The Impact of Motoring

Part 1 - Environmental

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Cover images: The Old Mill, Bourton-on-the-Water, today home to the Cotswold Motoring Museum and Toy Collection and cars associated with the museum.

Source of right hand image above: Metropolia University of Applied Sciences, Helsinki, Finland.
http://green.autoblog.com/2013/05/30/biofore-concept-car-is-a-plant-laden-sustainable-ride/

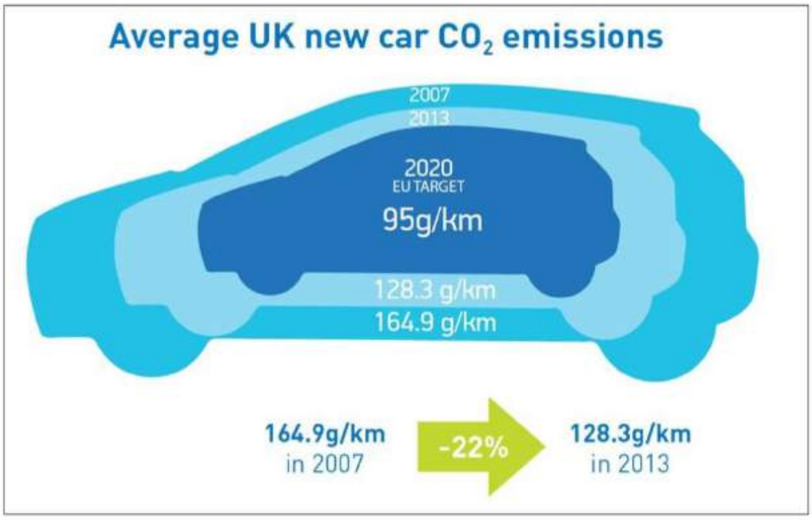
Contents of Part 1

Part 1 - Environmental

The change to our environment over the last 125 years as a consequence of motoring is clearly vast and in some cases the changes have crept up on us almost subliminally. Emissions from burning the products of fossil fuels in our cars and the depletion of the planet's reserves of oil and gas may be amongst the most prominent of our environmental concerns. A time-traveller from the turn of the 20th century however, would undoubtedly be astounded at the incessant noise levels around our main roads and the high level of artificial light, much of which is for the benefit of the motorist and which, largely, we accept as just part of modern life.

Equal astonishment would likely be aroused by the way in which the car and commercial vehicles have revolutionised what we today call our supply chain. Fresh produce to shops across the country within hours of being gathered or off-loaded at the ports provides choice and health benefits unavailable at the dawn of the motoring age, the car providing the final link to home in the chain.

In keeping with the personal responsibility theme of this book, there is an increasing realisation, clearly articulated by David MacKay[1] that if we are to leave a sustainable future to our children and grandchildren, then one action we need to take, above all else, is to use less of the planet's natural resources.



In this vein, the opening chapters of the book review how our usage and fuelling of the car may be managed to achieve this aim. An outline of global oil reserves is followed by a look at alternatives to oil and some renewable energy options. Not all are directly relevant to motoring but they could displace oil currently used for domestic and industrial power generation. Burning hydrocarbons to fuel our cars has produced measureable changes to the composition of the Earth's atmosphere. The role of legislation[2] in trying to slow and then reverse these changes is the subject of one chapter but this alone may not be sufficient, reducing our usage and better management of our journeys also has to be part of the solution.

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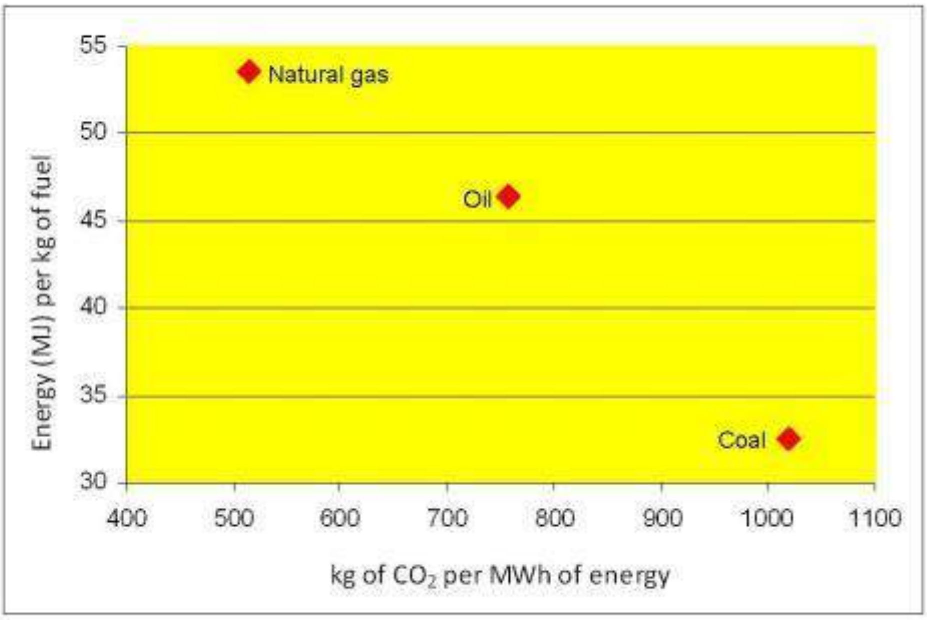
[1] "Sustainable Energy without the Hot Air". http://www.withouthotair.com
[2] The CO_2 graphic is taken from "The SMMT New Car CO_2 Report 2014"

Will the plastic dinosaur soon become extinct?

How much oil do we have left and how long will it last? What is known for sure is that with increasing use, the world's supply of crude oil will run out. In this chapter, we discuss whether estimates of the amount of oil still to be discovered and exploited are realistic or exaggerated. With an increasing global population and industrialisation in India, China, and African and South American countries, will there be enough oil to last beyond 2050? As readily accessible oil becomes scarcer, previously uneconomic and technically challenging reserves are now being exploited. Is the associated risk to our environment and personal livelihood acceptable? This chapter addresses these questions and briefly looks at alternative energy sources to oil, including sources of renewable energy.

Introduction

Fossil fuels are formed from the organic remains of plants and animals, subjected to the heat and pressure of the Earth's crust over tens of millions of years. The fuels in most common usage today are coal, oil and natural gas. In addition to burning oil and its derivatives to release stored energy, it is also used to make medicines, chemicals, plastics and fertilizers. In all cases, burning the fuel releases energy stored in the fuel to generate power for homes, agriculture and industry and to enable land, sea and air transport. The effect of burning each fuel is different. Burning 1kg of natural gas releases around 65% more energy than burning 1kg of coal and releases roughly half of the carbon dioxide (CO_2) produced in burning the same weight of coal. An indication of the relative properties of these three most common fossil fuels is shown in the chart. [MJ is an abbreviation for Mega Joules – a unit of energy and MWh is a measure of the rate at which energy is used]. The graph illustrates why Winston Churchill, First Lord of the Admiralty in 1911, was keen to fuel British war ships on oil rather than coal and why today, in a quest to reduce CO_2 emissions, power generators switch from coal to gas.



In 2010, when the first issue of this chapter on Oil Consumption was prepared in support of the Impact of Motoring exhibition at the Cotswold Motoring Museum, the emphasis was on the source of the fuel used by the motorist and when supplies of that conventional crude oil might be exhausted. Since that time, the number of oil and natural gas discoveries along with enhanced extraction techniques, for example 'fracking', have rapidly evolved and some estimates of the number of years of economically extractable fossil fuel remaining have stretched well beyond the end of this century. Given that coal and natural gas can be and are being used to manufacture liquid fuel and that at least one major oil company now makes more profit from gas than oil, it is appropriate that the scope of the Oil Consumption chapter has expanded to try to reflect an ever more complex picture of fossil and non-fossil fuels. At the same time, the focus remains on motoring and the motorist.

What is oil?

What is oil and when was it first discovered?

Crude oil, or petroleum, is a black treacly liquid found underground, formed from the remains of masses of animal and plant material, particularly from the relatively shallow seas, thick with algae, which covered the majority of the planet millions of years ago. It is generally accepted that the major sources of conventional crude oil were formed during periods of global warming approximately 90 and 150 million years ago. Organic material formed a carbon rich sedimentary rock, which over time sank below the surface, and subject to the Earth's heat and pressure, formed the dark dense liquid.

When was oil first used?

Oil was first exploited in China in approximately 200 B.C. Though only with the use of bamboo poles and brass fittings, they were able to penetrate some 3,500 feet. The properties of oil were known well before this. As early as 3000 B.C., in what is now known as Iraq, the Sumerian people used a bitumen as an adhesive for bricks, and as a sealant for boats. In 2200 B.C. the Babylonians built tunnels, bridges, walls, sewers and roads, including the famous Hanging Gardens and Tower of Babel, using asphalt in the bonding material.

The ancient Egyptians mummified their dead with, amongst other things, bitumen from the Dead Sea. The Roman scholar Marcus Terentius Varro wrote of the disinfectant properties of petroleum vapour. The Indians and Chinese also produced medicines from it.

Arab nations, by the late 11th century, had discovered that the crude oil could be distilled into fractions with varying properties.

The first 'conventional' drilled oil well of modern times in the western world is accredited to Edwin Drake of the Senecca Oil Company, who in 1859 drilled a well in Titusville, Pennsylvania. Using the same techniques as the salt miners in the area, his men were soon able to achieve a drilling rate of three feet per day! They began drilling in August, and by the 27th had reach sixty-nine and a half feet where the oil was discovered. Drake's discovery started an 'Oil Rush'. Within one year there were about seventy productive wells, and by 1864, Oil Creek, as the region had become known, was producing 200,000 gallons of crude oil per day, relatively easily transported in wooden 'barrels' by raft and road.

The next process discovered was the ability to separate crude oil into its constituent fractions by distillation. The most useful constituent at this time was moderately light paraffin oil for use in lamps. The highly volatile constituents (eg petrol) had no real use and were disposed of by burning in pits.

Since its first discovery, oil has been used in a multitude of forms, with different additives and properties, and as an essential lubricant to reduce friction wear, particularly when metal-to-metal contact wear has to be minimised.

Modern day oil usage

It was the commercialisation of the internal combustion engine in the form of sea, air and land transport, but especially the car, which rapidly and drastically increased the demand for fuel products from crude oil, and by 1910 the production of petrol had overtaken that of paraffin oil (kerosene). Previously the dense energy rich crude oil had been found to make a superior fuel to coal for powering shipping. Although with no indigenous supply of oil, the British government of the time, under the guidance of Winston Churchill, set about converting Royal Navy ships from coal to oil. High-octane petrol was to become the fuel of choice for piston engine aircraft. Subsequently jet engine aircraft were also to utilise their own fraction from the mix.

As well as advanced distillation techniques, 'cracking' using heat and, later, 'catalytic cracking' are able to produce a myriad of organic compounds for use in virtually every industry and in the manufacture of countless items from plastics to fertilisers. In addition to a fuel and lubricant, oil in a multitude of forms is used as a rust inhibitor, hydraulic fluid, a heat conductor in transformers and a cutting fluid. Oil now makes the world go round.

Availability of cheap fuel to the industrialised world also meant improved agriculture. In turn, this meant a vast increase in world population. At the beginning of the oil age (150 years ago), the world population was 1.3 billion. This reached 7 billion in 2012, and is projected to be 9.6 billion by 2050.

Today, the world appetite for crude oil *and* liquid fuels is nearly 90 million barrels[3] per day. This is projected to rise to a peak of 100 million barrels per day by 2030.

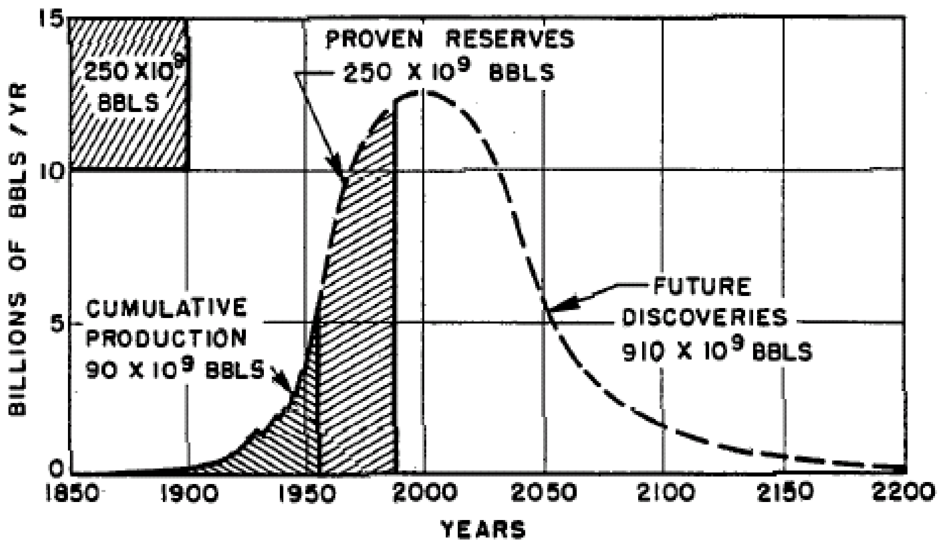
The top three oil-producing countries today are Saudi Arabia, Russia and the United States. About 80% of the World's readily accessible reserves are located in the Middle East, with 62% coming from the Arab 5: Saudi Arabia, United Arab Emirates, Iraq, Qatar and Kuwait. A large proportion of the world's total oil exists as what are termed 'unconventional sources'. Examples include bitumen in Canada and Venezuela, and shale oil. Whilst significant volumes of oil are extracted from oil sands, especially in Canada, logistical and technical hurdles remain, and Canada's oil sands are not expected to provide more than 3 to 5 million barrels per day; only around 3% to 5% of the projected requirement by 2030.

[3] One barrel is approximately equal to 159 litres, 42 US gallons and 35 Imperial gallons.

The Peak Oil debate

The Peak Oil Theory refers to a point in time when the amount of oil extracted from a given resource, whether an individual oil field, region, or the planet as a whole, follows a bell shaped curve and reaches a peak, following which it begins to irreversibly decline. It was first proposed in 1956 by Dr. Marion Hubbert, a prominent geologist working for the Shell Oil Company. He predicted that oil production in the US would peak between 1965 and 1970. Ridiculed by his colleagues at the time, in 1970 US oil production peaked. In 1969, he went on to predict a peak for World oil production of between 1995 and 2000. This theory became known as the Hubbert Peak Theory.

World crude oil [*defined as: a mixture of hydrocarbons that exists in liquid phase in natural underground reservoirs and remains liquid at atmospheric pressure after passing through surface separating facilities*] production has stayed more or less flat at around 75 million barrels per day since 2004, amidst record high oil prices. Whilst it may be premature to say for sure, the longer that production continues at this rate, or declines, the more certain it will be that Peak Oil from conventional sources, has been reached.



Hubbert's Peak graph from his 1956 paper

Some facts on peak oil usage and discovery, plus further reference material, reinforce this conclusion:

- Oil production in 33 out of 48 countries has now peaked, including Kuwait, Russia and Mexico.
- The biggest growth in oil demand is actually coming from the Middle East itself. Saudi Arabia was a country of 6 million people in 1970. Today that number is 26.5 million and yet the 1970's peak in production has never been reached since.
- Worldwide discovery of oil peaked in 1964 and has followed a steady decline since
- Production from Europe's North Sea oil field is in decline

- World oil demand rose markedly in the decade to 2010 as improvements in energy efficiency did not offset the upward pressure from a growing world population and rising per capita income levels in developing countries

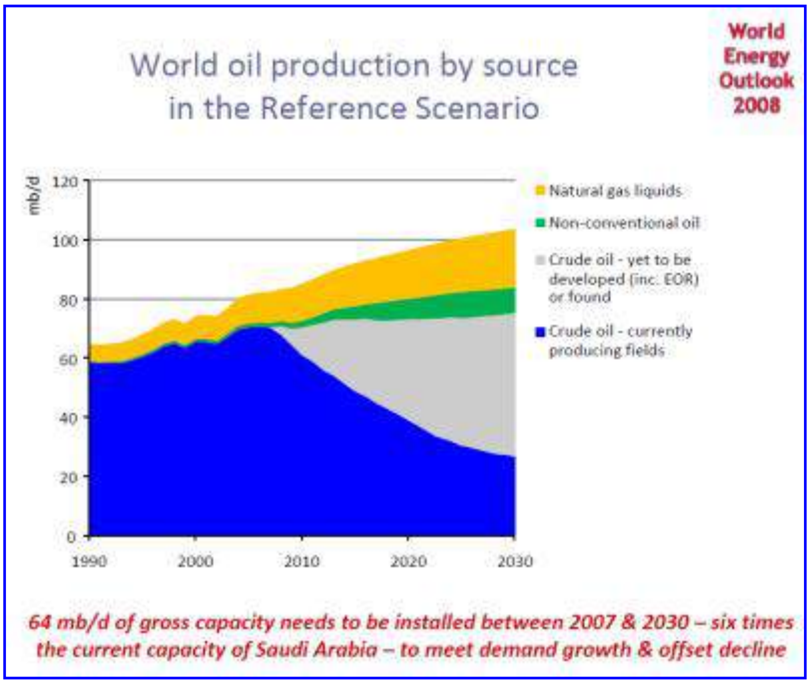
- Demand growth from China, India, Indonesia and the developing world will be extremely high over the next decade. This will by far outweigh any decline in consumption seen in the US, Japan and European countries

- Russian oil production, having seen a revival since the 1990's, is likely to be soon entering a precipitous phase. Russian oil reserves are estimated to be 77.4 billion barrels, a great deal lower than those of the Middle East

- The latest available data suggest that OPEC production has been flat since 2004

Many OPEC nations have 'manipulated' oil reserve data, making accurate forecasting of oil reserves difficult. Under the quota regime of the cartel, the OPEC countries were allowed to produce oil in proportion to their reserves. During the oil crash of the 1980's, many OPEC nations found themselves with a currency shortage and upwardly revised their oil reserve data facilitating an increase in their quota. In 1994, Kuwait doubled its reserve data on paper, without ever finding a single new oil field. Other nations followed suit. All these nations have produced billions of barrels since, yet without finding any significant new resources, their reported reserves have stayed the same since 1990. Some critics estimate that for the biggest Middle Eastern oil producers (Iran, Iraq, Kuwait, Saudi Arabia and the United Arab Emirates) the reserves are less than half of that their respective governments claim.

The Uppsala Hydrocarbon Depletion Study Group (UDGSG), Uppsala University, Sweden, has, among other research and recommendations, made a study of a crash program scenario for the Canadian Oil Sand Industry. It concludes that even in a very optimistic scenario, Canada's oil sands will not prevent Peak Oil. If a crash program was introduced immediately, it would only barely offset the combined decline of conventional crude oil production in Canada and the North Sea.



In considering the questions as to when peak oil will occur and what reserves are available, it is fundamental that these forecasts require accurate sources of information. Not only have the OPEC countries knowingly overstated their oil reserves, but the forecasts made by the International Energy Agency (IEA) appear to have been deliberately upgraded in terms of its estimate of the world's oil supplies, apparently in the interest of not frightening the markets. The Agency has been forced to downgrade its projection of daily oil supply requirements by 2030. In 2004 this forecast was 123 million barrels, by 2005 it was 120 million barrels, 116 million barrels in 2007, 106 million barrels in 2008 (see adjacent chart) and a 2011 projection (a BP figure) of 102 million barrels required per day in 2030. According to so-called ‘whistle-blowers’ from the agency, even the most recent figures are much higher than data supports.

The Uppsala report, published in the journal Energy Policy, anticipates that a maximum global production of all kinds of oil in 2030 will be 76 million barrels per day. Analysing the IEA’s figures, it finds that to meet its forecasts for supply, the world’s new and undiscovered oil fields would have to be developed at a rate “never before seen in history”. Assessing existing fields, the likely rate of discovery and the use of new techniques for extraction, the researchers find that “the peak of world oil production is probably occurring now”.

However, not all published estimates tell a tale of shrinking supply. A more optimistic, near-term forecast has been produced by Harvard University. Their summary states that “*Contrary to what most people believe, oil supply capacity is growing worldwide at such an unprecedented level that it might outpace consumption. This could lead to a glut of overproduction and a steep dip in oil prices*“. They forecast global production by 2020, boosted by ‘unconventional oil’, to be 110.6 million barrels per day.

The UK Energy Research Council recently published a massive review of all the available evidence on global oil supplies. It found that the date of peak oil will be determined not by the total size of the global resource but by the rate at which it can be exploited. New discoveries would have to be implausibly large in order to make a significant difference. If a field the size of all the oil ever found in the US was miraculously discovered, it would delay the peak of oil by four years. As global discoveries peaked in the 1960s, such a find does not seem likely.

In summary, there is much debate between experts as to when the peak in World oil production will occur. This is perhaps not surprising when considering the discrepancies in the available data concerning estimates of oil reserves by certain oil producing countries.

A perhaps somewhat pessimistic view comes from Dr. Colin Campbell, Petroleum Geologist and Energy Consultant:

“The world's oil and gas production will start to decline within most people's lifetimes. Although this will have a dramatic effect on lifestyles and the course of civilization, vested interests have deliberately kept both policymakers and the public in the dark”.

A more optimistic assessment is that of Richard Jones, deputy executive director of the International Energy Agency:

"We're the ones that are out there warning that the oil and gas is running out in the most authoritative manner. But we don't see it happening as quickly as some of the peak oil theorists”.

In reality, the issue only becomes critical when world demand outstrips accessible world supply. If the economically depressed world markets continue for another decade and new discoveries continue, then the date of peak oil moves into the future. A further quote captures the current situation quite succinctly:

"The era of cheap oil is over, but we're a long way from peak oil - costs will go up but then technology will respond."

We are, however, dealing with a finite, non-renewable resource, so ultimately it is not a question of what will happen *if* we run out of oil, it is what will happen *when* we run out of oil?

Politics and the power of oil

The oil crisis of 1973 showed the vulnerability of 'superpowers' to a modest shortfall in global oil supply. In October, Middle East OPEC states stopped exports to the US and other western nations. It was in retaliation for their support of Israel and was a demonstration of the power that these countries held in being able to bring the rest of the World to a potential stand still. Blocking just 5% of the oil supply had the effect of raising the price of oil four-fold overnight. This was not the first time that the power to control oil supply was used for political ends: the sabotage of German fuel supply lines in World War II was considered a major factor in the outcome of the war.

In late summer of 1985, the US Reagan administration, with a clear knowledge that the economy of the Soviet Union was based on two exports, oil to Europe and military weapons and training to anti-western countries and organisations, decided to make a pact with Saudi Arabia. High oil prices from OPEC kept Soviet oil exports to Europe profitable. It also allowed Iran, Iraq and Syria to purchase advanced Soviet weapons. These countries had been a threat to Saudi Arabia for many years.

The plan was to have Saudi Arabia drop the price of oil below a level the Soviets could afford to sell. Once non-Soviet prices were lowered, former Soviet clients would cease buying from USSR, harming their economy. At the same stroke, Iran, Iraq and Syria, with their oil price so low, would no longer be able to afford to purchase Soviet arms. In December 1985, the oil price was $26.46 a barrel but by March 31st 1986, it had plummeted to $10.25 per barrel. The Soviet Union was unable to keep up and their economy began to collapse. Recognition of Saudi Arabia's valuable help in bankrupting the Soviets came later during Operation Desert Storm. This collaboration with Saudi Arabia subsequently had a down side. Having been shown once how to enhance the estimation of oil reserves and control market prices, it became common for other OPEC countries to adopt such a practise. Today, many OPEC countries see their oil reserves as more political than geological.

Recent oil discoveries

Before discussion of alternatives to conventional crude, we should note that, ironically, in very recent history, there have been significant new fields discovered, and others previously discovered by one region being made available, literally to the highest bidder.

Examples of reserves, which with the latest extraction technology are considered viable, include the Bakken oil field in North Dakota, possibly one of the largest ever found, with a disputed estimate of 250 billion barrels of recoverable oil. The Permian Basin in West Texas, an established oil field using the latest extraction technology, is estimated to increase its current oil production of 900,000 barrels per day to around 2 million over the next 4 years[4]. The recent discoveries of oil beneath California are estimated at 15 billion barrels whilst the estimate for Venezuela is 300 billion barrels, making it the largest reserve in the world, overtaking Saudi Arabia. An indication of the abrupt upturn in US oil production since 2005 is reproduced from the US Energy Information Agency on the BBC website.
Brazil's off shore Tupi oil field, with an estimated 14 billion barrels of recoverable oil, is being developed as two pilot projects and is forecast to yield 6 million barrels per day by 2020. There are also vast oil and gas reserves beneath Alaska yet to be exploited. Over 200 million barrels

[4] TIME Magazine 14 and 28 October 2013

were pumped along the Alaska pipeline in 2012. Estimates of Russian reserves are typically between 60 and 70 billion barrels but some are as high as 200 billion barrels.

In December 2009, the Iraq government held an auction, the second of two since the country's invasion in 2003. On offer were10 oilfields, providing a rare opportunity for oil companies from the West, China and India to obtain access to significant and readily pumpable Middle East oil reserves. Royal Dutch Shell and Malaysia's Petronas won the right to develop the Majnoon oil field, proven to have a massive 12.6 billion barrels of reserves. A consortium comprising the Chinese company CNPC, Total and Petronas, secured the 4.1 billion barrel Halfaya oil field. Several oil fields, such as those with 8.1 billion barrel reserves, in East Baghdad were considered too dangerous at this time for Western commercialisation. The Iraqi Oil Ministry are reportedly developing them on their own.

Recent oil discoveries are not universally popular. Those lobbying for reduced burning of fossil fuels on the grounds of the threat to the planet's climate through further increases in the CO_2 released as the fuel is burnt, fear that further affordable fossil fuel will shift the focus away from renewable energy sources which, ultimately, must represent the future.

Oil spills and pollution

The leak in 2010 from the well beneath the BP Deepwater Horizon offshore oil rig in the Gulf of Mexico, just like the grounding of the Exxon Valdez in 1989, brings into sharp focus the environmental risks associated with meeting the world's demand for oil. The Deepwater Horizon well was approximately 1.5km (5000ft) below the surface of the sea and a further 5.5km (18,000ft) beneath the ocean bed. At these depths, all work on the seabed has to be accomplished using robots; just one illustration of how technically challenging oil extraction has become as ready access to oil on land diminishes. [For comparison, the Brent Field in the North Sea is in 140m (460ft) of water]. Unsurprisingly, the risks posed by the leak to employment, dependent upon fishing, boating and tourism, as well as the risk to the coastline and wildlife habitat, resulted in an immediate reaction of "no more offshore drilling". For the USA, the increasing use of offshore, deep water drilling was meant to ease the transition to non-fossil fuels by buying time for those sceptical of climate change to accept the need to move away from fossil fuels and for renewable energy technology to gear up to meet future demand. Ironically, any moratorium on offshore drilling could have just the opposite effect and increase reliance on other national producers with lower environmental standards.

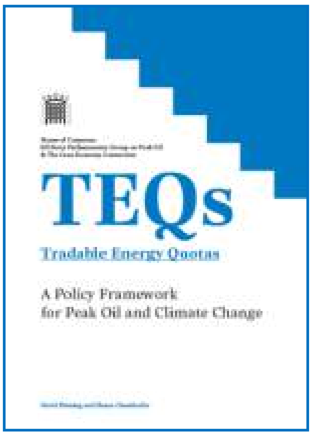
UK government view

The All Party Parliamentary Group on Peak Oil was set up in 2007 to review estimates of future oil production and to consider the effect of declining world oil production on the UK and world economy. An initial report was produced in July 2008 and a follow-up report in January 2011. The Chairman of the All Party Group introduces the 2011 report with:

"*I .... have raised the issue [of peak oil] with the government many times. Regrettably, the government is still unable to grasp how serious the threat of peak oil is, and so the UK remains inadequately prepared to cope with this looming crisis*."

The report summary includes:

> "*Nations around the world are experiencing deepening energy scarcity. There is no doubt that the needed steep reduction in reliance on fossil fuels will not be achieved unless there is a sense of common purpose within nations, with citizens and communities fully involved and strongly motivated to invent their own solutions. We need a revolution in the way we use energy*."



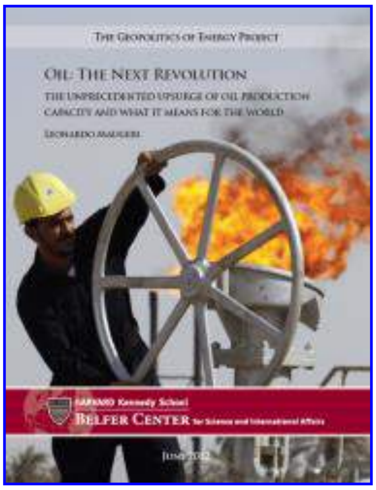
The focus of the report thereafter is on a concept of Tradable Energy Quotas (TEQs) in which individuals, business and governments would receive an annual allocation of TEQs. In practice, these would correspond to litres of fuel or kilowatt-hours of electricity; effectively an individual carbon footprint. The aim of the report's authors is to put in place a system of managing the use of a declining resource *before* the problem needs to be addressed as a matter of immediate urgency and ad hoc, inappropriate steps are taken. Whilst there have to be reservations about the complexity of implementing the specific concept of TEQs in the way presented in the report, the prospect of fuel rationing returning in some guise – maybe through financial affordability - cannot be ruled out and to be prepared for such measures seems eminently sensible.

Alternatives to oil

Whenever 'Peak Oil' is to occur, if it hasn't already, it is clear that the world will no longer be able to rely as heavily on a supply of cheap conventional crude oil for its energy requirements. Recent discoveries, whilst maintaining supply continuity, involve greater complexity and hence greater extraction cost. It is also probable that no one alternative energy source is ready or of sufficient magnitude to make up for a conventional crude oil deficiency. One leading school of thought is that our only alternative is several alternatives.

These can be categorised as 'unconventional' crude oil, that which thus far has not been able to be harvested due to logistic or economic barriers, other non-renewables such as coal, gas (and their products) and nuclear, and most topically, renewables such as solar, wind, wave, tidal, geothermal, hydroelectric, algal, fermentations etc. Each of these has their limitations and challenges, but the technologies for their use are either in their infancy or at differing stages in development and require investment by energy companies and governments. This urgency, accompanied by the threat of irreversible 'global warming', has been focusing attention for some time, such that now it is barely missing from the headlines.

Alternative 'unconventional' crude oil and liquid fuel sources



Over the next 20 years, the ability to extract oil from sources previously technically too difficult and / or economically unviable will shift. Included in these resources are the 'tar sands', a mixture of sandy clay and black viscous bitumen, predominantly found in Canada[5,6] and Venezuela, 'shale oil', a sedimentary rock containing kerogen and liquid fuels produced from coal or liquefied gas.

The International Energy Agency (IEA) estimates that these forms of reserves total 9 trillion barrels or nine times the volume that the world has utilised since the beginning of the oil age. However, such are the difficulties in terms of energy and other costs involved in their processing, until recently, less than 2 million barrels per day were produced from these materials. This figure is increasing. In December 2011, 530,000 barrels per day were produced from the shale oil in North Dakota. A forecast, in a June 2012 report from Harvard University, suggests the possibility that oil from these unconventional sources may result in a global surplus of 110 million barrels of crude oil and natural gas liquids per day by 2020. A BP Energy Outlook for the year 2030 estimates that 57% of the US gas supply could be met from these shale gas deposits.

Production from 'unconventional sources' usually involves a greater release of carbon emissions than conventional refining. There are also concerns that horizontal drilling and fracturing the oil/gas bearing rocks – fracking technology - can cause contamination of aquifers and even minor earth tremors.

Globally, only about 35% of the oil in any well is extracted[7]. The primary approach is that oil is recovered under its own energy, secondary production supplements this with pumping water or gas injection and then a third strand of advanced methodologies are employed. In an effort to develop the recovery, several techniques are being progressed including Steam Assisted Gravity Drainage (SAGD) and Toe to Heel Air Injection (THAI). Similarly, several techniques are being investigated to heat shale oil underground prior to its conventional recovery by drilling. This includes the use of microwaves, high temperature gas injection and radio waves combined with Supercritical Fluid Extraction (SFE).

Methane Hydrate is a crystalline form of natural gas found in layers beneath the sea bed. The methane is trapped in a crystal lattice of water and research to mine and utilise this gas has been undertaken by the US and Japan since the early 1980s. Estimates of reserves vary enormously but the one thing they have in common is that they are vast. The relevance of natural gas to the transport sector is as a displacement for oil in power generation (thus 'freeing-up' oil for transport and manufacturing), as a fuel, in the form of compressed gas replacing diesel, for buses, lorries or ships and for conversion into liquid fuel.

[5] Engineering & Technology, Volume 8, Issue 4, May 2013, p16
[6] New Scientist, 16 August 2014, p10
[7] Engineering & Technology, Volume 8, Issue 1, February 2013, p48

Manufacture of liquid fuel from coal and natural gas

The production of liquid fuel from coal was a process developed by two German Chemists in 1920. The Fischer-Tropsch process involves the heating of coal to release a mixture of hydrogen and carbon monoxide, subsequently catalysed to produce diesel and kerosene. The process was used in Germany during the Second World War and in South Africa during the time of sanctions over apartheid. Some petrochemical companies in the UK during 1930-1945, namely Carless and the National Benzole Company (NBC), also produced a liquid fuel from coal for use as a 'motor spirit', although utilising a different process from Fischer-Tropsch, resulting in a mixture of 50% benzene and the rest a mixture of toluene and xylene. This would not be acceptable today, as even if mixed with conventional petrol, benzene is now known to be a potent carcinogen.

The same Fischer-Tropsch process can be used to produce high quality liquid fuels from natural gas. The process emits less carbon than coal to liquid fuel, but takes up to 300 cubic metres of gas (half of which is burnt in the reaction) to produce one barrel of liquid fuel. Despite this, there are three small plants at present producing 50,000 barrels of synthetic liquid fuel per day. This is estimated to rise to 200,000 barrels per day with new plants in Qatar and Nigeria coming on-line.

Underground Coal Gasification (UCG) has taken on a higher profile in recent years. Although the same process that was performed in the town gas works fifty years ago, in UCG the coal is partially burnt in-situ, a few hundred metres below ground. Oxygen and steam are pumped at pressure through boreholes into the coal seam and the gases (carbon dioxide, carbon monoxide, methane and hydrogen) forced to the surface[8].

In some parts of the world, coal has made a resurgence. In the UK, it remains at present the most utilised fuel for electricity generation in power stations. In this respect, the production of liquid fuel from coal is releasing oil reserves for purposes coal cannot fulfil eg manufacturing.

Biodiesel

Most people are now aware of biodiesel made from crops such as corn, soya beans, palm oil and even bananas. However, there are problems with biodiesel made from crops. These include the displacement of food, environmental damage as large areas of Amazonia, Malaysia and Indonesia are cleared for biofuel growth and the amount of crops needed to produce a gallon of oil. In June 2013, the European Parliament's Energy Committee voted to cap the proportion of food-crop fuel at 6.5%. In September 2013, the Parliament backed proposals to limit the amount of food crops used to a maximum of 6% by 2020, amending the target from 10%.

Biodiesel produced from algae[9] has been widely discussed among experts in the petroleum industry and conservationists who are looking for a more reliable and safer source of energy that is both renewable and easy to attain. One of the key reasons for this is their yield. The US Department of Energy has reported that algae can give up to 30 times more energy per acre than

[8] New Scientist 15 February 2014

[9] Engineering & Technology, Volume 5, Issue 5, March 2010, p42

land crops such as soya beans, and some estimate even higher yields of up to 15,000 gallons per acre. Action of sunlight on algae, in the presence of water and carbon dioxide, produces lipids or oils from which fuel can be processed. Solazyme claim "Solazyme's renewable oil production technology allows us to do in a matter of days what it took nature millions of years to do". Genetically engineered organisms, designed to optimise fuel production, have been developed by Joules Unlimited with pilot production demonstrated at their plant in Austin, Texas.

Ethanol

One product of the fermentation of organic matter, such as maize or sugar cane, is ethanol (or ethyl alcohol). When mixed with petrol, it has a long history of powering motor vehicles. Some brands of motor spirit in the 1930s and 1940s were sold as a mixture of petrol and alcohol, one example is Cleveland Discol, advertised as 'the alcohol blend' being able to provide more power than petrol alone when used in some internal combustion engines. In America, during the oil crisis of the 1973, a similar mixture of alcohol and petrol (gasoline in the US) was marketed as 'gasohol'. Today, in Europe a 5% ethanol mixture (known as E5) is in widespread use and since 2013 the standard (BS EN228) for petrol allows up to 10% (E10). The objective of these measures is to cut the amount of fossil fuel burnt. Some manufacturers already produce vehicles that run on a 25% ethanol mixture, for example in the Brazilian market, however, for older, classic vehicles, even the E10 blend will cause problems.

The trend with biofuels has been to move away from food crops with second-generation biofuels being created largely from non-food material such as corn stalks, leaves, hardwood and softwood, while algae-derived fuels represent the current (third) generation[10].

Nuclear power

Although not strictly an alternative to oil in terms of transportation fuel replacement, in a world of inevitably increasingly scarce and expensive oil, no discussion on oil and its alternatives would be complete without a mention of nuclear power. Nuclear-fuelled power stations have been a part of our society for many years, along with much criticism of their use, based largely on the unique associated dangers. On the positive side, carbon emissions are lower than those from conventional coal fired power stations. They are also comparatively efficient in financial terms. The main problems arise from the radioactive materials used, together with the radioactive waste products produced in the process, their transport and disposal. These materials remain hazardous due to typical radioactive half-lives of many hundreds of thousands of years.

Other concerns also focus on safety. The disastrous consequences of a major accident on 26th April 1986, when nuclear reactor number 4 at a power station at Chernobyl in the Ukraine (then part of the Soviet Union) suffered a catastrophic power excursion, led to the worst industrial accident of all time. Radioactive fallout was 400 times higher than that formed by the Hiroshima atomic bombing in World War II. An estimated 800,000 people were exposed to radiation. The number of deaths attributed to related cancers may never be known. Today and for generations

[10] Engineering & Technology, Volume 9, Issue 4, May 2014, p56

to come, children growing up in the areas of Ukraine and Belarus affected by the fallout suffer a disproportionately high rate of serious illness due to their contaminated environment.

The consequences of nuclear accidents such as Chernobyl, together with other radioactive incidents and leakages, such as the problems surrounding the Fukushima nuclear plant damaged in March 2011 by the earthquake and tsunami, highlight concerns over nuclear safety. Additionally, the proliferation of radioactive materials and concerns about material falling into the hands of terrorists, whether for producing a weapon of mass destruction or a 'dirty bomb' have a negative influence on this method of powering our societies.

Nuclear reactor technology has been used as an alternative to oil to power military ships and submarines. Again, the risk of accidents remains an environmental concern. Very few nuclear powered cargo ships remain operational today, the remainder interestingly having been converted to diesel. 'Nuclear Batteries', refrigerator-sized reactors, have been discussed since the 1950s and are again newsworthy. Modest scale schemes have also been proposed that use nuclear waste products in a molten salt reactor to produce carbon free energy and to address the disposal of hazardous waste.

There are differing opinions regarding the world supply of uranium and how long it can be sustained. These range from 40 to at least 200 years at today's rate of use. One alternative to uranium is thorium but in spite of being a more abundant, less hazardous material than uranium, this has not moved beyond demonstrations of feasibility.

All nuclear power generation is based on nuclear fission. By comparison, the production of commercial nuclear fusion energy has been the topic of research for more than 50 years and remains a distant – more than 30 years – possibility to solve global energy requirements.

Biomass and waste to energy

Biomass, burnt along with coal in a power station is, in a similar way to nuclear power, a displacement technology for oil, gas and coal. The efficiency of the biomass pellets can be increased by 'toasting' the pellets: a process known as torrefaction. Conversion from coal to biomass is a means by which some of the UK's coal burning power stations will meet their reduced CO_2 targets. Processing of household waste into energy in the form of methane, used for electricity generation, is also providing an alternative to fossil fuels as well as avoiding the waste going to landfill.

Ammonia

Ammonia has been proposed as an alternative fuel, since it can run in spark ignited or diesel internal combustion engines with minor modifications and despite its toxicity, some references claim it to be no more dangerous than petrol or LPG. It can be made from renewable electricity and having half the density of petrol or diesel can be readily carried in sufficient quantities in vehicles. On combustion, it has no emissions other than nitrogen and water vapour. During and following WWII it was used to power buses in Belgium.

For more information see New Scientist and the Wikipedia link.

Renewable energy

A brief mention of renewable energy sources has a place in a chapter on Oil Consumption in the transport sector since 'renewables' become 'displacement technologies' for oil; leaving oil to be used in roles for which it is uniquely suited such as manufacturing, plastics and pharmaceuticals.

Solar power

Domestically, solar energy is used in two ways to provide power. Solar heat exchanger panels for water heating and the more expensive photovoltaic (PV) panels for direct generation of electricity are increasingly being installed on home and business rooftops. Of renewable energy forms, solar photovoltaic is one that has benefitted from financial incentives, in the form of feed-in-tariffs, helping to increase its presence over recent years. Beyond use in individual domestic premises, a few large-scale, industrial arrays have been deployed. In 2011, a 30 acre, 21,000 PV panel solar park was completed in Cornwall and is providing power for local businesses and a feed-in to the National Grid. Also in SW England, near St Austell, is the National Solar Centre whose aim is to increase deployment of PV capacity through cost reduction and to improve efficiency, which, under ideal conditions, is currently around 20%.

On a small scale, it is easy to fit solar panels to the roof of a domestic dwelling or outhouse. Even some road signs, particularly in remote areas, now carry their own mini solar panels and the use of solar power to operate LED road studs (basically an 'active' cat's eye) is well established.

When the environmental impact of producing solar PV panels is factored into the equation, there is an argument that they are not as 'green' as they may first appear. The materials used in their production and end-of life disposal can be harmful to humans and the environment and the fossil-fuel-derived energy used in their mining, fabrication, installation and maintenance may exceed that produced during their working life.

Returning to the direct use of solar thermal energy on a large scale, for those with the appropriate climate, concentrated solar power[11] has a lot to offer. The Ivanpah project in California is the biggest solar thermal plant in the world. The 150m high tower is at the focus of 173,000 steerable mirrors that reflect the sun's energy onto the top of the solar tower where the steam produced is used to power turbines for the generation of electricity. In comparison with photovoltaic power generation, the short-term loss of sunlight does not mean a fall in the power fed to the grid. The thermal inertia of the massive boilers provides continued power should the occasional cloud pass over the dry Californian lake. The unit shown above is the first of three planned for the site[12].

[11] Engineering & Technology, Volume 8, Issue 5, June 2013, p30
[12] TIME Magazine, 24 June 2013

Hydroelectric power

Generation of electricity by driving turbine generators with water stored by the damming of a river has been exploited for many years. This clean and renewable source is obviously geographically dependant and has traditionally required a large initial financial investment. It provides one way in which renewable energy can effectively be stored. For example, wind power that may be available at times of low consumer and industrial demand, can be used to pump water for storage behind the dam until it is required for power generation.

Whilst hydropower has long been used for milling and industrial purposes, there is renewed interest in old mill sites as locations for hydroelectric power generation.

One interesting new use for the Archimedes spiral, used for centuries to raise water for irrigation, is in such generation schemes. The picture shows an installation on the River Dart in Devon. Water flowing *down* the spiral drives a generator via a gearbox. The spiral can operate with a head of water as low as 1m and with a flow rate of a few cubic metres per second and is capable of generating a few tens of kilowatts. The spiral has been demonstrated to be particularly 'eel and fish friendly'. A further installation, powering a renovated mill and feeding surplus energy back into the national grid, is on a tributary of the River Thames in Oxfordshire.

Wind power

Like water power, wind power is nothing new. Man has used wind power for hundreds of years, including windmills for the production of flour from wheat and the wind pump for land drainage.

Wind power is renewable, does not cause pollution at the point of power generation and does not need fuel. However, obviously, it is only available when the wind is blowing! Despite a widespread acceptance that this is a resource of the future that should be exploited now, some concerns are voiced over the effect on the landscape, the effect on birds and interference with TV and radar signals. Increasingly, new capacity is likely to be built in coastal waters (up to 25m depth) and further out to sea at depths of up to 60m. Successful bidders for the next 'round' of UK offshore wind generation were announced in early 2010. Physically, these towers will rise 100m above the water surface and, in 50m of water, will place 500 tonnes of blades and turbine on top of a 150m cantilever [13]. A formidable and expensive, civil engineering challenge! One proposed method to ease the construction task is to assemble floating wind

[13] Engineering & Technology, 6-19 February 2010, 40-43. http://www.theiet.org/resources/magazines/

turbines in the shelter of the quayside and then tow these, once assembled, to be moored in their designated, deep-water location[14].

Estimates of just how much energy can be generated by offshore wind farms vary depending on the underlying assumptions. They range from around 4kWh per person per day, which assuming a UK population of 60 million equates to around 90TWh per year[15], to around 250TWh per year by 2050: approximately 70% of current national annual usage. The Offshore Valuation Group, which produced the 250TWh estimate, goes on to state that, with significant further investment, this figure could be exceeded, making the UK a net exporter of wind power generated electricity. This however, would only be feasible with a very expensive, Europe-wide electricity 'super grid' to smooth the effect of variable wind across the continent. An interesting, real-time insight into just how much wind generation is contributing to UK power demand is available at the BMRS website (Generation by Fuel Type – Table & Graph).

Like solar panels, 'mini' wind turbine generators are now available for rural road signage and domestic use, although their efficiency is low and they are particularly poor in urban areas.

Wave and tidal power

The Atlantic coast of UK and Ireland is an ideal location to generate wave energy. The wave energy is produced from the action of the prevailing westerly winds across the Atlantic and will therefore vary with wind conditions. To make a significant contribution to the UK energy requirements, many hundreds of kilometres of coast would need to be lined with wave generation hardware but for west coast islands, from Islay to Alderney, wave generation is highly likely to have a role in providing renewable energy.

Tidal power, unlike wind, wave and solar power, is entirely predictable and using tidal lagoons, energy can be stored to deliver power on demand. Given the spread of high tides around the UK coast, a number of tidal farms around the coast could provide a uniform feed of power into the grid and, unlike wind generation, the visual impact would be minimal.

Proposals for harnessing the tidal range of up to 14m in the Severn Estuary have been reviewed by UK government. One scheme, based on a barrage between South Wales and Weston, using the ebb tide to drive over 100 turbines, could provide 17TWh per year; 5% of the current UK power requirements. A further four, smaller and less expensive schemes were also included in the review, however, plans to exploit this energy source are, depending on the information source, either unlikely as they are considered too expensive to develop, or, back on the agenda.

Another approach to harnessing tidal energy is through the use of underwater, impeller-driven or hydrofoil-driven turbines anchored to the sea bed. These do not present the visual impact of a barrage and also present a lower impact on wildlife[16]. The installation of one such turbine in Pembrokeshire at Ramsey Sound is currently the subject of a 12 month trial.

[14] Engineering & Technology, 23 Oct – 12 Nov 2010, p46-47
[15] TWh: a Terawatt hour is equal to one billion kilowatt hours (kWh)
[16] Engineering & Technology, Volume 7, Issue 12, January 2013, p38

Ocean Thermal Energy Conversion (OTEC)

OTEC[17] is a technique that exploits the natural thermal gradient found in many equatorial regions. To be effective, a minimum temperature difference between surface water and the deep ocean needs to be at least 20ºC although in some parts of the globe differences of up to 50ºC can be found in depths as little as a few hundred metres. Using a closed system with a refrigerant such as ammonia, the refrigerant is vaporised by heat from the warm surface water and used to drive an electric generator. Cold water, pumped from the deep ocean, circulates through a second heat exchanger and cools the ammonia ready to repeat the vaporisation / condensation cycle.

The technology has attracted a number of serious investors, including Lockheed Martin, and projects ranging from pilot trials to modest scale installations are underway in several equatorial countries.

Geothermal power

Geothermal energy has been used for thousands of years in some countries for cooking and heating. More recently this resource has been used to generate electricity. It relies on residual volcanic activity to heat water to generate steam to drive turbine generators. Geothermal energy is an important resource in volcanically active places such as Iceland and New Zealand. Disadvantages, include geography and the presence of toxic gases and mineral compounds that have to be taken into consideration from a safety standpoint. This however, has not stopped Iceland looking at the feasibility of a 730-mile long cable to provide geothermally generated power to Scotland.

In non-volcanic areas, extraction of energy from hot rocks at a distance of 5km to 10km below the surface has been attempted. In the UK a pilot at Rosemanowes in Cornwall, was terminated in the 1980s as it was unlikely to prove technically or commercially viable at that time. New drilling techniques that offer lower cost and faster drilling speeds were scheduled to be tried on the site of the Eden Project in Cornwall during 2012/13 but are currently stalled and awaiting finance.

Storage

The availability of many sources of renewable energy is intermittent. Dependence on the output of solar, wind, wave and to some extent tidal generators is not ideal for the energy supply business where a steady base load capability and rapid on-demand power is required. In theory, one solution is to capture energy when it is readily available and store it until domestic, commercial and industrial demand increases. Whilst OTEC provides a massive, constantly replenishing store of thermal energy in the top 100m of ocean, there are many areas of the globe where this is not a viable option.

A number of novel techniques have been developed to address storage with the hydroelectric example mentioned above being one example. Other techniques use 'surplus' energy to refrigerate a material from a gas to a liquid or a liquid to solid and then use the latent energy released as the material changes state to drive electricity generators.

Looking at more conventional battery storage in the context of the requirements of a national power grid, costs for the batteries can greatly exceed generation costs. One new technology that

[17] New Scientist, 1 March 2014

offers some promise is that of flow batteries[18]. These use organic electrolytes, have been demonstrated to survive hundreds of charge / discharge cycles and have the potential to be developed at an industrial scale.

