This paper briefly examines the various factors that will shape future vehicle design, fuels, infrastructure, and industry. We find that forecasting what will happen in any of these areas is becoming an increasingly difficult task, although some trends have appeared which provide some degree of insight.

Keywords: Automated highway systems, future fuels, future manufacturing methods, future materials, future propulsion systems, future vehicle design.

Reference to this paper should be made as follows: Honnery, D. and Moriarty, P. (2004) 'Future vehicles: an introduction', *Int. J. Vehicle Design*, Vol. 35, Nos. 1/2, pp. 1–8.

Biographical notes: Dr Damon Honnery is a Senior Lecturer in Mechanical Engineering, Monash University, Clayton Campus, and Deputy Director of the department's Laboratory for Turbulence Research in Aerospace and Combustion. He is a mechanical engineer whose research interests include, fuels, engines, emissions, transport, and transport policy.

Dr Patrick Moriarty teaches and researches in the Mechanical Engineering Department, Monash University, Caulfield Campus. A civil engineer by training, his research interests include energy issues and alternative transport fuels, transport and land use policy, and the social impacts of the new Information Technology.

1 Introduction

At the start of the 21st century, the global road transport system showed surprisingly little change from 50 years earlier, apart from the many-fold increase in vehicle numbers and travel volumes. Total vehicles (four or more wheels) in 2000 numbered some 835 million, of which 610 million were passenger vehicles [1–3]. In addition, there were perhaps 130 million motor cycles, mainly in Asia. In recent years, about 55 million new cars and other light passenger vehicles were produced annually, along with 2.2 million heavy commercial vehicles (trucks and buses) [4]. The car vehicle fleet was heavily concentrated in the core countries of the Organisation for Economic Cooperation and Development (OECD) [5], as to a lesser extent, was the commercial vehicle fleet.

While the last 50 years have not seen the radical changes in transport that were perhaps once predicted, it has seen a maturing in much of the technology used in passenger vehicles. Continued improvement and optimisation may provide further gains, but will this be enough for what could be the very different environment the future shows every sign of becoming? Anyone pondering the future of passenger car travel must consider at least the following sets of questions:

- What propulsion systems will future vehicles use? Will internal combustion engines still power vehicles, or will electric drives take over?
- What fuels will future vehicles use? Will petroleum-derived fuels still dominate, or will new fuels be required? If so, which fuels?
- What materials and manufacturing methods will be used? Will composite plastics take on a much larger role?
- Will the vehicle industry be organised the same way as it has been for many decades, or will new materials, manufacturing methods, and propulsion systems, see the rise of new competitors?
- Will basic infrastructure still be largely publicly provided and free, as in the 20th century? Or will electronic road pricing become common, especially in traffic-congested cities? In the longer term, will automated highway systems take over the control of vehicles on freeways?
- Will transport systems continue to be seen as relatively independent, or will they integrate with non-transport systems and networks to the point where the notion of a system used just for transport, a transport system, is obsolete?

This short paper seeks exploratory answers to these basic questions, and argues that radical changes are on the horizon for all areas of the private car transport system.

2 Vehicle design

Vehicle design details have of course changed over the past century, but these changes may be dwarfed by those needed in the future. The internal combustion engine may give way to fuel cells; the major car companies are investing heavily in this area, and optimistically promise commercial models in a few years. As demonstrated by both the Rocky Mountains Institute Hypercar[®], and the General

Motors AUTOnomy vehicle, fuel cell propulsion, coupled with ‘drive by wire’ systems, enable (or even demand) an unprecedented rethinking of vehicle design [6–8]. Yet bringing fuel cells costs per kW of power down to those of internal combustion engines could still be decades away. Murray [9] argues that fuel cell’s present shortcomings are ‘knowledge-limited rather than resource-limited’. Providing more money and resources will not therefore guarantee success, as was the case for putting an astronaut on the moon in 1969. This suggests an important shift in the controlling forces for passenger vehicle design, compared with those of the previous 50 years.