Conclusion

Finally, two quotations that summarise the world's consumption of oil and the realisation that it is a finite resource:

'If today's teenagers have children and live to be grandparents, the population of the planet will be 9 billion by 2050' – Sir David Attenborough, 1999

and

"*Anyone who believes in indefinite growth in anything physical, on a physically finite planet, is either mad or an economist*" – Kenneth Boulding[19] -
(Environmental Advisor to President Kennedy, 1966 – from the 2011
Presidential address by David Attenborough to the RSA, March 2011)

Today's global population is around 7 billion. With that figure increased to 9.6 billion by 2050 (note the increased estimate since the 1999 quote above) and greater prosperity, health and expectations in the developing world, there will be even greater pressure on oil and other, non-renewable natural resources to provide for our way of life and even our survival. Even if the fossil fuel supply is maintained at a level to meet demand, the associated CO_2 and methane emissions are likely to continue to increase the greenhouse gas composition of the atmosphere.

Whilst globally, the peak of conventional crude oil may be upon us, the exploitation of reserves of 'unconventional' crude oil and gas in the Americas: the USA, Canada, Venezuela and Brazil, will delay the inevitable exhaustion of economically exploitable fossil fuels for perhaps two or three generations. Even then, the viability of exploiting these options will be determined by local geography, environmental considerations, political alliances and by the size of population served by the new oil / gas reserves.

In the next 20 or so years, the shift of the USA from being a net importer of oil and gas to being self-sufficient or even an exporter, could seriously disrupt today's oil exporting nations that rely on the USA as their market. Similarly, if the UK and continental Europe exploit the available shale oils and gas, the eastern European exporters, particularly Russia, may find their market diminishing. Just further examples of the heavy interplay between oil and politics!

In conclusion, for the UK, wave or tidal power may supply the majority of energy for a Hebridean island but for the majority of the mainland population, all forms of renewable energy[20] along with serious energy saving measures are likely to be needed to offset the diminishing North Sea supply and increasing cost of alternative fossil fuel derived energy.

[18] Engineering & Technology, Vol 9, Issue 2, March 2014
[19] Kenneth Boulding ***was*** an economist
[20] For a detailed, quantitative and objective analysis of sustainable energy, the publication of "Sustainable Energy Without the Hot Air" by David MacKay is an excellent source of reference. http://www.withouthotair.com/

Picture Captions and Credits

Page 6: Edwin Drake. http://en.wikipedia.org/wiki/Edwin_Drake
Page 7: Fuel pump from Cotswold Motoring Museum collection
Page 7: Grangemouth oil refinery. Source unknown
Page 15: National Benzole tanker. Source unknown
Page 15: Palm Oil nuts
Page 16: Cleveland Discol sign from Cotswold Motor Museum collection
Page 16: Nuclear power generation: http://www.freedigitalphotos.net/
Page 18: Energy Resources website: http://www.darvill.clara.net/altenerg/solar.htm
Page 18: Solar powered road stud
Page 18: Concentrated Solar Power: photos-and-videos | BrightSource Ivanpah
Page 19: Hoover Dam: http://www.darvill.clara.net/altenerg/hydro.htm
Page 19: Hydropower being generated by an Archimedes spiral, River Dart Country Park, Devon.
Page 19: Inshore wind farm, Caister, Norfolk
Page 20: Pelamis Wave Power website: http://www.pelamiswave.com/
Page 21: Energy Resources website: http://www.darvill.clara.net/altenerg/geothermal.htm

Why is it called a "Bowser Pump": surely, it's just a fuel pump?
The word "Bowser" is not in common usage today but, when used, it usually refers to a tanker for water or fuel. However, this is an example in changing use over time. In 1885, Sylvanus F Bowser invented and produced a measuring and pumping device for dispensing paraffin; the forerunner of today's fuel pump.

How many of us, when we stand at the filling station, fuel nozzle in hand watching the price digits rolling up faster than the litres, remind ourselves that what we are pouring into our tank is derived from a finite, irreplaceable natural resource that within a generation or two may be so scarce as to be unaffordable?

Tucked behind the Mark V Jaguar in a corner of the Cotswold Motoring Museum's Mill Gallery is a petrol pump that, despite being bright red and 2.5m high, is not particularly imposing and could be passed over quite easily. But missing it would be a pity because this pump earned its place as one of the "Ten Objects" in the museum's history of motoring. Made in about 1925 by S.F. Bowser & Company, the Bowser Standard Pump (type 1041) was operated by turning a large crank handle. By means of a ratchet, this operated pistons in two brass cylinders that pumped the fuel. Conveniently, one full stroke of the cylinder delivered one Imperial gallon, but by using a clever stop lever the amount could be adjusted to deliver half gallons, quarts or pints. Various dials, counters and glass viewers were used to ensure accurate delivery.

Forty years before this particular pump was made, the company's founder, Sylvanus F Bowser, invented a safe and efficient means of delivering fuel. The original version had marble valves and wooden plungers. It was used for pumping paraffin (kerosene in the USA) for heating and lighting, but this was in 1885 and the world was about to change.

The introduction of the car greatly increased the demand for fuel. In 1888, Bertha Benz borrowed her husband's newly commissioned automobile and set out with her two young sons on a pioneering 65-mile journey across Germany from Mannheim to Pforzheim. The little car could only do about 25 miles to the gallon and given that a world without cars was also one without petrol stations, Bertha had to plan her route carefully. Fortunately for her, she knew of a pharmacy along the way where she could buy fuel (Ligroin), which was actually being sold as cleaning fluid. The Weisloch town pharmacy still exists today and is regarded by many as the world's first filling station.

The practice of buying fuel in two-gallon cans from chemists, blacksmiths, hardware stores and even hotels, became the accepted practice for many years. As motoring became more popular and the demand for petrol increased, providing a quick and safe means of storing and delivering fuel became a priority. Modest, hand-operated machines such as the 1925 Bowser pump were soon replaced by electric pumps capable of gushing gallons of petrol to quench the automobile's insatiable desire for fuel.

Consequently, kerbside Bowser pumps began to appear outside country garages and newly established filling stations as businesses expanded to meet demand. Storage tanks were placed underground and the pumps were moved to a central island, sometimes covered with a canopy to protect the customer from the elements and keep rain out of the fuel. Once fuel was no longer dispensed from calibrated, glass measuring cylinders, either pumped or under gravity, assurance that fuel really was flowing into the car's tank was provided by a clear glass window or dome with a rotating paddle inside indicating fuel flow. The accuracy of metering improved and, over time, hand-operated pumps were completely replaced by electrically powered pumps. We said goodbye to the attendant as we entered a world of self-service and, eventually, pay-at-the-pump.

Petrol stations today provide a quick and convenient method of refuelling. No longer are pumps individually branded and competing side by side on the forecourt; instead the whole setting expresses the image of a single company from the glowing canopy to the massive logo-emblazoned price sign at the entrance. Fuel delivery is now part of a self-service retail environment offering the motorist life's essentials, ie milk, bread, flowers and £50 of premium unleaded.

Footnote:
Supplying the pumps with the fuel needed by today's motorist is a much wider story. The first drilled oil well of modern times is accredited to Edwin Drake of the Senecca Oil Company, who in 1859 drilled a well in Titusville, Pennsylvania. Drake's discovery started an 'Oil Rush' which was soon producing around 300 barrels[21] of crude oil per day. By comparison, global consumption is now around 88 million barrels of oil every day. There is a serious debate about whether the human race has passed the date of 'peak oil' – the date from which future discoveries of oil will be less than the volume already extracted. For more on future oil supplies and alternative energy sources, see the previous chapter on Oil Consumption.

Picture Captions and Credits

Page 24: Bowser pumps and photograph of Jack Lake's Garage from Cotswold Motoring Museum

Page 25: Items on display at the Cotswold Motoring Museum

Page 26: Garage forecourt from The Vintage Garage website:
http://vintagegarage.co.uk/garage%20photos/gaspumpgary%20collection.htm
and its modern equivalent

[21] One barrel is approximately equal to 159 litres, 42 US gallons and 35 imperial gallons

Is the air we breathe becoming more or less polluted?

This chapter on Air Pollution attempts to address questions such as just how polluting is the car and how has the situation changed over time? How has legislation helped to reduce the harmful components of the exhaust gases from our cars in everyday use and is this the whole story of the environmental impact from our use of cars? What improvement do electric vehicles provide given that the energy for re-charging the vehicle's batteries may have been derived from power generated using fossil fuels?

In this chapter, these questions are expanded, some answers are offered and historical and technical background, plus further references, provided.

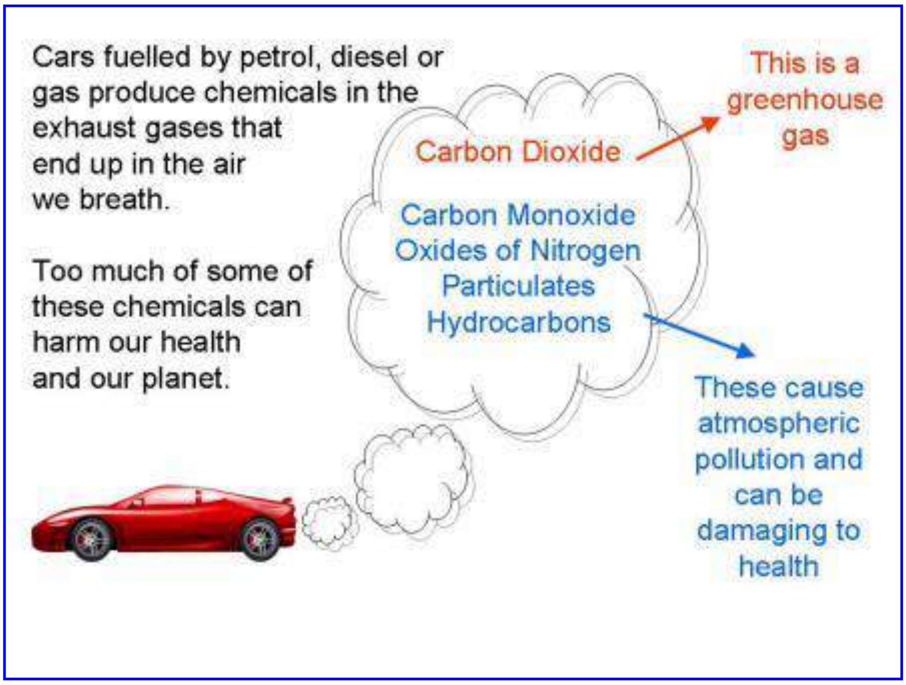
Introduction

With the 40th anniversary of the first Apollo moon landing still fresh in our memories, it is interesting to recall the impact that those first, widely seen images of Earth from space had on our perception of the planet. In particular, there was a heightened awareness of the fragility of Earth's atmosphere and of the importance of protecting the few hundred kilometre thick layer that plays such a vital role in sustaining life on Earth. The global initiative on reducing damage to the ozone layer through the reduction of compounds of hydrogen, chlorine, fluorine and carbon (CFCs) in domestic and industrial appliances is one example of the benefit of this increased awareness. The former UN secretary-general Kofi Annan has hailed the Montreal protocol to phase out CFCs as "perhaps the single most successful international agreement to date". Whilst, in the Western world, much of the visible urban atmospheric smog that characterised the first half of the 20th century has been largely eliminated, attention continues to focus on the less visible but equally harmful emissions produced by domestic power generation, industry and rapidly increasing global transport. Additionally, in spite of a downward overall trend in the UK's annual production of greenhouse gases, the cumulative increase of these gases in the Earth's atmosphere is a further cause for global concern.

Car exhaust gases

In the case of road transport, the mixture of gases from the exhaust system of a motor vehicle comprises those that, when present in sufficient volume, can be harmful to our health and over a prolonged period, affect the Earth's climate.

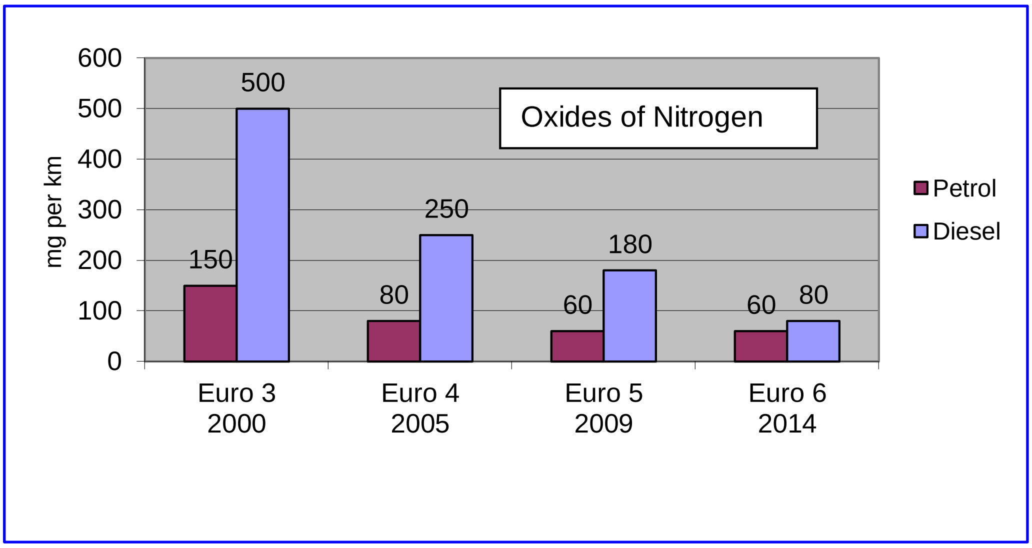
Historically, attempts to reduce atmospheric smog arising from vehicle exhaust emissions started in California with the California Air Resources Board (CARB) being at the forefront of legislation to reduce the harmful components of vehicle exhaust gases. Emissions legislation is now common throughout the United States, the European Union and other countries, with increasingly tight restrictions being placed on those global vehicle manufacturers who offer vehicles for sale in these markets.



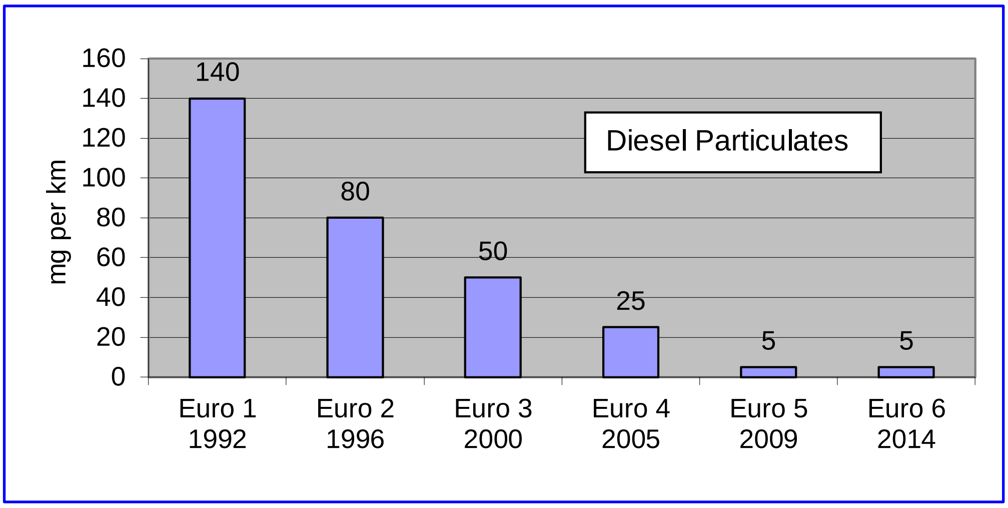
The magnitude of the effect on human health, particularly in a dense urban environment, is not easy to quantify. Globally, the World Health Organisation estimate 7 million people died in 2012 as a result of air pollution. In the UK, estimates of the number of premature deaths attributable to road transport emissions, range from 5,000 to 29,000 respiratory deaths per year with nitrogen dioxide (NO_2) from diesel vehicles being a particular source of concern in areas of high traffic density. A recent report[22] claims 4,200 premature deaths per year, in London, are due to air pollution. For comparison, the number of fatalities through road traffic accidents in Great Britain during 2012 and 2013 were 1,754 and 1,713 respectively.

European legislation

The latest EU legislation, Euro 5 (2009) and Euro 6 (2014), addresses both petrol and diesel cars and continues the trend of legislating for decreasing levels of harmful gases and fuel-derived particulates. (Particulates produced by wear from tyres and brakes are excluded from these figures). Two examples of the Euro 5 and 6 levels, along with earlier limits, expressed as milligrams (mg) per kilometre driven, are shown in the adjacent graphs.



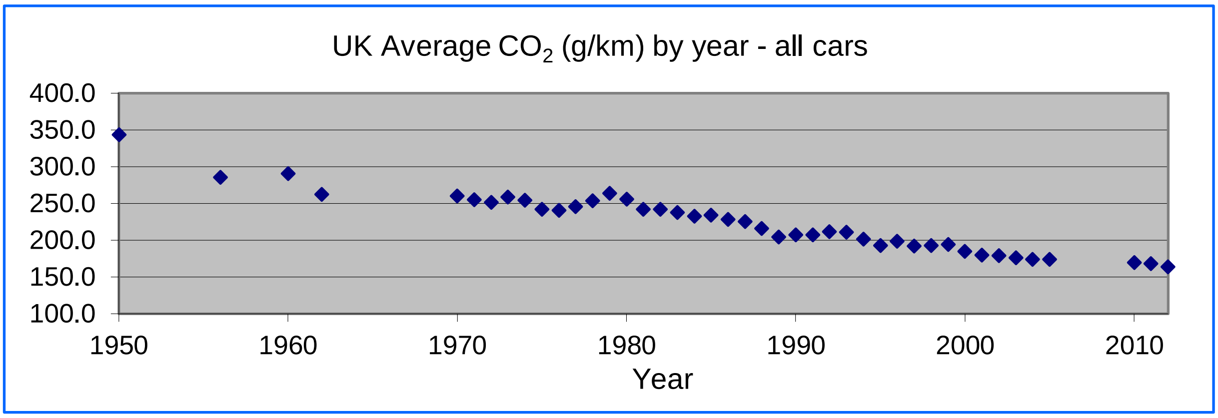
22 New Scientist, 1 March 2014, p6



In addition to specifying the emission levels to be met by new vehicles, Euro 5 also specifies levels of access to manufacturer-specific coded electronic fault information and to the manufacturer's supporting repair information. The fault codes, including those compliant with the European On-Board Diagnostics (EOBD) standards, are viewed on a PC via the car's electronic diagnostics port. The purpose behind legislating this access is to facilitate, throughout Europe, a commercially competitive vehicle servicing network required to maintain low emission levels throughout the car's life.

Carbon dioxide

Historically, carbon dioxide (CO_2) emissions from road vehicles have not been covered by EU legislation. With the increasing evidence that rising CO_2 levels have a role in global warming, this changed in 2007. The pre-industrialisation level of CO_2 in the Earth's atmosphere was around 280 parts per million (ppm) but today this annual average has increased to nearly 400ppm with peaks in excess of 400ppm having been recorded. The Commission for Integrated Transport in their advice to UK government back in 2007 concluded that the UK transport sector generates 28.4% of the country's carbon emission and of this 54% is produced by cars. At that time, transport was the only sector (in comparison with Industry, Energy Supply, etc) to have increased CO_2 emissions since 1990.



EU legislation now requires the CO_2 emissions to be achieved by 65% of new cars registered in the EU from 2012, from each manufacturer, not to exceed 130 grams per kilometre (g/km). A sliding scale of limits applies from 2012 to 2015 at which time 100% have to meet the 130 g/km value. The European Commission is looking at the feasibility of a 95g/km target by 2020. The historic trend in the UK since 1950 is shown in the graph above.

Today's average for all cars on the UK roads is around 164 g/km. For cars first registered in 2012 the average figure is 133.1 g/km. These compare very favourably with all cars on display in the Cotswold Motoring Museum. For example, the stylish 3.4 litre XK140 Jaguar was manufactured in 1956. In that year, there were around 3.4 million private cars on the UK roads in comparison to today's 29.08 million. The average annual mileage was less than 8000 miles per year[23] compared with a 2012 figure of around 8200 miles (an annual figure that has been falling since the mid-1990s as the number of cars per household has increased). Hence average CO_2 emissions of just under 300 g/km in 1956 (and the XK140 is undoubtedly above average) equates to a total equivalent CO_2 emission figure of 13 million tonnes in 1956 in comparison with 63 million tonnes[24] in 2012. Over the last 56 years the benefit of 'cleaner' cars has been more than offset by increased numbers and increased usage.

The UK Vehicle Certification Agency has a website to help car buyers make an informed decision on the CO_2 emissions of the vehicles that they intend to buy. However, no matter how efficient the design, cars propelled just by petrol or diesel will struggle to achieve levels of CO_2 much below about 80-90 g/km. One frequently proposed way to reduce CO_2 emissions from cars below this figure is to consider electric rather than internal combustion power: either stand-alone electric or as a hybrid with internal combustion. The rapidly evolving topic of Electric Vehicles forms a seperate chapter to this book.

Production and end-of-life

So far in this chapter, only the CO_2 produced during normal driving of the vehicle has been considered. If the overall CO_2 emitted during the manufacture of raw materials from which the vehicle is built, the vehicle build itself, fuel production and energy expended when the vehicle is scrapped is taken into account, then the additional effect on the CO_2 emissions over the vehicle life is significant. Work by the University of Technology, Finland in 2006 has quantified the CO_2 emissions for an average 2004 European light vehicle[25] over its life. If the CO_2 produced during manufacture of the vehicle and its fuel, distribution and end-of-life scrappage of the vehicle is taken into account, then over a car's 10 year life, the CO_2 per kilometre driven was calculated as 295g/km. If averaged over a 20 year life, this reduced to 265g/km. These compare with a 2004 average of 174g/km for UK cars in normal driving. Assuming the '2004 European light vehicle' of the Finnish study is roughly comparable with the average 2004 UK car population, then this implies the CO_2 created during production, distribution and when scrapped would account for approximately 34% of the CO_2 produced during a 20 year vehicle life.

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[23] DfT statistics: 3.61 million vehicles covering a total of 46.2 billion kilometres

[24] The product of 164g/km, 8200 miles (13,197 km) and 29.02 million cars

[25] Assumptions: kerb weight 1290kg, travelling 8440 miles per year, fuel consumption of 38.7mpg. Data used is an average for new vehicles sold in 2004 and is based on >14 million cars and 1.8 million vans and pick-ups

The same university used data from nearly 5000 *global* vehicles (European and US markets) that are " … used as cars …" (this includes pick-ups and SUVs) and concludes that taking account of emissions of CO_2 during vehicle and fuel production, distribution and vehicle scrappage adds on average 54.7% to the normal operation figure. Restricting the analysis to just 2006 model year European cars, results in a one-off manufacturing contribution of around 35% of the lifetime average figure of CO_2 produced during normal vehicle operation (assuming a vehicle lifetime of 14.4 years and annual mileage of 8420 miles).

A more recent reference by Professor Julia King to an SMMT (Society of Motor Manufacturers and Traders) figure, quotes just 15%: 10% in manufacture and 5% in disposal. A higher figure is quoted by the ERTICO[26] who state "Fuel consumption during vehicle operation, for example, contributes to around 60% of the life-cycle greenhouse gas emissions of a passenger car"; leaving 40% down to manufacture and scrappage.

The differences between these sets of figures are not surprising since a lot will depend on the assumptions made. For example:

- was the energy used in the steel and other raw material production taken into account?
- was this derived from coal-burning power stations or from renewal energy sources?
- how consistent is the vehicle mix between the various studies?
- how old is the data? Production techniques have become more efficient in recent years.

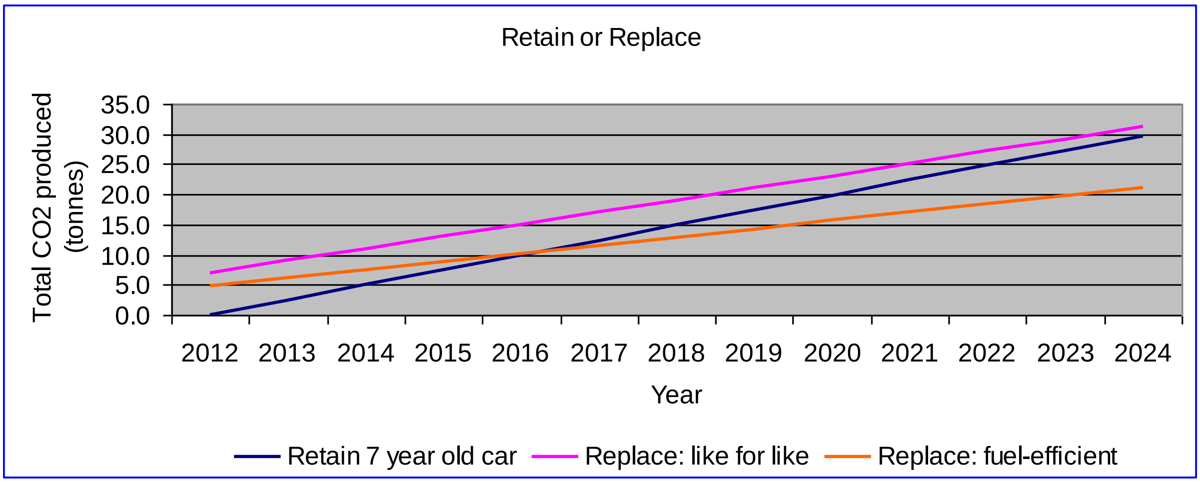
What is clear however is that the energy used and CO_2 released in the manufacture of the vehicle is significant in comparison with the CO_2 emissions throughout its life but becomes a diminishing proportion if that life is extended. Hence, from an environmental point of view, there is a strong argument for maintaining a car well beyond the average life of 7.9 years (in 2013: up from 6.6 in 2005).

The economics of modern vehicle ownership and maintenance however, do not encourage this approach.

Replace or retain

To quantify the conclusion stated above and to look at what happens if we decide to change the type of vehicle we drive, consider the case of an owner of a 2005 car contemplating replacing that car with a *similar* 2012 model. Consider the decision to be made solely from a CO_2 emission point of view, assume the owner travels 8900 miles each year and both the old car and potential replacement have average CO_2 for the year in which they were registered: namely, 173.1g/km for 2005 and 133.1g/km for 2012. For the older car, assume the one-off energy associated with manufacture, distribution and scrappage is 35% of the operational emissions over 14 years and that this reduces to 25% for the new car. How do the CO_2 budgets compare?

[26] An EU organisation devoted to Intelligent Transport Systems



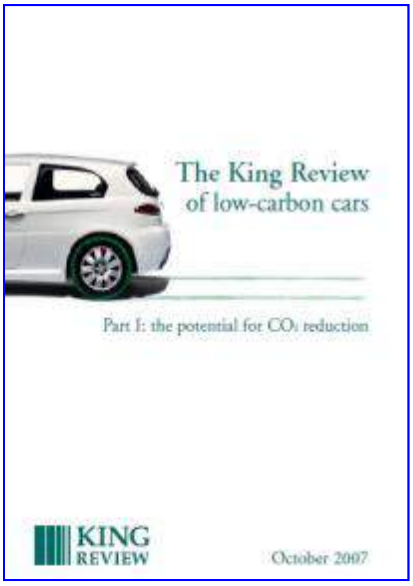
At the time of making the decision, the 7-year old car will have generated 29.6 tonnes of CO_2: 12.2 tonnes in manufacture and 17.4 tonnes in 7 years of use. If it is given a further 7 years of life, the additional CO_2 contribution will be a further 17.4 tonnes by 2019. If a newer car is chosen, then, after 7 years it will have generated 22.4 tonnes of CO_2: 7.5 tonnes in manufacture and 14.9 tonnes in 7 years of use. In this example, both cars would need to be kept running for over 10 years before the total CO_2 budget of the newer car fell below that of the older car. However, if one of the most fuel-efficient 2012 cars was chosen, producing less than 95g/km, then the decision would be justified, on CO_2 emission grounds, in less than 5 years. The graph above illustrates, for these three examples, the effect that the customer's choice can have on their CO_2 motoring emissions.

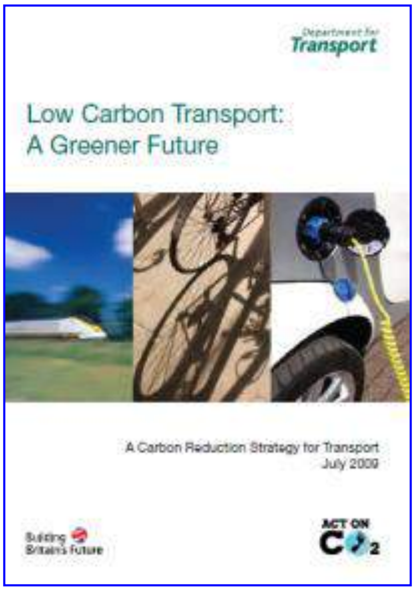
In summary, apportioning the up-front energy used in vehicle production and distribution, plus the energy used during scrapping the vehicle, over as long a life as possible, especially for low mileage, well-maintained cars, can make more environmental sense than scrapping and replacing the vehicle. On the other hand, a small, efficient modern vehicle replacing one of average emissions performance from 7 years ago, covering high annual mileage, can provide an emissions benefit within the following few years.

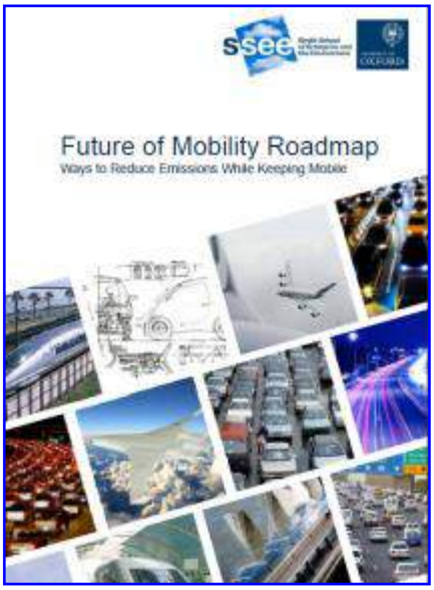
Further information

For further information on the future of low carbon cars, five recent documents are particularly relevant.

A report produced for the UK government and published in April 2009 addressed Ultra-Low Carbon Vehicles in the UK. It envisages a technical evolution from ever more efficient internal combustion engines, through hybrid to mass-market electric vehicles and ultimately to hydrogen powered vehicles in which energy is produced by fuel cells and the only bi-product of the process is water. A similar trend towards hydrogen-powered vehicles by 2050 is outlined by Prof Julia King in a two-part review of the potential for low carbon cars and recommendations for action. This also addresses overall CO_2 emissions associated with running the vehicle, its production and the extraction and processing of materials used in construction: sometimes referred to as the 'Well-to-Wheels' energy use. A July 2009 Department for Transport publication, "Low Carbon Transport: A Greener Future" sets out a strategy, statistics and targets for reducing CO_2 emissions within the UK and global transport sector. Finally, in January 2010, a report by the University of Oxford entitled "Future of Mobility Roadmap – ways to reduce emissions while keeping mobile" addresses the diminishing supply of fossil fuel and increasing greenhouse gas emissions across the transport sector.







Picture Captions and Credits

Page 27: From the Greenpeace website
Page 27: Earthrise taken by Apollo 8 crew, December 1968. © NASA
Page 29: Diagnostic Connector J1962 specification. Mandatory on all cars sold in the EU
Page 30: Jaguar XK140 at Cotswold Motor Museum, Bourton-on-the-Water, Gloucestershire.

Is technology the route to lower usage?

Driving into an unfamiliar town, setting off on a route that we have not travelled before, avoiding road closures with enforced detours; these are all perfect opportunities to become lost and incur additional mileage. Car drivers who are lost or stuck in congestion are clearly using more fuel than if they were to complete their journey by the optimum route and without being held up. This in turn results in a potentially avoidable addition to the vehicle's exhaust emissions during the journey. This chapter describes how driver information technology has developed to support services aimed at reliable route guidance and congestion avoidance. In addition, can we improve the management of our roads to reduce congestion? Is road charging part of the solution? What steps are open to us as drivers to achieve lower usage and are they worth the effort?

Introduction

Given that there will always be journeys that need to be undertaken by car, then knowledge of the optimum route and prevailing traffic conditions are key to minimising our travelling time and / or distance. If the route is an unfamiliar route, then basic knowledge such as our starting and finishing point are quite important as well. Whilst mapping and in-car satnav are the subject of separate chapters, the dynamic information on road traffic conditions that can be used to make our journeys less stressful and more environmentally friendly are addressed in this chapter. A summary of advice from national motoring organisations on how best to ensure we arrive at our destination by the optimum route and with the minimum of congestion, concludes the chapter.

Traffic Information

Satellite navigation technology can help us when we are lost, or can help us avoid becoming lost in the first place, and hence should help us to minimise unnecessary mileage on our journeys. Traffic information technology is aimed at helping us to avoid congestion. We may listen to traffic news before setting off on our journey or keep up-to-date en-route via the car radio. Visual indications of congestion are available on our PC or portable device and may be on display in some motorway service areas. Increasingly though, as described in the satnav chapter, the information is used to influence the route displayed, in-car, by our satnav device or satnav application on a portable device.

Gathering the data

Inductive Loop detectors and CCTV are the most common types of technology employed by the Highways Agency to detect congestion on the motorway and trunk road network. The number of vehicles per minute crossing a loop detector on a motorway is used, together with variable speed limit signs, to reduce traffic speed and smooth the vehicle flow rate, as congestion increases. The lifetime costs of loop detection can be high and the need to close the carriageway whilst work takes place is also not ideal. Consequently, other less disruptive techniques are being investigated and developed.

Watching a map display screen, overlaid with the track of a vehicle fitted with a GPS receiver as it reports its position at regular intervals, enables a visual indication of the speed of the vehicle. Widely spaced locations along the road network indicate unimpeded progress; a cluster of points along the road indicates a slowly moving or stationary vehicle. This is the principle behind the use of Floating Vehicle Data (FVD) to provide information about traffic congestion. Piloted in the UK by ITIS Holdings (now owned by INRIX), the use of FVD is the basis of the traffic information that INRIX provide to such customers as broadcasting organisations and the Highways Agency. Information providers such as INRIX typically have partnerships with vehicle fleet operators and mobile phone network operators. The GPS equipped fleet vehicles provide their location information to enable both real-time and historic congestion data to be derived. The back-office software has to be 'smart' enough to recognise when a vehicle is intentionally stationary and when it is stationary because of congestion. In addition to using GPS locations, mobile phone locations are also used, anonymously, to provide FVD. Although not as accurate as GPS locations, they are far more numerous. Working with a mobile phone network operator benefits the operator by increasing the usefulness of data already available in their network and provides an additional service to their customers.

Trafficmaster was founded in 1988. It started to gather data on traffic speeds on the UK motorway network using speed sensors mounted over each carriageway of the motorway. Over the years, cameras on both motorway and trunk roads have replaced these speed sensors. The blue camera system is based on automatic number plate recognition. A coded tag derived from the vehicle number plate is used to identify vehicles travelling between cameras and hence to calculate the average speed. The congestion data derived from these sensors is displayed on the Trafficmaster website and is supplied to broadcasters, car manufacturers, route-planning applications, telephone services and in-car devices.

Using the data

One widely used and standardised method of coding traffic congestion data into a form that is useful for an end user has been through the development of RDS-TMC: Radio Data System-Traffic Message Channel. The original development work took place under an EU programme and, although now rather dated, the detail of RDS-TMC is well described in this link.

RDS-TMC is based on a coding process for events (ie congestion and its cause; ice, snow, accident, etc) and locations. Assuming the same coding and decoding protocols are used by the originator of the traffic message and the end user (ie the driver), a simple code can be transmitted via an RDS-TMC broadcast. The radio receiver in the car then only needs to de-code the incoming data in order to reconstruct the original message. For this to work reliably the receiver must always have an up-to-date copy of the code database. However, there is one big advantage: namely, it is language independent. UK drivers travelling through mainland Europe can continue to receive traffic information in English from RDS-TMC broadcasts in the countries through which they are travelling. The language benefit of RDS-TMC is clearly important if the traffic event is described in text on a vehicle display but, much more commonly, it is used to update the satnav's recommended route; a process that may even occur without the driver being aware.

Although Event Codes are standardised, clearly Location Codes are country specific. Hence, for the coded location of the traffic event to be compatible with the driver's satnav, the unique link identifiers used in the digital mapping database must be assigned the same Location Code by the originator of the traffic message and the supplier of the satnav map data. Since there is more than one RDS-TMC provider in UK and there is more than one digital mapping data provider to the satnav manufacturers, this can lead to some incompatibility.

Distributing the information

The RDS-TMC data is transmitted with FM and digital radio broadcasts as well as via mobile phone networks.

Many FM radio broadcasts carry the RDS-TMC data on a sub-carrier of the broadcast channel: this means that it is inaudible to the listener. From a driver perspective, probably the most effective way to benefit from RDS-TMC traffic information is to use a navigation system with this feature incorporated. Many manufacturers offer this as an option with new vehicles but it is also possible to use RDS-TMC with several of the portable, after-market satnavs. These may require a separate FM radio receiver, dedicated to picking up the RDS-TMC broadcast, with a data link to the satnav.

Traffic information, in RDS-TMC format, is also distributed over the mobile phone packet data network (GPRS) to in-car satnav equipment. This can be either via an integral SIM card in the satnav or via a Bluetooth link from a phone to the satnav. In the case of a smartphone, the navigation device and the phone may be the same piece of hardware!

No matter how the information is delivered to the satnav device, the effect of congestion on a link(s) is to increase the impedance of that link(s) so that the satnav will conclude that a faster journey is possible through a change of route and, either automatically or with a prompt from the driver, will calculate a new route.

From around the mid-90s until 2011, relatively low cost, in-car devices were available that received traffic information about a motorway and the neighbouring trunk road network from short-range radio transmitters alongside the road. Alerts typically occurred within a radius of one or two junctions on an urban motorway and information was conveyed to the driver by either coloured lights or a voice prompt. These devices and their associated networks are no longer supported.

Over a similar period, Trafficmaster provided national traffic information coverage to a customer's in-car unit. In this instance, a 4", monochrome LCD screen displayed a map of the UK road network at multiple levels of zoom. On this map were superimposed icons showing those locations at which the TrafficMaster sensor network had detected traffic speeds of 25mph or less. The driver's own location was not displayed on the screen: there was no GPS within the unit. It was designed purely as an information tool to enable the driver to spot congestion on their planned route and to re-route around the congestion if desired. Information was conveyed to the unit via the Vodafone paging network.

The cost of 'Lost'

Having considered the technology available to help a driver find their destination with the minimum of delay, it is appropriate to look at the cost-benefit of guidance and information technology. Is it possible to quantify the cost, in terms of pounds spent on wasted fuel and emissions, associated with lost drivers? Is reliable data available to enable a realistic estimate to be made of wasted fuel and associated additional CO_2 emission because of drivers losing their way or being forced into unplanned diversions? The Annex to this chapter shows the spreadsheet used to estimate this figure.

Department for Transport (DfT) statistics provide a reliable source for some of the required data. The average annual mileage covered by drivers of company cars and private cars is available from the DfT website and this is subdivided into usage categories of Business, Commuting and Private. In addition, the number of company and private cars is known from the same source.

In terms of arriving at a figure for the average CO_2 output from the company car and the private car, a reasonable assumption may be to take the figure for a typical company car: for example, a 2012, 2 litre diesel-engine Ford Mondeo (140PS) Automatic Estate. The UK average of CO_2 per km of all cars, taken from the 2013 SMMT report on CO_2, is the basis of the private motorist's figure.

The lowest quality data (not much more than an intelligent guess) comes from estimates of the frequency with which drivers become lost and the impact of the departure from the planned route on addition mileage. It may be 'reasonable' to assume that, due to increased familiarity, the company car driver becomes lost less frequently than the private car driver on business journeys and that when commuting, the occasions when additional mileage is incurred is no more than two journeys per year (0.4%) for both groups of drivers: for example, through a road closure. It has been assumed that in becoming lost an additional mile is added to a 20 mile journey ie a 5% increase. These however are just guesses and as such will reflect on the validity of any result derived from their use. The spreadsheet used to calculate an estimate of annual excess CO_2 and increased fuel costs as a consequence of becoming lost, shows colour coding used to represent the quality of the data: red, amber and green.

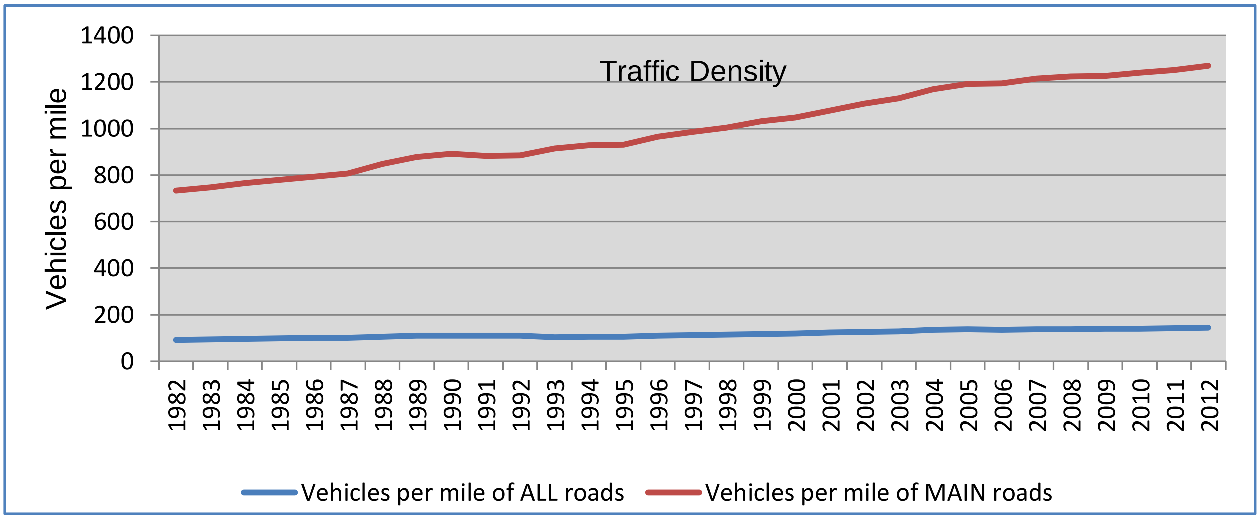
Making what appear to be 'reasonable' assumptions about the frequency and impact of drivers departing by accident from their planned route, the annual, avoidable increased fuel cost is around £30 million whilst the increase in CO_2 is over 46,000 tonnes or around 0.07% of the 63 million tonnes[27] CO_2 generated annually by all cars in the UK. For comparison, this is of the same order of magnitude as the CO_2 output of 6,200 UK families in one year. Note however, that this figure is just based on the UK's car population and excludes the effect of lorries, vans and public transport. According to the Commission for Integrated Transport, (before it was abolished!) cars are responsible for 54% of all UK transport sector CO_2 emissions whilst lorries, vans and buses account for a further 38%. Simply scaling the lost driver figure for cars, suggests that at least a further 33,000 tonnes of CO_2 may result from other road transport.

[27] The product of 164 g/km, 8200 average mileage and 29.2 million cars

Congestion

Many of the roads on which we travel today owe their origins to some of the early animal tracks mentioned in the satnav chapter of this book. They were later used by drovers and then developed for wheeled, animal drawn carts and marching Roman legions[28]. In the UK, some of the earliest roads are based on Ridgeways dating from between 5000BC and 2000BC. Those that survive include the Hogs Back in Surrey and parts of the Pilgrims Way over the North Downs. Trade routes developed on these Ridgeways: one example being the old salt road from Droitwich to the River Severn cutting through the Malvern Hills at the Wyche Cutting[29]. (Wyche or Wich – as in Nantwich and Droitwich - meaning salt in old English).

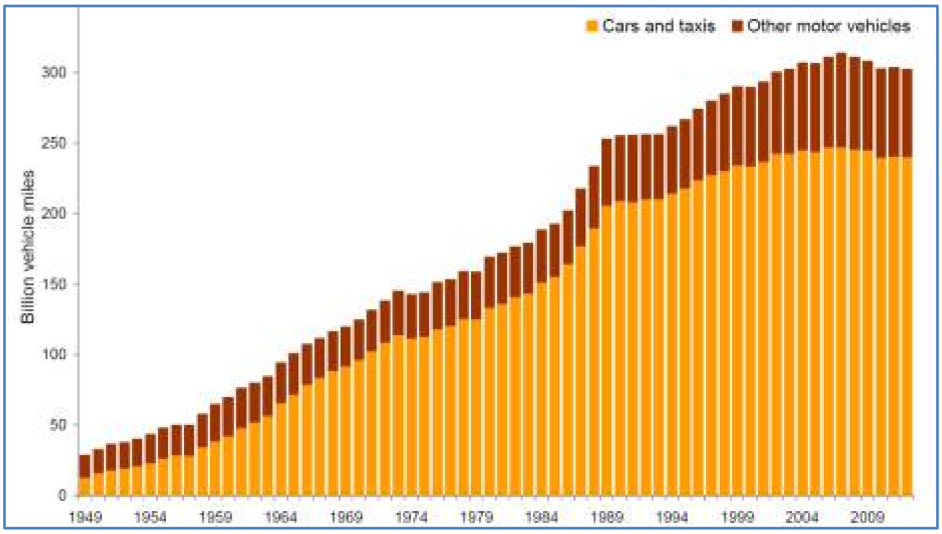
Today, there are over 31,300 miles of motorways, trunk roads and other primary 'A' roads and, in total, over [245,370 miles of driveable roads] of all categories in the UK. This sounds plenty to avoid ever seeing another vehicle! However, given that, in September 2013, there were approximately [29.2 million cars and 6 million] other licensed (and license exempt) vehicles in the UK, the trend



in the ratio of vehicles per mile of road, as shown in the graph, is quite clear.

It is of little consolation that the Department for Transport (DfT), "[Annual Road Traffic Estimates 2012]", states that:

"In the last ten years, traffic volumes for all vehicle types have decreased (eg, cars and taxis: -1.0%; HGVs: -11.6%) except for LGVs which have increased by over a fifth (21.5%)."



The graph alongside shows these recent

[28] "Roads and Tracks of Britain" by Christopher Taylor
[29] "Ways of the World – A History of the World's Roads and of the Vehicles That Used Them" by M G Lay

falls in the context of earlier decades of rapid increases in vehicle usage. Two points to note from these graphs and the DfT 2012 Estimates:

a. the increase in LGVs coincides, of course, with a decade of rapid growth in internet shopping

b. the first graph shows the number of vehicles per mile of road increasing annually while the second shows that the annual mileage per vehicle must be decreasing: a point addressed in the chapter on “Responsibilities of Ownership”.

Assuming these recent trends to be the short-term effect of an economic downturn and a couple of particularly harsh winters, the issue of how to manage and ideally reduce congestion is a question that is likely to continue to be highly relevant.

Measures to reduce congestion – the road network

Over the last two decades, much effort has been devoted to the study of traffic management with the aim of reducing congestion. Within Europe, the EU DRIVE project (1988) provided an impetus to work on applying Information Technology to the improvement of road safety and the reduction of environmental pollution caused by road traffic.

Smoothing the flow

A publication from the University of California at Riverside contains the results of a study and computer modelling of measures to mitigate the effect of congestion on CO_2 emissions. It measured the range of speeds on a motorway and compared these with levels of congestion. As congestion increased, so the *range* of speeds increased: on a clear motorway speeds from 47mph to 75mph were recorded; on a congested motorway this range widened to zero to 50mph. As CO_2 emissions rise with increased acceleration and deceleration, so the congested motorway scenario produced more CO_2 than a smoothly flowing scenario. The aim of the mitigating measures was therefore to achieve a smooth flow of traffic within a narrow band of speeds. Recommendations made to achieve this objective were:

- Manage congestion on the motorway through measures such as ramp metering – something that is now appearing on UK motorway entry slip roads in some urban areas eg M6 J10S – and better incident management eg Highways Agency Traffic Officers
- Variable speed limits to reduce ‘bunching’ and hence the amount of acceleration / deceleration – a feature on parts of the M1, M25, M6 and M42
- Variable speed limits to reduce excessive speeds

The ‘bottom line’ to the study was that “ ….. each of the three methods above could potentially lower CO_2 by 7-12%”.

The point that free-flowing traffic is essential to minimise CO_2 is made by the International Road Transport Union (IRU) with their headline about a 40 tonne lorry travelling at 30mph. If it stops twice per kilometre (due to congestion) the CO_2 emissions increase by 300% in comparison with maintaining a steady 30mph.

In the UK we have also seen the extension of hard-shoulder running that was first implemented on a section of the M42. This effectively creates an additional motorway lane at times of peak traffic flow and is part of an overall Active Traffic Management (ATM) scheme. Results from the initial M42 ATM were encouraging with an extra capacity provided by hard-shoulder running of 7% to 9%, an extra 7% of users reporting no congestion on their journey and between 4% and 10% reduction in vehicle emissions.

Road pricing

Road pricing has been proposed as one candidate to reduce congestion. In the UK, the first large-scale scheme was the London Congestion Charge introduced in February 2003. On the first anniversary of the introduction of the charge, the then Mayor of London, stated that:

" …..traffic had been cut by 18% and delays were down 30%".

However, subsequent Transport for London publications have updated that early conclusion:

"Sadly, congestion has risen back to pre-charging levels but would be much worse without the charge"

In summary, London road pricing did provide a short-term benefit in easing congestion but other factors are, and will continue, to cancel out the initial gain.

In Stockholm a congestion charge was introduced in January 2006 and traffic is down by 18% and CO_2 emissions in the inner city have been cut by between 14% and 18% or 25,000 tonnes annually.

In June 2005 the then UK Transport Secretary, Alastair Darling, admitted that changes to road transport policy were needed to prevent complete gridlock, and unveiled proposals to replace fuel tax and possibly road tax with a satellite-operated, distance-based road charging system which would cost motorists up to £1.30 a mile to use the roads. In 2008 however, this proposal for a UK national road-pricing scheme was ruled out by the government in favour of extending hard shoulder running to more motorways and possibly using the extra capacity created for high occupancy vehicles or a tolled lane.

Measures to reduce congestion – the driver

A list of steps, that we as individuals can take, to minimise our risk of delay is in the Conclusions section to this chapter. A couple of measures however, are worth expanding here.

As well as being intuitively self-evident, a number of studies have demonstrated that a smooth, safe driving style is one that results in good fuel efficiency. To encourage such behaviour in fleet drivers, some organisations are fitting driver monitoring equipment to fleets of vehicles. This monitors, location, harsh acceleration and deceleration and other business-specific parameters. Used constructively, so that they are not perceived as a 'big brother', these measures can help to encourage fleet drivers to adopt an economical driving style.

Humans in general are very tolerant. We largely accept the inconvenience, delay and frustration that accompany traffic congestion as an inevitable part of life. However, such acceptance is likely to have its limits. The improvement of fixed and mobile broadband and the beneficial economics of 'hot-desking' in the office have helped to bring about a change in some working practices over the last decade. It is now easier to work from home, to video-conference ('Skype'), to arrange meetings at motorway service areas, conference centres and other out-of-town locations whilst still having access to corporate IT systems and the internet. A consequence of this is going to be less traffic on the busiest roads at peak times. Are we saying, "enough is enough" and taking a solution to congestion into our own hands? Is this part of the reason that the DfT figures for congestion are showing an unprecedented fall or is it just the present economic climate? All may become clearer in the next decade!

The cost of congestion

The DfT has estimated the financial cost of congestion to the country: *"Congestion poses a very real long-term economic threat. If left unchecked it could cost us an extra £22 billion a year in wasted time by 2025, in England alone*."

An overall figure for the incremental CO_2 produced because of vehicle congestion is not easy to find in published literature. In response to a 2001 Freedom of Information request, the Highways Agency estimated a reduction of 32,000 tonnes per year as a consequence of tolling the Dartford Crossing – in comparison with the 'no toll barrier' scenario that now prevails. However, with this rather dated figure and those for reductions in CO_2 from the Stockholm and London congestion charges, there must be a suspicion that these 'savings' are actually partly offset by drivers taking alternative, un-tolled or uncharged routes. Admittedly, very difficult to quantify.

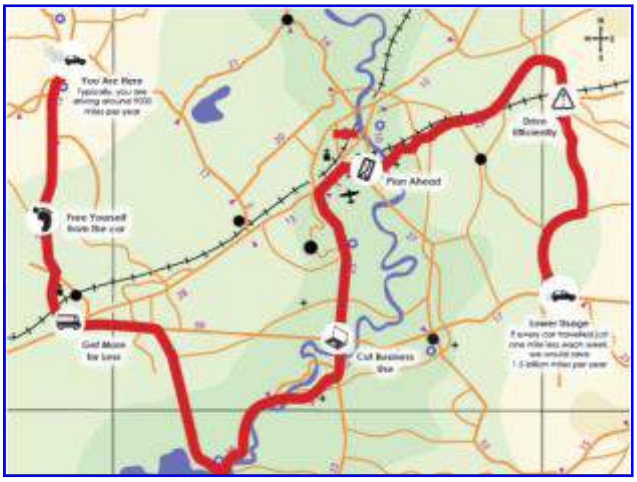
As a 'sanity check' on the previous estimates of CO_2 produced through becoming lost and through vehicle congestion, it is interesting to compare figures with the environmental statement from the Teletrac website, namely:

"*Teletrac is currently saving 28 million gallons of fuel and 280,000 tonnes* of *CO_2 annually by encouraging smarter driving. Combining intelligent navigation and fleet management, we have the power to cut average fuel consumption by 28% and driving time by a third (32%)".*

So, in summary, recognising that the 46,000 tonnes of CO_2, estimated as a consequence of car drivers becoming lost, 33,000 tonnes from other lost road users, individual figures of 32,000 tonnes as 'savings' through *reducing* congestion at the Dartford crossing, then Teletrac's annual figure of 280,000 tonnes suggests that the estimates are consistent and of the correct order of magnitude.

Conclusion

From a review of technology available to help us on our car journeys (satnav is addressed in a later chapter of this book), it could appear that if we embraced all of this technology, then we should never become lost or encounter congestion. (Arguably, with a satnav we should never be actually *lost*, even though we may not be in the place that we intended). Sadly though, it seems unlikely that technology is the sole answer to these two characteristics of modern motoring.



This chapter has shown that, making 'realistic' assumptions, there are significant additional contributions to the environmental CO_2 that are produced as a consequence of drivers becoming lost or held up in congestion during their journeys. In mitigation, what can be done? What is the elusive "Route to Lower Usage"?

All of the main motoring organisations have advice to offer and the following summary has been compiled from the websites of: AA, Britannia Rescue, Green Flag and RAC.

- Journey preparation is crucial. Use either up-to-date paper or website maps
- Ensure the satnav maps are up-to-date
- If using in-car navigation, ensure batteries are charged and that the charger is available and working
- Don't assume the satnav knows best. Even if using an updated Satnav, be careful not to follow it blindly. Use common sense, and if in doubt about the route being offered, turn around and try another one
- Keep an up-to-date map in the car as back-up, just in case

Avoidance of congestion is perhaps less under the direct control of the car driver. The random nature of traffic accidents and other incidents causing a tail back means that avoidance of congestion includes a strong element of luck. However, some mitigation steps are possible, for example:

- Travel outside of peak times if possible. This can help to reduce the stress of the journey as well as the risk of delays
- Check for Traffic Information on the intended route using local radio or websites such as the Highways Agency or TrafficMaster
- Check the Traffic Information features of the satnav (if included)
- Check the Traffic Information available through the mobile phone eg dial 1740 (59p per minute)
- For regular routes eg commuting, rehearse alternative routes and diversions for the day when the main route is closed or congested
- When in heavy traffic, drive smoothly: avoid acceleration and sudden braking, not only does this reduce fuel consumption it helps towards a steady flow of the traffic
- Consider car sharing
- Consider splitting the journey before congestion starts eg Park and Ride
- Consider alternative modes of transport for the entire journey
- Consider avoiding some journeys eg work from home some days, use video / audio conferencing

As illustrated in the earlier DfT chart, reducing usage is happening today in the UK. Whether this is a temporary blip, following an economic downturn, or the start of a longer-term trend, remains to be seen.

Annex: An estimate of the CO_2 'cost' and financial cost of becoming lost on our journey

		Company Cars (Type of Journey)			Private Cars (Type of Journey)		
		Business	Commuting	Private	Business	Commuting	Private
Average annual mileage (2012)		7600	7100	4600	600	2500	4700
Probability of becoming lost / enforced detour		1.5%	0.4%	2.0%	2.0%	0.4%	2.0%
Effect on journey length of becoming lost - incremental journey distance		5.0%	5.0%	5.0%	5.0%	5.0%	5.0%
Company cars on UK roads in 2012	2,376,600						
Privately owned cars on UK roads in 2012	25,701,121						
Annual incremental mileages when lost (millions of miles)		13.55	3.37	10.93	15.42	12.85	120.80
Average CO2 in g/km for company cars	149						
Average CO2 in g/km for private cars	164						
Annual incremental CO2 as a consequence of becoming lost (tonnes)		3,248	809	2,622	4,070	3,392	31,882

Annual Cost	£30.187	million		Annual CO2	46,023	tonnes

DfT National Travel Survey September 2012 Table NTS0901	https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/243957/nts2012-01.pdf
Statistical Data Sets Cars (VEH02) Table VEH 0202	https://www.gov.uk/government/statistical-data-sets/veh02-licensed-cars
VCA (part of DfT)	http://carfueldata.dft.gov.uk/search-new-or-used-cars.aspx
SMMT New Car CO2 Report 2013	http://www.smmt.co.uk/co2report/

Picture Captions and Credits

Page 34: Variable Message Sign
http://webarchive.nationalarchives.gov.uk/20120801131740/http:/www.highways.gov.uk/knowledge/334.aspx
Page 35: Traffic Information displayed in a 2013 VW Beetle
Page 36: TomTom RDS-TMC Traffic Receiver - TMC module for GPS receiver
Page 36: TrafficMate, TrafficMaster Freeway, RAC Traffic Alert 1210
Page 36: TrafficMaster YQ2
Page 38: © John V Nicholls, www.geograph.org.uk/photo/83470
Page 39: Active Traffic Management signage.
http://webarchive.nationalarchives.gov.uk/20120801131740/http:/www.highways.gov.uk/knowledge/334.aspx
Page 41: The Route to Lower Usage display, Cotswold Motor Museum, Bourton on the Water

The Cotswold Motoring Museum and Toy Collection is not just about cars. Toys that our parents and grandparents played with as children, everyday artefacts from the Victorian and Edwardian era plus an insight into the social history of the village of Bourton-on-the-Water and much more can be found in the Old Mill, alongside the River Windrush.

The Impact of Motoring

Part 2 - Social

Disclaimer

Whilst every effort has been made to ensure the accuracy of the content of this book, in a world where technology moves so rapidly, it is inevitable that some content will be out of date very soon after publication. Cotswold Motoring Museum & Toy Collection can accept no liability for any errors or omissions or any consequences of such errors or omissions.

For those accessing this book in electronic form, all web links were functioning at the time the book was prepared but Cotswold Motoring Museum & Toy Collection can accept no responsibility for content hosted on third party systems that may have been removed or updated.

Cover images: The Old Mill, Bourton-on-the-Water, today home to the Cotswold Motoring Museum and Toy Collection and cars associated with the museum.

Source of right hand image above: Metropolia University of Applied Sciences, Helsinki, Finland.
http://green.autoblog.com/2013/05/30/biofore-concept-car-is-a-plant-laden-sustainable-ride/

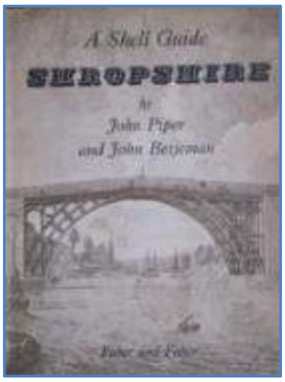
Contents of Part 2

Part 2 - Social

It is surely not an exaggeration to claim that the impact of motoring on the world we inhabit must rank as one of the most far-reaching influences ever introduced by mankind to our planet? The specific invention of the car is, of course, only a small part of the story. The requirements for fossil fuels, the industry and infrastructure to enable the car to function, the social and health benefits (and hazards), some of the changes to the natural world and challenges being faced in the 21st century owe their existence to the rise of motoring. They would merit a book in their own right. In this section, just a few of these influences are presented.

Part 2 - Social | Popular Motoring

Mass production in the USA, mainland Europe and the UK in the early 20th century took the car from the realm of a rich man's (and it was usually a man) pastime to an affordable commodity. More specifically in the UK, the Austin Seven, launched in 1922, revived the fortunes of the Austin Motor Company. During its 17-year production run, it was in competition with the Morris Minor of its day and Model Y Ford, with all striving to offer the "£100 car" to the rapidly expanding motoring public.



Between the World Wars, spurred on by that competition during the 1930s to deliver the "£100 car", motoring for leisure became increasingly popular. Again, in the 1950s, as the availability of new cars in the home market increased following the immediate post-WWII "Export or Die" campaign, a further impetus was given to the number of cars on British roads. Along with this transformation of the domestic tourism and leisure business came the need for maps, road atlases and touring guides. One of the iconic guides of the period 1934 to 1984 was the Shell County Guide. Over the 50-year span that these guides were in print, they had just two editors, John Betjeman and John Piper, both of whom made frequent contributions to the contents of the guides.

Rapidly rising numbers of cars at the start of the 20th century required an associated motor repair industry. Trade directories of the time show blacksmiths turning their skills to motor engineering. Organisations set up to address political issues, such as the repeal the Red Flag Acts, developed in to mobile rescue and recovery organisations.

Finally, as maps give way to satellite navigation for many motorists, this section on the Social impact of motoring concludes with a review of the satnav topic and a look forward to the next evolutionary steps in the technologies that help us find our way around our ever increasingly busy roads.

Why is the Austin Seven so significant?

The Austin Seven revived the fortunes of the Austin Motor Company, added a new small car to their product range and provided the 1920s motorist with an affordable (£165 but as low as £105 in 1934[1]) 4/5 seater car in a design that endured for 17 years. It is over 90 years since its creation and around 7,000 are still in existence.

Introduction

Good King Wenceslas went out, in his Austin Seven,
bumped into a Morris Eight, and landed up in heaven.

This is just one of hundreds of jokes about what is possibly our favourite car of all times. Yes, the Mini was iconic and was built in greater numbers, around 1.6 million against about 290,000[2] Austin Sevens built between 1922 and 1939, but the original little car found its way into the hearts and minds of the British working man and woman for very sound reasons.

For the first time in history, it gave an opportunity for the ordinary working man to purchase a simple, small, but perfectly practical vehicle in which he, his wife, and two or three children could ride in comparative comfort and safety, come rain or shine. The previous option of a motor bike and sidecar had meant being unable to hold a conversation, getting wet and cold, and coping with the inherent instability of a three wheeled vehicle. There were some light 'cyclecars' available but these were not always well designed and never became that popular.

So how did the Austin Seven come to be? Was it a product of market research and a vast development team assessing marketing needs? Not really. It was more the case of one man with a vision and a desire to get his company out of receivership, a brilliant young engineer, and a billiard table!

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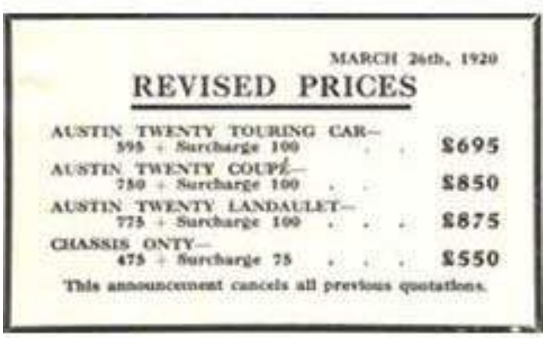
[1] The Motor, 3rd Oct 1933

[2] It is estimated that 290,904 Austin Sevens were manufactured. If you include those made overseas and chassis provided to other manufacturers, the figure goes up to about 416,000

In 1922, the brief post First World War boom had evaporated and the beginning of a depression was on the horizon. The huge Austin factory at Longbridge, south of Birmingham, was one of many in trouble. In fact, it went into receivership in April 1921, having gone from employing 22,000 people in 1919 to just 8,000 in 1922. So it was not surprising, therefore, that the board initially refused the Managing Director Sir Herbert Austin (later Lord Austin: 1866-1941) any funds for the development of a new small car, as they feared that the additional expenditure could result in the demise of the Austin factory.

At the time, the factory had cut their model range to just one car, the large and expensive, 3.6 litre Austin Twenty; to try and achieve economies of scale as Ford had with their very successful Manchester-built Model 'T'. Sir Herbert Austin wanted to produce a small car as an alternative to the motorbike and sidecar, and to the rather limited 'cyclecars' of the day.



MARCH 26th, 1920

REVISED PRICES

AUSTIN TWENTY TOURING CAR— 595 + Surcharge 100 . .	£695
AUSTIN TWENTY COUPÉ— 750 + Surcharge 100 . .	£850
AUSTIN TWENTY LANDAULET— 775 + Surcharge 100 . . .	£875
CHASSIS ONTY— 475 + Surcharge 75 . . .	£550

This announcement cancels all previous quotations.

The design

The great success of the Austin Seven was due to it being a very well designed car, made of high quality materials, but scaled down.

There were several influences to its design. The engine itself owed much to the Austin 20, but with a two-bearing crankshaft, supported by a ball bearing and a roller bearing mounted together at the front, and a large roller bearing race at the rear. A four cylinder Belgian FN Type 'A' motorcycle had a similar arrangement. Originally, the capacity was 696cc, but this was changed to 747cc after the first hundred cars.

The chassis was a very simple 'A' frame, of top hat section, with a transverse front spring (like the Model T Ford) and two rear quarter elliptic springs clamped into the open ends of the chassis rails. An American 'Grey' truck in use at the Austin works had a similar arrangement and may well have been an inspiration. The French 1920 Peugeot Quadrilette may also have provided some ideas.

Having been refused the necessary finances by the directors, Sir Herbert Austin decided to do it anyway, and enlisted the services of a talented designer, Stanley Edge (1903-1989), who was at the time only 18 years old, and a draughtsman at the factory.

Maybe because of the personal investment made by Sir Herbert Austin in the design and development of the Austin Seven, he was later successful in negotiating a two guinea (£2.10) royalty on every Austin Seven sold and did eventually get approval for the development funds he wanted.

Sir Herbert drew up the initial design concept on the billiard table at his home in Lickey Grange, near the factory, and he and Stanley Edge worked there to complete the design.

AUSTIN SEVEN
REVISED PRICES

Effective from August 13th, 1935

RUBY SALOON -	£125
RUBY FIXED HEAD SALOON	£118
PEARL CABRIOLET -	£128
OPEN ROAD TOURER	£112
TWO-SEATER	£102 . 10 . 0
NIPPY SPORTS -	£142

Prices are at Works.

NOTE—The Two-Seater is now available with new radiator.

The first prototype emerged in July 1922, and the production version was released at the London Motor Show in November 1922. The car cost £165, though this was later reduced to £110 in 1932 (around £6,000 in today's money), to try to compete with the very basic, open Morris Minor, which cost just £100.

It was however, the £100 1936 Ford Model 'Y' that had the greatest effect on sales, and was said to have contributed to the eventual demise of the Austin Seven.

Road Fund Tax (Vehicle Excise Duty) for the Austin Seven cost just £8 a year, as opposed to £22 for the Austin Twenty. This low rate, (which was based on the rate of £1 per RAC horsepower) was another reason for the popularity of the Austin Seven

The car had an aluminium body on a wooden frame, conventional for the time, a three-speed crash (i.e. no synchromesh) gearbox and narrow beaded-edge tyres on 19-inch rims. The tyre type changed to wired-on/well type in 1925.

A non-removable starting handle was provided and a manual pull starter, like a lawn mower, was originally fitted but this was changed to an electric starter mounted inside the car in 1925. The owner was advised to use the electric starter only when the engine was warm.

The car had magneto ignition, with manual advance/retard timing adjustment on the steering wheel.

A pram-type hood was fitted and kept out most of the weather for most of the time. The shape of the hood was later changed to give more headroom for rear passengers.

It was economical to run, and could cruise at 45-50 miles per hour, though the speed reduced dramatically if an uphill slope was encountered. Having said that, the Austin Seven could usually climb any hill using its low first gear, or in extreme circumstances, its even lower reverse gear.

The Austin Seven was marketed as being equally suitable for men or women drivers.

Advertising aimed at the female driver

Sales of the Austin Seven increased steadily from about 2,000 in 1923 to a maximum of 26,000 a year in 1929. Though there were many improvements over the years, the basic design of the car did not change much and many parts remained interchangeable throughout the production run, particularly the basic chassis layout.

The biggest change occurred on the 13th August 1935, when the Austin Ruby was announced. This was a major updating of appearance, with a pressed steel radiator grille and more curved lines to the bodywork. It is said that Lord Austin was reluctant to change the radiator grille but acknowledged the old rectangular shape was becoming old fashioned.

From June 1936, the engine had three main bearings and the gearbox had synchromesh on second, third and top gears. Wheel size dropped from 19 to 17 inch and engine power was increased to 16.5 bhp on the New Ruby.

Variants

There must have been hundreds of variants of the Austin Seven, for in addition to their own standard models, specials, sports versions, military cars and racing models, they sold rolling chassis assemblies to other car and van manufacturers and engines to firms like Reliant of Tamworth for their three-wheeler vans and cars.

The Austin Seven was manufactured under licence in many countries, including:

- Australia (Holden)
- France (Lucien Rosengart)
- Germany (Willys Overland and the Dixi, made by BMW)
- Japan (Datsun/Nissan)
- USA (American Austin, Bantam)

The firm of Thomas Startin made vans with aluminium bodies on an ash frame, using the Austin Seven chassis and many firms made their own sports style cars, many of them very attractive.

One particularly elegant saloon car variation was the Swallow, made by the Swallow Sidecar Company, which was headed by William Lyons. This was launched in 1928 and had a split windscreen, luxurious upholstery, a distinctive chrome radiator shell and two marine type ventilators on the scuttle. The Swallow Sidecar Company went on to manufacture the magnificent SS100 sports car from 1933 but in 1939 changed its name due to the political situation in Germany. The name they chose was Jaguar.

The Austin Seven lent itself to home conversions, and once cheaper second hand cars became available, many were converted into sports, trials or utility vehicles.

What's an Austin Seven like to drive?

It was said it was easy to drive badly but hard to drive well. The following personal reflections are based on the author's experience of driving a 1930 AE Series Chummy.

Space – Not as cramped as it looks. The Austin Seven can accommodate two very comfortably built adults in the front and three small children on the bench back seat. However, very tall adults may have problems getting in and out. Needless to say, Austin Sevens were regularly overloaded. One or more adults regularly carried in the back would cause the rear of the tourer body to droop over time, as earlier cars did not have adequate support in this area. This was no longer a problem by the time the Ruby was introduced: it was a full four-seater.

Starting –The Austin Seven, even though it only has a six volt electrical system, will normally start using the electric starter, though its not a bad idea to give the manual starting handle a few turns if the vehicle has been standing for some days, to get the oil circulating.

Noise – The engine is fairly quiet if it is in good condition and is not really noticeable above the noise made by the gearbox, particularly the earlier 'crash' (no synchromesh) gearbox, which had straight cut gears. The differential also gives out a whine to a greater or lesser extent depending on how worn it is. Couple that with wind noise and the noise from overtaking traffic and earplugs become a serious consideration for the open touring cars.

Handling – one of the affectionate names for the Austin Seven is 'the road dinghy'. This stems from the way it reacts to undulations in the road, which causes the length of one of the rear springs to increase as the car goes over a bump, giving a degree of uninvited and unexpected rear wheel steering. If the driver over-compensates for this, the car can wander a bit. Once you get used to this little quirk, however, and relax, driving becomes great fun and a straight line can be maintained fairly easily.

Brakes – It pays to anticipate with Austin Seven brakes. The front and rear brakes were not coupled until 1930, so cars had quite good rear braking operated by the handbrake and an indifferent footbrake that operated on the front wheels only. Both brakes were cable operated and the single front cable exerted its force at 45 degrees, which reduced the efficiency and caused the braking effort to increase as the steering wheel was turned. Front brakes themselves were not commonplace in 1922, so this quirk would have been be overlooked by many.

With careful adjustment and regular maintenance, the front brakes can be made to lock if required, so in spite of the design, the modern VOSA test (MOT) is not usually a problem. The Semi-Girling braking system used on later cars, was more effective, and offered individual adjusters on the brake backplates.

Lighting – Early cars had CAV lamps mounted at the side of the windscreen. The problem with these was that the beam did not project far beyond the front of the car, so they could best be described as position indicators rather than headlights. There was also a warning in the early handbooks not to clean the electric light reflectors with brick dust! Later headlamps were mounted at the front of the car, and gave a much improved beam.

Spares – There are still about 7,000 Austin Sevens left. So many were built that most spares are still available from specialist dealers or clubs. Some parts, like early carburettors and body panels, are becoming more difficult to find, but overall the situation is still amazingly good, with a wide range of new components being made in the UK and abroad.

Fun – The Austin Seven is, above all, tremendous fun to drive. It seems to make people smile when they see one on the road, and other drivers will often give a cheery wave or toot on overtaking you, even if you have inadvertently held them up!

Bibliography

These books are packed with useful information, and though not always in print, are worth tracking down. The many Austin Seven clubs also have invaluable websites, and can answer individual questions. You do not have to be an owner to join a club!

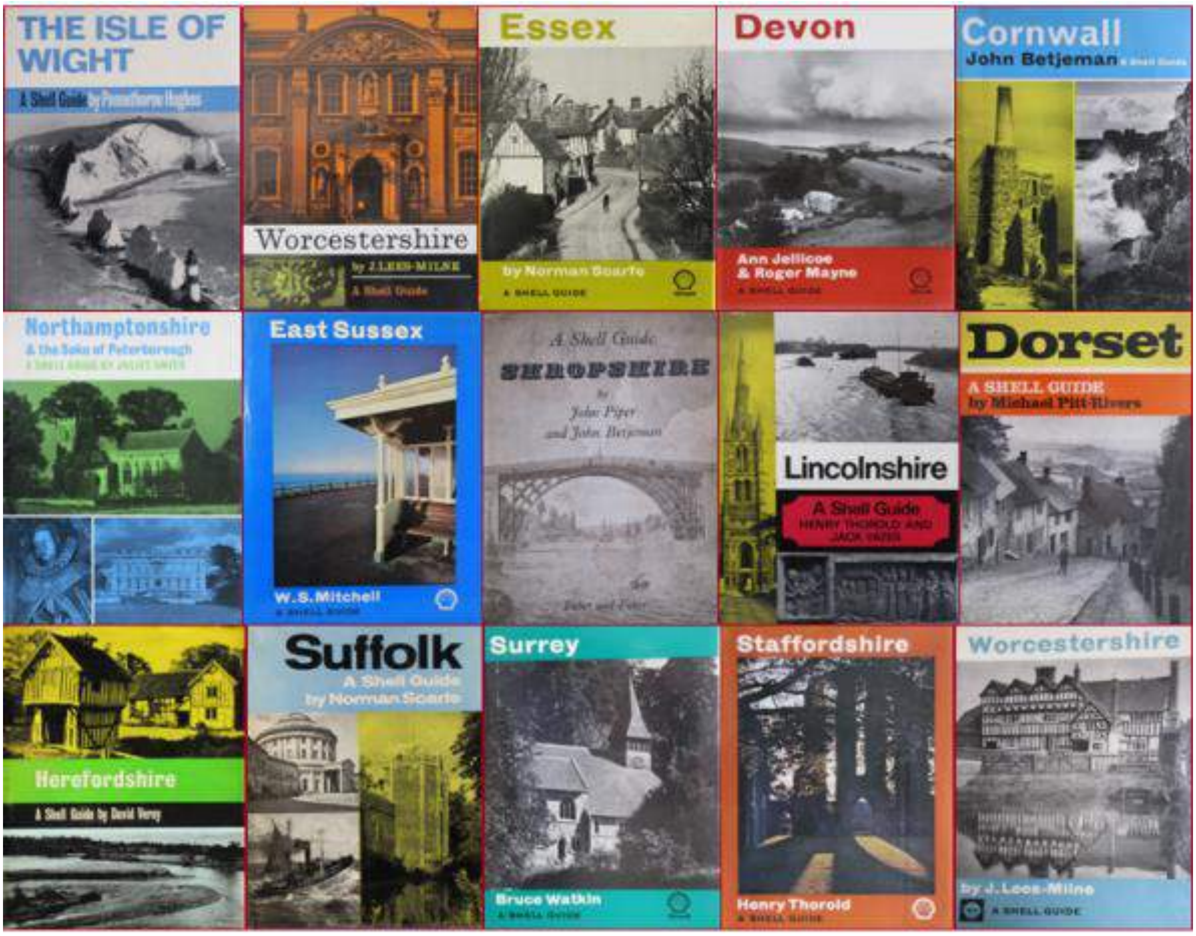
- “The Austin Seven”, R J Wyatt, David and Charles
- “The Austin Seven”, Jonathan Wood, Shire Publications
- “The Austin Seven Source Book”, Bryan Purves, Haynes

This short chapter has left out far more information than it contains, and has had to make many generalised statements. If this annoys the reader, please accept the author’s apologies.

Picture Captions and Credits

Page 6: Image taken at 2011 Royal International Air Tattoo
Page 6: 200 miles (and 7 hours travelling) in an Austin Seven Ruby for the annual holiday!
Page 7: Lord Herbert Austin:
http://www.birminghamstories.co.uk/story_page.php?id=5&type=fo&page=2&now=0
Page 8: Austin 20 Price List:
http://www.birmingham.gov.uk/cs/Satellite?c=Page&childpagename=Lib-Central-Information-Services%2FPageLayout&cid=1223092632571&pagename=BCC%2FCommon%2FWrapper%2FWrapper
Page 8: Stanley Edge: http://www.birminghamstories.co.uk/story_page.php?id=5&type=fo&page=5&now=140
Page 9: Advertising aimed at the female driver: property of the Cotswold Motoring Museum & Toy Collection
Page 10: Austin Seven AE Series Chummy 1930

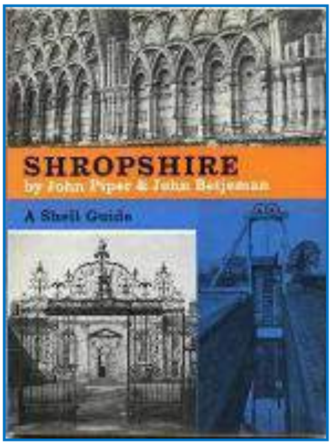
Why were the Shell Guides so influential?
This chapter on The Shell Guides provides an outline of the range, writing style and social significance of this popular series of travel guides to England, Scotland and Wales. The chapter also attempts to justify their presence in the Cotswold Motoring Museum's list of the ten most significant objects in the history of UK motoring.



Introduction
In preparing this chapter on the Shell Guides, it very soon became clear that there are two principle sources of reference. One is a 2010 book entitled "A Shell Eye on England"[3] and the other, a user-friendly, detailed website, dedicated to the history and chronology of Shell Guides over their 50-year lifetime. Between them, they would seem to cover all that anyone could reasonably want to know about the Shell Guides. So, either this was going to be a very short chapter, basically listing two references or it would have to follow a different route. Given the inclusion of the Shell Guides in the Cotswold Motoring Museum's exhibition on "A History of Motoring in 10 Objects", the emphasis of this chapter is therefore on arguing the case for their inclusion in that exhibition and in the process, providing an overview of the guides and their history.

[3] By David Heathcote, published by Libri Publishing

The first Shell Guide (to Cornwall) was written by John Betjeman and was published in 1934. Betjeman co-authored and edited some of the subsequent guides and, along with John Piper, remained general editor of all the Shell guides until 1967. Thereafter Piper continued in the role of editor until publication ceased in 1984. By the outbreak of World War II, thirteen Shell Guides had been published. The first of the post-war titles was the 1951 Shropshire guide shown in the centre of the title page to this chapter, jointly written by Betjeman and Piper. The series went on to cover 30 English counties, 4 areas of Wales, the Isle of Wight and the West Coast of Scotland: several in more than one edition.



Images of two editions of the Shell Guide to Worcestershire are also on the title page. The first edition, published in 1964, shows an image of the Guildhall in the centre of Worcester. By the time the second edition was published in 1968, the dust jacket photograph had been changed to a Grade II listed building; the black and white farmhouse at Middle Bean Hall Farm in Bradley Green, near Feckenham. As mentioned above, the central image on the title page shows the first edition of the Shell Guide to Shropshire, this 68-page guide reproduces a Victorian engraving of Ironbridge on the dust jacket. The re-issued guide, shown to the left and published in 1963, includes a photograph of Wenlock Priory. This guide went to a second edition in 1973 with Michael Moulder as a contributing author.

All the guides were sponsored by Shell as a means of promoting their brand and motoring products but were written by different authors. At the time of writing the first Cornwall guide, John Betjeman was writing for the Architectural Review. Perhaps not surprisingly, friends and colleagues associated with the Architectural Review became authors of the early guides, and this is reflected in their architectural emphasis. With the involvement of John Piper from 1937, the guides evolved with an increasing role for photographs and line drawings with new authors providing a shift in the balance of content. Perhaps reflecting the end user role, out on the road or in planning a holiday, the number of pages devoted to the gazetteer increased as the guides progressed.

To expand from a single guide of Cornwall in 1934 to a series of 36 guides, in print until 1984, indicates that they must have found a niche in the market of 1930s to 1980s motoring. The remainder of this chapter investigates how that niche may have arisen and why the Shell Guide filled it so effectively.

Why are the Shell Guides in "A History of Motoring in 10 Objects"?

Is it the numbers?

Department for Transport statistics enable us to quantify the increase in the popularity of motoring during the years that the Shell Guides were available. In 1930, there were approximately 1 million licensed, private cars on the roads of the UK. By 1939, this figure had increased to around 2 million and by 1984, the final year in which the guides were produced, the corresponding number was 16 million. It is clear that, with the exception of the war years, there must have been a ready and increasing market for publications relating to the leisure use of the car. Indeed, when we consider later in this chapter the typical content of the guides, we will see that the first guides were aimed at the holiday market. The very first guide, written by John Betjeman, was devoted to Cornwall: a county that he knew from boyhood holidays and whose attractions (particularly architectural) he was keen to share with his readers.

Thirty-six areas are covered by the guides. These are mostly individual counties but also some wider and more specific areas are described; namely the West Coast of Scotland, South West Wales, Mid-Western Wales, Mid-Wales, North Wales and the Isle of Wight. Over their lifetime, many guides were re-issued. In trying to estimate – at least to an order of magnitude – the number of guides sold, the figures from Chris Mawson's website provide a good starting point. A typical number of bound copies for each guide produced was about 4,000 to 5,000 with around 50% sold. If we assume that, on average, each guide made it to a second edition, then an indication of sales over their 50 year lifetime is between 100,000 and 200,000.

Above: Middle Bean Hall as it is today. Image used on the Worcestershire Guide, Second Issue, 1968
Below: Brockhampton Court as it is today. Image used on the Herefordshire Guide, First Issue, 1955

Original images are visible on the title page

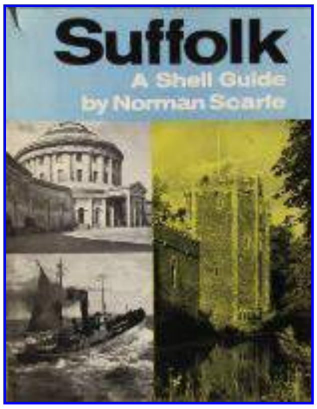
By way of comparison, in this Internet age, for a guide or manual to achieve a place in the Sunday Times top ten list of bestsellers, it has to sell around 100,000 to 200,000 copies but this is frequently achieved in a year or so. Therefore, for the Shell guides, we are not looking at vast numbers of sales. Indeed, Chris Mawson's research in the Shell archives shows that at several points in the 50-year history of the guides, Shell were concerned at the poor financial return on their investment. It appears that the guides survived, as a part of the Shell marketing strategy, in spite of making very little financial profit.

The Shell Guide was not the only choice available to the aspiring holidaymaker and explorer. After the Second World War, the County Books Series published by Robert Hale Ltd in the late 1940s and 1950s were potential competitors to the Shell Guides. Competition from the 1950s onwards was provided by the Pevsner Architectural Guides. These were more numerous than the Shell Guides and outlasted them in print. The first was published in 1951 and the last in 1974, the original series covered the architecture of English buildings in 46 county books and they are still in print today: indeed the series is being expanded and re-issued. The Nikolaus Pevsner guides to the buildings of England follow the detailed gazetteer format that helped to make the Shell Guides particularly suitable for the motorist setting out to explore a county, village by village and town by town.

Is it the content?

The content of the post-war guides and revisions of the pre-war guides followed a similar pattern. Typically, an introductory section would cover one or more specific aspects of the county such as its geography, geology, history, churches, art, architecture, antiquities, regional accents, planning and even early closing days. The bulk of each guide comprised the gazetteer. The 'social effect' of the Shell Guide is often mentioned as a driving force behind their longevity: a motivator to persuade motorists to explore their county and to gain the maximum benefit from motoring holidays. In this context, the gazetteer format was ideal and, at 9" by 7", the physical size of the guides was well suited to travelling in the car glove box. Those guides that went to a second and subsequent edition, generally expanded because of an extended gazetteer. Between the second (1966) and third edition (1976) of the Shell Guide to Suffolk, the gazetteer expanded from 93 pages to 147.

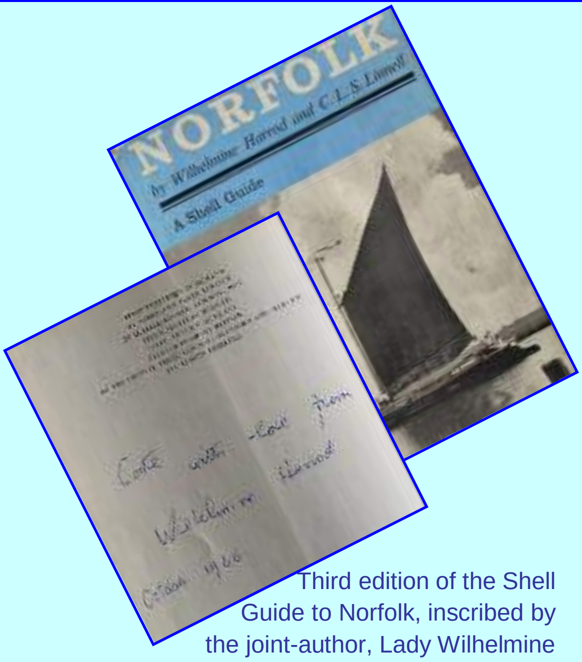
Betjeman and Piper sought authors for their expertise, whether that was in art, conservation and architecture or literature. Consequently, the guides, in spite of a uniformity of layout, are also very individualistic. Heathcote suggests that in adopting the gazetteer format, with brief entries for each location, the limited space would not allow the author to dwell on any negative aspects. However, the down side of a gazetteer approach, unless it is highly selective, is that it will include those locations that a tourist may prefer to avoid rather than to visit. (Arguably, still a worthwhile function of a guide!). Even with limited space to describe the town of Haverhill



in Suffolk, the author, Norman Scarfe, could find space to write, "1955 agreement with GLC to expand to 10,000, then to 18,500, now to 30,000. Why stop at 30,000? … 'The answer is in the character of Haverhill'. A frivolous answer". Whilst the neighbouring village of Kedington merits the complimentary entry, "Church amongst the first a visitor to Suffolk should see. Here, almost more than anywhere in England, crossing the threshold is like stepping back at least two centuries …". Whilst presenting a county with a 'warts and all' description is certainly useful for the tourist, there is clearly scope to offend the local population. This is a characteristic of many of the guides. The 1935 publication of the Shell Guide to Derbyshire showed "the unpleasant side of Derbyshire" alongside a scene of rural tranquillity. Guides to Worcestershire and Mid-Wales also caused some local embarrassment as outlined below.

Is it the authors?

For both John Betjeman and John Piper, initial involvement with the Shell Guides occurred early on in their careers. Both became widely recognised for their literature, artistic and creative skills and it would be difficult to argue that their involvement with the guides was anything but an early stepping-stone to greater things.



Third edition of the Shell Guide to Norfolk, inscribed by the joint-author, Lady Wilhelmine Margaret Eve Harrod (known as Billa) (1911-2005) to her friend Lady Dorothy Heber-Percy nee Lygon (known as Coote) (1912-2001)

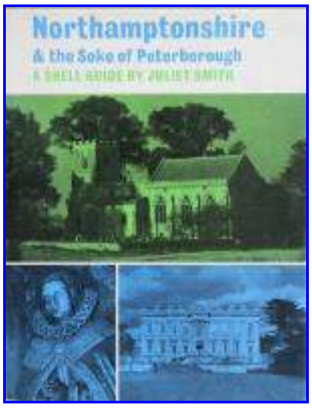
C L S Linnell, joint author of the Norfolk guide was a clergyman with several publications on church architecture to his credit; both within and beyond Norfolk. His co-author, Wilhelmine Harrod, went on to write at length about churches in Norfolk and their conservation. Norman Scarfe, author of the Suffolk, Cambridgeshire and Essex guides, wrote extensively about the history of East Anglia as well as contributing to works on modern history. David Verey wrote the Herefordshire guide and revised the Gloucestershire guide. He wrote extensively about Gloucestershire and Cotswold churches and contributed to the Pevsner series. Author of the Shell Guide to Worcestershire was James Lees-Milne, an architectural historian and native of the county. He was also architectural advisor to the National Trust and was not afraid of speaking his mind. According to the research of Chris Mawson, on seeing the finished draft, Betjeman wrote [to Lees-Milne] congratulating him for the "affection and delicious grumpiness" he had shown. Certainly, Lees-Milne had a trait of describing places in a manner that suggested a set of non-negotiable facts rather than (a very well informed) opinion. For example, “a sort of hill-slope Bournemouth without any sea” was his description of Great Malvern, “… contributes to the general disfigurement of the country”, “Lenchwick is a village of no interest.”, etc.

Much more detail on the authors is available in the two references cited in the introduction but the brief résumé above demonstrates that Betjeman and Piper were able to attract authors of the highest quality to produce the guides. John Piper’s photographs appear throughout the series and his black and white drawings (particularly of church interiors) are found in the immediate post-war guides.

Is it the sponsor?

From the perspective of the 1930s motorist, the guides provided a convenient source of local information on a county-by-county, town-by-town and village-by-village basis. However, the guides were sponsored by Shell (providing very little profit for the company) and the reason for this sponsorship was novel, far-sighted, apparently philanthropic but ultimately commercially motivated. From very early in the era of the internal combustion engine, certainly before World War One, Shell had used art as a means of promoting their brand and hence their products: much as the railway companies had done in the early 20th century. Examples of postcards and posters can be seen in various collections and a display is featured at the National Trust’s Upton House and Gardens. Many of the artists commissioned by Shell to produce advertising posters went on to become famous in British contemporary art. For example, Paul Nash (also author of the Shell Guide to Dorset), John Piper (co-author of the Shropshire guide and general editor), Vanessa Bell, Ben Nicholson and Graham Sutherland.

Whilst there was no reticence to use blatant advertising signage at the point of sale, such as that shown in the many enamelled signs at the Cotswold Motoring Museum, the posters of the 1930s were subtly clever in promoting the Shell brand by associating it with an enviable lifestyle. At the outset, it appears that the guides were viewed in a similar fashion. Yes, they fulfilled the basic role of increasing brand awareness in a highly competitive market for petrol but they also sought to fuel the aspiration of the 1930s young motorist to "traffic-free, rolling roads" (Shell Guide to Derbyshire 1935), "deserted, tree-lined byways" (Shell Guide to Devon 1935) and a sense of being 'at one' with nature.



Not all publicity is good publicity however: in any linkage of a brand to a product, there are hazards! In particular, when the author of the Shell guide was an expert in their field and accustomed to directly airing their views. The Mid-Wales guide, published in November 1960, included a reference to Llandrindod Wells and a suggestion that it did nothing but rain in the town. Unsurprisingly, this upset the people of Llandrindod Wells who retaliated with the threat to boycott Shell petrol! James Lees-Milne, an architectural advisor to the National Trust, wrote the Shell guide to Worcestershire. As noted above, this author wrote in a very direct, uncompromising style. He refers to the city of Worcester as "repeatedly sacked by Romans, Danes, Saxons, Welsh and Roundheads" but was prevented from adding ".... [and is] being sacked today by its own corporation". A reference to post war redevelopment of the city centre. A similar issue arose over comments by the author of the Shell Guide to Northamptonshire, Juliet Smith, who made derogatory remarks about the Norwich Union building in Peterborough. As sponsor of a guide intended to promote goodwill for Shell, it is not surprising that in both the Worcestershire and Northamptonshire cases, the final editorial decisions were made by Shell.

In the later guides, for example the 1975 reprint of Norman Scarfe's guide to Essex, the following disclaimer appears "While the author is here expressing his personal views, Shell-Mex and B.P. is pleased to be associated with this book". The same author's 1976 work on Suffolk appears to distance Shell somewhat further by the disclaimer "Although sponsoring this book, Shell U.K. Ltd would point out that the author is expressing his own views".

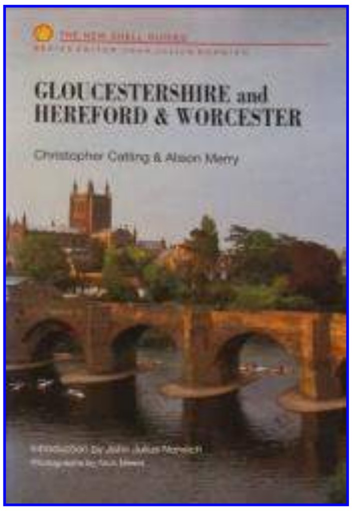
Conclusion

These adverts from The Motor in the 1930s and 1950s show fuel sales were extremely competitive.

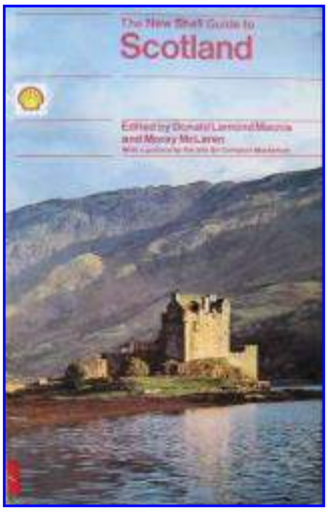
Shell used artwork and the guides to increase awareness of the brand and to associate the product with the finer aspirations of motoring

So, does this justify the inclusion of the Shell guides in "A History of Motoring in 10 Objects"? In reality, maybe it is a combination of all of these factors, plus the fortune of good timing. The guides appeared in their first edition at a time when motoring was becoming affordable to the mass market and again in the revival of motoring following the austerity and rationing of vital materials and fuel during WWII. To have survived for 50 years in multiple editions and re-prints under the direction of just two, like-minded general editors at a time when motoring was changing in scale, taste and affordability is a great achievement. Their longevity alone has been spectacular. Even though out of print, they are today still sought after as a unique description of county life and architecture. In 2008, to see how relevant the Shell Guide to Herefordshire is today, fifty years after publication, a light-hearted test was reported in the Guardian. In terms of change over the last 50 years, Herefordshire was probably a good choice for the experiment but the conclusion was that they can be "…enjoyed by any generation".

Even after Shell ceased supporting the John Betjeman / John Piper guides, they continued to endorse (with the usual disclaimer) further guides. There was a series of Shilling Guides, available even before the demise of the County Guides and also a series of New Shell Guides covering England, Ireland, Scotland, Wales and Britain, each published as a single guide during the 1960s and 70s. The New Shell Guides of the 1980s and 1990s tended to cover



larger areas than their predecessors: for example Gloucestershire, Hereford and Worcester[4] were covered in a single volume. Whilst perhaps more convenient for the motoring tourist, the architectural content was noticeably less than in the original Shell Guides, the gazetteer format was retained and the colour photography produced a greater visual impact. Chris Mawson's comment on the New Shell guides is as follows:



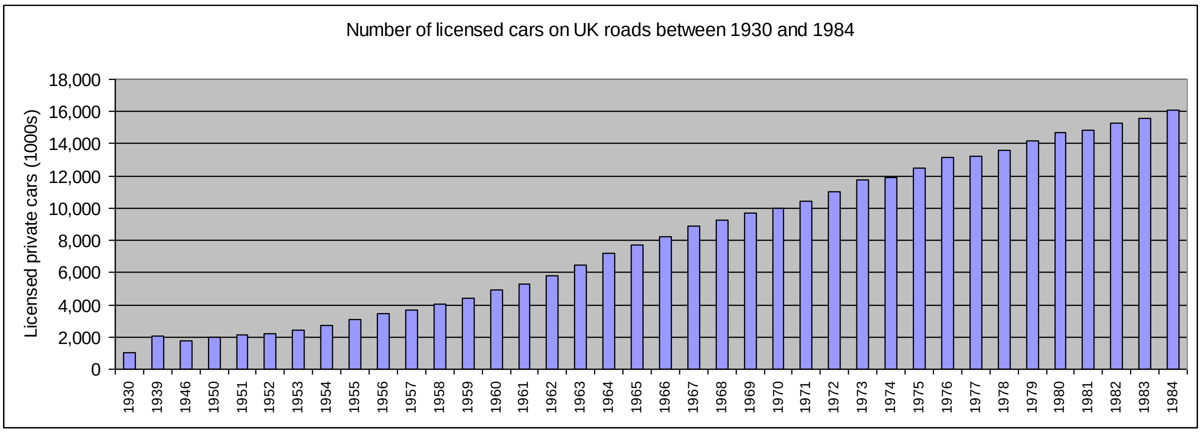
"*An 'official' attempt to revive the format came in the late 1980s when publishers Michael Joseph introduced the 'New Shell Guides' under the general editorship of John Julius Norwich. Rather than reproduce the county-by-county format, these new guides covered regions such as 'The North-East of England' and 'Devon Cornwall and the Scillies'. In tackling larger areas, the guides could only cover the more interesting or obvious places, like many a selective guide before. Perhaps as a result of this, the series faltered and within a few years, all the published volumes were out of print.*"

The original Shell County Guides still make fascinating reading and provide a unique record of Britain in the twentieth century. They are also a lasting tribute to John Betjeman and John Piper who oversaw the entire series throughout their 50 years in print and, in the opinion of the Cotswold Motoring Museum, deserve their place in the top 10 items in "A History of Motoring".

[4] Between 1974 and 1998, Herefordshire and Worcestershire formed a single administrative county

Annex A: Licensed cars on UK roads between 1930 and 1984

The earlier text quotes the number of licensed, private cars on UK roads over the period covered by the production of the Shell guides. These figures, along with those shown in more detail below, are derived from the Department for Transport website.



Annex B: Shell exhibits at the Cotswold Motoring Museum

The Cotswold Motoring Museum and Toy Collection has an abundant display of items that cover the main business of the Shell Oil Company: namely oil and petrol. You may like to see how many of these 16 items you can spot during your visit.

Further information

In addition to the references and links above, Shell Guides are (or have in the recent past been) the subject of exhibitions at:

The Museum of Domestic Design and Architecture (MoDA)
The National Motor Museum Trust
The National Trust property of Upton House

Picture Captions

Page 12: Montage of Shell Guide covers
Page 13: Cornwall by John Betjeman, 1964
Page 13: Shropshire by John Piper and John Betjeman, 1963
Page 13: Enamel advertising sign at Cotswold Motoring Museum, Bourton-on-the-Water
Page 14: Middle Bean Hall, Worcestershire and Brockhampton Court, Herefordshire
Page 15: Suffolk by Norman Scarfe, 1966
Page 16: Norfolk by Wilhelmine Harrod and C L S Linnell, 1966
Page 17: Enamel advertising sign at Cotswold Motoring Museum, Bourton-on-the-Water
Page 17: Northamptonshire and the Soke of Peterborough by Juliet Smith, 1968
Page 18: Copied from 1930s and 1950s copies of The Motor held at the Cotswold Motoring Museum, Bourton-on-the-Water
Page 19: Gloucestershire and Hereford & Worcester by Christopher Catling & Alison Merry, 1990
Page 19: Scotland edited by Donald Lamond Macnie from an original edited by Moray McLaren, 1977
Page 20: Montage of Shell related items on display at the Cotswold Motoring Museum, Bourton-on-the-Water

Introduction

In the subsequent chapter on "Responsibilities of Ownership", the environmental implications of retaining or replacing our cars are discussed. If the retain or replace decision is made solely from an environmental point of view, then the decision may be swayed by the 'unseen' atmospheric CO_2 contribution during the vehicle manufacture, transportation and disposal as well as the emissions during a lifetime of use. If however the attraction of a modern, efficient, reliable car (and the added attraction of a financial discount offered by a highly competitive new car marketplace) proves too tempting, then what can owners expect from those to whom our new vehicles are entrusted? When those new vehicles leave the showroom, they should be at their optimum performance. Engines and other moving parts may need to 'bed in' for the first few hundred miles but wear, spurious rattles and corrosion should not exist. As mileage increases, even with regular servicing, faults will develop – some slowly, some suddenly – accidents will occur and at some point, that new pride and joy will come to need the services of a repair organisation.