It is thus entirely possible that internal combustion engine vehicles will still be with us for decades. Alternatively, the optimists could prove to be correct, with fuel cell vehicles introduced soon. Given this uncertainty, together with the twin challenges of oil depletion [10] and global warming [11,12], it seems prudent to promote changes that all future vehicles will need, namely, big reductions in road load through reduced size and mass. The paper by Lovins and Cramer [6] shows how this might be achieved.

A recent report from the World Health Organisation gave 1998 world road traffic fatalities as 1.171 million [13], far higher than previously thought. Most of these deaths occur in developing countries; indeed China and India together accounted for 34% of the total. The core OECD countries, with nearly three quarters of all vehicles (excluding 2-wheelers), suffered only about 100 000 fatalities, or 8.5% of the total. Fatalities per vehicle in the rest of the world were therefore some 30 times higher than in the core OECD.

While increasing consideration is being given to vehicle occupant protection, far less thought has been given to unprotected road users – pedestrians, cyclists and motorcyclists, who together number several thousand million. These road users probably also account for most of the world’s traffic fatalities. Their share of fatalities is particularly high in countries with low levels of motorisation, such as China, India, and tropical African nations [14]. The absolute numbers of fatalities for this group could increase in the future in countries with low but rising motorisation levels. After all, if vehicle ownership is, say, only four per 1000 persons, a doubling to eight per 1000 greatly increases the accident risk to non-occupants, while reducing the use of non-occupant modes only slightly. These rising levels of non-occupant death and injury would, in an ideal world, lead to major changes in vehicle design to reduce injury severity. It is very difficult to imagine aircraft design and operation, for example, escaping radical change in the face of a similar rate of fatalities and serious injuries per year.

The typical car driver is also changing. In the core OECD, the share of older drivers in total vehicle-km is steadily rising as these countries’ populations age. The accident rate per vehicle-km driven for drivers 75 years and over is far higher than that for middle-aged drivers [15]. Elsewhere, rising car ownership inevitably means a high proportion of inexperienced drivers on the roads. Engineers will need to factor these considerations into their designs, both to enhance safety and improve ease of use.

Car designers will also need to make their designs more ‘green’. Particularly in the European Union and Japan, auto companies will increasingly be required to take back vehicles after their useful life. Further, legislation requires up to 95% of each

vehicle to be recycled by the year 2015 [16]. This requirement has impacts both on the materials used for manufacture and on manufacturing methods, especially if ferrous content is reduced in favour of lighter materials. Vehicle design has always been a compromise, but the number and intensity of conflicting demands looks set to rise in the coming years.

3 Vehicle fuels

The road fleet today is almost entirely powered by petroleum-derived fuels, mainly petrol and diesel, but change seems inevitable in a decade or so [10]. Vehicle fuelling has remained essentially unchanged for many decades. At various times and in various countries, alternative fuels have been promoted, then fallen from favour. Ethanol, for example, was a common transport fuel in many countries from the 1930s up to the 1950s, then largely disappeared as a motor fuel. However, in Brazil production was boosted after 1975, based on fermentation of cane sugar, then fell as the price of crude oil dropped. Recently, Brazil has once again revived its ethanol programme, this time around citing environmental reasons rather than oil imports as the program's justification [17]. The US also has a large and growing grain ethanol programme, mainly justified for its environmental (air pollution) benefits. In 2003, US transport ethanol production capacity reached 11 GL, nearing Brazil's [18]. Electric batteries have likewise seen their fortunes wax and wane as a vehicle power source. Battery electric cars now appear to have poor prospects, but electric bicycles are selling strongly [3].