An evolution of the blacksmith's skills

The observation by a Scottish clergyman and author, writing an early 20th century account of his town, Maybole, that "blacksmiths had practically disappeared but were replaced by motor engineers, and taxi hirers", could have been true of any town in the UK. The early era of cars required many of the skills associated with the trades of the blacksmith, wheelwright and coachbuilder. The pictures above, showing wheels and semi-elliptical leaf springs from the London to York Royal Mail coach and a French-built 1895 Panhard and Levassor, (both in the London Science Museum) illustrate the point. With oil or acetylene lighting and no battery, the magneto–based ignition system was often the only electrical component of the car.

1896 marked the first London to Brighton car run. A contemporary description mentions "…. the moment pioneer motorists set off from London to Brighton ….. each contraption shaking (as one observer noted) 'like a blancmange at a dance-supper' ….."[5]. This event was to celebrate the repeal of the Red Flag Act: the legislation that required a man carrying a red flag to walk in front of the new-fangled 'road locomotive' to warn of its presence. It was also around this time that the first British-built cars were appearing. It is known that in the summer of 1897, Major General Montgomery of Winchester ordered a Daimler car and thus became the first member of the public in the United Kingdom to own a British-built motor car.

[5] "The Motoring Century: The Story of the Royal Automobile Club" by Piers Brendon, Bloomsbury, 1997

However, the Santler brothers in Malvern, Worcestershire hold the British record for producing the first surviving petrol-engine car when, in 1894, they fitted a single cylinder petrol engine to a previously gas powered car. Although Santler continued to build cars until 1922, unlike Daimler, Santler never appeared to have planned to enter into volume production[6].

The decade following 1896 saw spectacular growth in the number of European and US car manufacturers. By 1905, there were 221[7] UK Motor Manufacturers, the majority in the Coventry area, and along with the growth in the number of motor vehicles came the need to maintain these vehicles.

Trade directories for the town of Malvern (home of the Santler Brothers) show that in 1907, there were 4 blacksmiths and only two motor engineers (one of which was Morgan and Co) but by 1922 there were still 4 blacksmiths but now 10 garages and 10 motor engineers (including Morgan Motor Company Ltd and Santler and Co) [8].

In Bourton-on-the-Water, Gloucestershire, the directories of the day[9] tell a similar story. In 1906, commercial activities relating to road transport included two blacksmiths, a cycle maker and wheelwright. In 1927, one blacksmith and the cycle maker remained but now there was a taxi business and four motor engineers. One was John William

[6] According to Dr R A Sutton in his publication "Malvernia: The origins and History of the First Motor Car built by Charles and Walter Santler", the brothers were much better at the technical rather than commercial side of their business.
[7] "The Motor Industry of Britain Centenary Book 1896 to 1996", SMMT
[8] Stevens Annual Business Directories for 1907 and 1922
[9] Kelly's Directories for Gloucestershire 1906 and 1927

(Jack) Lake, described as a "motor engineer and cycle repairer", whose garage exhibit is now a major feature in the Cotswold Motoring Museum.

The years of volume production

Some of the repairs that these early garages were called upon to perform would be familiar to today's motorist. Road conditions prior to the First World War were generally poor and wheel and tyre problems would have been common. Twenty years later, servicing schedules were still much more intensive than would be acceptable today. 1000-mile service intervals were common with the grease gun being applied to moving parts of the suspension, chassis, steering, drive train and brakes. Oil level checks for gearbox, rear axle, steering box and fluid checks for the lever-arm shock absorbers would typically be part of the 1000-mile service. After the first 500-mile engine oil change, oil changes were typically every 3000 miles, although 1,000 miles was the interval recommend by some manufacturers, with gearbox and rear axle oil changes every 10,000 miles. It was common for vehicles to require a 'de-coke' (decarbonise) every 10,000 miles. (Modern fuel additives, better lubricants and more complete combustion fortunately today render this procedure much less common). A letter to the Editor of Autocar in 1935, extolling the performance of a 10hp Lanchester, states: "My car has covered 23,000 miles in the 15 months or so that I have had it. During that time it has been decarbonised twice only, at about the 2,000 miles mark and at the 17,000 miles mark …..". There was clearly a market for accessories to address the 'de-coke' problem as seen by this 1931 Decarbo advertisement in Autocar.

There were also unusual and innovative electro-mechanical features whose control functions are now largely implemented using electronics. For example, the [Morris Oxford (1956–1959)] employed an optional 'Manumatic' transmission. This removed the need for any manual clutch operation during a gear change. The action of the driver gripping the gear lever operated a switch and solenoid, which in turn activated a vacuum-operated clutch and matched the rotational speed of the engine and gearbox before re-engaging the clutch.

Whilst replacement parts were generally vehicle-specific, the concept of all-makes servicing by a garage was common right up to the 1960s. Manufacturers would supply franchised dealerships with various pullers, jigs and other tools specific to their products but a well-equipped, independent garage would be able to tackle most jobs on most low and mid-range makes of vehicle. In 1938, Kennings introduced an [8-minute service] and valet for any make of car. National chains, including Kennings and Henleys incorporated specialist services such as engine tuning (eg Crypton, Sun) and lubrication (eg Castrol, Tecalemit) for all makes at major service intervals.

The time-travelling technician

What would be the greatest differences that a 'time-travelling' roadside or garage technician from the 1950s would notice if they were parachuted into a franchised dealership of the 21st century? Firstly, they would probably marvel at the build quality and functionality incorporated in the average family saloon and, as discussed in the "Responsibilities of Ownership" chapter, the value for money that the car represented when compared with its 1950s counterpart. They would notice that some mechanical aspects of servicing remain (eg tyres, coolant checks, oil changes, brake shoe/pad replacement) and that some are much simpler (eg far fewer fluid checks and lubrication points) in comparison with the '50s. In addition, some practises such as re-treading tyres, decarbonising pistons and cylinder head, have virtually disappeared. Instead, the understanding of electronic controls, sensors and diagnostics, driven in part by tighter legislation on the emission of particulates and environmentally harmful gases - implemented through sensors never feasible in the '50s - has become an essential skill for the technician.

Either within or outside of the franchised dealership, the growth of specialist services and suppliers, such as Electronic Control Unit (ECU) re-programming, windscreen, tyre, clutch, brake, audio and air conditioning specialists, would seem unfamiliar; as would the sophistication of the logistics supply chain providing 'just-in-time' parts to the dealership. New materials (eg long-life lubricants, asbestos-free clutch and brake linings) and treatment of waste (eg disposal of old batteries, used engine oil, old electrical – and now electronic - circuitry containing lead solder) would show a revolution in the industry's concern for the welfare of employees and for the environment. No longer is it acceptable to leave old batteries outside the workshop in the certain knowledge that they would disappear overnight!

Picture Captions and Credits

Page 22: The Blacksmith's shop at the Cotswold Motoring Museum, Bourton-on-the-Water
Page 22: Comparison of wheel and suspension from a London to York coach and an 1895 Panhard and Levassor car: both on display in the London Science Museum
Page 22: Acetylene lamp on Alldays and Onions 1911 Victoria, Cotswold Motor Museum, Bourton-on-the-Water
Page 23: Santler Dog Cart Copyright Christie's Images
Page 23: Montage of car manufacturer badges
Page 23: Jack Lake garage sign, Cotswold Motor Museum, Bourton-on-the-Water
Page 23: Print of Jack Lake Garage, Bourton-on-the-Water
Page 24: Advertisement for Decarbo, Autocar, 8 May 1931
Page 24: Sun 1120 Electronic Engine Tester, Cotswold Motor Museum, Bourton-on-the-Water
Page 24: Crypton Diagnostic Centre, Cotswold Motor Museum, Bourton-on-the-Water

Introduction

The UK's two earliest roadside rescue and recovery organisations were both founded over 100 years ago: earlier than any vehicle today on display in the Cotswold Motor Museum. RAC can trace its origins back to that first London to Brighton run in 1896 and the rival AA was set up in 1905. The remit of the AA's 'road scouts' was, initially, to warn members of speed traps and other forms of 'police harassment'. Indeed, well into the 20th century, failure of an AA motorcycle patrol to salute a car bearing an AA badge was understood by the driver as an indication that they may be about to enter a police speed trap.

Given the increasing reliability of modern vehicles, it may seem that the need for roadside rescue organisations such as AA, Britannia Rescue, Green Flag, Mondial, RAC and so on would decrease. However, the increasing complexity of modern vehicles, the reduction in our ability and willingness to tackle car repairs ourselves and the problems still associated with vehicles as age and mileage increase has ensured that many millions of UK motorists have some form of roadside breakdown insurance. In many instances, drivers may have multiple cover: for example, through the vehicle manufacturer's scheme, bundled with a 'premium' bank account, with car insurance, as a benefit of belonging to a car club or, the clear majority (61% according to a 2008 J D Power survey), as an independent purchase through direct membership of a roadside organisation.

In June 2013 there were 29.08 million licensed cars in the UK and, typically, each year roadside rescue organisations receive over 8 million calls for assistance. In 2011, the AA, RAC and Green Flag attended 3.5 million, 2.56 million and 1 million breakdowns respectively.

The distribution of these 8 million calls over a 12-month period is far from uniform. The first frosty morning of the year, the first day back at work after the Christmas and New Year break, the first Saturday of the school summer holiday, abnormal weather; these are all occasions that cause peaks in demand. By comparison, mid-morning on a sunny, mid-week spring day may barely register on the same scale. Predicting demand, and hence staffing levels in call centres and amongst the roadside technicians, is an exercise that all roadside organisations have to address. Historical data is clearly important, as are weather forecasts and special event information. Consequences of a forecast for service demand may result in staff operating split shifts, for example coinciding with morning and evening rush hours, and requires flexibility on the part of all staff.

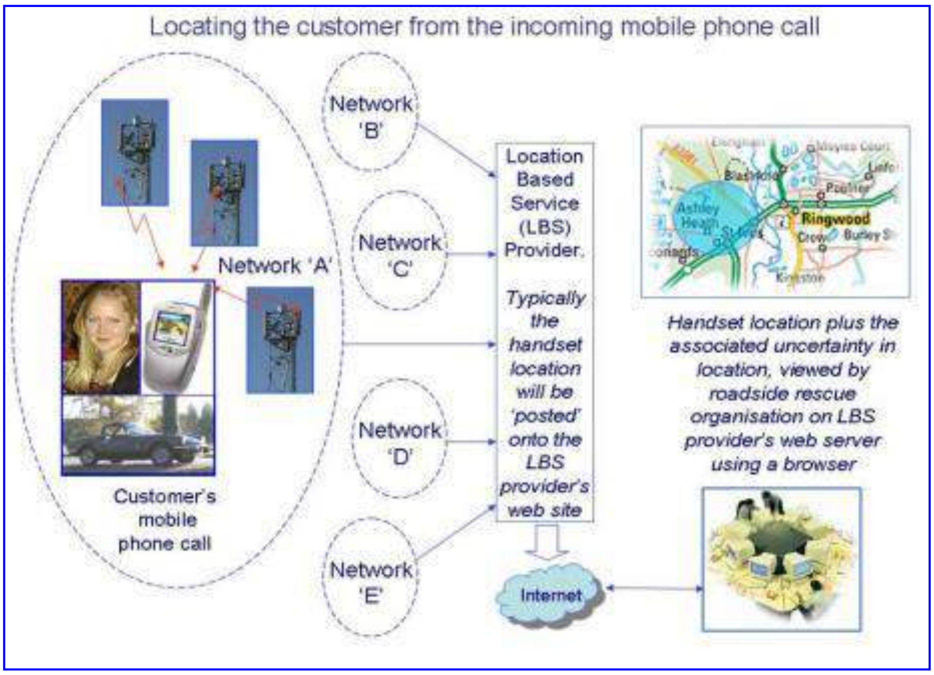
Specific processes will vary from one rescue organisation to another but the following basic steps will be common to most and represent best practice.

Dialogue with the customer

The sequence of events that follow a roadside breakdown usually starts with a phone call to the rescue organisation. Call centre staff are trained to recognise that the customer may be anxious. Not only has their vehicle broken down or been involved in an accident but also they may be more worried about how this will affect the remainder of their day than the immediate re-mobilisation of the vehicle. (39% of RAC patrols have had to deliver a customer to a major event eg a wedding and 2% have delivered a baby!)

Location

Having established the caller's entitlement to service, it is necessary to determine their location. The call handler's IT system, which is likely to feature both a mapping and a text and gazetteer interface, should be able to work with a range of location details that a customer may be able to provide. For example, road names, district, road numbers, motorway junctions, motorway marker posts, landmarks ie garages, pubs, points of interest etc. If this is insufficient to determine a location unambiguously, then there are some more technical options available. A customer calling from a landline may automatically provide the number of the calling line and this may either trigger a location from a database held by the rescue organisation or, as a minimum, the area code that will give an approximate geographic area. Even when an organisation has regional centres, there will be occasions when a single centre takes calls at a national level, so even a crude initial location can speed up the subsequent dialogue.



With mobile phone ownership at 93% of the UK population and 61% of adults having a smartphone, it is not surprising that over 80% of calls for assistance from a motorway originate from a mobile phone. Although the ability to locate a phone within the operator's network is an intrinsic feature of digital networks, it is only relatively recently that this feature has been commercially exploited. Typically, a roadside rescue organisation will enter into a contract with a Location

Based Service (LBS) provider and this LBS provider will manage the interface with the five[10] physical phone networks in the UK. Location of the handset uses the fact that, although the handset communicates via a single cell phone base station, the signal from the handset is received by other base stations within the network. Using the time difference of arrival of the signal at three or more of these base stations, an unambiguous area can be determined that includes the handset location. The size of this area can vary in radius from as little as 100m to 2km, with the final precision dependent upon the relative position of network base stations in the area of the breakdown. The increasing trend to incorporate a GPS receiver in the smartphone will improve the location accuracy to a few tens of metres: always assuming the roadside organisation's IT system is able to exploit this feature of the phone.

Consent of the customer will always be sought by the roadside service organisation before a request is sent to the LBS provider to attempt to locate the handset.

The symptom

The symptom as described by the customer to the call handler will have a major influence on subsequent decisions. Of the UK organisations, AA and RAC employ their own dedicated roadside technicians, referred to as patrols. In addition, some organisations operate branded services for their corporate motor manufacturer customers. There is no point in sending a patrol to a customer who has described a catastrophic problem that will require recovery of the vehicle, possibly using specialist lifting and towing equipment. On the other hand, the customer may only be able to describe the symptom in quite basic terms: "won't start", "cut out", "running roughly", etc. In these circumstances, insight to the underlying fault can sometimes be gained by smart, system-led questions from the call handler. The national databases of roadside organisations quickly reveal patterns of faults with vehicles. This is especially valuable to motor manufacturers following a new vehicle launch but it is also valuable in scripting the smart questions that a call handler may use in a dialogue with the customer. In a small percentage of breakdowns, the smart question and answer routine may result in a recommendation to the customers to try to resolve the problem themselves. An unusual warning light eg low screen washer fluid as shown here, will not prevent the vehicle being driven to a garage so the customer's journey can continue without risk. More frequently however, the outcome of the dialogue results in the optimum resources (eg a motorcycle patrol, a patrol with a vehicle having some towing capability, a flatbed recovery vehicle, a specialist locksmith, a taxi etc) being despatched.

Driver and passenger safety

Customer anxiety can be heightened by the realisation that the roadside, and in particular the hard shoulder of a motorway, is a very dangerous place. Although motorways themselves are the safest roads in the UK, some 250 people every year are killed or injured on the hard shoulder. Once details of the customer's location and problem have been gathered, the call handler should offer guidance on safety to the customer whilst he or she awaits rescue. Recognising the danger of the roadside environment, the SURVIVE Group (Safe Use of Roadside Verges In Vehicular Emergencies) whose members include Association of Chief Police officers, the Highways Agency, Vehicle and Operator Services Agency and representatives of roadside service organisations, was established in 1998. Their aim is to improve the safety of those who work on the road network as well as the travelling public.

[10] The five physical networks in UK are: '3', O_2, the merged Orange and T-Mobile networks (EE) and Vodafone

Patrol attendance

For those organisations with their own patrol force, typically 90% of calls for assistance will result in the attendance of a patrol. In 2008, the industry average for fixing the fault with the customer's vehicle at the roadside, reported by J D Power, was 76% although organisations with their own dedicated patrol force today typically achieve 80%.

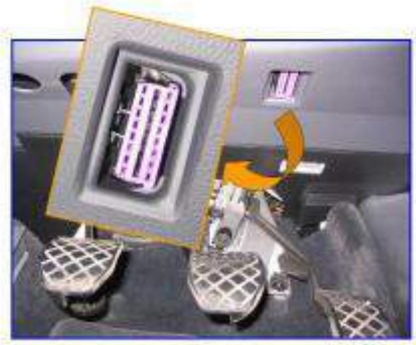
One reason that fix-rates remain so high, even as vehicle complexity increases and access to the engine bay decreases, is that the main reasons for calling a breakdown organisation are dominated by 'low-technology' faults. The hierarchy of faults includes:

- problems with the vehicle battery – especially in cold weather
- wheel and tyre problems – locking wheel nuts and large, heavy wheels are a deterrent to customer DIY
- electrical and mechanical engine problems
- road traffic accidents
- lockout - where the customer has locked the vehicle ignition keys in the boot or interior
- mis-fuelling ie diesel in a petrol vehicle and vice versa.

The number of replacement parts that can be carried in the roadside technician's vehicle is clearly finite and would typically be restricted to common types of battery, small quantities of fuel, lubricants, generic electrical repair items etc. If a roadside organisation is providing a branded service for a specific vehicle manufacturer, then clearly the parts and diagnostic tools carried will be much more focused on that manufacturer's vehicles. Equipment carried will include basic tools, jacking, towing and recovery equipment as well as test equipment. Repair and parts information, at one time paper-based, is now typically stored on the technician's PC.

Diagnostics

Until the advent of the digital data bus within a vehicle, electrical test equipment carried by a roadside technician would have included little more than a multi-meter and current clamp. Modern vehicles contain multiple 'data buses' associated with engine management, safety, braking, suspension, entertainment etc. Access to data is provided via a standardised interface to which a roadside or garage technician will connect their scan tool and PC. EU standards, derived from legislation on vehicle emissions and diagnostics, require the physical and electrical properties of this interface connector and some of the data accessible via the socket, to be common on all vehicles sold in the EU. A technician's ability to read and interpret the diagnostic fault codes presented at this connector is becoming an ever-increasing requirement to maintain high fix-rates.



The roadside technician arrives on the scene of a breakdown knowing about the symptom gleaned from the call handler's dialogue with the customer and possibly enhanced through a direct call to the customer whilst en-route. Following attendance at the breakdown the technician will understand the fault or faults that gave rise to that symptom. Ideally, this fault information will be coded, along with confirmed vehicle details such as the specific model, engine capacity etc, and fed back to the rescue organisation's database to refine the smart, system-led questions that form the starting point of the interaction with the customer.

Competition

Roadside service is a highly competitive market and new entrants regularly appear. As such, it is also a well-surveyed market and J D Power, the consumer organisation Which and UK Institute of Customer Service produce regular reports of roadside recovery service.

Picture Captions and Credits

Page 26: 1903 Cadillac at the end of the 2003 London to Brighton run
Page 26: Old AA box from Bourton-on-the-Water, now in the Cotswold Motor Museum, Bourton-on-the-Water
Page 27: Customer phone call to roadside rescue organisation
Page 27: Roadside rescue organisation call centre, courtesy of RAC Motoring Services
Page 28: Low screen washer fluid level warning indicator
Page 29: Britannia Rescue roadside technician
Page 29: Diagnostic connector J1962 specification. Mandatory on all cars sold in EU

Introduction

The next two chapters attempt to summarise some of the ways in which technology, from maps to satnav, helps us to understand our location and guide us along our intended route.

Maps and coordinate systems

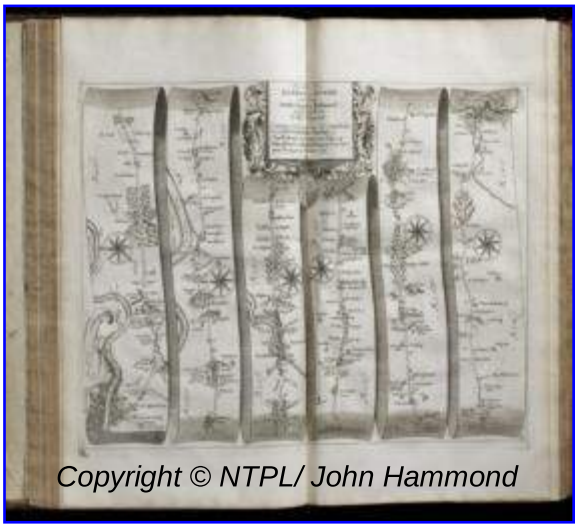
A personal, spatial knowledge of our homes and workplaces, our roads, subways, buildings, utilities, railways, rivers, coasts, seabed and airspace underlies every aspect of our day-to-day life: albeit not necessarily at the forefront of our consciousness. The concepts of communicating a position on the Earth, in three dimensions, and distance and direction via a drawing, do not seem to be the most intuitive concepts for human beings to have evolved. However, the evidence exists of portable maps from ages prior to agricultural settlements, when man was still a hunter-gatherer, and these could have made the difference between the survival or extinction of tribes and civilisations.

> Women of the Tubu tribe in southern Libya steer their caravans of camels and trek for days across the Sahara just to buy salt and dates at market. For water on the journey, they must find small wells: miss them and they die.
>
> These women use inherited skills to navigate by ‘dead reckoning’. They measure their distance along the route by the number of sand ridges that they pass – no small task when the wind re-shapes the desert sands – and elapsed days. Their direction (heading) is checked by the stars. Their aiming point is a well no more than one square metre in area.

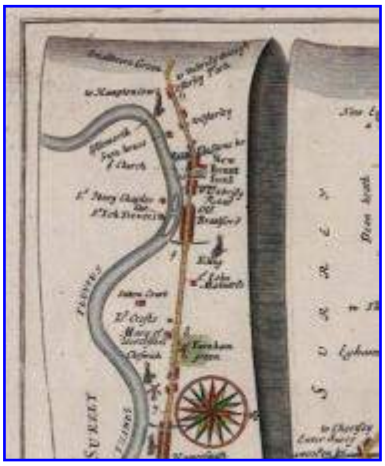
Paper maps

Etchings on stone from 14,000 years ago have been found in the Spanish Pyrenees and are believed to represent the earliest maps. Biblical stories, Chinese records of solar eclipses 4000 years ago and the orientation of ancient Egyptian tombs and temples from 2500BC are all evidence that humans have used their astronomical knowledge to understand their own location and orientation. Possibly the earliest known city map is of the Turkish city of Catal Hoyuk and is 6200 years old.

Old UK maps, (eg Mappa Mundi) from the 13th century onwards are often considered to be works of art, as well as works of science. The 1660 John Speed map of Cardiff, shown here and now held in the University of Wales, is an example of the artistic quality and detail of early maps.



John Ogilby (1600-1676) ended his varied career by producing maps. He produced the first British road atlas (left) in 1675 and was the first to use a statute mile of 1760 yards. For specific journeys, he created ribbon maps of many routes across England and Wales. These were based on a series of ‘ribbons’ of road, typically 70 miles in length, covering specific journeys. A sample of [Hampshire mapping by Ogilby](), from his Lands End to London ribbon map, is shown on the right.



In many ways these ribbon maps resemble the route books, typically produced by RAC and AA for members’ routes in the 1960 to 1990 period; before web-based routing was available. The concept of [herringbone or fishbone]() maps, used in motor sport, also follows the ribbon map idea. In these maps, the straight line from bottom to top (or left to right) of the navigator’s instruction sheet represents the direct line from start to finish of the journey with missed junctions along the route shown as lines branching off the straight line.

The maps we use today have their origins in war. The Board of Ordnance commissioned maps of the Scottish Highlands in 1747 and following more than half a century of intense mapping by a few brilliant pioneers, the first Ordnance Survey map[11] of part of Kent was displayed to the public in 1801.

Mapping coordinate systems

If our holiday or rally route instructions start with a map grid reference or a latitude and longitude, then it is easy to believe that this will unambiguously define the location of the start of the journey. Unfortunately, this is not the case since it will depend upon the coordinate system from which the latitude and longitude are derived. From the point of view of a motorist in the UK, the most likely situation when this will be encountered is in the use of a GPS satellite navigation receiver (GPS is discussed in the Satnav chapter of this book) and a [large-scale]() Ordnance Survey (OS) map.

[11] “Map of a Nation: a Biography of the Ordnance Survey” by Rachel Hewitt, Granta.

The extent to which our native language determines how we express the concept of location and directions is discussed in “Through the Language Glass: How Words Colour Your World” by Guy Deutscher (Heinemann). In English, we often describe a journey using ‘ego-centric coordinates’ based on the speaker’s position (left, right, forwards, backwards) and also using geographical coordinates (north, south, east, west). One particular Aboriginal language does not use ‘ego-centric coordinates’ – there are no words for left or right - but relies solely on points of the compass. A native speaker may describe Long John Silver as missing his north-westerly leg, depending on the orientation of the TV on which he is watching Treasure Island. This requires the speaker to always understand the direction of north in order to express himself.

The problem arises from the fact that the mathematical description of the shape of the Earth – a slightly squashed sphere – varies from one coordinate system to another and historically has been optimised for the region of the globe to which the coordinate system refers. For UK, the coordinate system used is OSGB36 (Ordnance Survey Great Britain 1936). For GPS, a global satellite system, the coordinate system is WGS84 (World Geographic Survey 1984). A latitude and longitude read from an OS map, based on OSGB36, could be a few hundred metres different from one read from a GPS receiver set to the WGS84 coordinate system. A significant error for anyone on foot or driving. A webpage to calculate transformations between these coordinate systems is provided by the OS. The above 200m square of map has been reproduced from the OS website to illustrate two points with the same latitude and longitude but in two different coordinate systems.

Errors can occur in transferring or ‘projecting’ locations from a spherical surface (the Earth) on to a two-dimensional plan (the map); however, this is moving beyond the scope of this chapter. An excellent introduction to coordinate systems and map projections has been produced for those wishing to take the topic further.

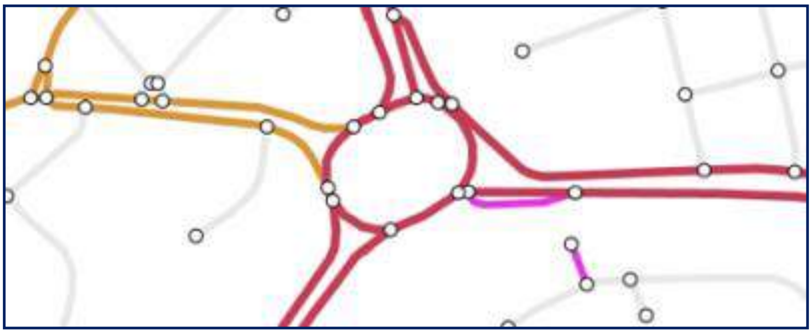
Digital Maps

The first significant move away from using paper or film as the basis of a map display occurred in the 1980s with the capture of electronically scanned images of a paper map stored on video discs: typically the size of dinner plates. Reading these images from a disc player, or bank of disc players, allowed the computer controlling the players to superimpose simple overlays on the map display, for example, to aid planning and logistics processes. Manipulation of the maps, such as pan and zoom, was limited by the original selection of the scanned maps. Although rather basic by today’s standards, this move to electronic mapping also marked the start of the now widespread, GIS (Geographic Information System) market: more on this later.

When we use digital mapping today, we are accessing a database comprising segments of the road network (links) and intersection points of these links (nodes). A digital data set of the UK typically comprises 6 million links and nodes. Associated with each link is a range of attributes that include the type of road (motorway, A-road etc), road name, number, locality name etc and a unique identifier. If the data set is to be used for route planning, then additional data is required (sometimes referred to as Drive Restriction Information – DRI) which identifies one-way streets, banned turns etc. In practice, when roads are surveyed to collect the DRI data, a lot of additional information may be gathered, such as height, width, weight restrictions, speed limits, images of roadside signs, lane markings and so on. If the data set is to be used for in-vehicle navigation or logistics, then such information can add to the saleability of the end product. If traffic information is to be used in conjunction with the map data, then the unique link identifier will enable a cross reference to the location codes used with the traffic information. Again, more on traffic information and location codes is provided in the chapter on Reducing Usage.

Two global organisations that are major gatherers and resellers of digital map data are Navteq and Tom Tom (formerly Tele Atlas): they frequently work in collaboration with national mapping agencies such as the Ordnance Survey in UK.

An overview of two data sets provided by the OS, Asset Manager and Traffic Manager, can be found at this link. The sample shown here is from the OS MasterMap® data set and shows typical spatial information available in that data set.



Conclusion

Two primary markets exist for digital mapping data; these are the GIS and vehicle navigation markets.

Users of Geographic Information Systems (GIS) are typically central and local government, the utilities – gas, electricity, water, telecommunications – the emergency services and vehicle fleet operators. Suppliers such as ESRI, MapInfo, Intergraph and many others will typically use digital mapping data to develop a GIS for their end customer.

The proliferation of portable, in-vehicle satellite navigation devices and the addition of mapping to smart phones and tablets has produced a surge in the requirement for digital map data. In the UK, the first area to be digitally mapped for use in satellite navigation systems was within the M25 motorway (1994). Coverage rapidly spread to other major cities and within a few years to the entire UK road network. A similar situation occurred in other Western European countries and today a portable satnav covering all roads in Western Europe can be purchased for less than £100.

Picture Captions and Credits

Page 31: John Speed map of Cardiff, University of Wales
http://upload.wikimedia.org/wikipedia/commons/5/58/John_Speed%27s_map_of_Cardiff_1610.jpg
Page 32: John Ogilby map, Lands End to London
http://www.geog.port.ac.uk/webmap/hantsmap/hantsmap/ogilby/og25smaf.htm
Page 32: John Ogilby atlas at Scotney Castle, Copyright © NTPL/ John Hammond
Page 32: The error introduced by inappropriate choice of coordinate system
http://www.ordnancesurvey.co.uk/docs/support/guide-coordinate-systems-great-britain.pdf
Page 34: Ordnance Survey OS MasterMap® sample
http://www.ordnancesurvey.co.uk/oswebsite/products/os-mastermap/itn-layer/index.html

Lost without your satnav?

In 2012, over 1000 visitors to the Cotswold Motoring Museum and Toy Collection voted the satnav as the 10th item in the “History of Motoring in 10 Objects” exhibition. Those of us who regularly use a satnav soon become dependent on the device. This chapter provides a brief look at what lies behind that colourful screen and those concise instructions.

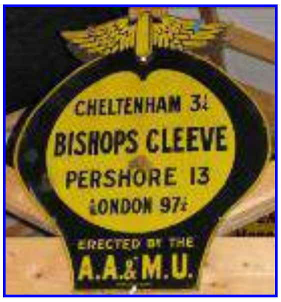
The option of adding a satellite navigation device to your vehicle first became viable in the UK in the early 1990s. It was then that satellite constellations were becoming sufficiently populated to provide 24-hour coverage and significant areas of the UK, initially within the M25, were covered by digital mapping. Before looking at the benefits that a modern-day satnav can bring, a brief look at how the essential parts of a satnav system came about is explored.

Life (long) before satnav

In July 1714, Parliament passed the Longitude Act. The purpose of this act was to provide a safe means of determining the position of a ship at sea and was in response to a tragic loss of over 2000 lives off the Scilly Isles in 1707. The financial reward offered by the act produced great advances in both astronomical navigation and in precision timekeepers.

Some 10,000 years earlier, as Britain warmed and the glaciers retreated northwards, our hunter-gatherer ancestors must have faced similar, life-threatening issues around knowing their location on land. With their only reward being the prospect of their own survival, they would have measured time in terms of days walked and orientation with reference to the sun, moon and stars. A successful return to hunting grounds, following animal tracks between places of human shelter and animal grazing, would be an adequate reward for their navigational skills.

By comparison, becoming lost on a day out with the family to a safari park may seem of little consequence but, based on a survey by the RAC Foundation, becoming lost, along with congestion and various traits of driver behaviour, is rated as one of the most stressful aspects of driving today.



Directional guidance, through roadside signs conveying distance and direction, has been in existence since the time of the Roman Empire. Marble shafts about 2m high and at 1 mile spacing were used as markers or milestones along Roman roads. In 1698, an English law required each parish to place guideposts at its crossroads pointing out directions to adjacent villages and towns. The development of toll roads and the postal services in the 18th century led to great improvements in signposting with some signs even including travel times to the next location[12].

So, nothing is completely new – modern variable message signs around the motorway and trunk road network frequently provide an indication of traffic congestion by telling drivers what they really want to know; namely the time, as well as the distance, to their destination. Time of arrival at our chosen destination and distance to go are also typically displayed on the screen of a modern in-car satellite navigation (satnav) device.

The 'Points of Interest' databases on the portable satnav or the route-planning website are providing a similar function to those marble, Roman marker posts and parish guideposts, pointing out the nearest inn (hotel), blacksmith (garage) or fuel.

This chapter summarises some of the ways in which technology, from digital maps to satellite location, helps us to understand our location and guide us along our intended route and how dynamic information on road traffic conditions can be used to make our journeys less stressful and more environmentally friendly.

How does satnav work?
In addition to routing software and satnav hardware, such as the touch-screen, there are two essential requirements for a portable or vehicle-based satnav system to operate. These are:

- A digital map database covering the area in which the car is travelling
- A means of determining the location of the car

Digital maps
The principles of this topic have been covered in the earlier chapter on Mapping. The concept of the digital map comprising a database of links and nodes each with associated attributes such as one-way street, speed limit (impedance), banned turns, no entry and so on is essential to the operation of the satnav device. The concept of the unique 'link identifier' is a requirement of the satnav's digital map database if dynamic traffic information is to be incorporated in a route calculation. This is because congestion on a link in the database will be quantified as an increase in the link impedance and may result in a route calculation offering a longer distance but reduced journey time. Today, most satnav products offered for sale in the UK will include, as a minimum a database of the UK and the Republic of Ireland, in many cases all of Western Europe will be included and in some cases North America as well.

[12] "Ways of the World – A History of the World's Roads and of the Vehicles That Used Them" by M G Lay

Location Technology

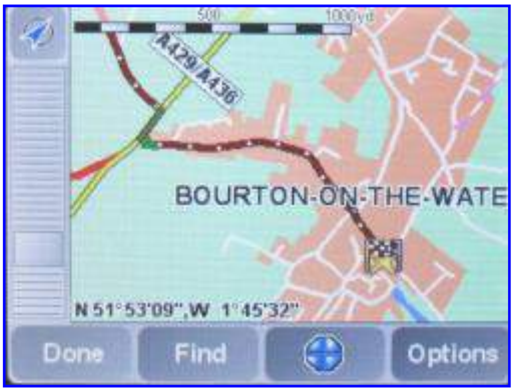
Terrestrial radio frequency (RF) location systems, with varying levels of coverage, precision and configuration have been in existence since World War II and today's mobile phone location technology operates on exactly the same principles. Satellite location systems for wildlife tracking and safety applications have been operational since the 1970s. Today, the most common satellite system configuration is one in which the satellites transmit a RF signal that is picked up by a portable receiver. Using the time difference of arrival of signals from three or more satellites, an unambiguous location of the receiver can be determined. If four satellites or more are 'in view' of the receiver then height above sea-level can also be found. The system of greatest relevance to the motorist (plus walker, cyclist, explorer, surveyor, mariner, aviator, etc) is the Global Positioning System (GPS).

The GPS network is a US Department of Defence (DoD) system designed for military use. However, from the outset, it was expected that the greatest number of users would be civilian. The network comprises 24 active satellites in orbits approximately 20,000km above Earth. Because this is lower than the 36,000km geostationary orbit, used by the majority of communication satellites, the period of each GPS satellite's orbit is around 12 hours. This means that a receiver on Earth 'sees' a continuously varying set of satellites from which it calculates its position. Each satellite transmits data about its own position in orbit. Hence, by measuring the time at which the signal is received and knowing the satellite position, a receiver can calculate its range from the satellite. Receivers are multi-channel; this means that, for example, a 6-channel receiver can receive signals from up to six satellites simultaneously. So, in this example, up to six simultaneous range measurements from up to six satellites can be used to uniquely calculate the location of the receiver. Each GPS satellite carries a very accurate atomic clock and these clocks are synchronised throughout the network. The receiver, by contrast, has a relatively cheap (and hence inaccurate) clock so rather than measuring the absolute time of arrival of a signal from each satellite, it measures the Time Difference Of Arrival (TDOA) between the signals. All locations with an equal TDOA between two satellites lie on a hyperbola. Using a second pair of satellites, all points of equal TDOA lie on another hyperbola. The point where these two hyperbolae intersect is the location of the receiver. This link provides more background to TDOA and hyperbolic navigation for those keen to read more.

There are many sources available on the internet to find a description of GPS. One thorough description is provided by Trimble; a manufacturer of GPS receiving equipment since the early 1980s.

The satnav

We have now introduced the two key components of a satnav device for the motorist: digital mapping and the GPS satellite system. Portable satellite navigation devices, such as those manufactured by Tom Tom, Garmin, Navigon, etc embody a GPS receiver, digital map database for the area covered by the product and various 'points-of-interest' databases, with the user interface via a colour touch-screen. Route calculation between user-defined points is performed by routing software. Some satnavs include a component that senses changes in



heading of the vehicle. The GPS receiver determines the location of the vehicle to within 10 to 15 metres and the track produced as the vehicle starts to move is matched with the road map data for the area. Map data, such as the OS MasterMap® product mentioned above, have an accuracy of carriageway centre line to within 2m and it is this 'map-matched' location that is displayed on the satnav screen. Where a heading sensor is incorporated, this is able to continue to update the display when satellite coverage is lost, for example in a tunnel, under an extensive tree canopy or in urban, high-rise areas.

Whilst the majority of satnav equipment is portable, most vehicle manufacturers provide satnav as an option with a new vehicle. This tighter integration with the car data networks can provide some performance advantages. In addition to the heading sensor, speed information can be used to assist in updating the car's position when satellite signals are temporarily lost. Also, during manufacture, the GPS antenna can be integrated with radio and mobile phone antennas on an unobstructed part of the car body giving the best possible GPS reception. Typically, the navigation display touch-screen would also act as the interface with other vehicle functions such as the audio system, climate control and parking sensors.

The user interface on most satnav systems, portable or built-in, is not always the easiest for a driver to master; especially if the car or system is unfamiliar. Recognising this limitation, as well as the difficulty of finding space in the passenger compartment to accommodate a satnav screen, Smartnav started life as a system where the minimum user interface was a single button (a screen is now a standard feature) and the route calculation is performed in a control centre. Requesting guidance initiates a call to a control centre and the driver describes their destination to the call handler. The route is downloaded to the car and replayed as a set of audio and visual prompts as the journey progresses. Apart from the simple user interface, this configuration allows the control centre to always use the latest maps and to include the latest traffic information in the route calculation. Changes in the traffic conditions during the journey that may alter the recommended route are downloaded to the car as appropriate.

Traffic Information - summary

The gathering, distribution and use of traffic information are covered in the Reducing Usage chapter. The following brief summary is specifically in the context of satnav.

One widely used and standardised method of coding traffic congestion data into a form that is useful for an end user has been through the development of RDS-TMC: Radio Data System-Traffic Message Channel. RDS-TMC is a defined coding process for an event (ie congestion and its cause; ice, snow, accident, etc), expected duration and its location. Assuming the originator of the traffic message and the end user (ie the driver), use the same coding and decoding process, the RDS-TMC broadcast just needs to transmit a simple code to convey details of a traffic event. A radio receiver in the satnav de-codes the incoming data in order to reconstruct the original message. For this to work reliably the RDS-TMC receiver must always have an up-to-date copy of the code database. In a satnav, this would be on the memory medium (CD, DVD, RAM, HDD) which stores the map database. One big advantage of RDS-TMC is that it is language independent. UK drivers travelling through mainland Europe can continue to receive traffic information in English from RDS-TMC broadcasts in the countries through which they are travelling. The traffic 'event' may be described in text on a vehicle display or, used to update the satnav's recommended route.

The information is delivered to the satnav device via FM or digital broadcast or via a mobile phone network. The effect of congestion on map database links along the planned route is to increase the impedance of those links so the satnav will conclude that a faster journey is possible through a change of route and, either automatically or with a prompt from the driver, will calculate a new route.

The future

With ever-advancing technology in space, in the car and in the satnav itself, one thing is certain; over the next decade major changes to today's satnav will occur.

In space

Even in this brief review, we should note that GPS will not always be the only option for a global navigation satellite system. When GPS was first declared operational, the location accuracy was deliberately degraded by a feature known as Selective Availability (SA) that resulted in an accuracy of around 100m. The US administration under President Clinton, switched off SA (it has remained off ever since) and accuracy for the civilian user is now around 10m to 15m. Unease at the ownership and control of such a strategic asset as GPS by the US DoD and an anticipation of the technological and commercial spin-off from developing and running a European system has resulted in the EU development of Galileo. This will be a 30 satellite constellation in similar orbits to GPS. Following two 'proof-of-concept' satellites, a further two operational satellites were launched in 2011 with two more in 2012. It is likely that, in 10 years time, the majority of portable satnavs that we use in our cars and phones will use either Galileo or a combination of both GPS and Galileo.

The former Soviet system, Glonass, is being refreshed and China and India have both started to implement regional satellite navigation systems: at least one of which (the Chinese BeiDou-2) will to be expanded to global coverage. By the time Galileo reaches full operational capability by 2020, competition from other systems could be a real threat to its commercial future.

In the car

In the provision of driver aids to navigation and congestion avoidance, the dependence of in-car equipment on an external satellite (and terrestrial) infrastructure has been a recurring theme. One significant addition to that infrastructure over the next decade is likely to be car-to-car communication. A European consortium has been established to develop a standard for inter-vehicle and vehicle to roadside communications. The car-to-car communication will be based on current Wi-Fi standards with a maximum single hop range of 500m to 1000m. Applications will allow advance warning of hazards to be rapidly communicated to traffic near an incident. This may simply be an alert that a nearby vehicle has suddenly reduced speed or, as in this picture, avoidance of a potential delay. The two cars at the left of the picture have received a warning of an incident involving the white bus to the right of the picture. This prompts the satnav in both of the cars to re-route the driver along the green route, around the incident, rather than their originally planned red route.

Legislation will be another force for change. The European Commission has produced a proposal to encourage EU member states to move faster on rolling out the infrastructure for Emergency Call (E-Call). E-Call enables vehicles involved in road traffic accidents to send out an automated alert that is received and recognised by emergency services across the continent. Using GPS or Galileo for location, the alert would be initiated manually, by impact sensors in the vehicle or by deployment of the airbag, and the ensuing data transmission from the vehicle, via an embedded mobile phone module, would contain information about the vehicle itself eg Vehicle Identification Number (VIN), as well as location details. Once it becomes the norm for a vehicle to contain a GPS or Galileo receiver, then the opportunity arises for vehicle manufacturers or third parties to offer other driver services such as routing, traffic information, remote diagnostics or weather reports. Also, under those circumstances, implementation of traffic management schemes, possibly including road-pricing, would become technically and economically feasible.

Increasingly drivers, especially newly qualified drivers, are finding the cost of insuring their car is becoming a barrier to independent motoring. One premium-reducing measure, offered by some insurance companies, entails fitting a 'black box'. Vehicle parameters (speed, acceleration, cornering, braking etc), vehicle location and time of day are inputs to the calculation of the insurance premium giving the driver direct, personal control over their premium and helping it to remain affordable.

The satnav device

The stand-alone, dedicated satnav is already in fierce competition with alternative, more versatile hardware. As early as 2009, this competition was foreseen. One market research organisation predicted that:

" ….. *by 2014, usage of navigation-enabled smart-phones will rise to 305 million units, exceeding the 128 million PNDs* [Portable Navigation Devices] *that will be around by then*".

In fact by the start of 2014, there were 1.4 billion Smartphones in use worldwide and 47% of drivers have downloaded a mapping (not necessarily *navigation*) application. Meanwhile, the number of PNDs, worldwide, is estimated to plateau at around 51 million by 2015. It is clear where this trend is heading. The increasing inclusion of GPS receivers in smartphones, improved displays and battery life and the availability of on-board navigation applications from such well-known names as Tom Tom and Garmin that run on Apple, Android and Windows smartphones explain the trend.

The arrival in 2013 of the 'web-enabled' car may mean that even the smart-phone will no longer be the preferred option for viewing navigation guidance when in the car. A short-range radio link, for example Bluetooth, between the smart phone and the browser application sitting behind the in-car, colour touch screen is likely to provide a safer, more practical user interface. The image shown here is of the MyFord Touch: displayed at the 2010 Consumer Electronics Show in Las Vegas. At the 2014 CES, Apple and Google were demonstrating the in-car interaction with the phone for navigation and convenience controls (such as climate control and audio) through their work with Audi, Hyundai and other manufacturers. Finally, for this brief glimpse into the future, Ford, Hyundai and Mercedes-Benz are working with Google on delivering navigation guidance to Google Glass: *wearable* satnav may be the future?

Conclusion

Just as some drivers find using maps to be difficult, so some of us are not naturally 'at home' with devices such as satnav. However, it may not be too long before the satnav unit becomes as ubiquitous as the car radio [13] and offers congestion-free directions in response to spoken destinations such as "School", "Tesco", "Motor Museum", "Aunt Jane", etc. At this point the technology is likely to benefit the majority of our car journeys and we would truly become lost without our satnav.

(Or, you could encourage your 2-year old rear seat navigator!)

[13] and this may be assisted by forthcoming EU legislation on Emergency-Call (E-Call) and the increased uptake of Pay As You Drive, 'black box' insurance

Picture Captions and Credits

Page 35: TomTom portable satnav
Page 35: Sign at the Cotswold Motoring Museum, Bourton-on-the-water
Page 36: Variable Message Sign
http://webarchive.nationalarchives.gov.uk/20120801131740/http:/www.highways.gov.uk/knowledge/334.aspx
Page 36: Signs at the Cotswold Motoring Museum, Bourton-on-the-Water
Page 37: GPS satellite image © USAF Research Laboratory
Page 38: TomTom portable satnav
Page 38: Original Equipment Manufacture satnav in Jaguar X-Type
Page 38: Smartnav activation button © Trafficmaster
Page 39: Galileo image © European Space Agency
Page 40: Car to Car graphic from: http://www.car-to-car.org/
Page 41: Nokia Lumia Smartphone with Windows Phone 8 operating system running a satnav application
Page 41: The Ford MyTouch System

Introduction

Consider the definition of a 'responsible' car owner. What ideas does this conjure up? Driving at an appropriate speed for the road conditions? Complying with mandatory signage? Showing courtesy to other road users? Not 'tailgating'? Not hogging the centre lane of a 3-lane carriageway? Probably all these things. There are however, other aspects of motoring where 'responsible' choices need to be made. In selecting our car from the showroom or the used car lot there are choices, some of which have environmental as well as budgetary impact. For example, our choice of fuel – petrol, diesel, gas, electric - the fuel consumption and hence levels of pollutants and CO_2 emissions of our new or a used car with, for a new car, the one-off environmental impact associated with manufacture and shipping. These may all seem like secondary considerations in comparison with the cost, performance, seating and load capacity, aesthetics and comfort but they are not always mutually incompatible.

Statistics from the Society of Motor Manufacturers and Traders show a new car trend towards smaller, lower emission vehicles. To some extent, this may be driven by economic factors but it is a fortunate coincidence that this also has the effect of reducing CO_2 emissions from the domestic transport sector.

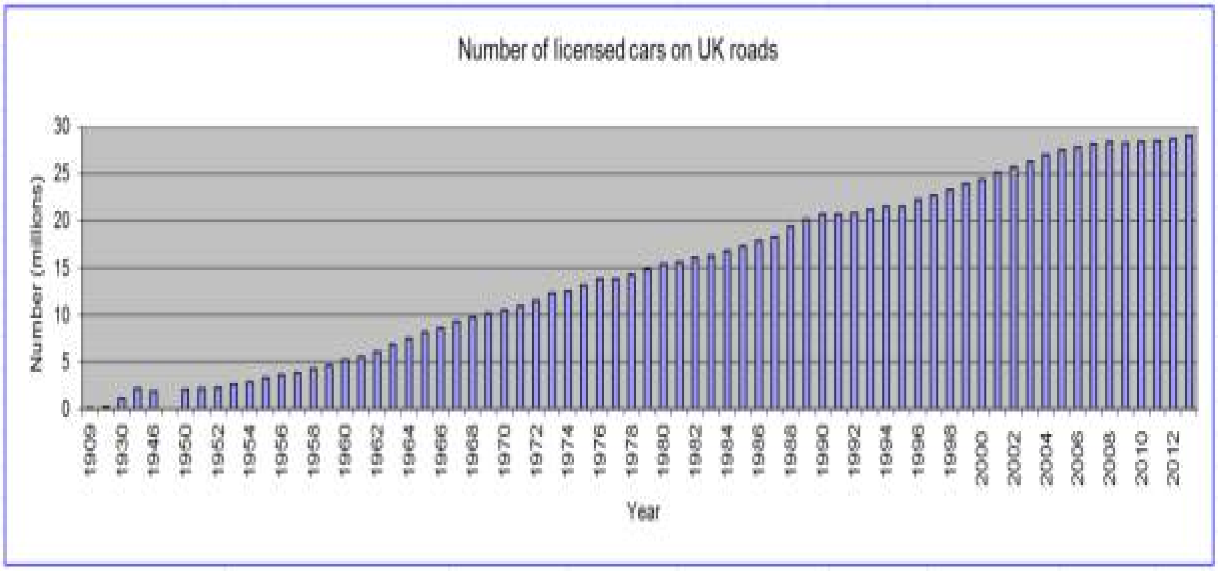
This chapter on Responsibility of Ownership considers the average life of a car and how it can be increased. Drawing on conclusions from the chapter on Air Pollution[14], the chapter also summarises the environmental implications of replacing an ageing car with a newer, lower emission car and concludes with hints, gathered from a number of recognised expert sources, on keeping our cars running efficiently and reliably.

The global environmental impact of motoring manifests itself in many ways and such a broad topic can be addressed from many perspectives. This chapter is largely constrained to UK national trends in car ownership.

Average age of cars

In June 1994, there were 21.03 million cars on the UK roads and the average age was 6.7 years. Over nineteen years later, by the end of 2013, there were 29.14 million cars on the roads and the average age was 7.9 years. In other words, the overall effect of improvements in vehicle manufacturing and servicing, economic factors such as the cost of insurance, vehicle purchase price, the second-hand market prices, maintenance, cost of fuel and changes in taxation have neither greatly changed the age mix of cars on our roads nor reversed the incessant increase in numbers. Against this background, the 2009/10 government car scrappage scheme replaced 400,000 cars of over 10-years old on UK roads. Although

[14] From Part One of this book - Environmental



the new cars met the latest emission standards and should be more reliable than those they replace, the environmental impact of the scheme was not universally supported.

Environmental effects of production, use and scrappage

One of the earliest attempts to quantify the whole-life carbon footprint of a car was undertaken by the Lappeenranta University of Technology, Finland in 2006 when they addressed the carbon dioxide (CO_2) emissions for an average 2004 European light vehicle[15] over its life.

The chapter on Air Pollution showed that the CO_2 associated with the production of a new vehicle represents a significant proportion of its lifetime release of CO_2. Depending on the source of raw materials for the car, the transportation of those raw materials, the transportation of the completed car, the age of the production process, sources of energy used in production and the allowance for end-of-life scrappage, then the incremental lifetime CO_2, over and above that associated with simply driving the car, has been estimated to range from just 15% to over 55%.

ERTICO[16] state that "Fuel consumption during vehicle operation ….. contributes around 60% of the life-cycle greenhouse gas emissions of a passenger car": this leaves 40% as the production and scrappage overhead.

A further rule of thumb links the value of the car to its carbon footprint through an equivalence of 720kg of CO_2 or equivalent for every £1000 value of the car, giving a £24,000 car a 17 tonne CO_2 overhead in the production and scrappage process.

For electric vehicles, a Low Carbon Vehicle Partnership report provides a good source of reference on the CO_2 contribution during production. Ozzie Zehner, a University of California professor, writing of "Green Illusions" contributes a more controversial opinion but again, much depends upon the assumptions made. For electric cars, with batteries re-charged from the UK grid with its current mix of coal, oil, gas, nuclear and renewables, the *lifetime* CO_2 will most likely be less than for the equivalent internal combustion engine powered car but the percentage of CO_2 produced during manufacture is likely to be higher.

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[15] Assumptions: kerb weight 1290kg, travelling 8440 miles per year, fuel consumption of 38.7mpg. Data used is an average for new vehicles sold in 2004 and is based on >14 million cars and 1.8 million vans and pick-ups
[16] An EU organisation devoted to Intelligent Transport Systems

A similar conclusion is reached in the Low Carbon Vehicle Partnership report that observes, with the trend to hybrid electric, plug-in hybrid electric and pure electric vehicles:

"The vehicle's embedded CO_2 from production and disposal is becoming a greater portion of the life cycle CO_2 emissions"

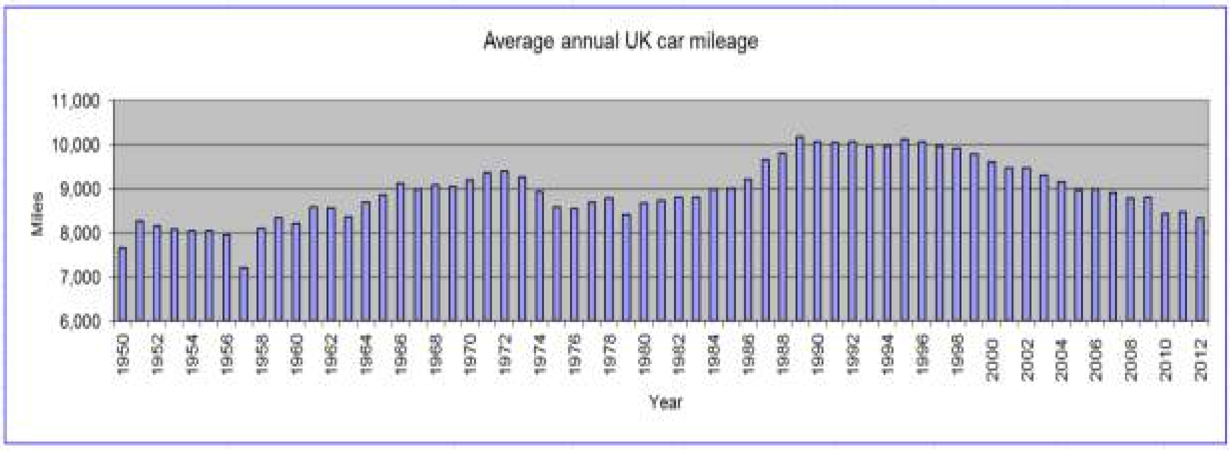
Samples of manufacturer's figures support this conclusion. Comparing a VW Passat Estate B6 (diesel 2 litre, un-laden weight 1510kg) with a Toyota Prius Hatchback (1.8 litre VVTi V, unladen weight 1420kg), shows 19%, 80% and 1% respectively as production, use and scrappage figures for the Passat and 26%, 71% and 3% for the Prius over a 150,000 km lifetime.

Average annual car mileage

In considering the environmental impact of car ownership on CO_2 emissions (and indeed all vehicle emissions[17]), it is not just the number of cars on the road and the average CO_2 produced per car, but also usage that affects the total emissions impact.

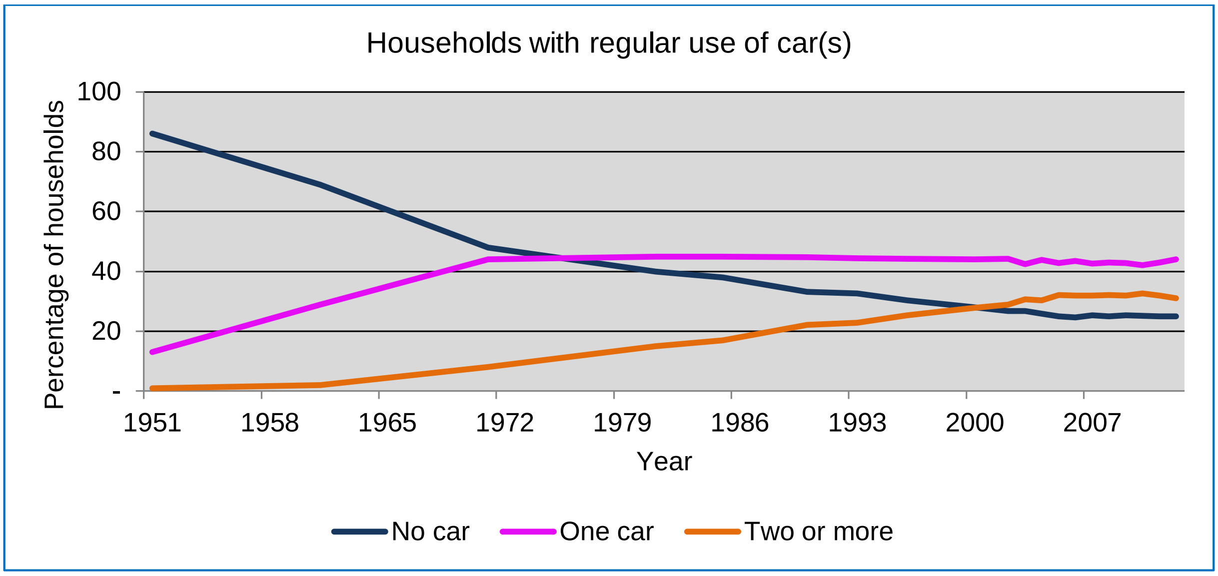
Whilst the *number* of licensed cars on UK roads has increased, almost without exception, year by year, the average *usage* has fluctuated. Using data from the Department for Transport, annual averages can be calculated from the annual total mileage for all cars and the number of licensed cars. The results from 1950 to 2012 are shown below.

Interestingly, there appears to have been a decline since the mid-1990s. However, the pattern of car ownership has also changed over that period. Again using Department for Transport figures, the proportion of UK households owning one car reached around 45% in late 1960s and has remained at that level ever since. However, the proportion of households with access to two or more cars has increased steadily since the same time and now accounts for 33% of UK households.

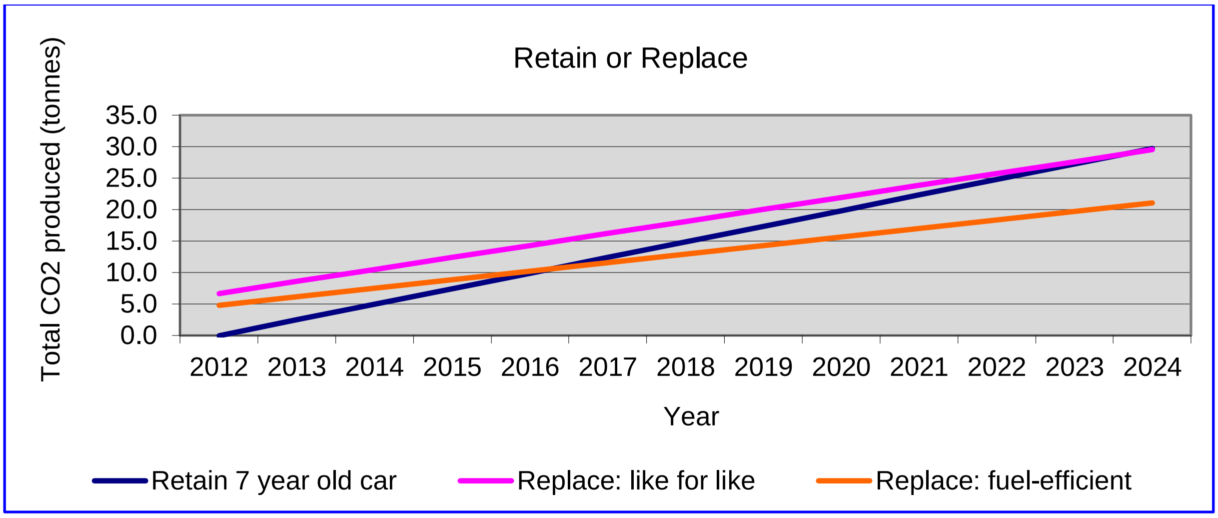


Multiple car ownership may explain the decrease in average annual mileage per car as households spread their journeys between more than one car.

[17] See chapter on Air Pollution



Replace or retain
An illustration of the effect of replacing a 7-year old car with an *equivalent* modern car or a modern, fuel-efficient 2012 car was presented in the Air Pollution chapter. For convenience, the graphic is reproduced here.



This analysis showed that going for a like-for-like replacement that was 7 years newer, it would take over 10 years to justify the decision just in terms of the CO_2 released. On the other hand, a small, efficient modern car replacing one of average emissions performance from 7 years ago, covering high annual mileage, would provide an emissions benefit within the following few years.

But is this the whole story? Availability of raw materials is becoming an increasingly significant factor, especially as the value of electronic components in a modern car continues to increase.

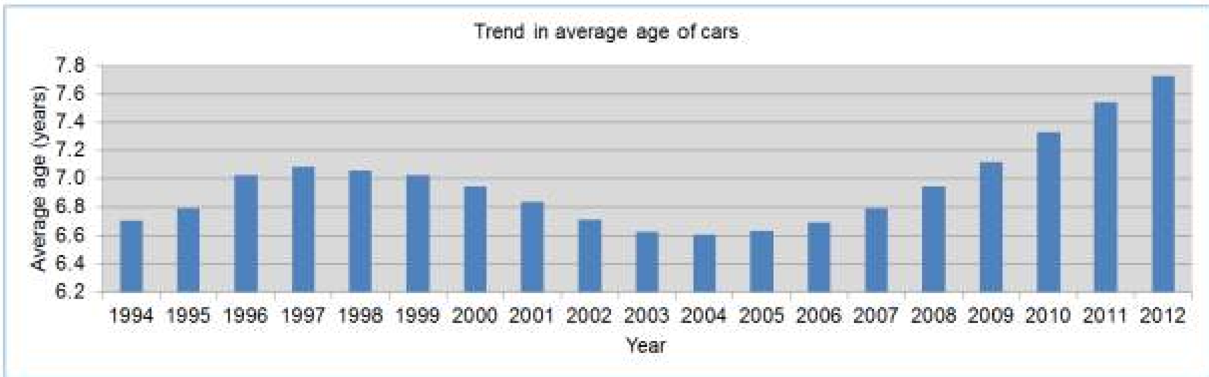
A recent ACEA report draws attention to the future limited availability of lithium if the projected global increase in electric vehicle numbers materialises. Lithium is a key battery component of modern batteries in the consumer electronics, power generation and automotive sectors.

Powerful magnets used in the traction motors of electric vehicles, make use of neodymium, one of the 'rare-earth' elements in the periodic table. Currently 97% of rare earth supply is within China which presents a possible geopolitical issue around availability. A survey by PWC revealed that 73% of automotive manufacturers "perceived mineral and metal scarcity as a pressing issue for the company".

Where retaining a car is not a possibility as it really has reached the end of its economic life, then reuse and recycling are areas where the automotive industry has developed considerable expertise. Within Europe, the End of Life Vehicle Directive was adopted in 2000 and the EU are currently looking to increase target percentages for 2015. These new targets would see 85% of material recycled. One estimate for the US industry is already at 86% of recycled material.

Age mix

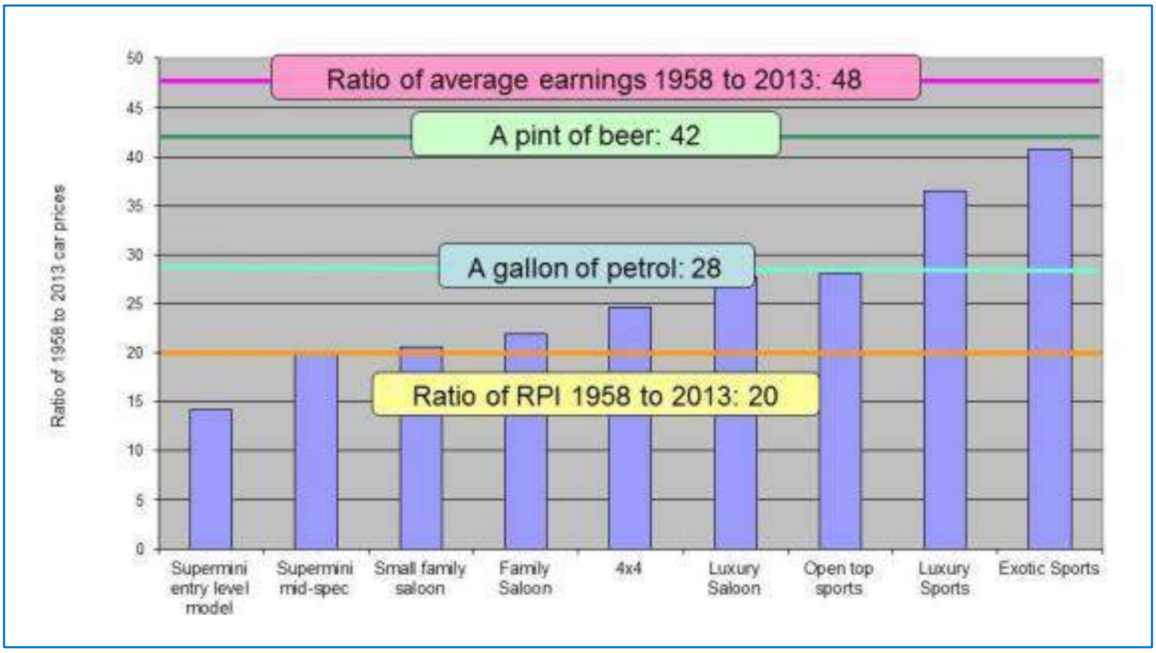
During the period 1994 to the present, data on the age of cars on the road is available from the Department for Transport website. The graph below shows that in the mid-1990s, and again since 2004, there has been an increase in the average age of registered cars: including the period of the scrappage scheme. This coincides with an increase in multiple car ownership within households (hence lower mileage per car) and improvements in build quality for the low and mid-range makes within the mass car market.



Cost of ownership

A 17-year old, newly qualified driver today faces a likely insurance premium on their new car, which may be significantly more than the cost of the car. The cost of fuel seems to move just one way (upwards!) and garage repair bills usually run into at least three figures. We think car ownership is expensive, yet, as we have seen, the number of cars on the road increases year after year. How do the costs of ownership today compare with those of over 50 years ago and how do they compare with the average family income?

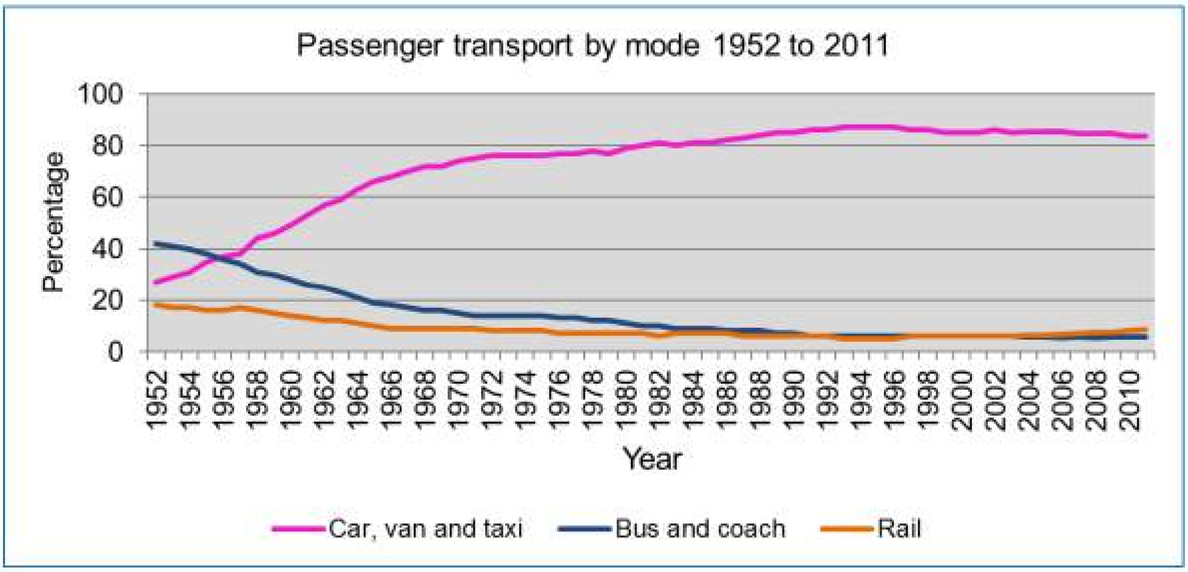
In 1958, average gross earnings were £514. Average gross earnings in 2013 (based on male and female, full time employment) are £24,866 ie an increase of 48 times. Over the same period, the Retail Price Index (RPI) has increased by 20 times. Comparing car prices with our increased purchasing power and increased RPI over this time requires a comparison of roughly equivalent types of car from 1958 and 2013. The specific contents of each generic category of car are shown in the Annex to this chapter and the results are displayed graphically in the chart below. For comparison, the relative increase in the cost of a pint of beer (42 times) and a gallon of petrol (28 times) over the 55 year period are also shown.



Whilst this chart does not include other costs such as insurance and maintenance, it is clear, that in terms of purchasing a new car, virtually all categories of car will take a lower proportion of our hard-earned cash than they would have done in 1958.

The public transport alternative

Whilst this chapter is predominantly about the implications of car ownership since the dawn of motoring history, it is worth a brief reminder that cars are not the only transport option available to travellers. We may read of new railway rolling stock and new bus and coach services but, whether for reasons of convenience, economics or simply lack of alternatives, as the following Department of Transport figures show, the car (van or taxi) is still the dominant mode of transport for most of us. [NB: In the chart below, percentage is the percentage of miles travelled].



Classic cars

Although the average age of cars on UK roads maybe just under 8 years, there are groups of vehicles that are never likely to go near the scrap yard. These are 'classic' cars. The definition of an historic vehicle, from the point of view of Vehicle Exercise Duty (VED) exemption, used to mean any vehicle manufactured before the 1st January 1973 but from April 2014, the critical date became 1st January 1974 and rolling out by a year at the beginning of every April. The term 'classic' however is widely applied to a broader range of cars. Currently, there are over 307,000 vehicles exempt from VED. Keeping older cars on the road serves an historical purpose but also, as illustrated above, an environmental purpose. Classic cars, by definition are long-life vehicles, which tend to be well maintained and cover low annual mileages. Hence, from an environmental point of view, there is a strong argument for maintaining a car well beyond the average life of 7.9 years.

The economics of modern vehicle ownership and maintenance however, do not encourage this approach.

Because of the strong base of owners clubs catering for specific marques, it is easier than may be imagined for an individual to own and run a classic car from the 1950s, 60s and 70s. The Federation of British Historic Vehicle Clubs (FBHVC) has almost 500 affiliated clubs and is a good starting point to search for a relevant club. Parts availability for popular vehicles is generally good. For the Herald-based Triumphs ie Herald, Vitesse, Spitfire and GT6, (part of the Triumph model range covered by the TSSC) most parts, including body panels, are widely available. Some clubs, such as the Stag Owners Club are active in the remanufacture of tooling and spare parts. Technical advice, detailed car specifications and Buyers Guide are all features of the MG Owners Club and the Octagon Car Club. Insurance for the popular classics is generally affordable and given the low annual mileages typical of classic cars, can often cost much less than a modern vehicle[18].

DIY servicing

A number of factors have caused the reduction in DIY servicing of modern cars. To adjust engine performance, it was straightforward on mainstream cars up to the mid-1980s to balance the fuel / air mixture at the carburettor(s), to set valve tappets, spark plug gaps and ignition timing. These functions effectively still take place in a modern vehicle but are now performed by software within Electronic Control Units (ECUs) that regulate mixture and timing according to the output of sensors monitoring air and coolant temperatures, throttle and crank positions, exhaust gas properties and other parameters. Not an easy option for DIY.

[18] The FBHVC estimates the annual benefit to the UK economy from Classic Car ownership to be worth £4.3billion

Some DIY tasks have been designed out of a modern vehicle. Lubrication is generally confined to engine oil changes at intervals up to 20,000 miles and improved materials and tighter manufacturing tolerances have largely removed the need for the grease gun.

Yet some tasks, formerly widely undertaken by the DIY enthusiast, such as replacing worn brake linings, coolant hoses or serpentine belts ('fan' belts) still tend to be left to garage servicing. Some are more complex (such as the rather extreme example shown here) than they would have been on a 1970s car but maybe this trend also reflects the current economics of car ownership, or changing driver demographics or perhaps it is related to a reduced confidence and familiarity with the cars that we drive?

Daily and weekly tasks that a car driver is expected to undertake still remain. Car Mechanics magazine from December 1962 contains 50 tips to help "Cut Costs". Some of these reflect driver behaviour and would still be sensible today. For example, weekly checking of tyre pressures and adjusting pressures to match the load being carried, avoiding scuffing tyres and light use of the throttle. Other examples such as replacing "sagging valve springs" and "adjusting toe-in" are tasks only for today's enthusiast. Also mentioned in the same edition of the magazine was an article on "Preparing your car for winter": still an important task. Checking battery condition, the strength of coolant / antifreeze mixture, screen washer fluid are all good advice but nowadays we take for granted the fact that our modern vehicles will not need a rubber glove " …. cut to fit the distributor to keep out the damp" - even assuming we could find a distributor!

Increasing the life of our vehicles

So are there things we can do to keep our cars running reliably for longer, to extend their roadworthy life and reduce the environmental impact of car ownership? Some key messages on Maintenance, Reliability and Fuel Economy, taken from the websites of five organisations with, literally, centuries of experience between them (AA, Britannia Rescue, Green Flag, Institute of Advanced Motorists and RAC) have been merged into the following sections.

Tyres

- Correct tyre pressures are essential to ensure maximum tyre life, good vehicle handling and good fuel economy. Over time, tyres will naturally lose some air. Check tyre pressures regularly and before long journeys. Under-inflated tyres create more rolling resistance and so use more fuel. Tyres under-inflated by 7 psi (0.5 bar) waste half a gallon of fuel per tank. (They are also illegal in the UK). Refer to the handbook, as pressures will normally have to be increased for heavier loads.
- Examine tyres for signs of uneven wear and for any cuts or small nicks in the sides of the tyres. Uneven wear may be an indication of suspension or steering alignment problems.

- Check the tread depth - a minimum of 1.6mm over at least three-quarters of the tread width is the current legal requirement, but they should be replaced long before this depth is reached.
- Don't forget the spare wheel.

Maintenance and reliability tips

- Have the car serviced regularly (according to the manufacturer's schedule) to maintain engine efficiency and optimum fuel consumption.
- Check the engine oil and coolant levels regularly and before long journeys.
- Ensure the correct specification of engine oil is used to top up the level (refer to the handbook).
- Most modern cars have plastic coolant reservoirs to help check the level. In an older car, when the engine is cold, remove the radiator cap to check the coolant level. Top up as necessary, and include antifreeze in the mixture, in winter and summer: it helps protect against overheating, as well as frost damage. It is important that the correct strength antifreeze and water mix is used.
- Check and top up the windscreen washer bottle, and include an additive to tackle grease and squashed flies in summer or icy conditions in winter. It is an offence to drive with an empty windscreen washer.
- If the car does not have a sealed-for-life battery, check the electrolyte level in the cells and top up with distilled water as necessary.
- Be alert for any sign of change. If, for example, the engine seems to be running a little less smoothly, the brakes seem less positive than usual, or the steering feels vaguely odd, don't dismiss it as imagination. Trust your instinct, and investigate the reason, or seek advice.
- One in 5 cars over 3 years old has faulty lights and would fail a MoT. So, before a long journey, check and clean both the headlights and indicator clusters.
- If hot water is poured onto an icy windscreen it may shatter. So, always carry a can of de-icer and a scraper. The de-icer will also free up frozen door locks and petrol filler locks.
- Check front and rear fog lights: remember these should only be used when visibility is reduced to around 100 metres and switched off when visibility improves.
- Brake lights can be checked unaided by seeing if they illuminate a wall, garage door or window.
- Test the horn.
- Number plates should be clearly visible from the front and rear.
- Make sure the brakes are in good working order and have them serviced regularly.
- Check that both front and rear wiper blades are not worn or damaged. If they are leaving smears across your windscreen, it is time for new blades. Split, cracked or perished wiper blades will lead to a MoT test failure as well as being dangerous.
- Clean the windows, inside and out, and wipe the lamp lenses and door mirrors.
- If a light suddenly appears on the dashboard, don't ever ignore it. Treat it as a danger sign and investigate.

Red – danger. Stop and check. A red light means potentially serious trouble. Do not drive the car.

Orange – caution. Shows something requiring urgent attention, such as low fuel, low oil level or low engine coolant.

Green – reminder. Indicators flashing, for example. A memory jogger, not a problem.

- Give the car a good wash and polish to guard against the bodywork ageing.
- Watch for the first signs of rust forming, and treat it before it gets worse. Look for any signs of water leaks that could trigger corrosion.

Fuel saving tips

- Don't carry unnecessary loads - the car was designed to be as aerodynamic as possible, so remove any unused roof rack or roof box. An empty car will use less fuel than one with an unnecessary heavy load in the boot.
- Don't get lost – plan unfamiliar journeys to reduce the chance of getting lost – try web-based route planners or consider a satnav if justified by regular use of unfamiliar routes. Check the traffic news before leaving home.
- Travel at off-peak times if possible - being stuck in traffic jams uses a lot of fuel. Not having to keep stopping and starting is also better for stress levels.
- Combine short trips – cold starts are inefficient so it pays to combine multiple short trips.
- Consider alternatives – if it's a short journey (a couple of miles or so) consider walking or cycling rather than taking the car – fuel consumption is worse when the engine is cold and pollution will be greater until the emissions control system gets up to normal temperature.
- Leave promptly – don't start the engine until you're ready to go. This avoids fuel wastage due to unnecessary idling and ensures that the engine warms up as quickly as possible. (In winter months, scrape ice rather than leave the car idling for a long period to warm up).
- Easy does it – drive smoothly, accelerate gently and read the road ahead to avoid unnecessary braking.
- Decelerate smoothly – when you have to slow down or to stop, decelerate smoothly by releasing the accelerator in time, leaving the car in gear.
- Rolling – if you can keep the car moving all the time, so much the better. Stopping then starting again uses more fuel than keeping rolling.
- Change up earlier – change gear as soon as possible without labouring the engine. Try changing up at an engine speed of around 2000 rpm in a diesel car or around 2500 rpm in a petrol car. This can make such a difference to fuel consumption that all cars in the future are likely to be fitted with Gear Shift Indicators that light a lamp on the dashboard to indicate the most efficient gear change points.
- Cut down on the air-con – air conditioning increases fuel consumption at low speeds, but at higher speeds the effects are less noticeable. So if it's a hot day it's more economical to open the windows and sunroof around town and save the air conditioning for high speed driving. Don't leave air-con on all the time but you should run it at least once a week throughout the year to maintain the system in good condition.
- Turn it off – any electrical load increases fuel consumption, so turn off your heated rear windscreen, heated seats, demister blowers and headlights, when you don't need them.
- Stick to the limits – drive at or within the speed limit – the faster you go the greater the fuel consumption and the greater the pollution. According to the Department for Transport driving at 70mph uses up to 9% more fuel than at 60mph and up to 15% more than at 50mph. Cruising at 80mph can use up to 25% more fuel than at 70mph.
- Don't idle – if you do get caught in a queue avoid wasting fuel by turning the engine off if it looks like you could be waiting for more than a few minutes.
- Consider taking advanced driving lessons - just a few tweaks to your driving style could really make a big difference to how efficiently you drive.

Several of the website links above also have useful tips on Trouble Shooting and Safety: both prior to a journey, on the journey and in the event of breakdown. These have been excluded from this chapter as they are out of scope of the document but are nevertheless worth browsing.

1958 Make / Model Autocar 12 December 1958	1958 price inc Purchase Tax (50%)	Generic category	Average price of Generic category	2013 Make / Model	2013 on the road price	Generic category	Average price of Generic category	Ratio 2013 to 1958
Ford Anglia	£571	Basic Mini	£588	Ford Ka	£8,795	Supermini entry level model	£8,348	14
Austin A35	£569			Fiat Panda	£8,945			
Fiat 500	£556			Fiat 500	£10,010			
Citroen 2CV	£598			Citroen C1 VT	£6,995			
Standard Eight	£646			Hyundai i20	£6,995			
Morris Minor Traveller de luxe1000	£734	Top of range of basic model	£696	Mini One Clubman	£14,570	Supermini mid-spec	£13,733	20
Ford Prefect de luxe	£658			Ford Fiesta Zetec - 1.4, 5-door, man	£12,895			
Morgan Plus 4	£968	Open top sports	£1,018	Morgan Plus 4 2 litre	£32,735	Open top sports	£28,615	28
Triumph TR3	£1,049			BMW Z4 2 litre	£27,615			
Lotus seven	£1,036			Caterham 7 Roadsport 175	£25,495			
Hillman Minx de luxe	£794	Small family saloon	£803	Ford Focus - Edge 1.6 5-door man	£16,200	Small family saloon	£16,565	21
Vauxhall Victor Super	£781			VW Golf Match	£16,495			
Morris Cowley	£834			Mazda 3 1.6 5-door Tamura	£17,000			
Sunbeam Rapier (1500 twin carb)	£1,043	Family Saloon	£1,019	BMW 3i8i ES	£23,185	Family Saloon	£22,264	22
Standard Vanguard	£1,043			Audi A4 1.8 TFSI saloon	£23,960			
Ford Zephyr	£916			Ford Mondeo Edge 1.6 5-door man	£20,495			
Vauxhall Cresta II	£1,073			Vauxhall Insignia 4 door saloon	£21,415			
Jaguar XK150 (convertible)	£1,793	Luxury Sports	£1,793	Jaguar XK 5.0L Coupe	£65,465	Luxury Sports	£65,465	37
Jaguar Mk IX (3.8litre 6 cyl)	£2,162	Luxury Saloon	£2,042	Jaguar XJ 3 litre 6 cyl diesel	£56,865	Luxury Saloon	£56,580	28
Rover 3 litre automatic	£1,921			Audi A8 diesel saloon SE Exec 2wd	£56,295			
Aston Martin DB4 (3.67litre DOHC)	£3,976	Exotic Sports	£3,976	Aston Martin DBS 5.9litre V12	£162,000	Exotic Sports	£162,000	41
Land Rover	£960	Utility	£960	Landrover Freelander 2	£23,705	4x4	£23,705	25

Annex: Comparison of generic car categories from 1958 and 2013

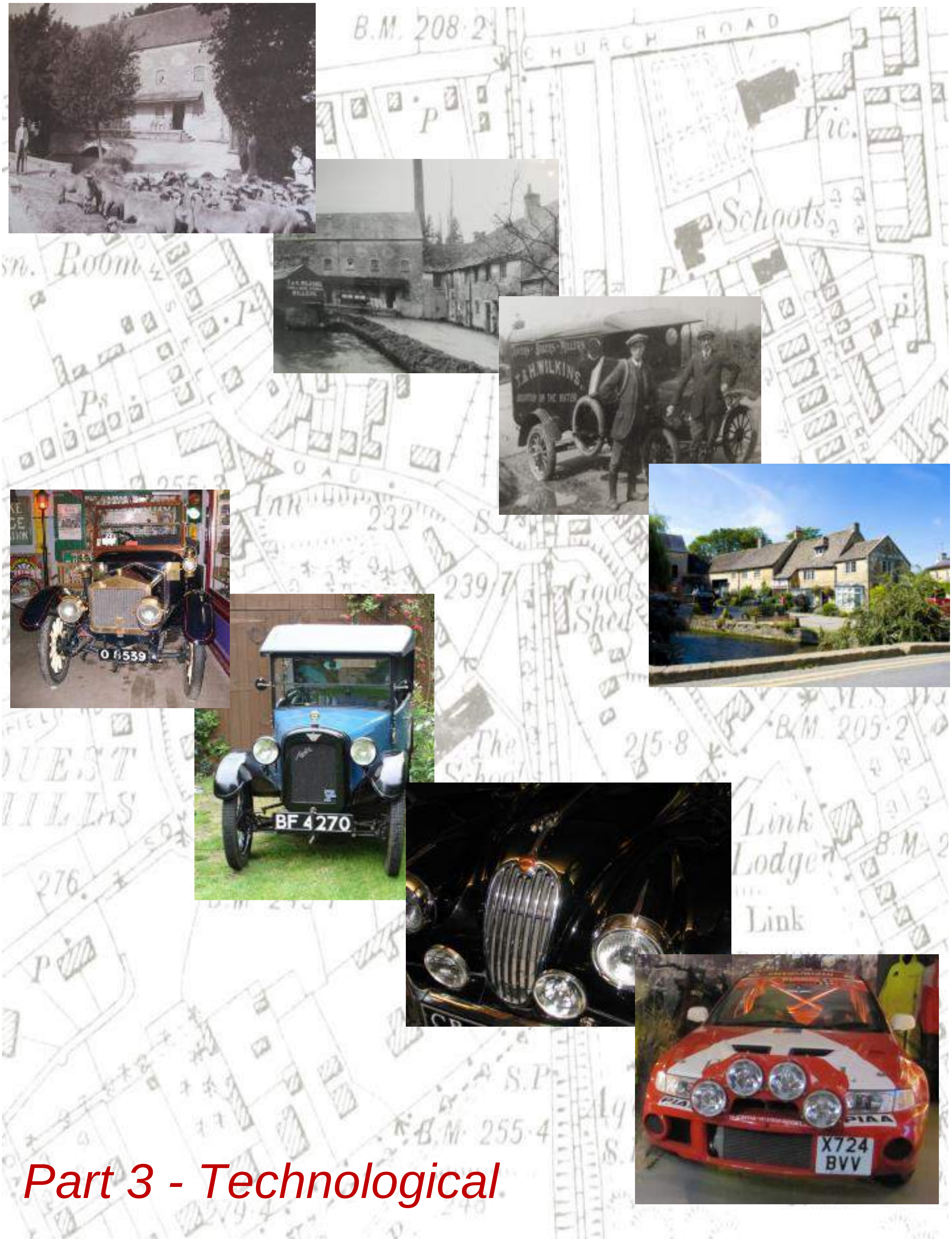
Generic category	Ratio
Supermini entry level model	14
Supermini mid-spec	20
Small family saloon	21
Family Saloon	22
4x4	25
Luxury Saloon	28
Open top sports	28
Luxury Sports	37
Exotic Sports	41

Picture Captions and Credits

Page 49: Morris Mini Minor, Cotswold Motor Museum, Bourton-on-the-Water
Page 49: 1972 Triumph Stag
Page 49: 1950s DIY magazines on car maintenance
Page 50: Serpentine belts on a Jaguar V12 engine
Page 50: December 1962 Car Mechanics
Page 50: Morris Mini showing the area vulnerable to rainwater passing through the radiator grill

The Cotswold Motoring Museum and Toy Collection is not just about cars. Toys that our parents and grandparents played with as children, everyday artefacts from the Victorian and Edwardian era plus an insight into the social history of the village of Bourton-on-the-Water and much more can be found in the Old Mill, alongside the River Windrush.

The Impact of Motoring



Part 3 - Technological

Disclaimer

Whilst every effort has been made to ensure the accuracy of the content of this book, in a world where technology moves so rapidly, it is inevitable that some content will be out of date very soon after publication. Cotswold Motoring Museum & Toy Collection can accept no liability for any errors or omissions or any consequences of such errors or omissions.

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Source of right hand image above: Metropolia University of Applied Sciences, Helsinki, Finland.
http://green.autoblog.com/2013/05/30/biofore-concept-car-is-a-plant-laden-sustainable-ride/

Contents of Part 3

Part 3 - Technological

Over the last 125 years advances in the science of materials and fuels, electronics, communications, computing and software have influenced all aspects of lives, including motoring. Following the “Impact of Motoring” theme, the chapters in this part of the book focus on specific areas of the car, consider the performance and possible effect on our lives of electric cars and conclude with a look at examples of how technology has improved the safety of our motoring lives.

In the early days of motoring, the internal combustion engine was not the only contender for powering cars. Steam and battery power were serious competitors at the start of the 20th century. The fact that internal combustion dominated the century gives a momentum to the development of the internal combustion engine that is not present for other contenders such as re-emerging electric and hybrid electric cars. Hence predicting what the private car will look like in the middle of the 21st century is no easy task. (Assuming that the concept of a *private* car still exists). Clearly many of the world’s major motor manufacturers share this same view as most seek to add at least one electric variant to their model line-up.

In a world of diminishing natural resources and increasing atmospheric (and oceanic) change, influenced by legislation, public opinion and political pressures and aided by ever more sophisticated and affordable electronic hardware, motor manufacturers are producing electric and internal combustion engine cars, that even a decade ago, would have seemed to be unattainable. Some argue that only complete autonomy for the car, namely a car in which all occupants are passengers, will meet the environmental and safety aspirations of legislators.

The Cotswold Motoring Museum exhibition, “A History of Motoring in 10 Objects”, featured the SU carburettor, the Electronic Control Unit, Tyres, the ‘Catseye’ and Seatbelt in the list of significant objects. These appear as chapter headings within this part of the book and remain on display in the museum.

Part 3 - Technological | Internal Combustion Engine

Has the internal combustion engine run its course?

The development of the internal combustion engine from a noisy, inefficient novelty enjoyed by the few to the smooth, powerful all-pervasive component of modern life must rate as one of the most far-reaching and influential developments of the 20th century. This chapter outlines the operation of the internal combustion engine. It looks ahead to alternatives and at further developments that will be necessary for the engine to survive into the mid-21st century: a century in which the ready, affordable availability of fossil fuels that have powered the previous century can no longer be taken for granted.

Introduction

The objective of this chapter is to provide a concise, introductory overview of the history, function and future of the internal combustion (IC) engine. So many high quality articles have been published on this topic, with many of these articles freely available on the internet, that any attempt to better what exists already is going to be a difficult task. Consequently, material has been gathered from various existing sources to meet the objective of the chapter. Hyperlinks or footnotes to original material are provided with the intention of fully acknowledging the original authors. Readers wishing more detail are encouraged to follow these references.

It is easy to think that in the late 19th century and early 20th century, the IC engine was the engine of choice for the newly emerging forms of motorised transport. In fact, this was far from the case; the IC engine faced competition from both steam and electric propulsion. In 1900, a steam-powered car held the land speed record.

The picture above shows a 1900, American, two-cylinder steam powered Mobile on display at the 2010 NEC Classic Car Show in Birmingham. A look at the Steam Car website pages for the 2013 London to Brighton run and the website's photo gallery show just how many steam powered cars remain in private ownership.

The 1903, US built battery-powered Waverley electric car is shown waiting in Hyde Park for the start of the London to Brighton run. In 1900 there were more than 50,000 electric cars in the US.

However, this chapter is about the Internal Combustion engine and it is to that topic that we must return. (Steam cars are, of course, *external* combustion engines; a less familiar term). Cars powered by the internal combustion engine, such as the mass-produced Model T Ford shown here, had an immense influence on the history of the 20th century and, along with other inventions, from the printing press, electric light and textile mills to personal computing and the internet, can be truly described as a 'disruptive technology'.

History of the Internal Combustion (IC) engine

As with the other aspects of the internal combustion (IC) engine, much has been published on the history and major milestones in the development of the IC engine (including the Cotswold Motoring Museum "Motoring Milestones" document). The concise history, from which the following list has been edited, appears on the about.com website

- **1680** - Dutch physicist, Christian Huygens designed an IC engine that was designed to be fuelled with gunpowder.
- **1807** - Francois Isaac de Rivaz of Switzerland invented an IC engine that used a mixture of hydrogen and oxygen for fuel.
- **1824** - English engineer, Samuel Brown adapted an old Newcomen steam engine to burn gas and used this to power a vehicle.
- **1858** - Belgian engineer, Jean Joseph Etienne Lenoir invented and patented (1860) an electric spark-ignition IC engine fuelled by coal gas. In 1863, Lenoir attached an improved engine (using petrol and a primitive carburettor) to a three-wheeled wagon that completed an historic fifty-mile road trip.
- **1862** - Alphonse Beau de Rochas, a French civil engineer, patented but did not build a four-stroke engine (French patent #52,593, January 16, 1862).
- **1864** - Austrian engineer, Siegfried Marcus, built a one-cylinder engine with a crude carburettor and attached his engine to a cart resulting in a drive of 500 feet. Later, Marcus designed a vehicle that ran at 10 mph: considered by some to be the world's first petrol-powered vehicle.
- **1866** - German engineers, Eugen Langen and Nikolaus August Otto improved on Lenoir's and de Rochas' designs and invented a more efficient gas engine.
- **1873** - George Brayton, an American engineer, developed an unsuccessful two-stroke paraffin engine. However, it was considered to be the first safe and practical oil engine.
- **1876** - Nikolaus August Otto invented and later patented a successful four-stroke engine, based on what became known as the "Otto cycle".
- **1876** - The first successful two-stroke engine invented by Sir Dugald Clerk.
- **1883 -** French engineer, Edouard Delamare-Debouteville, built an advanced single-cylinder four-stroke engine that ran on petrol.
- **1885** - Gottlieb Daimler invented the prototype of the modern petrol engine - with a vertical cylinder and with petrol injected through a carburettor (patented in 1887). Daimler first built a two-wheeled vehicle the "Reitwagen" (Riding Carriage) with this engine and a year later built the world's first four-wheeled motor vehicle.
- **1886** - On January 29, Karl Benz received the first patent (DRP No. 37435) for a petrol-fuelled car.

- **1889** - Daimler built an improved four-stroke engine with mushroom-shaped valves and two V-slant cylinders.
- **1890** - Wilhelm Maybach built the first four-cylinder, four-stroke engine.

In the last century, the IC engine has continued to develop, both in response to the need for improved performance and, more recently, in response to social concerns over the impact that the IC engine is having on our environment. All vehicles offered for sale in Europe today, have to comply with strict directives on, amongst other things, the noise that they produce, the content of the exhaust gases, their electromagnetic compatibility and their end-of-life disposal. Recognition of finite and increasingly expensive fossil fuels has prompted vehicle manufacturers to invest heavily in developments to improve the efficiency of the IC engine and the development of alternative energy sources.

Common uses of IC engines

The most common use of the IC engine in the transport sector is, of course, to provide the motive force for road vehicles (cars, trucks, motorcycles), although powering boats, aircraft, locomotives and portable machinery are other important categories of use. The fossil fuel powered IC engine has the advantage of a high power-to-weight ratio: a consequence of excellent fuel energy density ie energy produced per unit volume of fuel.

Globally, fossil fuels meet about 82% of the world's total energy needs. Within the European road transport sector, the proportion of energy needs met by fossil fuels currently exceeds this figure. By 2020, sustainable biofuels are likely to comprise only around 8% of the total.

Gas turbines are another form of IC engines – rotary rather than reciprocating – and are used where a very high power is required, such as in jet aircraft, helicopters, tanks and large ships. They are also frequently used for electric generators and by industry. Mainly because of high cost and high fuel consumption, they have not been used in production cars. The first jet-powered prototype Rover resides in the London Science Museum and, in the early 1960s, a number of gas turbine powered Rovers competed successfully at Le Mans.

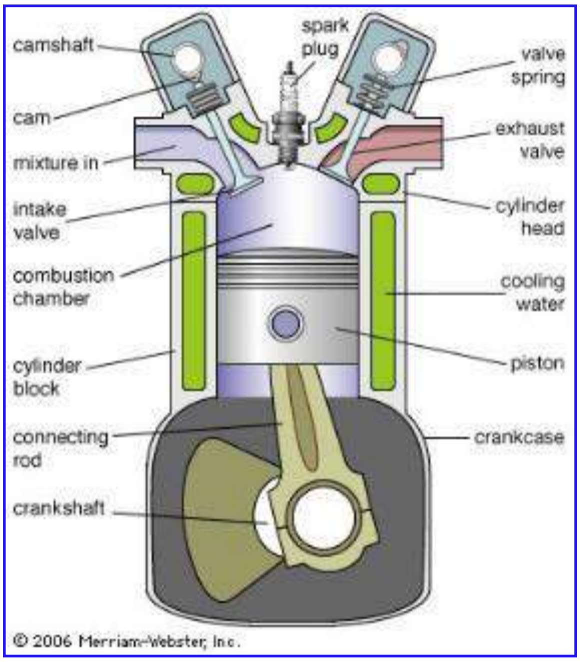
How does the IC engine work?

An internal combustion (IC) engine is any engine that uses the explosive combustion of fuel to push a piston within a cylinder. The most commonly used fuels for car IC engines are petrol and diesel: both of which are fossil fuels. In summary, they convert chemical energy to mechanical energy with heat as a significant by-product. The piston's linear movement turns a crankshaft – converting linear motion to rotational motion - that then turns the car wheels via a clutch, gearbox and final drive assembly.

The following sections provide a brief overview of the operation of the four-stroke petrol and diesel engine, the two-stroke engine and the rotary Wankel engine. The following short chapter outlines the principle behind the operation of a carburettor; a key component in 20th century motoring.

How a four-stroke engine works

The diagram to the right shows a cross-section of a single cylinder of a twin-camshaft IC petrol engine.



The intake valve allows the combustible mixture of fuel and air into the cylinder. As the inlet valve shuts, the rising piston compresses the mixture. When the piston is near the top of its stroke (typically a few degrees before 'top dead centre') a high voltage electrical discharge across the gap in the spark plug ignites the mixture forcing the piston down. On the next rising stroke of the piston, the exhaust valve opens and the waste gases from the combustion are expelled past the exhaust valve.

So, in summary the four strokes of this engine are:

- Intake or Induction — Suck
- Compression — Squeeze
- Power — Bang
- Exhaust — Blow

sometimes referred to as a memory aid as

Most vehicle engines today are four stroke engines with the four strokes (intake, compression, power and exhaust) occurring during two crankshaft rotations per four stroke cycle.

For further information and an animation of the 4-stroke engine, follow the [Wikipedia] link.

How a diesel engine works

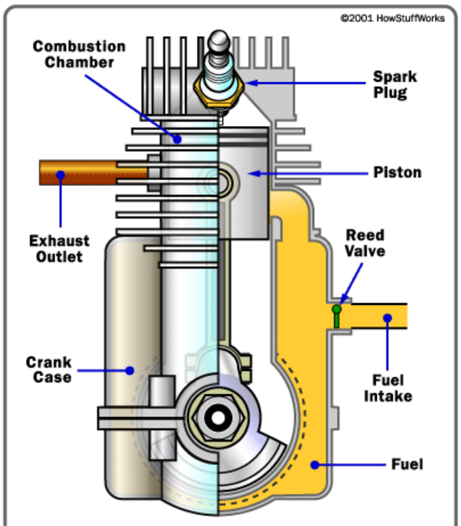
A diesel engine is an internal combustion engine that uses the heat generated by the compression of air in the cylinder to initiate ignition of fuel, which is injected into the combustion chamber during the final stage of compression. A cross-section view of a four-stroke diesel engine would look very much like the earlier picture of the petrol engine but with the spark plug replaced by a fuel injector. To aid cold starting a glow plug – basically a small electrical heater - in each combustion chamber provides a few seconds of pre-heating. The duration of the glow plug operation is indicated to the driver by an illuminated, coil-shaped warning lamp on the instrument cluster.