The main alternative fuels used today worldwide are LPG and compressed natural gas (both themselves premium fossil fuels in finite supply), and ethanol produced from food crops. Yet these are not the fuel sources mentioned when long-term alternatives to petrol and diesel are considered. The two most seriously discussed are ethanol produced from cellulosic biomass, and hydrogen, initially produced from natural gas or on-board fossil fuels, but eventually from renewable sources of energy, such as wind power. Papers advocating each of these fuels are included in this collection [6,19]. However, unlike LPG or corn/sugar cane ethanol, each with annual production for road vehicle use in the tens of GL, equivalent to the annual fuel use of millions of vehicles, commercial cellulosic ethanol production has not begun anywhere, and only a few demonstration vehicles are run on hydrogen.

One advantage of cellulosic (and grain) ethanol is that it can be blended with petrol and used in conventional engines. This fuel fits in well with the existing vehicle fleet and fuelling system, in contrast to hydrogen-fuelled fuel cell vehicles. Nevertheless, cellulosic ethanol's success is far from certain, as it faces serious problems [19]. In marked contrast to alternatives for power generation, where wind energy is growing rapidly and is already used in over 50 countries [20], no one alternative vehicle fuel seems poised to challenge petroleum fuels.

The number of possible alternatives to crude-based fuels makes speculation about future use difficult. What can be argued is that none of the present alternatives has the utility nor ubiquity of crude-based fuels. This points to the possibility of specialisation not only of fuel use, but type as well. This specialisation already occurs with diesel fuels, which in most countries are mainly used for heavy transport. Similarly,

countries using LPG and ethanol utilise it mainly for passenger transport. The ability of a country to produce a particular type of fuel at a particular time may therefore determine the choice of fuel for transport. In the short term, engine manufacturers may have to produce engines able to operate on a wide range of fuel types and blends without any modification by the owner. The greater efficiency and the ability of diesel engines to accept a wider range in fuel properties than other internal combustion engines may ultimately mean their much wider use than at present, both as the primary power source and as a coupled power source in hybrid engines. In the long term, the ability of most countries to produce hydrogen and the fact that it has the potential to be a zero-emission fuel may mean it becomes the most common fuel. However, problems with cost, infrastructure, and storage will have to be solved.

4 Vehicle infrastructure

Road vehicle infrastructure, like the vehicles which use it, has changed little over the past half century, except for its greatly increased extent. Road space is still largely publicly provided, and freely available to all road users, regardless of the resulting congestion. True, toll-roads, many of them privately owned, are becoming increasingly popular, but individual toll-roads have been around for many centuries. All this could change if electronic road pricing is introduced in urban areas as a solution to traffic congestion. Road pricing has operated successfully in Singapore for nearly three decades, and has been recently introduced in London. Large Asian cities are already very congested, even though their vehicle ownership levels (except in Japan) are usually only a fraction of those in the West. Rationing road space by electronic road pricing could become an important means of keeping congestion to tolerable limits.

For a century now, the driver has been in complete control of the vehicle, subject only to the highway code, roadside signs, and traffic control signals. Advances in IT open up the possibility of what is now called Automated Highway Systems (AHS), in which control of vehicles is handed over to the infrastructure/vehicle system. Yet there are problems with this approach [15]. AHS can only be feasibly implemented on freeways, which carry much less than half of all traffic; in any case, freeways are already much safer than other roads. Even on freeways, with their controlled access, reliably achieving today's safety levels and vehicular flow rates will prove very difficult in the face of the variety of unanticipated events that can occur in traffic.

Smaller vehicles are another means of reducing road and parking space requirements in severely congested cities [14,21]. As Adams and Brewer [21] point out, the present road system is very inefficient from an urban land use viewpoint. They propose that smaller vehicles – sized to match today's low occupancy rates – run segregated on correspondingly narrower lanes. Because of the low height of these vehicles, clearances needed are much reduced, allowing additional lanes to be built above existing road space, for example. The light vehicles would also result in wheel loads an order of magnitude lower than those imposed by heavy trucks, making possible lighter structures.