The engine operates using the diesel cycle (named after Rudolf Diesel). For a given engine capacity, a turbocharged diesel engine will provide better efficiency than the corresponding petrol engine. In part, this is due to the higher density of the diesel fuel which contains, for a given volume, around 15% more energy than petrol and the higher compression ratio of the diesel engine.

For further information, follow this link and for an animation of a diesel engine cycle see the following link.

How a two-stroke engine works

A two-stroke engine is an IC engine that completes the cycle of intake, compression, combustion and exhaust in two sweeps of the piston compared with four for a four-stroke engine. This increased efficiency is accomplished by using the beginning of the compression stroke and the end of the combustion stroke to perform simultaneously the intake and exhaust functions. Two-stroke engines can often provide a high power to weight ratio in comparison with a four-stroke engine. Petrol versions are widely used in lightweight, portable machinery such as chainsaws, generators and gardening and building equipment. Typically, such two-stroke engines are air-cooled and the lubricant is mixed with the fuel in a ratio of one part lubricant to 50 parts fuel. The role of the valves in the four-stroke engine is replaced by ports that are exposed or covered by the piston as it moves through the cylinder. Consequently, the two-stroke engine is a much simpler device than the four-stroke, with fewer moving parts and no coolant or lubrication passages.

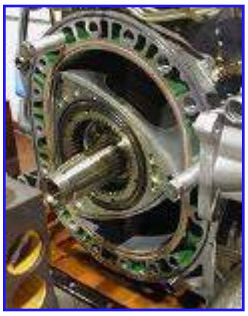


The basic components of a two-stroke engine

The concept is also used in diesel compression ignition engines in large and non-weight sensitive applications such as ships and locomotives. The disadvantages of two-stroke engines have been associated with the burning of lubrication oil and expulsion of unburnt fuel from the exhaust system resulting in the, now unacceptable, blue smoke typified by the East German Trabant in the 60s, 70s and 80s. Developments in two-stroke design however have gone some way to reducing these drawbacks.

For further information, follow the Wikipedia link.

How a Wankel rotary engine works



Rather than use the pressure generated by fuel combustion to produce a linear motion, which in a reciprocating engine is then converted into a rotational motion, the Wankel engine uses a rotary design to convert a pressure differential directly into a rotating motion. Its four-stroke cycle takes place in a space between the inside of an oval shaped combustion chamber and a rotor that is similar in shape to a Reuleaux triangle. The image shown is reproduced from the prelovac.com website.

This design delivers smooth power at high revs, from a compact size. There are fewer moving parts than in a corresponding piston engine and catastrophic failure (eg as a result of over heating) is uncommon. On the down side, the Wankel engine tends to be less fuel efficient than the piston engine and successful sealing between the rotor and combustion chamber has, historically, been a design challenge. The most extensive automotive use of the Wankel engine has been by the Japanese company Mazda.

Improving the efficiency of the IC engine

Developments of the IC engine to improve performance, economy and environmental impact are moving rapidly and have a momentum that many of the alternative power sources do not possess. Some pundits predict that by 2050, "most energy will still be derived from fossil fuels …. nuclear power will account for an increasing share of global electricity production, while wind and solar power will still be negligible"[1]. In the automotive sector, Uwe Kracht of Mazda Europe is convinced that "in 2020 more than 80% of cars will still use combustion engines"[2]

So with that in mind what can be done? The government's climate change watchdog recently warned that Britain should not rely on fossil fuels to produce power in 20 years' time. There are four key issues about conventional oil that have been apparent for at least a decade – declining output, declining and less accessible discoveries (eg beneath the ocean floor and beneath arctic ice), increasing demand and insufficient alternative energy projects in the pipeline. Automotive manufacturers and their suppliers are continuously improving the efficiency of the IC engine; helping to conserve remaining conventional fossil fuel supplies.

The efficiency of the automotive IC engine has improved from around 5% in 1900 to around 40% during the century that the IC engine has been in popular use. If the energy losses in the vehicle drive train, accessories, rolling resistance and aerodynamic drag are taken into account then typically less than 15% of the power produced by the burning fuel appears at the wheels of the car. Some measures to improve the IC engine efficiency are outlined below.

- One significant step in the continuing increase in efficiency of the IC engine has been the advent of variable valve timing. In the earlier diagram of the IC engine, it is clear that the twin camshafts are the means by which the opening and closing of the inlet and exhaust valves are controlled. With no means of adjusting the valve timing as the engine speed changes, the cam profile (for single or twin cam) is optimised to provide a compromise between good high speed performance and smooth running at tick-over. It will yield best engine efficiency at one specific engine speed. The advent of electronic engine control has enabled various designs of variable valve timing to be implemented. Techniques include enabling an alternative cam profile to switch in at high engine revs, variation of the timing of the existing camshaft(s) or providing continuously variable timing with engine speed: for example, by using solenoids to control valve operation.

- Cylinder deactivation, or variable displacement, saves fuel by deactivating cylinders when they are not needed. This is achieved by keeping the intake and exhaust valves closed for a particular cylinder while also cutting the cylinder's fuel supply. The result is improved fuel economy and reduced emissions. The technology has been around since the early days of internal combustion engine, but it is only recently, with the use of sophisticated engine management systems, that it has demonstrated its full potential. Powerful and fast on-board computers mean that deactivation and reactivation occurs almost instantly and there is little sacrifice of power.

[1] Michael Lind, TIME Magazine, 22 March 2010
[2] Autocar, 29 February 2012.

- Stop/start technology: sometimes known as mild hybrid technology, it automatically turns the engine off when the vehicle is stopped to reduce fuel consumed during idling. This feature is particularly advantageous for city vehicles. In order not to lose all functions when the engine stops, regenerative braking is used to convert mechanical energy lost in braking into electricity, which is stored in a battery or capacitor and used to power accessories, like air conditioning and the automatic starter. A Kinetic Energy Recovery System (KERS) was a feature of Formula One racing for a few seasons until, in 2014, it was replaced by a much more significant Energy Recovery System (ERS) using both kinetic and heat energy to supplement the power from the internal combustion engine.

- Turbochargers increase engine power, with lower fuel consumption, allowing manufacturers to downsize engines without sacrificing performance or to increase performance without lowering fuel economy. Turbochargers, powered by exhaust gases from the engine, force compressed air into the cylinder generating extra power from each ignition. The engine specification for the 2014 Formula One season has replaced the 2.4 litre V8 with a 1.6 litre V6 engine. To help maintain the power output of these new, hybrid power units, the turbochargers spin at up to 100,000 rpm[3]. In the aftermarket, electric superchargers are available, sometimes used in conjunction with a conventional turbo. They spin up faster than a conventional turbocharger and eliminate turbo lag. They are now also being adopted by OEMs[4].

- All but one of the cars on permanent display in the Cotswold Motoring Museum use carburettors to provide the engine with the correct fuel/air mixture. Modern vehicles rely on the more efficient fuel injector for this task. In these multi-port fuel injection systems, fuel is injected into the port and mixed with air before the air-fuel mixture is pumped into the cylinder. In direct injection systems, fuel is injected directly into the cylinder so that the timing and shape of the fuel mist can be precisely controlled. This allows higher compression ratios and more efficient fuel intake, which deliver higher performance with lower fuel consumption.

- Exhaust heat recovery. Much of the energy released by burning fuel in the IC engine is lost as heat via the exhaust. Automotive designers are working on methods to harness this heat to produce more power for the engine. Exhaust gas recirculation is already a common technique used to pre-warm the fuel air mixture. Potentially, this heat can also be used to create steam to drive the engine or used to generate electrical power via thermoelectric devices.

- Split-cycle engine technology has been developed by Scuderi Engine in the USA. They implement the four-stroke IC engine and conventional combustion cycle over two paired cylinders: one intake/compression cylinder (with no spark ignition) and one power/exhaust cylinder. The compressed air in the intake/compression cylinder is fed, at around 50 bar (~725 psi), into the power/exhaust cylinder and ignition takes place (unconventionally) after top-dead-centre. This engine requires just one crankshaft revolution to complete a combustion cycle whereas the conventional engine requires

[3] New Scientist 15 March 2014
[4] Original Equipment Manufacturers

two. Improvements are claimed in efficiency, emissions and torque over conventional petrol or diesel engines. The reference link contains a good animation of the cycle.

- Two and four-stroke engines have been described above but what about five and six stroke engines? Ilmor Engineering from Northamptonshire has been working on a five-stroke engine which delivers high power output with low fuel consumption. In the USA Bruce Crower has been working on a six-stroke engine. Following the exhaust stroke, water is injected into the engine and 'waste' heat generated by burning fuel in the engine is used to produce an additional power stroke delivered by steam. A final exhaust stroke completes the cycle. This means that instead on one power stroke in four, the engine has two power strokes in six and less heat is wasted.

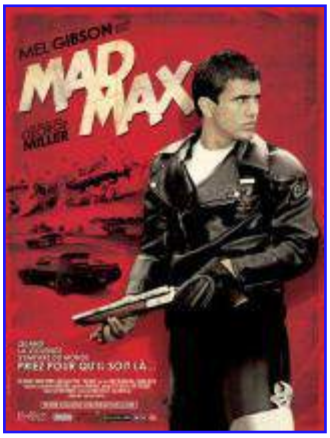
- Finally, a natural gas (90%) / diesel (10%) hybrid has been demonstrated by ETH in Zurich that produces half of the CO_2 of the corresponding diesel engine. Given the ascendancy of natural gas production in the US market, this may prove to be highly relevant.

Conclusion

Many of us, of a certain age, remember the Mad Max film that launched the career of Mel Gibson. It is sobering to recall that this was over 30 years ago! The film depicted a terrifying view of a world without oil, where gangs of grisly looking people roamed deserts in a post-apocalyptic world, killing each other to get their hands on the few drops of petrol that some had managed to produce in makeshift refineries. Social order had completely broken down.

This may all sound a bit far-fetched but just think back to summer 2008 when oil prices spiked to $147 a barrel – 10 times the level of a decade earlier. In petrol stations in some European countries, people started to drive off without paying and drivers had to be banned from filling their cars before they had paid. In Britain, people stole heating oil out of the tanks that sit outside many houses in the country. The future of the IC engine must have seemed pretty bleak at that point.

Although alternative forms of energy are currently under development most of them are still a long way from market-ready. One could argue that with the abundance of fossil fuel and its suitability for so many uses there has been a reluctance to invest in costly R&D projects to find alternative fuel types. With increased public and private sector support, it may be possible to speed up the development of these technologies and help free ourselves from such a heavy reliance on fossil fuels. Surely, it is better to save these increasingly scarce resources for pharmaceutical and industrial use than to simply burn them?



Oil companies will have to play their part since, with the finite life of fossil fuels, they would stand to reap enormous short to medium-term profits but, in the long term, their business would ultimately disappear. Driven by ever tightening vehicle emissions legislation, oil and other energy companies are working with automotive companies to develop technologies to both extend the life of and ultimately perhaps to replace the IC engine. Their own commercial survival, once all fossil fuel resources are exhausted, or no longer commercially viable, will be dependent on the outcome. The worrying thing is if we do not give sufficient priority to this task, it may be too late and we may have to face a Mad Max scenario.

A less melodramatic scenario is one of continuing incremental improvements in the efficiency of the IC engine over the first few decades of the 21st century, driven by legislation and cost, up to the point where the ability to produce hydrogen for our fuel cell-powered transport becomes affordable and carbon-free.

Hopefully the IC engine will pass gracefully into history, maybe around the middle of the century, to be replaced with another 'disruptive technology': this one based on hydrogen.

Picture Captions and Credits

Page 6: 2014 VW Beetle engine
Page 6: The Mobile steam car, November 2010
Page 6: The 1903 Waverley electric car
Page 7: A Model T Ford, London Science Museum
Page 8: JET 1 currently in the London Science Museum
Page 9: Internal combustion engine
http://bkachinsky.transworld.net/files/2009/06/internal-combustion-engine1.jpeg
Page 9: Glow plug warning lamp
Page 10: Two stroke engine
http://www.outboardmotoroilblog.com/wp-content/uploads/2009/02/two-stroke-engine-parts.gif
Page 10: Wankel engine
http://www.prelovac.com/vladimir/wp-content/uploads/2008/01/wankel-1.jpg
Page 13: Mad Max
http://www.google.co.uk/images?hl=en&xhr=t&q=mad+max&cp=4&wrapid=tljp129530366376508&um=1&ie=UTF-8&source=univ&ei=LsQ0TYKUDYeXhQfGI8zTCw&sa=X&oi=image_result_group&ct=title&resnum=5&sqi=2&ved=0CG0QsAQwBA&biw=1003&bih=516

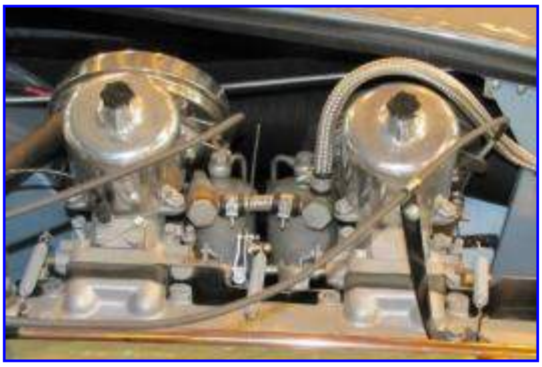
Lilley and Skinner for shoes or a handbag maybe but a carburettor?

For an internal combustion engine to work efficiently, the correct mixture of atomised fuel and air has to be delivered to the cylinders under all conditions of temperature, engine load and throttle opening. Until relatively recently this was achieved by way of a carburettor. And Lilley & Skinner …… ? Read on!



What is a carburettor?
A quick answer is that it is a component, which until recent years, was used with all petrol-engine cars. It produces the optimum mix of atomised fuel and air over the range of engine operating speed, load and temperature. This chapter goes on to explain why that is important, how it is achieved and to outline the development of one of the major designs of carburettor.

Ever since the invention of the internal combustion engine, devices for delivering a volatile mixture of fuel and air to the engine have evolved. One such iconic design is the SU carburettor: one in which both the air and fuel passages vary in accordance with the requirements of the engine. It was first designed and patented in 1905 by George Herbert Skinner and named SU after 'Skinner Union'. The family business was the manufacture of shoes, specifically the company of Lilley and Skinner: once a household name with a presence on most High Streets. In August 1910 Herbert, as he was known, along with his two brothers, registered the SU Carburettor Company Limited, in London. The company steadily grew, and by 1912 the factory was producing carburettors in large numbers. During World War I the company, like many others, was involved in munitions production, together with production of carburettors for aero engines.



After financial difficulties, ownership of the company changed to Morris Motors in 1926. Sound financial backing resulted in new models in 1929, and further aero engine types in 1932: one was used with the Rolls-Royce Merlin engine in the Spitfire, Hurricane and Lancaster aircraft. Another was used on the Napier engine, which powered the Tempest and Typhoon. During

WWII it was vital that production was secured, so 'shadow' factories were built in Birmingham. The company also developed a fuel injection pump for the Merlin engine.

After the war, production of carburettors and fuel pumps resumed, the company moving to a new site, and by 1947 production was approaching 223,000 units per year. Mr C T Skinner sold the fuel injection manufacturing business to the American company Stirling, and although not pertinent to the mass-produced car at the time, development in the 1980's meant it would become so.

The SU Company became one of the major fuel system suppliers in Europe, with its designs used in many motor vehicle engines. Wikipedia lists these manufacturers: including Austin, Morris, Triumph, MG, Hillman, Rolls-Royce, Daimler, Morgan, Riley, Jaguar, Wolseley, Saab and Volvo. The Hitachi Company in Japan manufactured derivatives for the Datsun 240Z and 260Z and other Datsun models. Until 1995, the Rover Group used variants in production cars: the Mini, Metro and Maestro.

The company subsequently changed hands several times. SU carburettors and fuel pumps are now manufactured, together with spares and reconditioning kits, mainly for the classic car market, by Burlen Fuel Systems Ltd. Documents on the Burlen Fuel Systems website, dating from 1974 and 1963, cover in detail the following brief outline description of operation.

How does it work?

Early SU carburettor models included a fine high quality hand stitched leather bellows [5] (a link to the shoe making business?), which held a tapered needle, inside an orifice or 'jet'. When the throttle opened the airflow through the carburettor increased, the bellows would rise taking the needle out of the stream of air, delivering a greater amount of fuel into the engine. This basic operating principle, once production challenges were overcome, became a feature of all further models the company would design and manufacture.

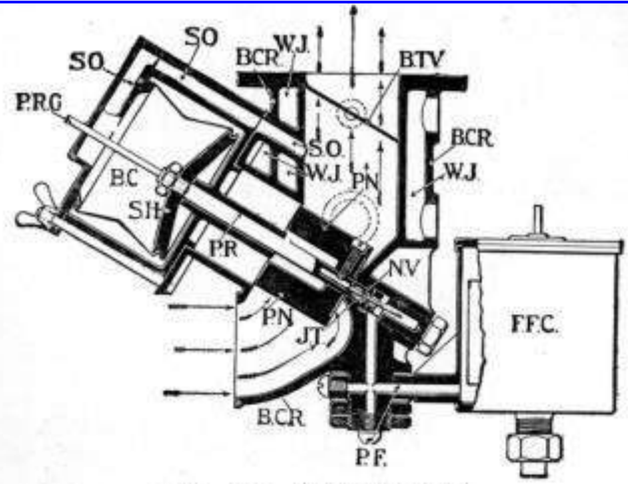


Fig. 157.—S.U. Carburettor.

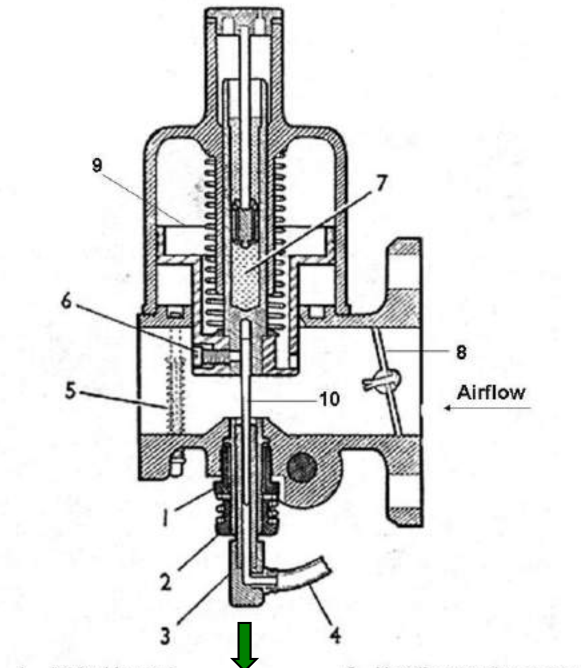
This piston is capable of sliding up and down in its cylinder, guided by the piston rod PR, which carries at its upper end a mushroom suction disc forming the bottom of a bellows suction chamber BC.

The carburettor works on Bernoulli's principle. This states that:

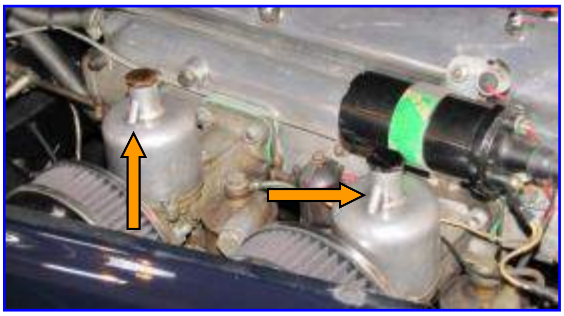
5 "The Book of The Motor Car Volume 1" by Rankin Kennedy, published by Caxton, London in 1913 (and still available on EBay) shows cross-sections of early SU carburettors in which the bellows can be clearly seen. The two images above are reproduced from this book.

"*The pressure in a fluid* [in this case the air] *decreases as the speed of the fluid increases".*

Relating this principle to the SU carburettor, the accelerator pedal linkage controls the flow of air drawn into the engine: in the case of the cross-section diagram of the SU carburettor on the right, this control is via a throttle plate or butterfly valve (8). The air drawn into the engine speeds up as it passes through the restricted carburettor body (which acts as a venturi) and produces a reduction in pressure above the piston (9) causing it to rise. A tapered needle (10) attached to the piston is withdrawn from a fuel jet, allowing more fuel to mix with the air. (Not visible in the cross-section diagram but indicated by the orange arrows in the picture below, is a passage in the carburettor casting that equalises the reduced pressure in the venturi with that on the upper side of the piston). With the lower side of the piston at atmospheric pressure, the piston rises against its own weight, resistance from a spring and oil-filled damper (7), thus enriching the fuel mixture. The profile of the needle and the strength of the spring are designed for optimum fuel-air mixture over the range of engine operation.



1. Jet locking nut
2. Jet adjusting nut
3. Jet head
4. Fuel pipe from float chamber
5. Piston lifting pin
6. Needle securing screw
7. Oil damper reservoir
8. Butterfly valve
9. Piston
10. Needle



The original SU design did not incorporate a device for cold starting; this requires a temporarily rich fuel mixture. Wolseley Motors Ltd included the addition of a second jet, operated by the driver when cold starting was required, to overcome this deficiency in design.

The cold-starting control on later SU models acts on the jet assembly, drawing it downwards in the direction of the green arrow in the cross-section view above. Lowering the jet increases the area between the jet and the tapered needle allowing an increase in fuel flow until the engine approaches working temperature. The driver action of pushing the choke control knob fully in raises the jet assembly and the fuel enrichment ceases.

Since petrol is pumped, either mechanically or electrically, from the fuel tank to the carburettor(s) – very rarely it is gravity fed - it is necessary to control the supply of petrol to the jet(s). This is achieved by a float chamber (effectively a small reservoir) linked to, or integral with, each carburettor body. The flow is regulated by a float and needle valve in the chamber(s). As the float rises, so the needle valve closes, reducing the flow of petrol from the pump. As fuel is drawn into the engine via the jet, the float will drop sufficiently for the chamber to remain full.

This design of carburettor, one in which both air and fuel passages can be varied, as the engine requirements change from idle to full power, is a simple design, and provides good flexibility and economy of manufacture, and a good atomisation of fuel under all operating conditions.

What is the future of the carburettor?
In the last few decades, atmospherically aspirated carburetion has been replaced by fuel injection by virtually all modern car manufacturers. Fuel injection was once considered the rich man's way of using petrol, and with poor economy and only modest increases in engine performance, it only found its way into expensive and high performance cars with many cylinders. With the massive leap forward in electronics, computer technology and hence electronic engine management, the direct injection of accurately measured amounts of fuel has become not only possible, but now common place in almost all car engines. It is the only way manufacturers can reduce vehicle emissions to meet environmental legislation. Even the last of the Rover cars produced, which had relied extensively on the SU Carburettor, for example the Rover 1.1 (Metro), had fuel injection.

In the more recent past, the enhancement of air induction into fuel injected car engines has become more common due to developments in turbocharger technology. For many years this technique, which uses the power of the exhaust gases leaving the engine to rotate a turbine, connected to an impeller that sucks cool air into the engine, was only found in diesel and high performance petrol engines. It is now common to find a small turbocharger in petrol engines of small hatchback and family cars, to enhance performance and fuel economy.

The place of the SU carburettor, having played such an important role in the motor industry for over 80 years, is now confined to the more limited but never ending classic car markets and historic racing, where it should live on forever. Many classic vehicle websites and manuals cover the reassembly and setting up of the carburettor(s), so continuing to extract optimum performance from SUs is not difficult.

Finally, the twin SU carburettors on the nearside of this 4½ litre, supercharged 'Blower' Bentley are clearly visible for all to see.

Picture Captions and Credits

Page 15: Images of single, twin & triple carburettors taken at the Classic Motorshow, NEC, Birmingham, in November 2011.
Page 15: Twin SUs in a 3 litre Austin Healy. NEC Birmingham, November 2011
Page 16: Images of early SU carburettor taken from "The Book of the Motor Car, Volume 1" published by Caxton, London in 1913
Page 16: SU Carburettor: http://www.mgexperience.net/article/images/su-hs4-section.gif
Page 17: Twin SUs showing exterior of the channel used to create a pressure drop above the piston
Page 17: Carburettor body and float chamber on display at the Cotswold Motoring Museum and Toy Collection, Bourton on the Water
Page 18: A pair of SUs on a 4½ litre 'Blower' Bentley

Have electronics made the car too complicated?

This chapter on The Electronic Control Unit (ECU) attempts to describe some of the benefits of electronics and software to the car as well as considering the effects of increasing complexity, the implications for non-franchised motor dealers and the slow demise of motoring DIY.

Introduction

Modern cars are full of electronics, making them complex, difficult and expensive to service without specialist equipment and generally beyond the DIY skills of the vast majority of owners. There is a school of thought that says: surely, this is not the route to a sustainable, environmentally friendly future?

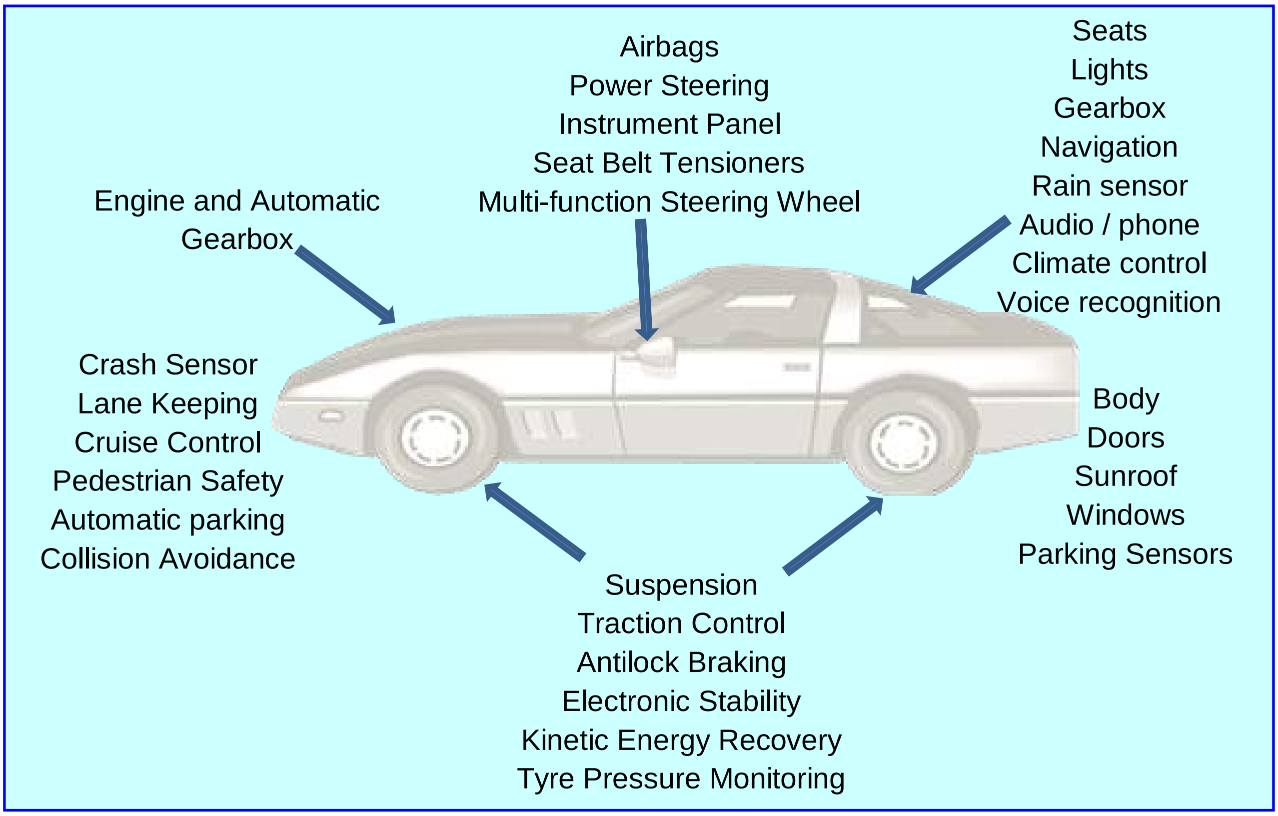
By value, electronics and software represent 35% to 40% of the cost of building a luxury car and one estimate suggests this could rise to 50% within a decade. Even a medium sized family saloon may have several tens of ECUs, each with its associated multiple electronic sensors and actuators, embedded in the body, doors, dash, seats or roof lining. Cars are complex and becoming increasingly so. One estimate is that 50% of ECUs exchanged by a garage technician exhibit neither software nor hardware faults: following diagnostics, replacement is the only option open to the technician. So, maybe there is merit in the earlier assertion?

The Cotswold Motoring Museum selected the ECU as one of the 10 most influential objects in the history of motoring. This selection is certainly not based on any aesthetic quality!

Typically, an engine management ECU appears as a metal or metal-lined plastic box with one or two multi-pin connectors along the box edges. The Siemens unit to the right measures around 160x140x30mm.

Siemens engine management ECU

Reasons for the ECU being in the top 10 include the environmental benefits such as cleaner exhaust gases, the social benefits such as the widening demographic spread of car owners and drivers, as well as performance and safety enhancements only achievable through the use of electronics and software. Virtually every function of the car is now influenced or directly controlled by an electronic ‘black box’. Just how widespread are the functions that depend upon the presence of an ECU and its embedded software is shown in the illustration below. For a hybrid vehicle, the list would be longer!



Typical functions of the Electronic Control Units (ECU) around a modern car

Throughout the 20th century, as cars became 'easier' to own and drive, so the number on the roads of developed countries soared. As examples of why cars became 'easier' to own and drive, consider: the advent of the electric starter motor, avoiding the need for hand cranking an engine, pneumatic tyres, improving ride comfort, power assistance for steering and brakes, and the automation of choke control and ignition timing - mentioned in the Prior Art panel below. Couple this with the real terms decreasing cost of purchasing a car[6], and it is easy to see why the number of cars on UK roads has grown from 14 or 15 in 1895 to 9.97 million in 1970 to 29.2 million today. Just as electronics has transformed the way we communicate with each other, the way commerce functions and the way we spend our leisure time, so electronics in the car has played a major role in the convenience, performance, environmental emissions, safety and affordability of cars over the last 40 years.

Performance, reliability, economy and emissions

In terms of the car's performance, reliability, economy and emissions, electronic control of the engine has had a profound influence. The engine ECU ensures optimum fuel combustion within the cylinders.

[6] See the chapter on "Responsibility of Ownership"

The Prior Art. Whilst today, electronics and software provide solutions to problems that the motorist of 50 years ago may not even have realised he faced (and it generally was a 'he'), how did the very early motor manufacturers provide solutions for the most fundamental functions performed today by electronics and software?

1911 Alldays & Onions

Take the basic function of producing a spark in each cylinder, at the appropriate time, to ignite the fuel / air mixture. The earliest car in the Cotswold Motor Museum is the Alldays and Onions 1911 Victoria. It has no battery, an air horn and acetylene and oil lighting. The only hint of anything electrical is the magneto, used to generate the high voltage applied in sequence to each sparking plug to burn the fuel. Levers in the centre of the steering wheel adjust the timing of the spark, along with control of the throttle opening. Advancing or retarding the timing of the ignition to achieve optimum starting and running was, in 1911, a purely manual task.

Advance / Retard lever

As vehicle design progressed, so the manual adjustment of the ignition timing became automated. Mechanical, centrifugal advance, which varied the timing depending upon the engine speed, and vacuum advance, which used the pressure in the inlet manifold to vary the timing, were introduced. In the late 1960s and 1970s, the (by now) conventional distributor components of contact breaker points and a condenser (capacitor) were starting to be replaced by electronic ignition; often as an after-market exchange, to improve reliability and performance.

Also in the 60s and 70s, electronic DIY kits existed to provide intermittent wiper actions, rev counters were becoming electronic, a few basic trip computers appeared in the US market and valve radios were being replaced with solid-state units.

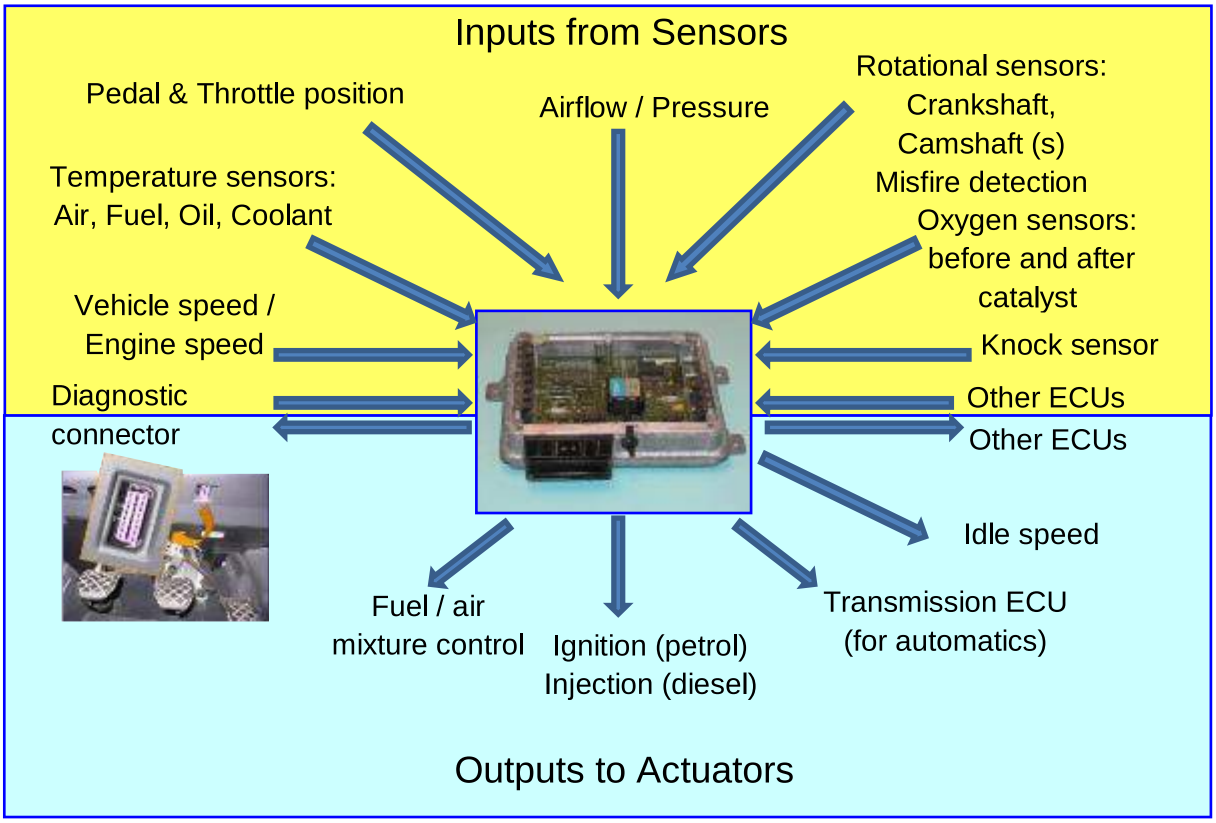
Garage diagnostics were performed using the type of diagnostic equipment produced by companies like Crypton or Sun; both of which feature in the Cotswold Motoring Museum display.

Electronic control of the drive train ensures optimum engine revs for a given gear ratio and improves the fuel efficiency of even small cars with an automatic gearbox. Such control, only possible through the use of electronics and embedded software, minimises particulate and gaseous exhaust emissions that are harmful to our health and our environment and has enabled vehicle manufacturers to keep pace with increasingly stringent US and European legislation on emissions.

Of all the areas of the motor car where electronics has been influential, management of engine functions has been the most far reaching.

The Engine Management ECU

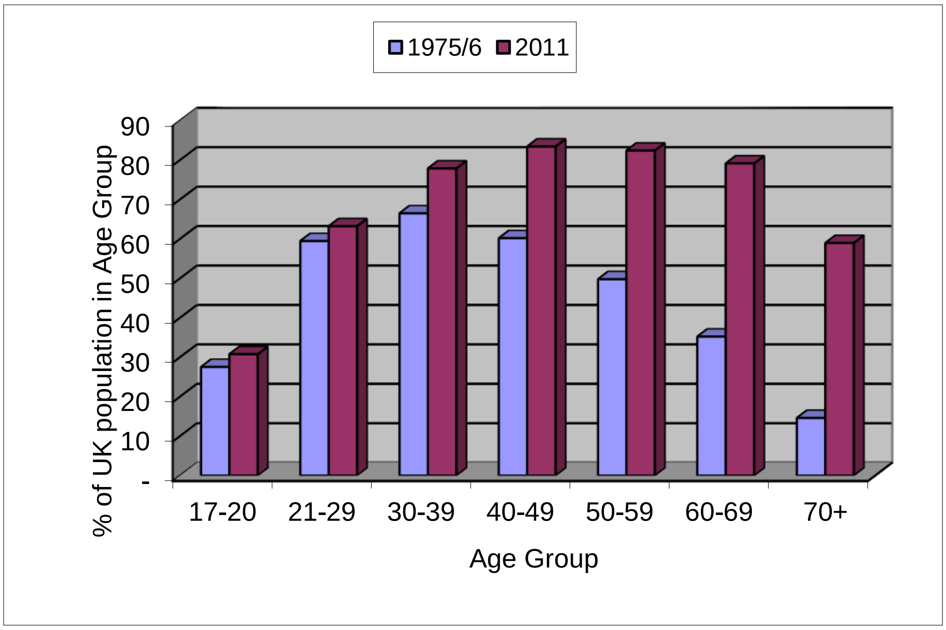
Fuel economy and exhaust gas cleanliness have seen major improvements from the adoption of electronics and software in the car.



The Engine Management ECU—inputs and outputs

Driveability, comfort and convenience

Year-on-year, the average age of the population of the US, Japan and Europe is increasing. As the chart on the next page illustrates, the proportion of the UK adult population holding a full driving licence has increased in all age groups since the 1970s. However, the largest percentage increase has been in the 70-plus age group. To these drivers, whose representation is set to increase up to 2035, driveability, comfort and convenience are key considerations when buying a car. Reversing and parking aids, seat position memory, suspension settings, automatic light and wiper operation and interior climate control are all likely to be on the list of selected options.

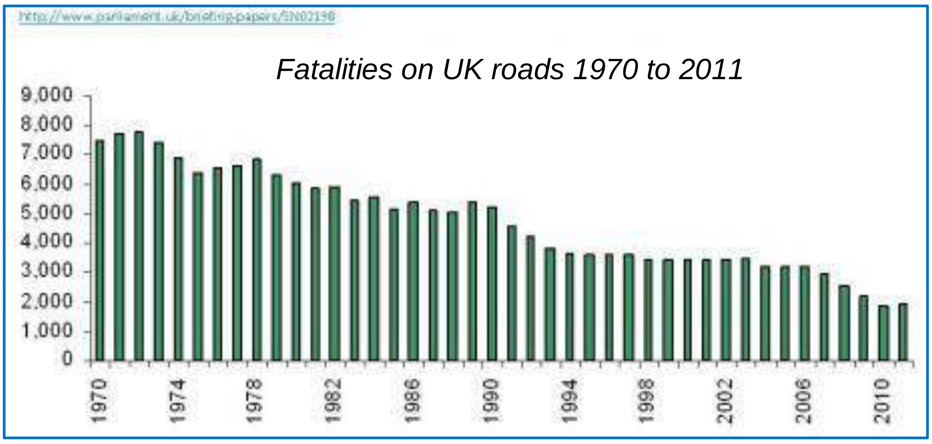


These features plus audio (digital audio broadcast or internet radio), in-car traffic information and navigation are features that are only possible through use of electronic memory and processing. Looking to the future, the increasing use of data buses around the vehicle and the electrical control of steering, throttle and brakes (the drive-by-wire concept) are helping to reduce vehicle weight and hence improve economy and drivability. Virtually autonomous vehicle control in the event of an emergency, along with an automated 'E-call' to the emergency services, is already well established in the development programmes of manufacturers such as BMW and Mercedes and is encouraged by European Union initiatives aimed at reducing injuries on the road.

Passive and active safety

In 1970, there were 7,499 fatal accidents on UK roads. In 2011, there were 1,901 fatalities with 833 being car occupants. Over this 41-year period, the number of vehicle miles (ie the number of vehicles on the road multiplied by the average annual mileage) has increased by 144%.

The contribution of electronics in cars to both passive and active safety has undoubtedly made a major contribution to that decrease. Seat belt pre-tensioners, airbag deployment, anti-lock brakes, electronic stability control and increasingly, emergency braking, lane keeping, collision avoidance and pedestrian safety, all owe their existence to the introduction of electronics to the car.



The future
Returning to that 50% statistic quoted at the beginning of this chapter (ie 50% of ECUs exchanged by a garage technician exhibit neither software nor hardware faults); how is this wastage to be reduced? A trend, particularly in the franchised dealer network, is to change the role of the workshop technician in the diagnostics process. With a secure data connection made between the diagnostic port of the car and the manufacturer's remote diagnostic system, the technician's role then becomes one of providing input to the computer-led diagnostic process and of taking the recommended actions, such as cleaning connectors, changing a sensor, authenticating software updates etc.

So, is there no downside to this takeover of vehicle functions by the all-pervasive ECU? Clearly, there are some and they tend to be those that affect both the vehicle repair market and the vehicle itself. As outlined in the previous paragraph, manufacturers would like to keep the end user of the vehicle heavily dependent on their network of franchised dealers. Whilst there are sound technical and quality control reasons for this, one obvious impact is that the non-franchised repairer, the roadside repair organisations and the DIY repairer will quickly be squeezed out of the picture when dealing with ECU-related faults. Such an outcome has long been viewed by the European Commission as anti-competitive and current legislation, primarily focused on cleaner vehicle emissions (Euro 5/6), includes requirements for the vehicle manufacturers to make repair information and diagnostic data available outside of the franchised dealer networks at "reasonable and proportionate" cost.

In spite of EU legislation and pressure from the independent sector requiring access to motor manufacturer's repair information, the manufacturers are reluctant to make software, such as updates and security software, available to repair organisations outside of their direct control: their argument being that these are not required for maintenance and repair. This clearly limits the range of tasks that can be undertaken by the independent and DIY repairer.

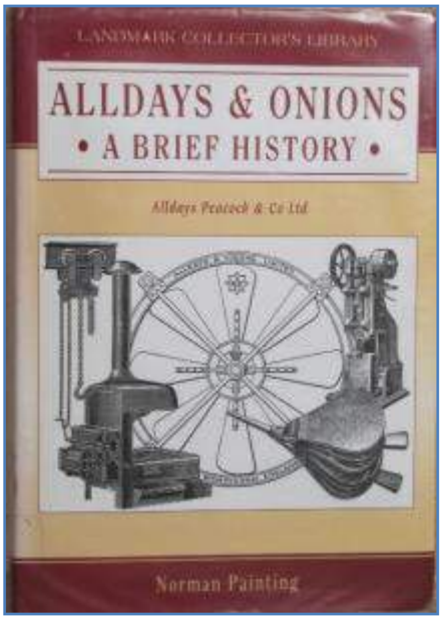
What is the future of electronics and software in the car? There seems little doubt that as it becomes ever more imperative to maximise remaining reserves of affordable oil, the development of new cars will be driven by maximising fuel efficiency and minimising CO_2 emissions over the life of the car. These objectives will only be met by ever more complex vehicle and engine management systems. One estimate is that 50% of the value of a non-hybrid car and 80% of the value of a hybrid will be down to electronics and software costs.

Tighter integration of an increasing range of vehicle components with the vehicle data bus is another feature of modern vehicles. Manufacturers claim that programming the code of replacement components, such as the battery, brake pads, switches and even light bulbs into the relevant ECU is the way to maximise fuel economy. Similarly, cancelling warning lights – such as a service indicator or a brake pad warning light - can become a franchised dealer task. This means that the independent sector, supplying parts, salvaged components and non-franchised servicing have to equip themselves, at significant expense, to be able to interface with each manufacturer's diagnostic software.

It is likely that, when reviewing the history of motoring in the 21st century, the electronic control unit will still be one of the 10 most significant objects in that history but the consumer's choice of repairer may look very different from today.

Postscript: The earlier 'Prior Art' panel focuses on the Alldays & Onions 1911 Victoria on display in the Cotswold Motoring Museum. It is probably fair to say that, to most of us, the manufacturer's name is not a familiar one. Like many carmakers from the early 20th century, Alldays & Onions came from a varied manufacturing background. Cycles, motorcycles, production tools and ventilation equipment were all part of the company's product range before and after the addition of cars and commercial vehicles. Norman Painting has produced a fascinating history of the company (which still exists today as Allday Peacock & Co Ltd) covering the period in which the 1911 Victoria was produced.

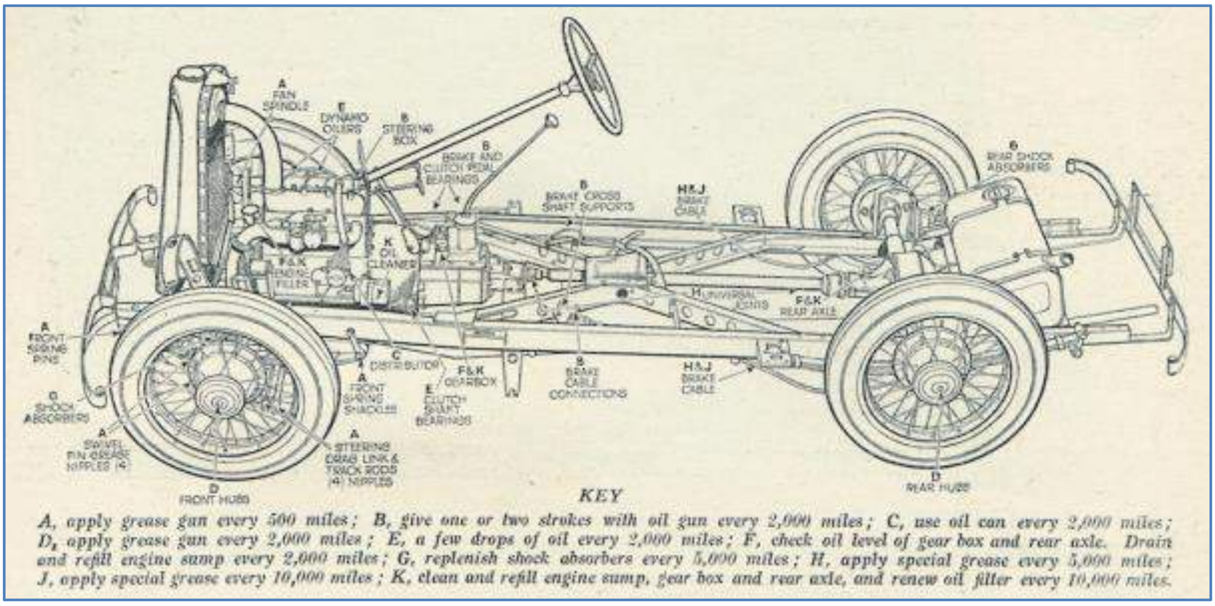
NOTE: To avoid any possible confusion, followers of the BBC series, The Archers, will recognise the coincidence of the name of Norman Painting who played the role of Phil Archer for 59 years and was also an author of books on 'Ambridge'. He was not however the same Norman Painting who is an authority on Alldays & Onions!



Picture Captions and Credits

The assistance of RAC Technical Training Department is gratefully acknowledged for providing the ECUs shown in this chapter and for display at the Cotswold Motoring Museum &Toy Collection

Page 20: Siemens engine management unit from a Renault
Page 22: 1911 Alldays & Onions Victoria on display at the Cotswold Motoring Museum & Toy Collection
Page 22: Sun and Crypton diagnostic equipment on display at the Cotswold Motoring Museum & Toy Collection
Page 23: Typical location for the engine management ECU
Page 26: Cover image "Alldays & Onions - A Brief History" by Norman Painting, Landmark Collectors Library, 2002



The picture above is from the 12 April 1935 issue of Autocar magazine and is part of an article on the service and care for a 1935 Standard Nine. It also provides an excellent view of what is now known as a car's powertrain. For a modern, rear-wheel drive, internal combustion engine car, all the essential components of the powertrain would be readily identifiable from this 80-year-old picture.

The main components of the powertrain are the engine, gearbox (or transmission) and differential (or final drive). A more rigorous list would include the clutch (torque converter for an automatic gearbox), propeller shaft, universal joint(s), drive shafts, rear hubs (or constant velocity joints for front wheel drive), wheels and tyres. The term drive train is also used, although strictly speaking this should refer to the powertrain, less the engine.

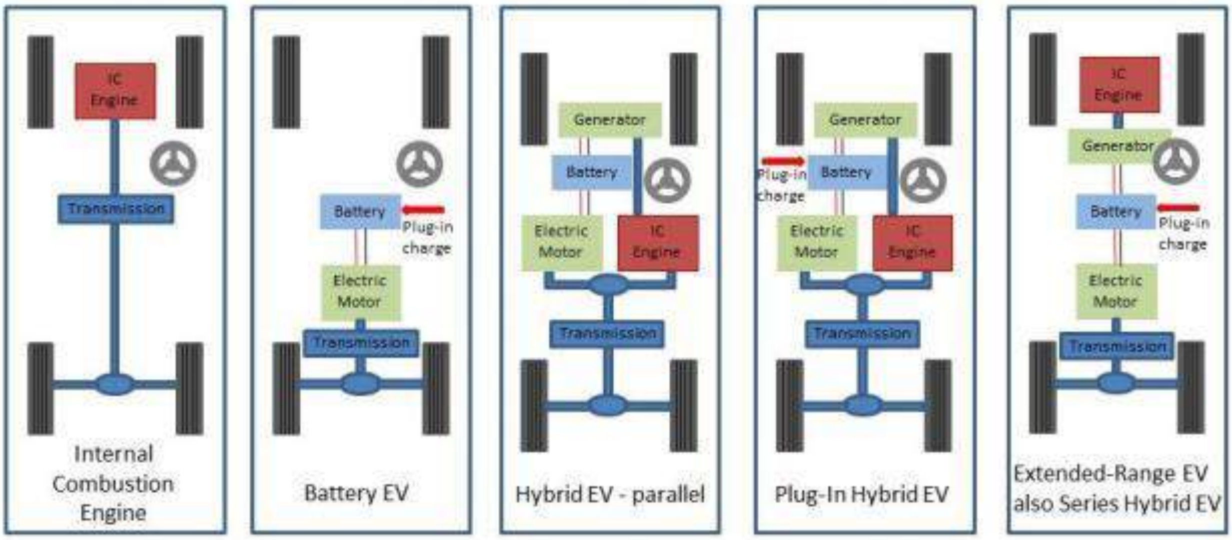
For a front-wheel drive, internal combustion engine car the powertrain would look very different but, with the exception of the propeller shaft, would comprise the same list of components. A four-wheel drive car requires a front, rear and centre differential to distribute power to the four wheels whilst a hybrid electric vehicle would have a powertrain that looks quite unlike the 1935 picture.

Some of the basics however have not changed since the 1935 Standard Nine was designed. The car's speed per engine revolution (often quoted at an engine speed of 1000rpm) will depend upon the gearbox ratio in each gear, final drive ratio and wheel and tyre rolling circumference. Choice of materials, low-friction coatings and specialist lubricants for engine, gearbox and final drive will affect the overall efficiency of the powertrain.

The aim of any powertrain design is to balance a range of (often conflicting) performance criteria. These include top speed, acceleration, fuel consumption, exhaust emissions – all of which depend, amongst other things, on the weight of the powertrain components - as well as serviceable lifetime and both production and lifetime costs. Powertrain designers work in close cooperation with body stylists - aerodynamic performance is a major factor in the overall efficiency of the car - with computer modelling being the starting point of any design process.

In addition to computer modelling skills, design of the powertrain for a modern car involves specialist mechanical, electronic and chemical input plus a good understanding of materials science. It is very much a cross-disciplinary task.

In recent years, powertrain design has seen a resurgence with the advent of hybrid electric vehicles. Electric vehicles are the subject of the following chapter but, for the purposes of powertrain design, it is informative to consider the relative merits of Battery Electric Vehicles (BEV), Hybrid Electric Vehicles (HEV), including plug-in hybrid electric vehicles (PHEV), and Extended-Range Electric Vehicles (E-REV). The following schematic drawings show these basic configurations. To retain focus on powertrain, these drawings are very simplified. No



regenerative braking is shown, super-capacitors and supplementary batteries are omitted along with any references to power conditioning electronics, ECUs and on-board battery charging components. Also, in some configurations, a single electric motor may be replaced by one at each driven wheel.

On the road, cars of competing powertrain designs have been ranged against each other in the RAC Future Car Challenge. The real-world environment is, in fact, the route from Brighton to London, including sections of motorway, urban and suburban driving. Entry is restricted to cars emitting less than 110g/km of CO_2: which, of course, allows some internal combustion engine cars to compete, making for an interesting competition. Events were held in 2010, 2011 and 2012.

A paper published on the 2012 challenge[7] measured the total energy used by all the configurations of powertrain design shown above. Electrical energy used during the challenge was logged in the car and (where relevant) brim-to-brim measurements of fuel consumed were converted into energy used through well-established conversion factors for petrol and diesel fuel. The challenge was to complete the course using the least amount of energy and, maybe

[7] "The 2012 RAC Future Car Challenge: The Impact of Hybridisation on Energy Consumption", von Srbik et al.

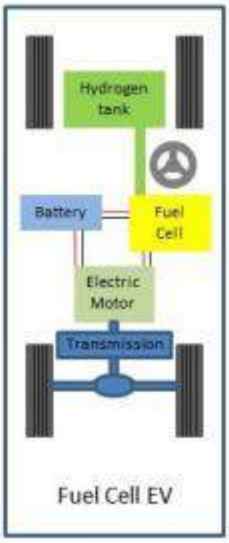
not surprisingly, the lightest BEVs proved to consume the least energy, followed by the Plug-In Hybrid EV and finally the Internal Combustion Engine car.

To allow for variations in weight between the vehicles, the measure of energy used throughout the challenge was expressed as Watt-hours per kilometre per kilogram of car weight (Wh km^{-1} kg^{-1}). When weight was included in the calculation of efficiency, the heavier vehicles were relatively more efficient with the Plug-In Hybrid EV giving similar performance to the BEV.

The 2011 winner of the challenge was the BEV produced by Gordon Murray, the T.27. In 2012, the first and second places were taken by prototype cars but third place overall went to a production car, the Renault Zoe EV with three prototype Jaguar XJ cars (E-REV/PHEV) coming 11th to 13th in a field with 33 finishers.

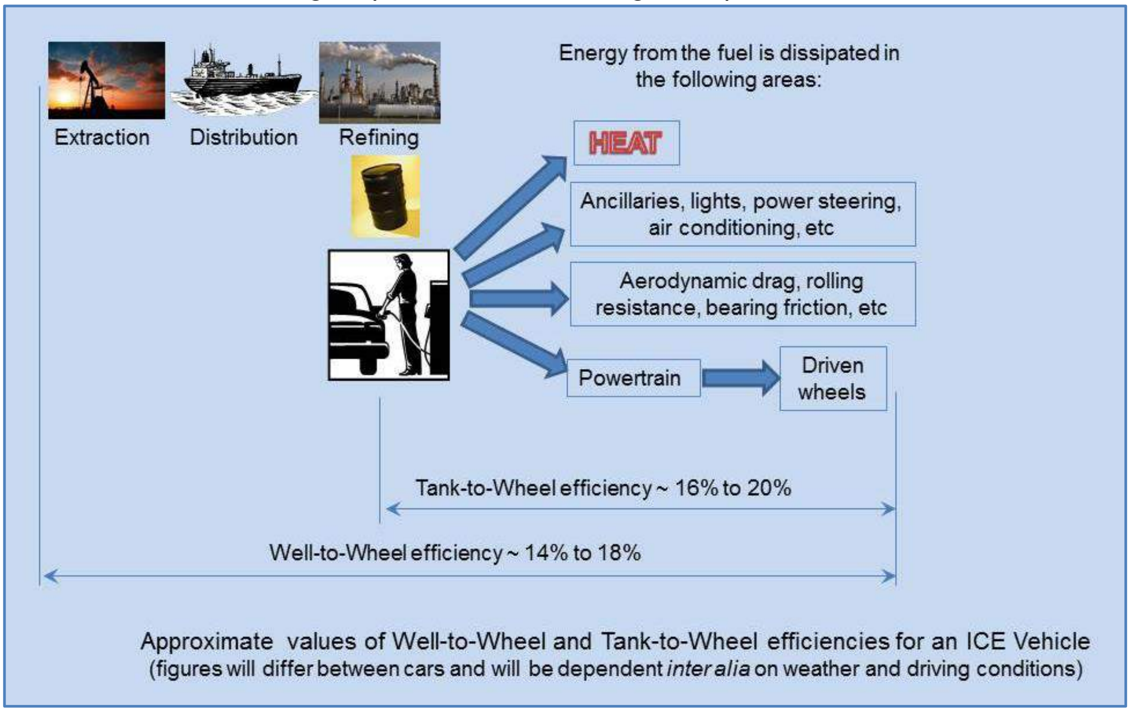
In 2014, one of the best examples of powertrain development was in the world of Formula One racing. Rule changes meant that the 2013, 2.4 litre V8 engine had to be replaced with a 1.6 litre turbocharged V6 and two Energy Recovery Systems (ERS) replaced the earlier Kinetic Energy Recovery System (KERS). In addition, unlike KERS, which was activated by the driver for a few seconds each lap, the ERS had to be available for over 30 seconds per lap and was activated solely through use of the throttle: in other words, much more akin to how a road car would use recovered kinetic and heat energy. The power outputs from the internal combustion engine and the ERS are around 600bhp and 160bhp respectively.

In 2013, UK registrations of hybrid and plug-in cars (ie BEVs, PHEVs and E-REVs) totalled 32,715. Of these, plug-in vehicles accounted for just 11%. This may, in part, be down to availability, with cars such as the Toyota Prius, a HEV, being firmly established in the market whilst plug-in and BEVs were later to market or it may be an indication of the motoring public's preference for energy recovery and an internal combustion engine to take over when batteries need recharging. Plug-in after all is not too easy when the car is parked at the roadside.

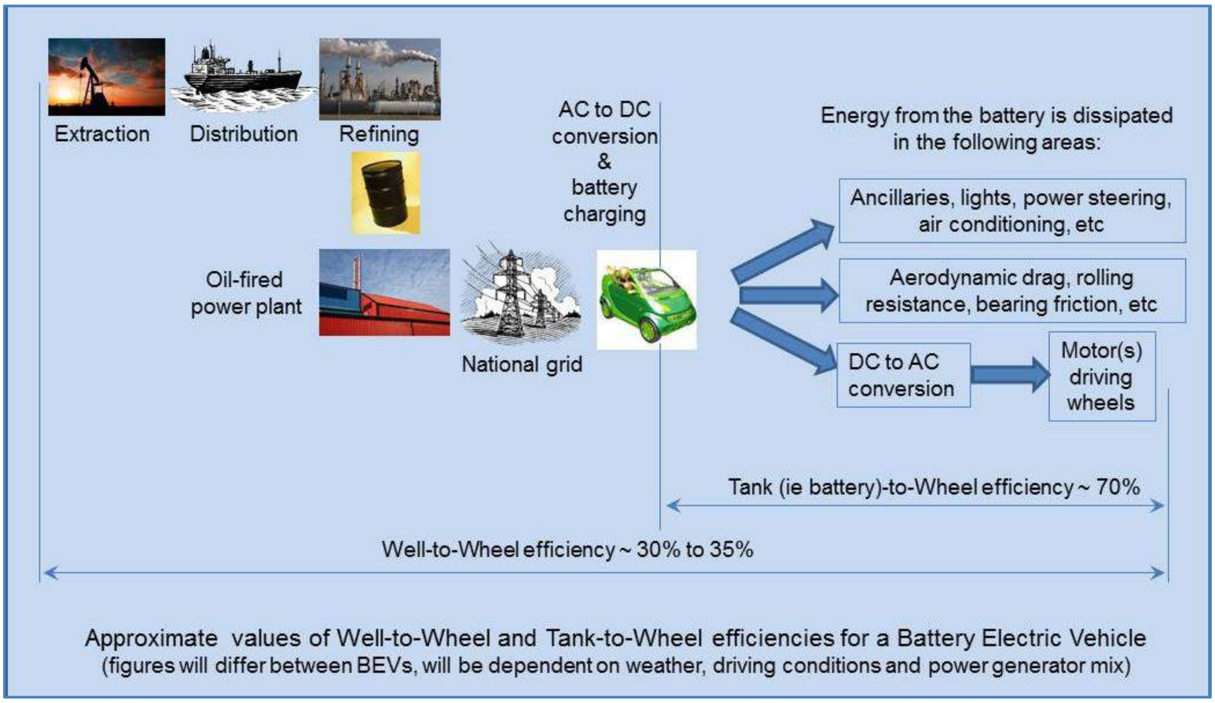


Finally, the fuel cell electric vehicle (FCEV) has been under development for more than a decade. A very simplified schematic is shown here with ancillary components associated with voltage conversion and regenerative braking omitted. This does not require a plug-in but it does require a hydrogen infrastructure which today, is conspicuous by its absence.

A fleeting reference was made to powertrain efficiency in the opening paragraphs of this chapter. A figure of [15% tank-to-wheel efficiency] was also previously mentioned as typical of an internal combustion engine powered car. This figure represents the fraction of the energy



stored in the fuel that is used to propel the car. The drivetrain of a modern electric car has far fewer moving parts than its petrol or diesel powered equivalent, emits much less heat and can achieve a 'tank' (ie battery) to wheel efficiency of around 70%. This is not quite a valid comparison since the energy stored in the battery of the electric car is derived from the national power grid with its mix of generating capacity, including fossil fuel. When the efficiency of power generation and distribution is taken into account, the tank-to-wheel efficiency of the electric car is more like 33%: still a significant improvement over the petrol / diesel counterpart.



When including the energy used in extracting and distributing the fuel to be burnt in either the internal combustion engine or the power generation infrastructure, the respective well-to-wheel efficiencies of electric and internal combustion become, approximately, 30% and 14% respectively.

Which of the powertrain configurations presented above will dominate as the 21st century evolves is still an unanswerable question. Motor manufacturers are investing heavily in all of the options with legislation a major driving force for CO_2 reduction: an area where the BEV is a strong contender.

One thing that is certain is that the service and care of the 21st century powertrain will be very different from the service and care of the 1935 Standard Nine at the start of this chapter.

Picture Captions and Credits

Page 27: Autocar 12 April 1935
Page 29: Gordon Murray T.27 BEV: http://www.gordonmurraydesign.com/previous/press-T27-unveiled.php
Page 29: Renault Zoe from the Green Car Website:
http://www.thegreencarwebsite.co.uk/blog/index.php/2012/11/05/renault-zoe-wins-rac-future-car-challenge/
Page 30: Well-to-Wheel diagrams use Microsoft Office clip Art throughout

Part 3 - Technological | Electric Vehicles

Are electric vehicles going to be the success story of motoring in the 21st century?

Fossil fuel, both liquid and gas, is coming into competition with battery power, hybrid vehicles, hydrogen-powered fuel cells and even solar power. Will the 21st century see just a single winner? These fuels and their associated environmental impact are outlined in this chapter.

Introduction

Electric vehicles have been around since the dawn of motoring. As early as 1835, Thomas Davenport, a blacksmith from Vermont, built an electric car and in 1899, an electric car held the world land-speed record at 66mph. Today's land speed record for an electric car, set in June 2013, is 204.18mph and 2014/15 will see the launch of Formula E, the all-electric version of Formula One, staged in 10 world cities and finishing in London in June 2015.

Even within today's minority market for electric vehicles, the battery powered car and hybrid face challenges from cars powered by hydrogen fuel cells and solar. Meanwhile, the mature technology of the internal combustion engine powered car has been rapidly advancing. Using lower weight materials, electric rather than hydraulic actuators and improved combustion, the fuel consumption and CO_2 emission figures of the average family saloon from just a decade ago look very poor when compared to today's performance.

The recent popularity of electric vehicles for urban use in cities such as Oslo, where nationally there are over 21,000 electric vehicles in a population of 5 million, can be heavily influenced by government and city incentives. What happens when these incentives are removed, as will inevitably happen one day?

There is also the consideration of how the electricity to recharge the electric car is generated. If generated from fossil fuel, there is the argument that whilst the dense urban environment may benefit from lower atmospheric pollution, the overall contribution to atmospheric gases is simply shifted from the city to the site of the generator.

This chapter seeks to shed light on some of these issues.

Battery Power

The Waverley electric car, shown here at the start of the London to Brighton run, was manufactured in the United States in 1903 and remains capable of travelling from London to Brighton on a November Sunday morning, carrying 3 adults, with just a couple of re-charging breaks.

Between 1950 and 1970, in the UK, electrically powered vehicles found a niche where the limitations of speed and distance imposed by battery operation were no great barrier to their role. Used as 'yard' vehicles, for the delivery of milk, they returned to a central depot for an overnight recharge and ran around well-defined, urban routes. They were quiet, suiting their early morning deliveries; it was just the bottles that were noisy!

Over more than 170 years, the issue of battery life and hence distance covered between battery charging, has been dominant. In more recent times, environmental concerns over fossil fuel use, accompanied by new battery technology (such as lithium-ion), government subsidies, plus tax and congestion charge advantages, mean that electric vehicles are being seriously marketed as alternatives to internal combustion engine cars and light vans.

Today, at least for short urban journeys, battery powered vehicles are becoming technically, operationally and financially feasible. A National Household Travel Survey in the USA showed an average daily commuting trip length of 12.4 miles. Also, 95% of journeys are less than 40 miles and 99% less than 60 miles. Even on the most pessimistic estimates of range, this puts those journeys within the capability of most electric vehicles on the market today. UK commuting appears to be similar. Based on Department of Transport figures, the UK average commuting trip length in 2012 was 9 miles.

The various configurations of electric vehicle (EV) and hybrid electric vehicle (HEV) are tabulated later in this chapter. In many configurations, the drive to the wheels is via an electric motor, which draws its power from an on-board battery pack. These batteries may be charged by a small on-board internal combustion engine or by simply connecting the vehicle to a mains power supply. For a normal domestic supply, they usually require an overnight charge to restore maximum capacity. A feature of most modern electric cars is the regenerative braking system, which allows the battery or a capacitor to be topped up with energy generated during braking.

Returning to the 'yard' vehicle, this time in a public transport role, an approach to top-up recharging is undergoing trials on a fleet of eight electric buses in Milton Keynes. At the end of their 15-mile route, the buses park over a pad in the roadway and lower a corresponding pad on the bus. These pads contain electric coils and the bus battery recharges via a current induced into the bus coil from that in the roadway. A 10-minute top-up during the driver's break restores two-thirds of the energy expended during the previous 15 miles. An overnight charge from the mains is necessary during the 7 hours a day that they are off the road.

For the privately owned battery powered car, the slow growth in numbers on the UK roads arises from a number of factors. These include an initial high purchase price, limited range on a battery charge, giving rise to so called 'range anxiety', few public charging points and a lack of standardisation of the charging connector. Particular stress is placed on the battery in cold, dark conditions. Performance falls with decreasing temperature and in these circumstances it is also likely to be providing not only the energy for propulsion but also powering the lights, heater, wipers, radio, etc. As an indication of progress, however, the Tesla electric sports car with a range of over 200 miles, is as far removed from the electric milk float of the 1950s or the Waverley of 1903 as it is possible to imagine.

Returning to the world land-speed record for a light electric car (less than 1000kg), this was broken in June 2013 by a converted former Le Mans Lola racing car that achieved an average speed of 204.18mph. Technology drivers such as this and the technology spin-off from Formula E cars, such as light-weight materials and tyre technology, can only benefit the prospects of future battery powered cars.

Fuel cell electric vehicles

A fuel cell is an electrochemical, energy conversion device. A fuel cell converts the chemicals hydrogen and oxygen into water, and in the process it produces electricity. Electricity can be produced constantly as long as the flow of chemicals continues. Fuel cell technology has been under development for many years but is currently still expensive in comparison with battery technology. Hydrogen production, for example through electrolysis of water, requires energy and unless this is derived from renewable sources, the overall carbon dioxide production associated with hydrogen propulsion may not be as little as first appears. Significant research funding is addressing cheaper and lower carbon techniques for hydrogen production from water. Solar powered, high temperature techniques and ambient temperature techniques using an affordable cobalt catalyst are two current research areas. Transportation of compressed hydrogen gas or liquid hydrogen is also an inefficient process, as typically, 99% of the transported load comprises the weight of the delivery vehicle.

A fuel cell electric vehicle (FCEV) has no internal combustion engine and, with the exception of the Audi battery hybrid model (see below), does not need to be recharged from the mains. Many manufacturers have already demonstrated fuel cell vehicles and there are some currently in use providing important information and feedback for the future development of FCEVs. Technical challenges include:

- safe storage of hydrogen in the car. Compressed hydrogen gas – at a few hundred bar - rather than liquid hydrogen, is likely to be stored in carbon-fibre reinforced tanks

- production, distribution and storage infrastructure for hydrogen
- reliable use in cold weather
- reduction in cost through minimising the use of the expensive catalyst, platinum

At the time of the 2012 London Olympics, a number of hydrogen fuelled London taxis were used to ferry VIPs around the Olympic venues. The cab has a top speed of 80mph and a range of more than 250 miles on a full tank with refuelling taking approximately five minutes.

At the 2014 Los Angeles motor show, Audi revealed a plug-in hydrogen hybrid capable of operating with the fuel cell only, fuel cell and battery or battery only. The hydrogen fuel cell is claimed to provide a further 342 miles range once the battery-only option is exhausted. At the same show Toyota unveiled their Mirai, a production-ready FCEV with a claimed 300 mile range.

Solar power

Using solar energy to charge an electric vehicle, when at home or at a public or work place charging point, is a step towards an overall reduction in the gaseous emissions associated with the internal combustion engine. The definition of a solar car, however, is an electric vehicle powered by energy obtained from solar panels *directly on* the car. At best, for practical cars, the solar energy can be considered as a top-up to the mains energy used for battery charging or for powering accessories such as air conditioning. Insufficient power can be generated by current solar panels on the roof of any practically sized and shaped vehicle to provide adequate performance. The Ford solar concept car, the C-Max Solar Energi, displayed at the 2014 Consumer Electronics Show, has a roof covered with solar panels but even a day in full sun is insufficient for a full recharge of the car's lithium battery. As 'technology demonstrators', solar cars are raced in competitions such as the World Solar Challenge and the North American Solar Challenge. Such challenges are used by universities to develop their student's engineering and technological skills as well as by motor vehicle manufacturers such as GM and Honda.

Electric vehicle summary

A number of configurations in which electrical power is used to propel the vehicle are emerging onto the global car market. Some of these are summarised in the table below.

Vehicle type	**Configuration**	**Examples in or nearing production**
Hybrid (HEV)	Battery powered electric motor and petrol engine (rarely a diesel due to weight) providing motive power. Batteries recharged from engine during driving and through regenerative braking. No need to plug into a charging point.	Toyota Prius (89g/km)

Vehicle type	Configuration	Examples in or nearing production
Plug-in Hybrid (PHEV)	Battery powered electric motor and petrol engine (rarely a diesel due to weight) providing motive power. Batteries recharged via a mains power connection and through regenerative braking. Permits larger battery capacity and hence a longer all-electric range than the HEV.	Toyota Prius Plug-In (49g/km) Mitsubishi Outlander (44g/km) BMW i8 (49g/km)
Extended-Range Electric Vehicle (E-REV)	Wheels always powered by an electric motor. Batteries recharged by plug-in and an on-board petrol IC engine. Electric only range 25 to 50 miles, overall range up to 360 miles.	Vauxhall Ampera Chevrolet Volt (27g/km)
Battery Electric Vehicle (BEV)	Battery powered electric motor with batteries recharged via a mains power connection. Typically 80 to 110 mile range (over 200 for the Tesla) before a recharge is required.	Renault Fluence ZE Nissan Leaf Tesla BMW i3
Fuel Cell Electric Vehicle (FCEV)	Wheels always powered by an electric motor. For the fuel cell / battery hybrid, the motor is powered by lithium ion batteries and by energy from a hydrogen fuel cell. London Taxi for 2012, Honda production by 2015, Hyundai production of 10,000 in 2015.	Honda FCX Clarity London Taxi Hyundai ix35 Audi A7 hybrid

In the luxury vehicle category is the Jaguar Limo-Green (120g/km), another example of an Extended-Range EV. In this vehicle, the wheels are driven by the electric motor and a 1.2litre, 3-cylinder petrol internal combustion engine charges the batteries. In addition, the car can also be plugged into the mains and the batteries charged overnight. For further information, see the Green Car Website.

The wider picture

Zero polluting emissions from a battery or fuel cell powered vehicle are clearly good news for people coexisting with these vehicles in a congested urban environment. However, the stored energy in a battery is replenished through recharging and this is not necessarily a pollution-free process. There is an argument that suggests the harmful emissions are just shifted from one place to another rather than being reduced.

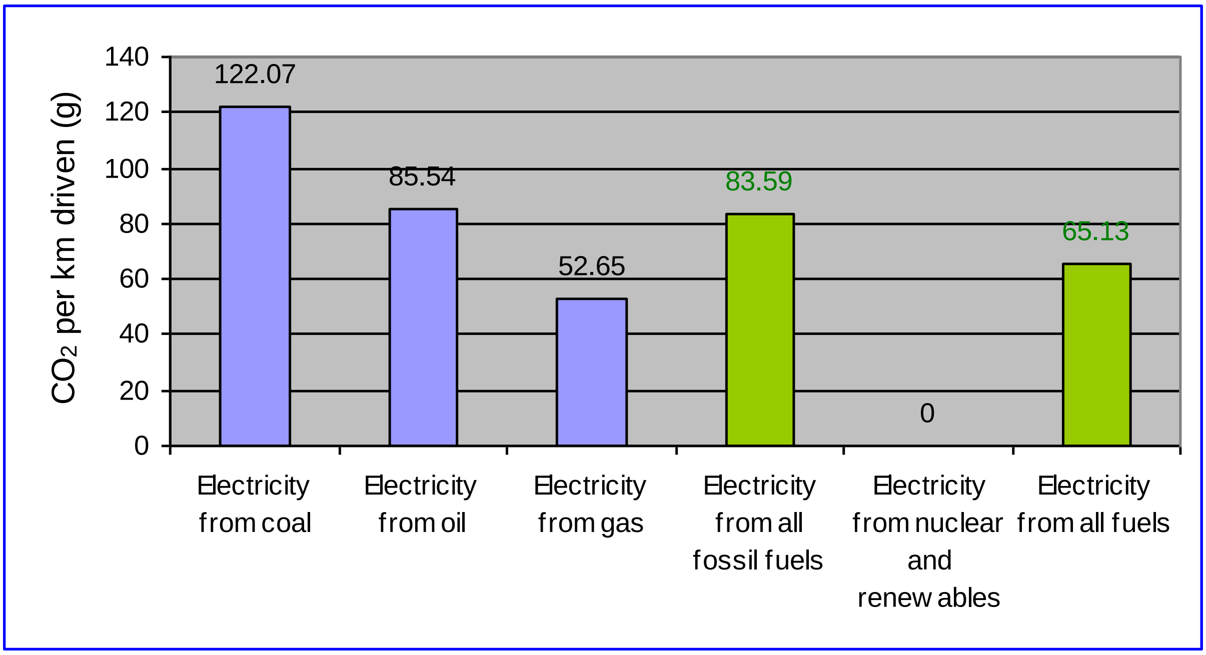
For the solar powered demonstrator vehicles mentioned above then strictly, just in terms of energy use (ignoring factors such as diminishing availability of raw materials), the energy equation should include terms reflecting the energy used in the solar cell production and end-of-life disposal balanced against the energy produced by the cells during the vehicle lifetime. For hydrogen-powered vehicles, the energy used and associated emissions in hydrogen production and transportation will offset the zero CO_2 emissions at the tailpipe. For a battery-powered vehicle, the energy used to manufacture, transport and recharge batteries throughout their life should be reflected in the overall environmental impact of the vehicle.

Quantifying the overall lifetime CO_2 budget for an electric vehicle should reflect the energy consumed in production, distribution and disposal of the whole vehicle as well as during operation. However, very different conclusions can be reached depending upon the assumptions made. A Low Carbon Vehicle Partnership report provides a good source of reference and a standard for calculating the CO_2 contribution over a vehicle's lifetime. Ozzie Zehner, a University of California professor, writing of "Green Illusions" contributes a more controversial opinion on the scientific rigour behind frequently quoted electric vehicle environmental performance.

Once on the road, from an environmental point of view, battery recharging, or hydrogen production, using electricity from a renewable energy source is clearly more environmentally friendly than charging using electricity generated from fossil fuels. Coal, oil, gas, nuclear, biomass, hydro, wind or other renewable power generation for recharging batteries will determine the effective, overall carbon dioxide emissions of each vehicle configuration.

Charging the batteries of an electric vehicle from a renewable power source, such as wind energy, will result in zero overall CO_2 emission throughout the car's journey. However, most power used to recharge the batteries of an electric vehicle is derived from a power grid fed by a mixture of coal, oil, gas, nuclear and renewable power plants. When taking into account the CO_2 emissions created in the generation of electricity, a 2009 submission by the Institution of Engineering and Technology (IET) to UK government on renewable energy has shown that the equivalent CO_2 emissions of an electric vehicle can be comparable with those of a modern petrol or diesel vehicle.

The diagram below is derived from data in the IET submission. The 'green' bars are the average of the preceding values and represent the current mix of coal, oil, gas, nuclear and renewable in UK power generation.



The CO_2 limit for exemption from the London congestion charge reduced on 1 July 2013 from 100g/km to 75g/km. A battery electric vehicle, recharged from the UK grid, has an effective CO_2 emission figure of around 65g/km. It is therefore appropriate that battery electric vehicles are exempt from the London congestion charge. In addition, the Chevrolet Volt and Vauxhall Ampera (both specified as 27g/km) and the Toyota Prius Plug-In Hybrid (specified 49g/km) are exempt from the charge.

For comparison, along with many small cars, some medium sized cars such as the 2013 VW Golf 1.6 TDI petrol and diesel saloons achieve 98 or 99g/km. The 1.1 Hyundai i20 diesel achieves 84g/km. Currently no petrol or diesel vehicle can meet the 75g/km limit.

Conclusion

Finally, returning to the whole life cycle CO_2 budget, for electric vehicles, with batteries re-charged from the UK grid with its current mix of coal, oil, gas, nuclear and renewables, the *lifetime* CO_2 will most likely be less than that of the equivalent internal combustion engine powered car but the percentage of CO_2 produced during manufacture is likely to be higher.

In summary, the Low Carbon Vehicle Partnership report states:

"……… results show hybrids and EVs [electric vehicles] will have lower life cycle CO_2 emissions, but embedded emissions [ie during manufacture] will be more significant"

and

"The technology evolution to plug-in vehicles will lead to higher embedded CO_2 emissions due to the addition of new components"

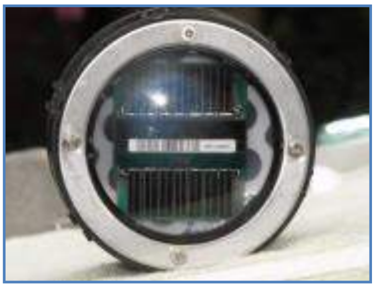
Picture Captions and Credits

Page 32: Electric car public charging points
Page 33: 1903 Waverley electric car at the start of the 2003 London to Brighton run.
Page 33: Electric Milk Float http://www.milkfloats.org.uk/spmf2.html
Page 34: Tesla Roadster http://www.teslamotors.com/en_GB/roadster
Page 35: http://www.worldsolarchallenge.org/about_wsc_2013/photo_highlights/day_1_action

The wheel rim of the London to York stagecoach and that of the first petrol engine car were remarkably similar. At best, a band of solid rubber may have been laid over the iron tyre of the car wheel. The fact that the footprint of the car on the road comprises just four small contact areas between rubber and tarmac has been the driving force for 125 years development of the pneumatic tyre. The aim of that development has been to improve ride comfort, reduce noise level, reduce wear rate and, above all, to enhance the safety of the car occupants through good grip under all weather conditions.

Throughout the history of motoring, manufacturers have sought to attract buyers to their products through emphasising various aspects of their products. These have included performance, economy, aesthetics, environmental friendliness and safety. The advent of the seatbelt was one such occasion when, particularly in the USA, safety formed a major pitch in car advertising. Some manufacturers have successfully built a brand recognition that revolves around a body designed for safety and, during the 1970s, much of this association started with the seatbelt.

Recognising that the safety of vehicle occupants depends not just on the vehicle construction and maintenance but also on driver behaviour and the road network itself, an EU directive aims to halve the number of deaths on EU roads by 2020 and move close to zero fatalities by 2050.



Selecting just one aspect of the environment in which the car operates, the “Catseye”, was chosen as one of the Cotswold Motoring Museum’s “10 Objects” for the 2012 special exhibition and continues to be a feature of the museum display.

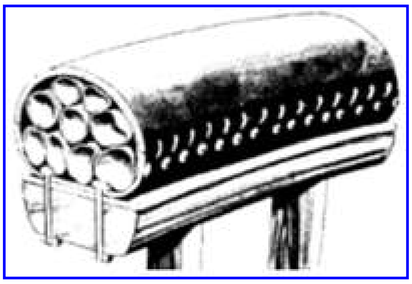
These four topics, tyres, the seatbelt, the car body and the ‘Catseye’ form the chapter headings of this section on car safety.

The Dunlop Tyre

This chapter outlines some inventions and developments that have led us to the car tyres that we today take for granted. Like many great inventions, the men with the original ideas, those remembered by history, are not necessarily the ones who saw the greatest benefit.

Introduction

The person most commonly associated with the invention of the pneumatic tyre is John Boyd Dunlop (1840 – 1921). John Dunlop was born in Ayrshire, Scotland, qualified as a veterinary surgeon and moved to Belfast in 1867. It was in 1888 whilst trying to make a more comfortable cycle tyre for his son, by wrapping an inflated tube of canvas around the wheel rim, that his idea of a pneumatic tyre was conceived and patented. After a local cyclist enjoyed competitive success through adopting Dunlop's idea, the patent was purchased in 1896 by William Harvey du Cros. At this time, Harvey du Cros was working in Dublin with John Dunlop producing pneumatic tyres for bicycles. Following the purchase of the patent, Harvey du Cros became a founder and Chairman of the Dunlop Pneumatic Tyre Company in 1896 and went on to successfully develop and exploit the manufacturing process for the pneumatic tyre.



There is however an earlier, legitimate claim to the invention of the pneumatic tyre by fellow Scotsman Robert William Thomson. Thomson was granted a patent in France in 1846 and in the USA in 1847. Thomson's "Aerial Wheels" as they were known, were demonstrated in London's Regent Park in March 1847 and were fitted to several horse-drawn carriages, greatly improving the comfort of travel and reducing noise. Frustrated by the poor availability of thin rubberised canvas tubing to fit inside a leather outer casing, he abandoned his attempts to build on his early success with inflatable tyres for horse-drawn carriages. He devoted his subsequent effort in this area[8] to the development of solid India-rubber tyres for road steamers[9] and the new omnibuses. He is remembered in his home town of Stonehaven by a bronze plaque, presented to the town in 1922 by the Royal Scottish Automobile Club which reads:

The Birthplace of Robert William Thomson
The inventor of the pneumatic tyre
Born 29th June 1822
Died 8th March 1873

In spite of the granting of the Dunlop patent in 1888, in 1890 he was officially informed that it was invalid as Thomson's patent had preceded it. As with many inventions though, it was not the initial inventor who reaped the benefit but the individuals who exploited the idea and turned it into an affordable product capable of mass manufacture.

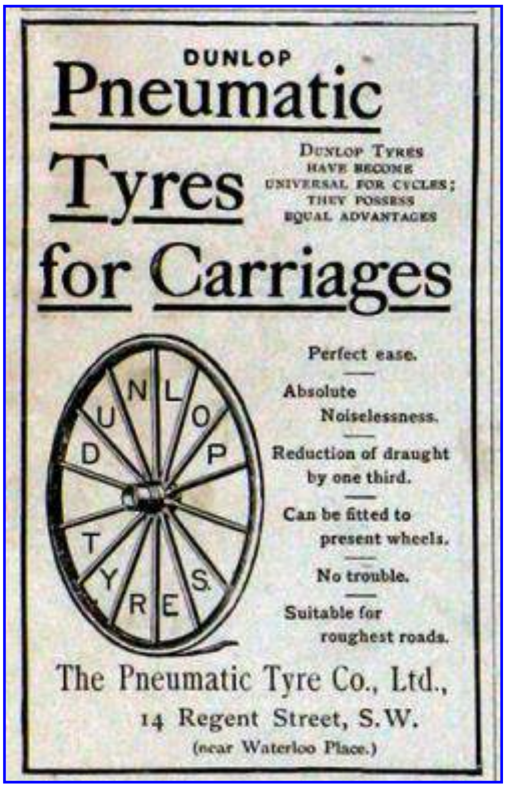
It was in 1900 that Dunlop began the manufacture of car tyres. Initially production was subcontracted but by 1902 it went into production in its own right at its subsidiary company the Dunlop Rubber Co. Ltd which was located at Manor Mills, Aston, Birmingham. The business relocated in 1916 to larger production facilities in Birmingham called 'Fort Dunlop'. It continued here until the late 1980s and after standing empty for 20 years, the property, alongside the M6 near junction 5, is now redeveloped into commercial and residential property. At its height, it was the world's largest factory, employing over 3200 people under one roof and, by 1955, producing almost half of all tyres sold in the UK.

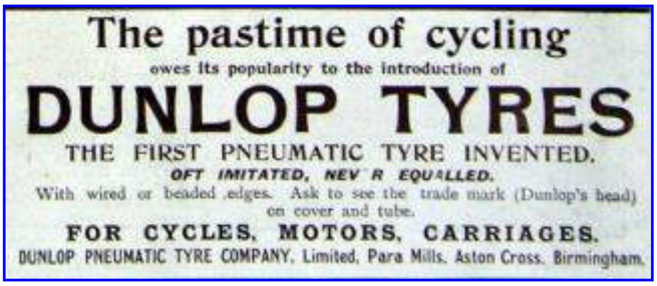
Although it appears that the Dunlop Company made rapid progress following the re-invention of the pneumatic tyre in 1888, it was not Dunlop but André and Edouard Michelin, two agricultural engineers from Clermont-Ferrand, who produced the first pneumatic automobile tyre in 1895. Dunlop patents in 1893 and 1894[10] continued to focus on pneumatic tyres for "velocipedes and other vehicles": perhaps showing a lack of realisation that, in the near term, high volume production lay with automobile tyres?

[8] Thomson's inventions were not confined to rubber tyres; a list is shown at the Stonehaven hyperlink

[9] Steam powered vehicles independent of the rail network

[10] Patents GB10850 and GB11820



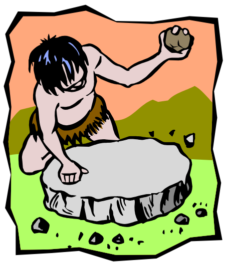


These two advertisements for Dunlop, from the Vintage Garage website, are dated 1896 and 1902 and do suggest that maybe the focus is still rather too heavily on carriages and cycles. Meanwhile the 1903 Notice used in Dunlop advertising also suggests that they were well aware they were in a commercial battle!

On the left below is the tyre of a 1900 Napier, produced in Tenterden in Kent, which now runs on pneumatic tyres. However, when 'discovered' in 1944, it was on solid rubber tyres. In contrast the 1903 French built De Dion Bouton (right), described as "very original" started life on pneumatic tyres. Notice, in both cases, the majority of the wheel is constructed from wood.

The Prior Art

It [is claimed](#) that the origin of the word “tyre” derives from the wheelwright’s habit of referring



to the steel rim around a wooden spoked wheel as the item that ‘tied’ the wheel together. Hence a tyre! Before moving on to look at the composition and usage of modern pneumatic tyres, it is worth briefly considering life before the inflatable tyre. The image to the right shows a [chariot](#) found in the tomb of King Tutankhamen dating from 3300 years ago. The wheels have no tyres!

In Monteleone, on the Swiss / Italian border, 2600 years ago, a chariot was mislaid and it was not until 1902 that it was rediscovered. The chariot, from an ancient Italian civilisation (Etruscan) was found along with other bronze, ceramic and iron items as if placed in a burial

mound. It is one of the best-preserved finds from before the Roman period and is now in the [Metropolitan Museum of Art](#) in New York. The photograph on the left is a reconstruction but significant, major parts of the original chariot were in relatively good condition. This included one wheel, which was riveted with bronze and fitted with an iron tyre. Fundamentally, the technology of wheel construction and the materials used continued, largely without change, for nearly 2500 years; the images below are from the most recent part of that long period.

The left-hand image shows, the iron-tyred wheel of a London to York mail coach. Coaches reached their heyday in the late 1700s before being displaced by the railway; the pioneer of which was the wooden-wheeled, iron-rimmed 1829 Stephenson’s ‘Rocket’ locomotive (centre). Whilst early cars, such as the French-built, 1895 Panhard and Levassor car, used wooden wheels and an iron rim covered in solid rubber (right).

The use of rubber in road transport and other industries is outlined in the following section.

The key to developing a hardwearing rubber cushion between the iron rim of a wooden-spoked wheel and the road surface lay with the American inventor Charles Goodyear. In 1839, Goodyear (and, independently, Thomas Hancock in Britain) developed the process of vulcanising rubber: a process that transformed an interesting, natural latex into a resistant, elastic material that was showcased in the Great Exhibitions of London (1851) and Paris (1855). Applications on show included use as a solid rubber tyre for coaches.

Rubber[11]

Materials that in everyday conversation we may refer to as being made from "rubber" can be broadly divided between those derived from natural rubber and those produced from synthetic rubber; as well as mixtures of the two. Natural rubber, also known as India rubber, is produced from the white liquid – natural latex – produced from cutting the trunk of some plants and trees; in particular the rubber tree (Hevea Brasiliensis) originally from the Amazonian rainforests. European awareness of rubber probably started with Spanish colonists in South America in the 17th century where its waterproof properties were exploited for clothing and footwear. In the 18th century, it was found that small balls of dried latex were good for erasing pencil marks from writing material; hence the name rubber became associated with a material that had previously been known as *caoutchouc* from the Amazonian word for 'weeping wood'.

From the point of view of tyre fabrication (and indeed other processes), natural latex has a number of undesirable qualities. In cold weather, the material becomes brittle; in hot weather, it becomes very sticky. In the 19th century, there was much experimentation in Europe and America to try to stabilise its properties. Success is generally credited to Charles Goodyear who, in 1839, discovered that by adding sulphur to latex and heating the mixture, the resulting material became stronger whilst retaining flexibility. The process became known as vulcanisation and a patent was granted in the USA in 1844.

Between 1880 and 1911, the world demand for rubber soared with the majority of the raw material coming from the Amazonian rainforests. In 1910, 2.5 million tyres were produced: by 1990 this had risen to 860 million and today exceeds 1 billion. This demand has been met in two ways. In the 1870s, seeds from the Amazonian rubber trees were used to start plantations in Malaysia and Indonesia, expanding and diversifying the sources of natural rubber, and, in addition, synthetic rubber was developed.

[11] Some of the material for this section is based on information displayed at The Eden Project, Cornwall

A rubber tree takes 7 years to mature before starting a productive life of 25 years. So, when each new area of Asian plantation matured and entered production the world price of rubber fell abruptly, such as in 1925, and this has been a continuing trend as production capability fluctuates and competition from synthetic rubber moves with oil prices. Natural rubber from Thailand, Malaysia and Indonesia now dominates the world's supply; representing around 40% of the total global rubber production.

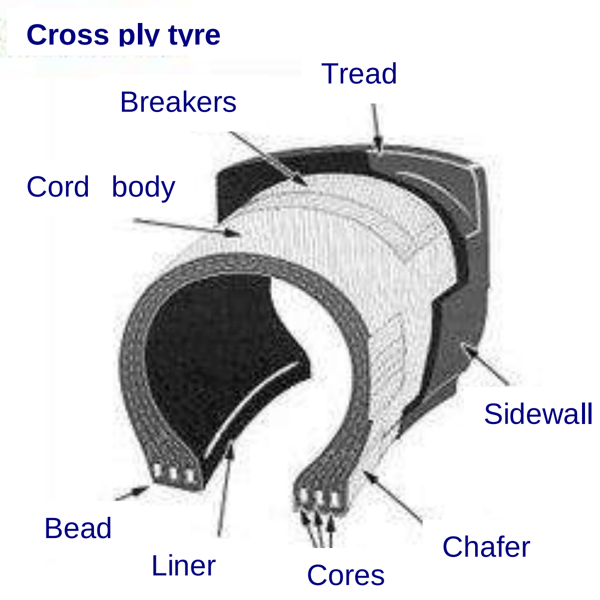
Synthetic rubber is man-made: a product of a petrochemical plant and, today, accounts for the other 60%. The development of synthetic rubber was a consequence of restricted access to natural rubber. Reasons included volatile or rising prices for natural rubber on the world market, long transport distances, the increase in global demand for rubber and, in particular, political events (such as WWI and WWII) which cut customers off from the suppliers of raw materials.

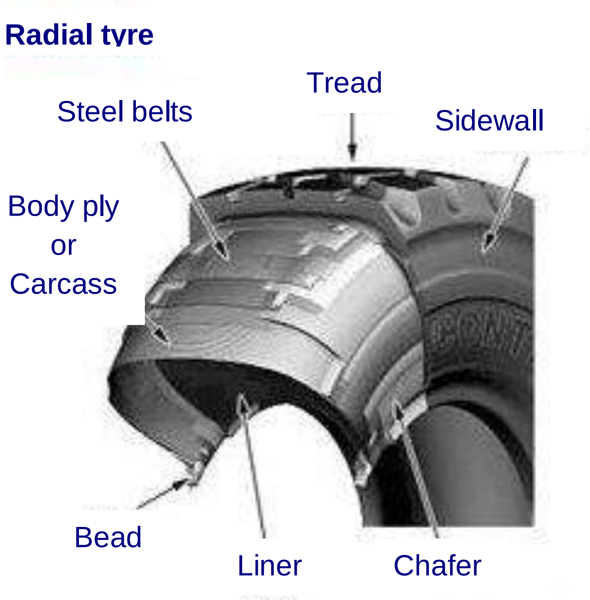
There are many compositions of synthetic rubber that vary with the end use of the material. Commonly known names such as neoprene have excellent oil and fuel resistance and are used in the automotive industry for fan / alternator / water pump belts, fuel hoses and gaskets. Butyl rubber is a common sheet material used for roofing. The modern pneumatic tyre is made up from several synthetic rubbers in specific parts of the tyre, as well as natural rubber. Carbon black is added to the rubber compound to improve wear properties. Some contain natural rubber and maize, reducing the amount of carbon black, road friction and hence fuel use. A summary of materials used in tyre construction can be found at this link and on Wikipedia.

Construction of the Pneumatic Tyre

Prior to 1924, the majority of European car manufacturers fitted wheels for use with beaded edge tyres. A hard rubber bead around the tyre's sidewalls engages in a hook or clincher on the circumference of the wheel rim and a pressure of up to 60 pounds per square inch in the inner tube is required to keep the tyre on the rim. A diagram is included at the above link. The modern wheel and tyre configuration arrived in the mid 1920's. It was a significant improvement being easier to fit and remove, much safer and needed lower pressure. This type of tyre has a wire bead which allows the tyre to sit firmly against the wheel rim, yet is fairly easy to remove by deflating and pushing the tyre rim inwards, into the well of the wheel.

Many websites show the construction of tyres. The image below shows the major parts of a cross ply tyre and radial tyre and is based on the Tyres Online website image. Perhaps surprisingly, rubber, of multiple types, constitutes only around only 40% of the weight of a modern car tyre. Steel, carbon black and fabric comprise the majority of the other 60%.





Until the 1970s, the majority of cars on European roads used cross ply tyres. These were so named because the construction of the body or carcass was based on multiple layers of rubber-coated nylon or rayon fabric cord laid across each other at an angle and moulded to metal hoops or rings that formed the tyre bead. The angle between the plies determined the stiffness of the tyre and the number of plies determined the load rating. The angle between the plies varied from around 25 degrees for racing tyres to around 40 degrees for standard tyres and the number of plies varied from 2 to 6.

Two developments in the 1940s were, ultimately, to radically change the performance of the pneumatic tyre to that which we are familiar with today. These were the development of the tubeless tyre by Goodrich in 1947 and the radial ply tyre by Michelin in 1946. A patent for the tubeless tyre was awarded in 1903 to the Goodyear Tyre Company but this was not exploited until 1947. Similarly, the radial ply tyre was patented in 1915 by Arthur W Savage but exploitation had to wait a further 30 years.

The carcass of the modern radial ply tyre is made from fine cords of material such as Kevlar, moulded into rubber and providing a major part of the physical strength of the tyre. Unlike the cross-ply tyre, these are laid across the tyre at 90 degrees to the direction of travel ie radially.

Main tyre sidewall markings

205	Width of the tyre in mm	R	Radial construction
60	Aspect ratio - the side wall height is 60% of the tyre width	15	Diameter of the wheel in inches
		91	Load index of 615kg per tyre
		V	Maximum speed rating 149mph

For a full definition of tyre markings see: http://en.wikipedia.org/wiki/Tire_code

Date of manufacture 48th week of 2008

The steel belts are fabricated from multiple cords of rubber-coated, carbon steel wire: often assembled from more than a single layer and bonded together during the curing of the tyre under heat and pressure. They provide resistance to road surface shock and a flat surface to maximise contact area with the road. A hoop of steel forms the bead: holding the tyre to the rim under the forces exerted during cornering. The synthetic rubber liner is the air-tight equivalent of the inner tube found in an earlier generation of pneumatic tyre.

Associated developments

For the last 120 years, car tyres with inner tubes as well as tubeless tyres all use the Schrader valve for inflation. This was invented by August Schrader in 1891: just as John Boyd Dunlop was starting to see the success of his pneumatic cycle tyre. The above link to Wikipedia shows a simple animation of the valve operation.

Dust cap, valve body and Schrader valve

A modern development, building on the Schrader valve, provides the car driver with a remote, real-time indication of the air pressure in the tyre. This feature may be available as original equipment with a new vehicle: either standard fit or an option and is also available as an after-market accessory. The most common configuration uses a small, battery-powered radio frequency (rf) transmitter, usually operating in a licence-exempt part of the rf spectrum, linked to the pressure sensor. For the after-market product, the rf receiver will typically display the pressure and temperature of each tyre. For the more tightly integrated original equipment, a light on the instrument cluster may illuminate to warn of a tyre pressure outside safety limits. Sensors are either used to replace the four dust caps (in the after-market role) or mounted within the tyre. An alternative, cheaper technology is based on sensing changes in wheel rotation as a tyre deflates but this is generally considered inferior to the direct sensing systems described above. Tyre pressure monitoring systems (TPMS) have been mandatory on new vehicles in the US since 2008 and will become mandatory on new cars in the EU from November 2014. From 2012 TPMS, when fitted, is subject to the UK MoT test.

A revised presentation (see Annex) of tyre performance data to the motorist purchasing a new tyre becomes mandatory from the same date.

Conclusion

There is much more that could be written about the pneumatic tyre and its future but space is limited. The pros and cons of low-profile tyres, the effect of tyre pressure on car handling, the lessons that can be learnt from the Formula One world, Goodyear's self-inflating tyre, recycling of tyres: all are worthy of more detail. But, there is one view of the future that could see the demise of pneumatic tyres. Run flat tyres have been available for some years (and certainly require use in conjunction with a TPMS) but the future may see the end of any air inside the tyre as Bridgestone make strong claims for the environmental friendliness of their 'Air-free tyre' and Michelin have been showing prototypes of their Tweel since 2005.