Enhanced transport land use efficiency may also come about through integration of transport into other systems or networks. Use of IT in vehicles and their

connection to global computer networks is already occurring, allowing their use for business and entertainment. Such IT also enables control and monitoring of the vehicle and could provide the framework for a use-based pricing system. Widespread use of fuel cells could result in their use as remote power generators, or through connection to the grid as additional providers [6]. This could occur either locally while the vehicle is parked at home, or centrally if parked in a parking station. If the vehicle's fuel cell was fitted with a reformer, it could be used to generate fuels for external use or storage.

5 Vehicle manufacture and industry

In Europe and North America, a number of car manufacturers that were leaders in the early 20th century are still major car manufacturers today. Indeed, Ealey, an industry analyst, claims that all the key elements of today's auto industry were in place by the middle of the second decade of the 20th century [22]. As he puts it: 'the fundamentals of the industry – that cars with internal combustion engines, built on a massive scale by integrated companies, and distributed and sold through (mostly) independent networks in standard market segments – have not changed appreciably since that time – until today'.

Ealey sees this situation changing profoundly in the coming years, and puts forward a number of hypotheses regarding the industry future. He predicts that auto firms will widen their focus to include the entire supply chain. Vehicle manufacture only accounts for 10% of total profits available from autos. Vehicle finance and spare parts sales bring the figure up to 50% of total profit accruing to the car manufacturers. These companies are keen to become more involved in downstream operations [23]. One way of achieving this aim is to sell the customer a continuing travel service, rather than just make a one-off car sale [24]. Already, large numbers of new cars in the US are leased. But at the same time as auto companies become more involved in downstream operations, they will also, Ealey argues, offload even more of vehicle manufacturing to others.

Above all, Ealey stresses the uncertainty facing the industry in the coming years. When will the internal combustion engine era, already a century old, come to an end, to be replaced (possibly) by fuel cells? How do auto companies, and major components suppliers, work out investment plans given this uncertainty? It is even possible that in the coming years, components supplier brands will become more important for car buyers than traditional auto brands. A precedent for this is personal computers, where Intel and Microsoft are more important for customers than computer manufacturers themselves [24]. Given that already in top-of-the-range cars, 40% of the value is IT products [15], this precedent must be taken seriously.

Car companies of the core OECD countries presently dominate vehicle manufacture, accounting for nearly 90% of world production [23]. This dominance is set to change [25]. A number of other Asian countries, particularly China, are keen to follow Japan's lead. Over the next decade, Asia is expected to account for 50% of the growth in world sales of light vehicles. The rising importance of Asia for both sales and manufacturing make attempted prediction of the future shape of the vehicle industry even more difficult.

6 Conclusions

Many researchers doubt that the car can continue on the course of the past half-century or more. Environmental and resource problems arising from the manufacture, operation, and disposal of cars will require major changes in vehicle design and manufacturing methods, and in the materials and fuels used. Growing world car ownership is increasing both road congestion and traffic fatalities, and both factors could also influence car design. At the same time, advances in information technology appear to offer new approaches to vehicle design, congestion and safety. The new technology could even subtly change how cars are used. Globalisation has resulted in heightened competition in an industry already suffering from serious overcapacity. Radical technology changes will profoundly change both the nature of vehicles themselves and the industry that manufactures them.

The discussion presented in this paper points to an uncertain future in many areas of transport. Forecasting the future for passenger vehicles is therefore risky. However several strong trends have appeared and from these we may draw some conclusions. Future vehicles will likely be lighter, smaller and safer. They will have a power source able to operate on a wide range of fuel types and blends. They will be provided by suppliers offering a continuing service from ‘cradle to grave’, outfitted by a variety of manufacturers offering a high degree of personalisation. They will have on-board information technology systems able to monitor, control and price their movement on a variety of transport networks. Finally, greater use of information technology and the push for enhanced transport land use efficiency could see urban transport systems becoming more and more integrated into other non-transport based networks and systems. It is entirely possible that this integration will see an end to the concept of the transport system as we presently understand it.

References

- 1 United Nations (2002) *Statistical Yearbook, 46th Issue*, UN, New York (also earlier editions).
- 2 World Bank (2002) *World Development Indicators 2002*, Oxford U.P., New York (also earlier editions).
- 3 Worldwatch Institute (2002) *Vital Signs 2002–2003: The Trends That Are Shaping Our Future*, Earthscan, London.
- 4 Auto Industry Statistics (2003) www.autoindustry.co.uk/statistics/production/world/html
- 5 Moriarty, P. and Honnery, D. (2003) ‘Forecasting world transport in the year 2050’, *Int. J. Vehicle Design*, this issue.
- 6 Lovins, A.B. and Cramer, D.R. (2003) ‘Hypercars[®], hydrogen and the automotive transition’, *Int. J. Vehicle Design*, this issue.
- 7 Burns, L.D., McCormick, J.B. and Borroni-Bird, C.E. (2002) ‘Vehicle of change’, *Scientific American*, October, pp. 40–49.
- 8 Baum, D. (2002) ‘Object in mirror may be closer than it appears’, *Wired*, August, pp. 100–107.
- 9 Murray, C.J. (2003) ‘Fuel cell R&D is far from easy street’, *Electronic Engineering Times*, May 26, pp. 12–13.
- 10 Laherrere, J. (2003) ‘The future of oil’, *Int. J. Vehicle Design*, this issue.

- 11 Intergovernmental Panel on Climate Change (IPCC) (2001) *Summary for Policymakers*, A Report of Working Group 1 of the IPCC. Accessed at www.ipcc.ch/pub/spm22-01.pdf
- 12 Pearce, F. (2003) 'Heat will soar as haze fades', *New Scientist*, 7 June, p. 7.
- 13 World Health Organisation (1999) 'Injury: A leading cause of the global burden of disease'. Data accessed at www.crashtest.com/explanations/stats/stats.htm
- 14 Moriarty, P. and Honnery, D. (1999) 'Slower, smaller and lighter urban cars', *Proceedings of the Institution of Mechanical Engineers*, Vol. 213, Part D, pp. 19–26.
- 15 Moriarty, P. and Honnery, D. (2003) 'Safety impacts of vehicular information technology', *Int. J. of Vehicle Design*, Vol. 31, No. 2, pp. 176–186.
- 16 Sutherland, J., Gunther, K., Allen, D., Bauer, D., Bras, B., Gutowski, T., Murphy, C., Piwonka, T., Sheng, P., Thurston, D. and Wolff, E. (2003) 'A global perspective on the environmental challenges facing the automotive industry: state-of-the-art and directions for the future', *Int. J. Vehicle Design*, this issue.
- 17 Anon. (2002) 'Science and technology: driven to alcohol; renewable fuels', *The Economist*, September 7, pp. 70–71.
- 18 Renewable Fuels Association (2003). Accessed at www.ethanolfra.org/eth_prod_fac.html
- 19 McLean, H.L., Lave, L.B. and Griffin, W.M. (2003) 'Alternative transport fuels for the future', *Int. J. Vehicle Design*, this issue.
- 20 World Energy Council (WEC) (2001) *Survey of Energy Resources*, WEC, London.
- 21 Adams, R. and Brewer, T. (2003) 'A plan for 21st century land transport', *Int. J. Vehicle Design*, this issue.
- 22 Ealey, L. (1999) 'Metamorphosis: a critical appraisal of the global auto industry's future', *Motor Business International*, 3rd Quarter, pp. 162–170.
- 23 Booz, Allen & Hamilton (2000) 'Challenges facing the global auto industry', *Insights*, Vol. 1, Issue 1, pp. 1–7.
- 24 KPMG (2000) 'The future of auto retailing', *Momentum*, Winter, pp. 1–6.
- 25 Veloso, F. and Fuchs, E. (2003) 'The future of the Asian auto industry: regional integration, alternative designs and Chinese leadership', *Int. J. Vehicle Design*, this issue.