As this chapter has been produced in support of a display at the Cotswold Motoring Museum

and Toy Collection, it is fitting to end with an exhibit in the museum. The 1911 Alldays & Onions Victoria (left) in the museum collection is fitted with an air compressor and storage cylinder under the floor on the driver's side. Although a 1911 patent by William Allday to use compressed air to operate a pneumatic starter never made it into production, the compressed air cylinder is connected to pressure gauges and a length of hosing within the car. In practice, this ensures the tyres are maintained at the requisite pressure of 50 pounds per square inch at all times. However, it also makes an implicit and not very subtle statement about the reliability of the pneumatic tyre and the road conditions during the early part of the 20th century!

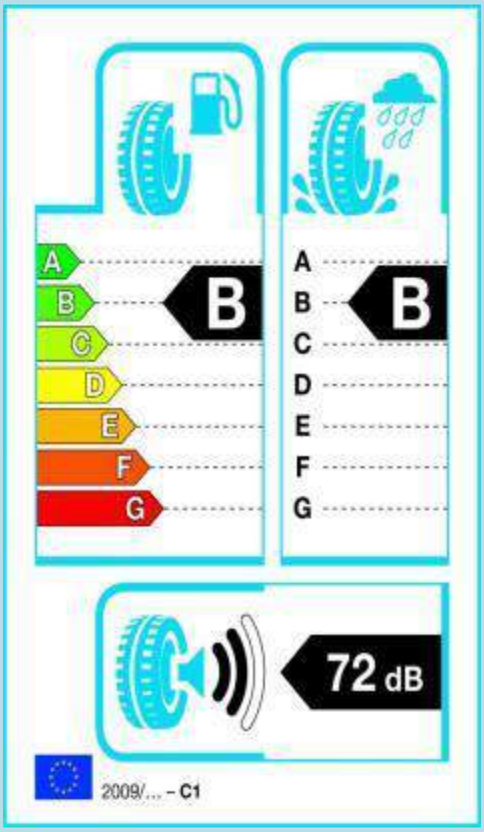
Annex: European tyre labels

New European tyre labelling - mandatory from November 2012.

Fuel efficiency is related to the rolling resistance of the tyre. The lower the rolling resistance, the lower the fuel consumption and the less the CO_2 emissions and the cost of driving. The difference between each grade means a reduction or increase in fuel consumption of between 2.5% and 4.5%.

Wet grip relates to the tyres ability to stop a vehicle quickly on wet roads and can be expressed in terms of stopping distance. The difference between each grade means an increase or decrease in stopping distance of between 3 and 6 metres when braking from 50mph.

The external noise made by the tyre is measured in decibels. The more black bars shown on the label, the louder the tyre.



Picture Captions and Credits

Page 40: Images taken at: the Eden Project, Cornwall; the Cotswold Motoring Museum & Toy Collection; the NEC Classic Vehicle Motorshow and from the website http://www.ulsterhistory.co.uk/johndunlop.htm
Page 41: Unknown credit for the drawing of Thomson's pneumatic tyre
Page 42: Images taken at the NEC Classic Vehicle Motorshow
Page 43: Follow hyperlinks for credits to chariot pictures. Inset image from the Ashmolean Museum, Oxford, shows the elm wood hub of a chariot wheel from 1350BC.
Page 43: Wheel images taken at the Science Museum, London
Page 44: Image taken at the Eden Project, Cornwall
Page 45: Image taken at the Eden Project, Cornwall
Page 46: Sidewall markings of a modern pneumatic tyre
Page 47: Schrader valve circa 1930
Page 48: Alldays & Onions Victoria at the Cotswold Motoring Museum and Toy Collection
Page 48: Montage of enamel tyre advertisements at the Cotswold Motoring Museum and Toy Collection

How did the Seat belt come to be invented?

This chapter describes the background to the invention of the seat belt. The motor manufacturers response to increasing customer concern over occupant safety and government legislation have been critical in reaching today's level of 95% seat belt usage in the UK.

Introduction

"Clunk Click Every Trip" was a safety advertisement in the early 1970s that was drummed into us, just like our kerb drill, until it became an automatic action as we settled into our car. Today, whenever we get into a car, we fasten our seat belts; at least most of us do but why? Is it simply because we know it is the law and risk a possible fine for not complying? This may be so in some cases but not the majority. Most of us, confident as we are of our own consummate skill as a driver, nevertheless recognise the danger posed by other road users less competent than ourselves and belt up just to be on the safe side. However, whose bright idea was the seat belt anyway and why is it now the law to wear one?


1959 poster showing how to use the seat belt

When visiting a motor museum, take a close look at any of those pioneering automobiles that were not so far removed from the horse drawn carriages on which they were modelled. The driver sat high up, often on a rudimentary bench seat. Roads as we know them did not exist; they drove on cart tracks often poorly constructed, potholed and badly drained. There being very few other vehicles, the danger was not from a collision but from being thrown out of the vehicle itself. For the driver this would be not only dangerous but also embarrassing; to lose a passenger was worse and considered the height of bad manners! As cars developed with more power and speed, with a lower slung chassis and more enveloping bodywork so other inherent dangers became apparent. Steering wheels pointing straight at the chest, flat windscreens directly in front of the face and other switches and fittings, were all awaiting the chance to fracture bones and tear skin of the unfortunate occupants.

From an early date, it became apparent to many that the main cause of injury resulting from a motoring collision or incident was due to the occupants being flung about helplessly inside the vehicle. Put an egg in a tin box and shake it hard; chances are the egg will be smashed. Put it in a properly constructed egg box and shake it hard; chances are it will remain unharmed. Exactly the same principles apply to the occupants of a car. In the event of a collision, the occupants are unable to control their own movements; they are flung about by the force of the impact. Should the vehicle roll over the occupant would very likely suffer head, neck and back injury, if not death. The first safety rule therefore is to restrain the occupants in the safest possible position within the vehicle: hey presto, enter the seat belt.

The history of the seat belt goes back a long way, much further than most of us would believe and many individuals and manufacturers lay claim to some of the glory in its development. All can be justifiably proud of their contribution to in-car safety if for no other reason than they cared enough to try. Even those designs that were destined to be abandoned or superseded, at least stimulated thought and development. First, let us examine briefly the different types of seat belts that have been used over the years.

Seat belt classifications

Seat belts are generally classified by the number of anchorage points and the location of the strap or straps.

1. Two point system – having two separate end anchors. Most commonly, a lap belt secured either side of the hips. This type of belt is usually found in passenger aeroplanes and long distance coaches. Whilst this type of belt allows freedom of movement, the upper torso is unprotected and the sudden violent movement occasioned by a collision would often result in serious back injury. An alternative two point system is the diagonal chest belt worn like a sash, where the belt stretches from above the outboard shoulder diagonally downwards to a fixed point below the inboard hip. Although allowing freedom of movement it was possible for the wearer to slide downwards out of the belt, a situation called “submarining”.

2. Three-point system – having three separate anchor points. This is the most common type of belt found in cars today and combines the best features of both the lap belt and the sash or diagonal chest belt; both sash and lap belts utilise a common anchor point below the hip. The earliest three point systems required two hands to secure but later development led to the single-handed operation commonplace today.

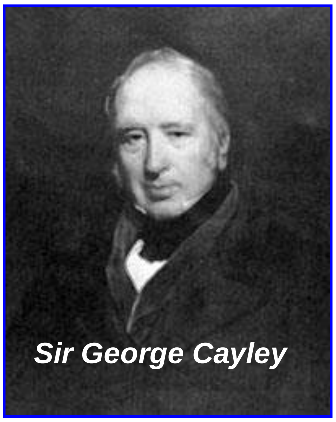

The 3-point system

3. Four, five and six point systems – rarely found in road cars other than very high performance models. The four-point belt has two shoulder straps worn like braces. Ease of movement within the vehicle is less important than being securely fastened in the seat. A five-point system has an extra strap between the legs to prevent the “submarining” effect whilst six-point systems have a strap around each leg. For racing and rally drivers, it is really a matter of choice which gives greater security and control of the vehicle in extreme driving situations not experienced by the normal car owner.

Seat belts are not just heavy duty webbing straps, they are scientifically designed and carefully manufactured to provide durability, the necessary strength to restrain the occupant, and a permissible degree of stretch which helps cushion the impact forces and minimise belt inflicted injury or bruising. The modern automatic latching buckle must be fool-proof and easy to use as well as being able to withstand immense force. Most cars now feature audible and visual warnings which encourage the seat occupant to secure their seat belt if only to stop the bleeping noise! Automatic inertia reel belts are now the norm: a spring tensioned spool allows the belt to extend or retract automatically to accommodate occupants of varying size or bulk, as well as when they change position. A hanging pendulum, incorporated in the spool mechanism, swings in response to any dramatic change in speed or direction and locks the spool to restrain the occupant. Pre-tensioners, fitted to an increasing number of cars, employ sensors located at the extremities of the vehicle to activate small explosive charges within the belt mechanism to pull the occupant back into the relative safety of the seat.

Origins of the seat belt

So, who first thought up the idea? The first accepted application of a seat belt (or seat restraint) is attributed to an 18th century English engineer Sir George Cayley (1773–1857), often called the "Father of Aviation". Indeed, had he had the fortune to be born a hundred years later in the fledgling years of the internal combustion engine, he would unquestionably have been famous in many other fields. Amongst other engineering projects, Cayley designed and built gliders in which he and his employees made a number of flights, some more successful than others. Falling out of a glider whilst in flight was more than likely to be a less than exhilarating once only experience! Landings too were a very uncertain event in which our intrepid aviators had little choice as to the precise spot. Plunging headlong into the unknown involved a risk of being thrown helplessly from the craft. Cayley recognised that his best chances of survival lay in staying secure within the airframe even while it disintegrated around him, so he used belts to secure himself to the seat of his craft. Since Sir George lived to tell the tale and died of old age it is safe to assume his ideas worked.

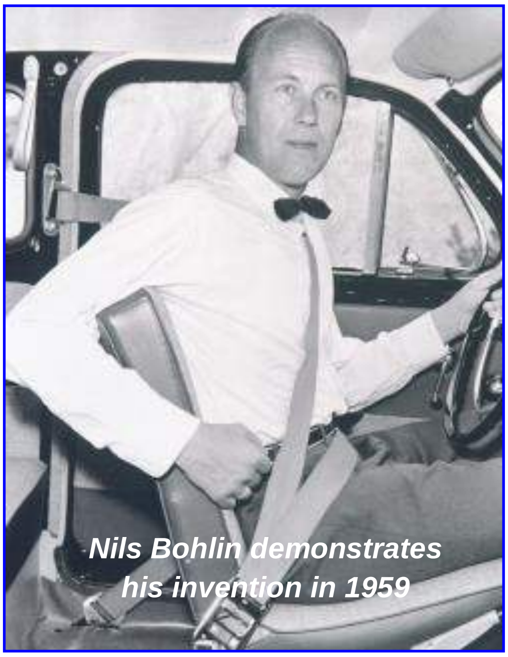


Sir George Cayley

Move forward now to the end of the19th century and the dawn of the motorcar as we know it. In 1885 an American, Edward J Claghorn, patented a safety belt "designed to be applied to the person, and provided with hooks and other attachments for securing the person to a fixed object". Although Claghorn's safety belt was not designed with the car in mind, its possible application was soon obvious. With the rising number of motorists, there were increasing accidents and, particularly in America, a number of physicians became concerned with the nature and cause of motoring related injuries. During the 1930s, a number of prominent physicians fitted seat belts to their own vehicles and began a campaign urging motor manufacturers to fit belts in new cars.

First out of the starting blocks was the American car manufacturer Nash who offered lap belts as an option from 1949. In 1956, Ford and Chrysler offered optional lap belts in the front and Ford's advertising campaign focused heavily on seat belts. That same year the Swedish manufacturer Volvo offered the two-point diagonal chest belt as an option. Motor manufacturers were now increasingly aware that in-car safety was becoming an important selling point for new models. Previous reluctance to fit seat belts, largely because of cost, was replaced by a desire to attract the emerging body of safety conscious motorists. Indeed, around this time a number of manufacturers began to include seat belt anchorage points in their newer models. The 1958 New York International Auto Show saw the introduction of the Saab GT750; for the first time front seat belts were fitted as standard. The stage was now set for other manufacturers to follow suit.

In 1959 Volvo introduced a three point lap and diagonal belt as a standard fitment on all cars sold in Sweden. This belt was destined to become an industry standard familiar to every motorist today. It was designed by Nils Bohlin, a design engineer with Volvo, who had formerly been employed by Saab's aeroplane division working on ejector seats. His three-point lap and diagonal belt was not an original idea, being based on an earlier design patented in 1955 by the Americans Roger W Griswold and Hugh DeHaven. Their design required two hands to secure the belt and left the buckle near to the middle. Bohlin recognised that the average motorist was essentially idle and would not bother with anything complicated that was not quick and easy to use. The brilliance of his design was that only one hand movement was required to position the belt across both chest and hips and secure it to a fixed anchorage point; an action that is now familiar and second nature to us all. It was perfect, it didn't take much time and anybody could do it, so why not use it?


Nils Bohlin demonstrates his invention in 1959

From this time offering seat belts as an option for both front and rear seat became more commonplace amongst all motor manufacturers. Increasingly seat belt anchorage points were fitted as standard allowing any motorists who wished to do so to buy and fit belts as an aftermarket accessory. In 1965, it became compulsory to fit front seat belts to cars built in mainland Europe. The UK followed in 1967 and the 1970's saw the "Clunk Click" advertising campaign promoting their use. Increasing awareness of the danger posed by and to unsecured rear seat passengers encouraged forward thinking manufacturers to provide anchorage points for rear seats too. Unsecured in the back seat, in a head on collision at 30 mph, even your frail old grandma became a potential killer.

Legislation

Legislation governing both the fitting and wearing of seat belts is varied across the globe; individual countries and states setting their own rules. Despite strong campaigning by safety groups and medical evidence as to their value, legislation regarding seat belts was a long time in coming. Honours go to the State of Victoria, Australia for being the first to pass a law making wearing a seat belt compulsory. Although there were no specific laws in the USA, by 1964 more than half of the states required belts to be fitted in the front but not until 1984 did it become a requirement to use them. In Europe, Belgium and France led the way (1973), making the wearing of seat belts compulsory but only in certain circumstances. In the UK it was not until 1983 that the driver and front seat passenger were legally required to use belts; eventually (1991), this was extended to include rear seat passengers as well.

Although not the inventor of the seat belt, or the first to fit them either as an option or standard, Volvo, to their credit, have not sought to prevent any manufacturer from copying their design. In fact, just about every manufacturer has. Anyone who has had the misfortune to be involved in a serious collision while wearing a seat belt and been fortunate to escape without serious injury, should offer up a word of thanks to Volvo and Nils Bohlin in particular, as well as those earlier pioneers of seat belt design. According to independent research, the chances are more than 60% that it was the seat belt that saved you.

Conclusion

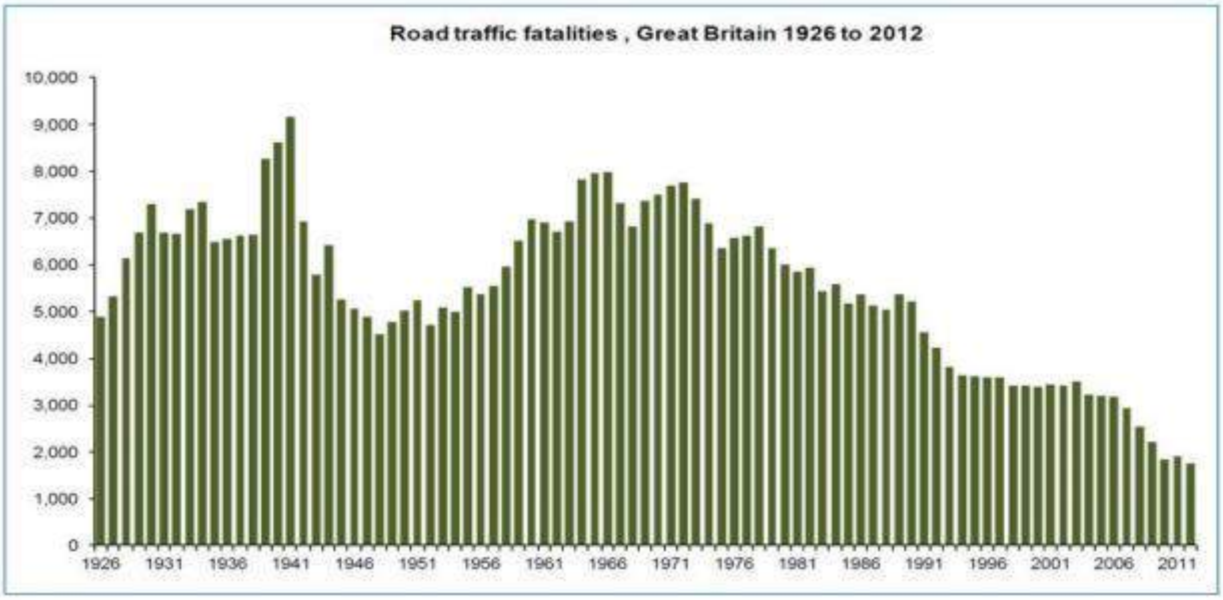
So, what is the future of the seat belt? Clearly, it is here to stay but measures to increase the comfort and effectiveness of the seat belt continue. In a development by Ford, a small airbag has been introduced in the diagonal section of the belt. When the car is involved in a collision, sensors determine the severity of the crash and initiate a rapid flow of gas into the belt. In comparison with a conventional belt, this spreads the crash forces over five times the area of the body, lessening the risk of injury to the occupant.

Maybe the most effective and lowest cost way to improve occupant safety is through encouraging the existing seat belts to be used. Front seat belt usage in the USA in 2010 is reported at 85%: a steady year on year increase. Corresponding figures for the UK show front seat belt usage as 95% and 88% for rear seat passengers. However, a significant minority (28%) of all drivers aged 18 or over do not *always* wear a seat belt. Encouraging all occupants to wear a seat belt is estimated to have the potential to save around 300 lives in a year.

Inevitably, there will always be those opposed to wearing seat belts of any description citing various arguments for not wearing them. Such arguments are invariably flawed or so improbable as to be unrepresentative. We have all heard tales of someone who would have died if they had been wearing a seat belt. Even if true they are a minority; accident research shows overwhelming evidence that wearing seat belts saves lives. Tell them to belt up!

Annex: Fatal accident trends

Whilst it is not possible to separate the effect of seat belts on the safety of vehicle occupants from other advances in vehicle safety design and road improvements over the last 80 plus years, the chart below shows the number of fatalities on the roads of Great Britain over that period. Clearly, since the early 1970s, when there were just under 10 million cars on the roads of Great Britain, the trend has been in the right direction, with a low of [1,754 deaths (801 being car occupants) in 2012](): a year when there were [27.28 million cars]() on the road and falling still further to [1,713]() in 2013.



Reinforcing the statistics, subjectively, drivers feel safer in their cars than at any time in the past. The 2012 RAC Report on Motoring found that technology of all forms has increased the feeling of safety that drivers experience in their cars. It states:

> *"Two thirds of drivers aged 70 and over also take comfort from this* [in-car safety features], *against just 43% of drivers aged 17-24, who perhaps never experienced driving cars without many of the safety and hi-tech features that we take for granted today"*.

Picture Captions and Credits

Page 50: Save yourself poster at
http://www.safetycamera.org/Content/filemanager/upload/file/Save_Yourself_seatbelt_poster.jpg
Page 50: 1959 advertising poster
http://www.dailymail.co.uk/motoring/article-1206112/Clunk-click-trip-The-modest-seatbelt-celebrates-50-years-lifesaving-today.html and
http://www.independent.co.uk/life-style/motoring/features/the-man-who-saved-a-million-lives-nils-bohlin--inventor-of-the-seatbelt-1773844.html
Page 51: The three-point system: http://www.securon.co.uk/seat_belt_harness_road_vehicles.htm
Page 52: Sir George Cayley
http://www.flyingmachines.org/cayl.html
Page 53: Nils Bohlin demonstrating the 3-point seat belt.
http://www.wired.com/science/discoveries/news/2008/07/dayintech_0710 and
http://www.automotivetestingtechnologyinternational.com/news.php?NewsID=15216

Construction

Car body design has evolved over the last century in response to many pressures. Some have been social and legislative pressures, some a consequence of improving passenger protection from the elements, some aesthetic, some related to longevity, some to cost of assembly and some to improving safety. Whilst everyone will have a view on the aesthetic qualities (or otherwise) of the four cars shown here (classic, quality or mildly eccentric?), this short chapter concentrates on the pressure to improve safety and its effect on car body design.

The majority of cars manufactured in the period up to World War II were built on a separate chassis. This provided the structural strength and the body was not, generally, a structural part of the car. Although a few specialist companies, such as the Morgan Motor Company, continue to use a separate chassis with a wooden framed, aluminium-skinned body, the last UK mass-produced range of cars to use a separate chassis was the Triumph Herald based range: namely, Herald, GT6, Vitesse and Spitfire. The last Spitfire was produced in August 1980.

The alternative to the chassis-based design was the monocoque or unitary construction. The first mass produced British car to use a monocoque was the 1937 Vauxhall H-Type. In the post-war years, this became the L-Type Wyvern and Velox.

Claims for the new construction included "… greater strength with less weight and freedom from squeaks and rattles …". Other manufacturers quickly followed in adopting this type of construction. Morris and Hillman in the pre-war years were joined by Standard (the 1949 Triumph Mayflower), Austin (1951 A30), Jaguar (1955 Mk1) and others whilst the 1956 Jaguar XK140 in the Cotswold Motoring Museum collection still has a steel and aluminium body on a separate chassis.

In a monocoque construction the car floor pan, reinforced with box-section sills, a transmission tunnel and wheel arches, forms a base for passenger, engine and luggage compartments to be welded in place. These structures share the torsional loads experienced by the body when the car is in motion and are the basis of Vauxhall's claim to reduce "squeaks and rattles". Loss of the separate chassis allowed a lower floor pan, lower seating position and lower roofline so the outward appearance of the mass produced car also changed with the adoption of the monocoque construction. Costs for tooling for the new construction method were high and this may explain its relatively slow adoption and the fact that large volume production was required to offset the initial tooling costs.

The monocoque construction was not all good news for manufacturers. Closed box sections for sills, the inaccessible cavities created between inner and outer wheel arches, front suspension housings and blocked drain holes in sills and doors all contributed to unseen corrosion and 'body rot' on some monocoque designs. Apart from cosmetic problems, more serious structural weakness would usually accompany such corrosion with serious safety implications if the car was involved in a collision. Increased use of galvanised steel, cavity treatment with a wax coating and non-ferrous body sections have all but rendered this problem obsolete on cars over the last couple of decades.

Materials

From the everyday family saloon car to the land speed record challenging Bloodhound via Formula One racing, today, computer modelling and simulation play a major role in car body design. Aerodynamic performance of the body, a key parameter in overall fuel consumption and CO_2 emissions, aerodynamic down force and structural strength in a collision are all modelled in software before a single metal or carbon fibre panel is formed. Modelling allows the selection of steel, aluminium or composite materials to be made to provide an optimum balance between strength and lightweight construction.

A one-piece carbon fibre monocoque body on the new Alpha Romeo 4C provides a lightweight body that is lighter than steel, corrosion resistant and structurally stable and its aluminium monocoque construction looks like being a selling feature on the next generation small Jaguar, the XE model due for launch in 2015. Meanwhile the BMW electric vehicle range is also adopting extensive use of a carbon fibre monocoque.

Safety Testing

Euro NCAP (New Car Assessment Programme) testing was launched in 1997 with the objective of reducing the injury to car occupants and pedestrians in the event of an accident. Members of the independent organisation include government transport departments plus consumer and motoring organisations throughout Europe. The current rating system for car safety considers the performance of the car in protecting the safety of adult and child occupants, pedestrians and the potential of advanced driver assistance technologies such as stability control. An overall rating of up to five stars is awarded and below the star rating, further percentage ratings are awarded in each of the above four categories. Finer detail is published in each category, for example, adult safety comprises a points score for driver and passenger frontal and side impact and whiplash. A typical assessment report for a Skoda Octavia is shown in the link.

It is important to recognise that ratings are awarded to a range of vehicle classes from "Supermini" to "Large Off-Road 4x4" (eleven classes in all). Within each class, cars that are within 150kg of each other are considered to be comparable. It would be a mistake to assume that a 2013, five-star rating for a Supermini and a large off-road car would afford the same protection to both sets of occupants should the vehicles collide with each other or with an immovable object. In general, the occupants of the larger, higher vehicle fare better than those in the smaller vehicle.

In spite of resistance from some motor manufacturers in the early days of crash testing, there is no doubt that the improvements in safety achieved by those same manufacturers in response to the Euro NCAP initiative is reflected in the increasing number of five star awards in all vehicle classes whilst, simultaneously, the performance to achieve the top rating has become stricter over the years.

Picture Captions and Credits

Page 56: Cadillac rear light cluster, Vauxhall PA Cresta, 3½ litre Bentley and E-Type Jaguar from 2013 and 2014 Classic Motor Show at the NEC, Birmingham
Page 56: Assembly underway in the Morgan factory, 2014
Page 56: Rolling chassis of a 1972 Triumph Spitfire – origin unknown
Page 57: Jaguar XK140 at the Cotswold Motoring Museum
Page 57: Inner and outer sill corrosion above a jacking point - origin unknown
Page 58: Euro NCAP logo http://www.euroncap.com/files/Euro-NCAP-Guidelines-2011---0-a4da2bfa-3d4f-4ec5-8429-7a0bf665b89d.pdf

How did the "Catseye" come to be invented?

Safety of a driver depends not only on the properties of the car being driven but also on the quality and design of the road infrastructure. This chapter on the "Catseye", or more correctly, the reflective road stud, sets out to describe the background to this invention, the principle on which it operates and how the technology is moving on.

Introduction

"Catseyes" were invented and patented in 1934 by Percy Shaw (1890 - 1976) from Halifax in Yorkshire. Specific events that prompted the invention have been widely reported. They include his observation of his car head lights being reflected from the eyes of a cat by the side of the road, thus avoiding him driving off of the road, and the use of reflections from tram lines to provide guidance and the problem encountered when the tram lines were removed. Perhaps it was both of these events that sparked the invention but one theme common to both tales is that the observations were made whilst travelling home, downhill from the Old Dolphin pub in Queensbury one misty night.

The company, Reflecting Road Studs Ltd, was founded by Shaw in 1935 to produce the item that we still use today and "Catseye", although widely used as a generic description, is a registered trademark of that company: hence the quotation marks. Their website also provides a good background to the "Catseye" road stud product.

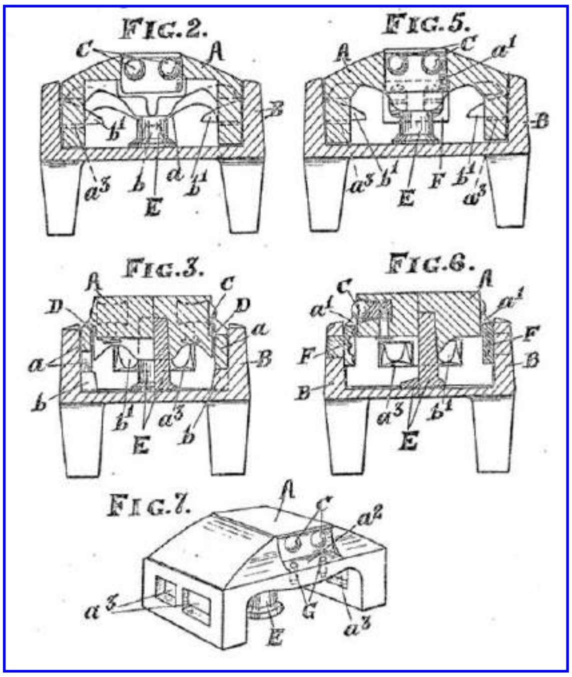
Depressing the rubber insert wipes the front of the reflectors

The twin reflectors are mounted on each face of a black or white rubber insert: the reflector colour being selected depending upon the location of the stud (see Annex to this chapter). Depression of the insert by passing traffic causes the outer surface of the reflectors to be wiped against the rubber thus helping to keep them clean. The third component of the "Catseye" is the cast iron base. This has to be sufficiently robust to withstand heavy traffic and occasional snow ploughing. The rubber inserts can be exchanged without having to remove the cast base from the carriageway.

Patents

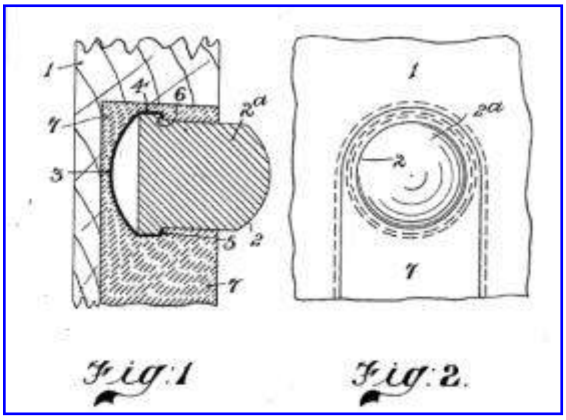
Shaw applied for and was granted two patents in respect of the "Catseye". The first application (Patent GB 436290) was made on 3 April 1934 and concerned the concept of "Blocks for Road Surface Markings"; specifically the displacement of the block when driven over by a vehicle and the embedding of reflectors in the walls of the blocks.

The second application (Patent GB 457536) was made on 31 May 1935 and addressed the self-cleaning of the reflectors by both the squeegee effect of wiping the reflector surface on a lip in the rubber mount and by air or water flow (if the road was wet) over the reflector as the block was depressed. What is apparent in reading both patents is the extent to which they focus on the mechanical design of the "Catseye". The reflectors receive very little mention and the optical principles of their design are not mentioned at all.



There are however, other claimants to the invention of one critical component of the reflective road stud. In particular, Richard Hollins Murray, at one time resident at Dinmore Manor, Herefordshire, patented the use of reflecting lenses for reflective markers or advertising signs. Patent GB 289619, applied for in 1927, addressed techniques for assembling light-reflecting devices to form "indicators, advertising signs or the like". It references two earlier patents of Richard Hollins Murray, namely patent GB 256475, applied for in 1926, which focused on assembly of a two-part light reflecting device and techniques for its fabrication.

His earlier patent, GB194034, applied for in 1921 and completed in 1923, concerned the design of the optical reflecting device itself. Although still including the aspects of how to mount the device for practical usage, this patent also addresses the optical properties of the plano-convex lens (the convex surface being the front of the device – item 2 in the diagram right) and the separate concave reflector (item 3) mounted behind the plane surface of the lens.



Diagrams from Patent GB194034

The use of reflectors in kerb stones or on roadside markers was also the subject of a patent application by Fredrick Lee in 1932. In his application, which was not funded to completion, the reflector is described as "a bi-convex crystal lens combined with a burnished reflector" or a "plurality of prismatic-like elements". (See panel at the end of this chapter). The image below is taken from the Fredrick Lee website link and shows prototypes of his reflective studs in three different colours. The image to the right is of two studs extracted from a modern "Catseye" with part of the protective surround removed from one stud. In addition to the similarity between these images of hardware produced eighty years apart, the folded, crimped metal attachment between lens and reflector in the Fredrick Lee patent application is remarkably similar to the diagram and "embodiment of the invention" specified by Richard Hollins Murray in his 1926 patent; GB 256475.


Reflective studs from amber and red "Catseyes". The surround of the red stud has been cut away to reveal the silvered backing to the concave mirror. The convex lens and concave mirror are formed from a single piece of glass.

With many inventions it is often the case that, rather than a single flash of inspiration, the invention is an iterative process, building on earlier ideas and proven concepts but applying them to a fresh set of circumstances or implementing them in a specific fashion. The history of the reflecting road stud appears to have followed this path. What is beyond doubt is that Shaw built on the known optical properties of reflecting lenses, mounted these in a robust, practical housing and established facilities to cost-effectively mass produce the "Catseye". He is the person to whom thanks are due for an item that has made driving in poor visibility much safer than it was during those misty nights, descending the hill from the Old Dolphin pub in Queensbury, in 1934. Further images of Percy Shaw, "Catseyes" and their installation are contained in a Design Museum reference.

The alternatives

What has changed in the design and implementation of reflective roadstuds since Percy Shaw started manufacturing the "Catseye" in 1934? With the exception of the solar powered, LED roadstuds shown later, the basic principles of operation have not changed. Lighter supports than Shaw's cast iron base are used for the reflective surfaces and their mounting. Epoxy adhesives as well as the more traditional bitumous-based adhesives are used to fix the studs to the carriageway and some of the low profile designs avoid the need to form a recess for the stud in the carriageway. Some manufacturers replace the clear or coloured glass reflectors of Shaw's "Catseyes" with protected, plastic prismatic reflectors (See panel at end of this chapter).

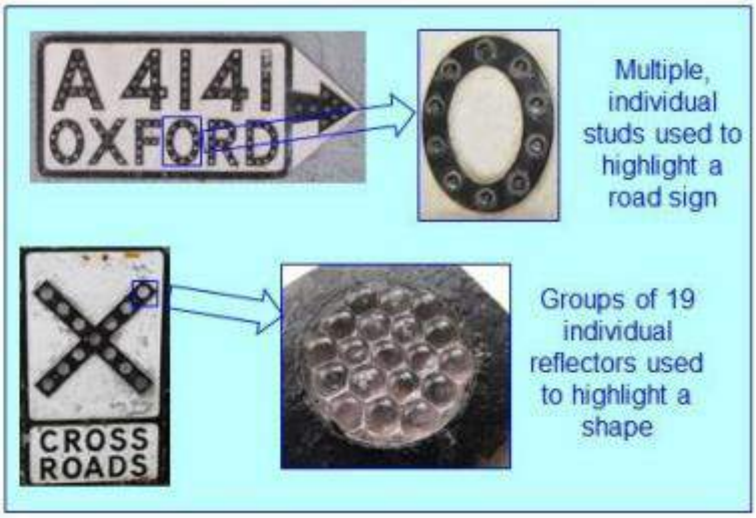
Still based on the "Catseye" principle but now providing reflection of incident light over 360-degrees, is the Holophane roadstud: shown to the right. These, unlike the "Catseye", have no moving parts. They are sunk into a circular recess in the carriageway or pavement edge and are of sufficiently robust glass construction to withstand the abrasion and impact of a roadside environment. In particular, the reflective surface is below the road surface and therefore unlikely to suffer abrasion.

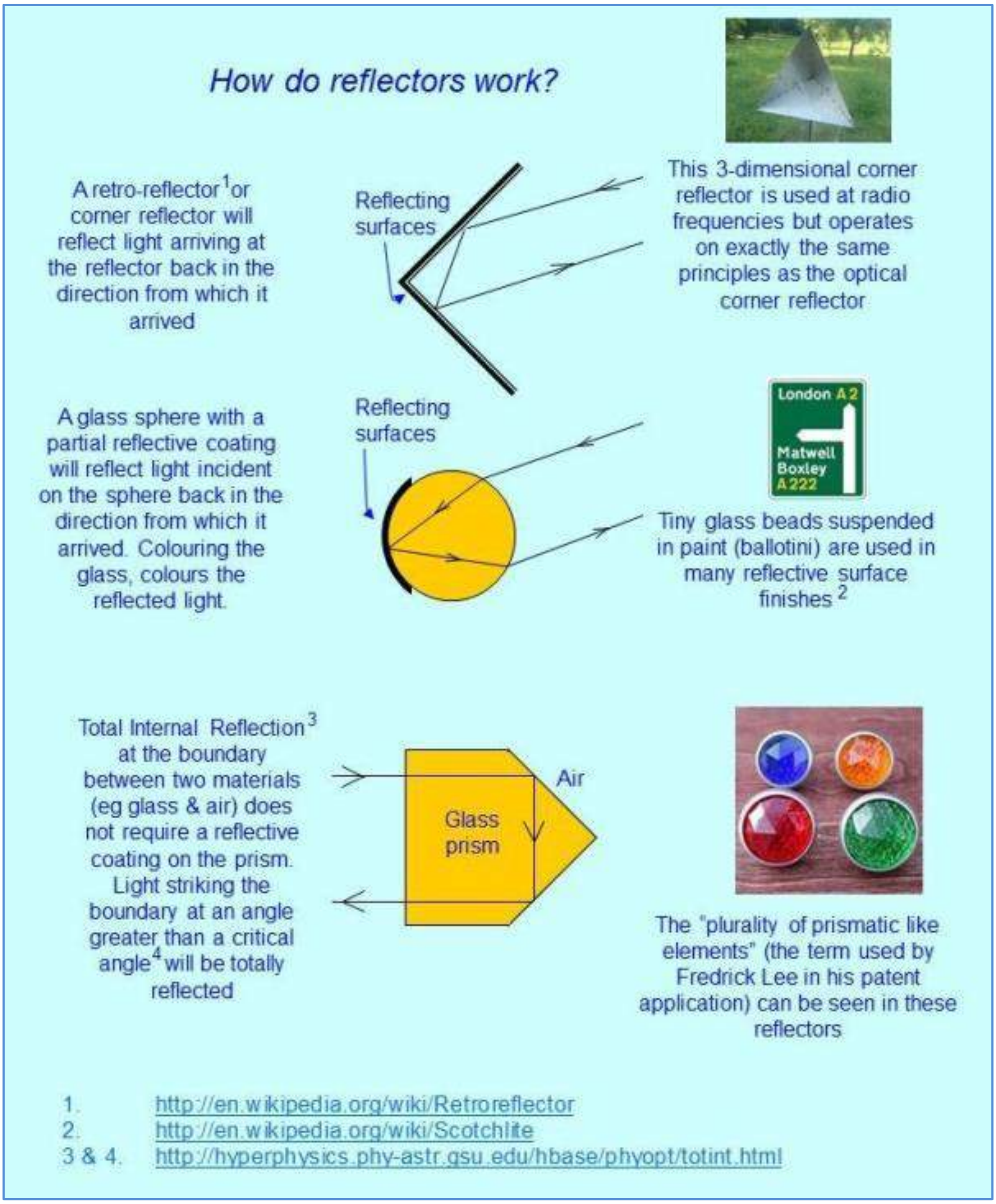
Relatively recent additions to the range of studs available are those based on the use of a battery-powered Light Emitting Diode (LED) with the battery recharging via a solar cell or inductive power transfer. The solar powered example on the left below is embedded in a bored recess in the carriageway with just 4mm protruding and claims to improve visibility range by a factor of 10 over a reflective stud. The stud on the right is designed to be surface mounted on the carriageway. Similar, solar powered rechargeable studs are available to the consumer market for emergency hazard beacons in the event of a roadside breakdown.

Powering the LEDs through inductive power transfer has been considered for over 15 years but only relatively recently have studs based on this concept been deployed.

Spin-off

The aforementioned Richard Hollins Murray and Fredrick Lee both proposed the use of reflectors mounted vertically by the roadside to act as a warning of crossroads, bends and other hazards. In addition, Fredrick Lee suggested that reflectors on the outside of a bend should be of a different colour to those on the inside of a bend; a feature still used today on unlit, rural roads.

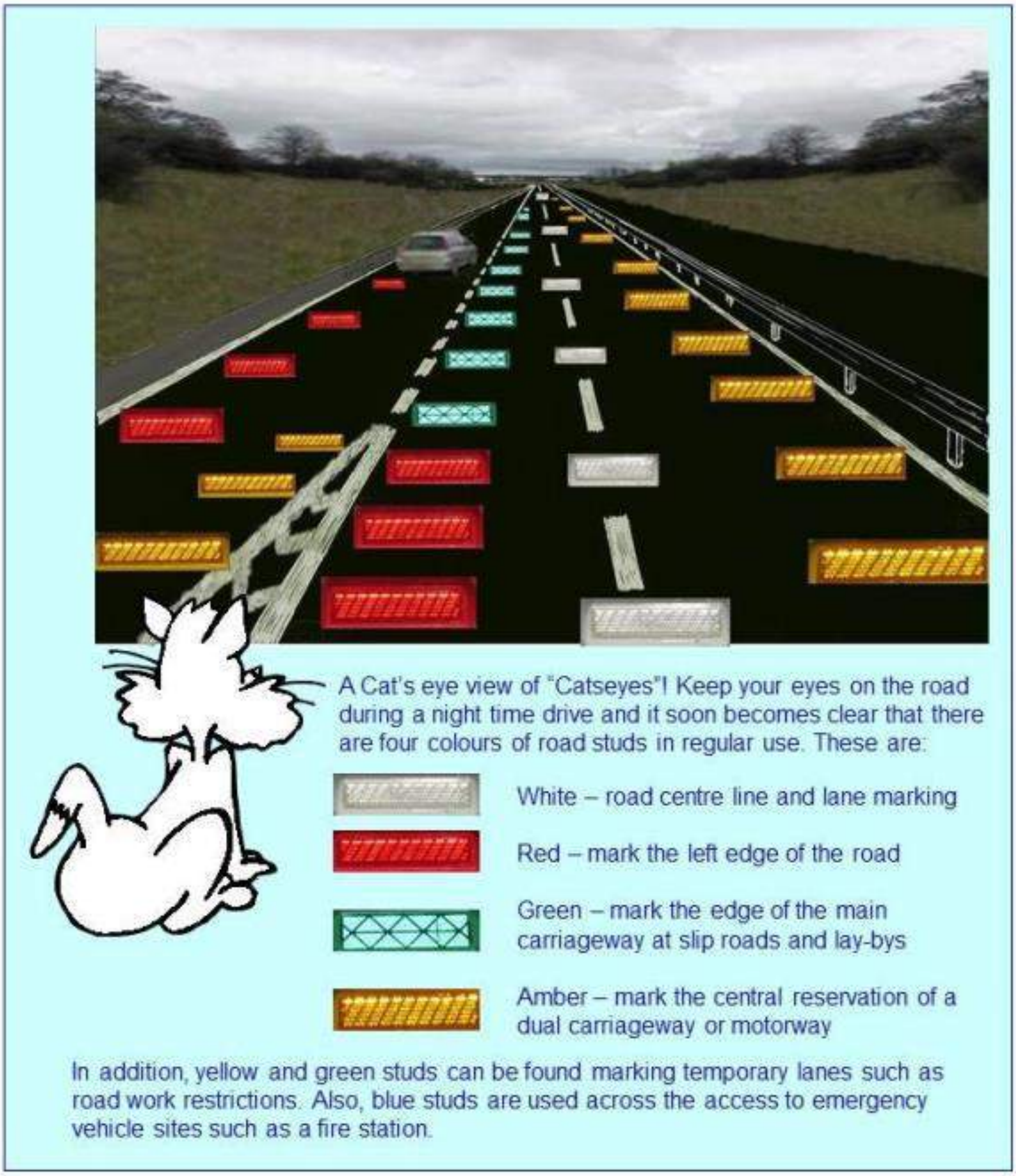




Conclusion

Percy Shaw OBE would no doubt be amazed at just how long his invention has survived, virtually unchanged, and also how others have built on his ideas and exploited 21st century technology to provide carriageway illumination and hence enhanced driver safety. It is recorded that Percy Shaw did not move from his house in West Yorkshire and did not let the fortune, amassed through retaining all rights to his invention and keeping manufacture within his own company, change his life style. Apparently, his only extravagance was to keep his basement well stocked with a favourite beer for his frequent parties. Whether the Old Dolphin pub in Queensbury suffered a fall in business as a result is not recorded!

Annex: Coloured "Catseyes"

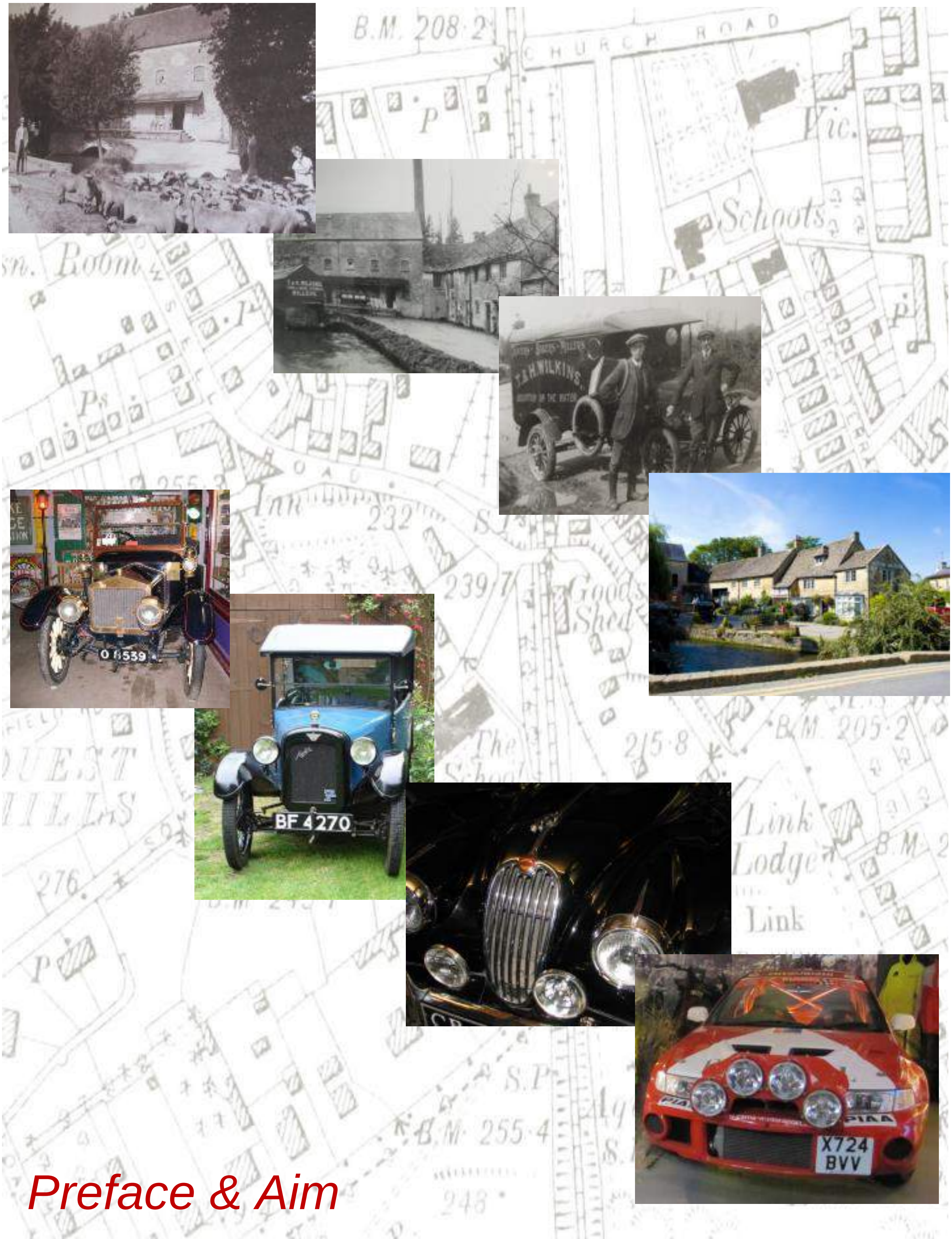


Picture Captions and Credits

Page 59: The genuine Percy Shaw "Catseye"
Page 60: Cross-section of the "Catseye"
Page 60: Reflective sign at the Cotswold Motoring Museum & Toy Collection
Page 61: The Fredrick Lee studs sourced from the website (http://www.catseyes.com/)
Page 62: An assortment of reflective roadstuds from "A History of Motoring in 10 Objects" exhibition
Page 63: A pair of LED roadstuds from "A History of Motoring in 10 Objects" exhibition
Page 63: Detail of road signs at the Cotswold Motoring Museum & Toy Collection
Page 64: Prismatic reflector from Google images

The Cotswold Motoring Museum and Toy Collection is not just about cars. Toys that our parents and grandparents played with as children, everyday artefacts from the Victorian and Edwardian era plus an insight into the social history of the village of Bourton-on-the-Water and much more can be found in the Old Mill, alongside the River Windrush.

The Impact of Motoring



Preface & Aim

Disclaimer

Whilst every effort has been made to ensure the accuracy of the content of this book, in a world where technology moves so rapidly, it is inevitable that some content will be out of date very soon after publication. Cotswold Motoring Museum & Toy Collection can accept no liability for any errors or omissions or any consequences of such errors or omissions.

For those accessing this book in electronic form, all web links were functioning at the time the book was prepared but Cotswold Motoring Museum & Toy Collection can accept no responsibility for content hosted on third party systems that may have been removed or updated.

Copyright and Usage

Cover images: The Old Mill, Bourton-on-the-Water, today home to the Cotswold Motoring Museum and Toy Collection and cars associated with the museum.

Source of right hand image above: Metropolia University of Applied Sciences, Helsinki, Finland.
http://green.autoblog.com/2013/05/30/biofore-concept-car-is-a-plant-laden-sustainable-ride/

Preface

What a visitor may expect to see on entering the Cotswold Motoring Museum & Toy Collection (CMM&TC) is fairly evident from the name. However, the purpose of any museum is more than to just conserve objects of rarity, beauty and historical significance. The purpose is also to understand the origins of those objects; the needs of the people who invented and built the objects, the social pressures that led to their development and the impact that those objects had on their lives and the lives of subsequent generations. If we can learn lessons from the objects exhibited and their history that affect our future actions, then so much the better.

There is clearly a practical constraint (and visitor boredom threshold) around the level of detail that any museum exhibition can explore. This, together with the rationale in the opening paragraph, is the main reason that the CMM&TC has built up the web-based background information to exhibitions that have run at the museum since 2009. The "Tell Me More" series on:

- The Impact of Motoring
- A History of Motoring in 10 Objects
- Motoring Milestones, and
- Mud, Track and Tarmac

supplements the associated exhibitions in much greater detail than is possible within the museum and survives after some of the exhibition hardware has been returned or replaced.

The purpose of this book is to focus on a few of the most significant objects in the museum and look at the role those objects have played, directly and indirectly, in the history and the social impact of motoring. Whilst there is an element of factual detail necessary to 'tell the tale' the book also steps back from the objects themselves to pose questions about our dependence on the car, the wider environmental impact of that dependence and where this might be leading us; as well as offering some answers to these questions.

This is not a book extolling the virtues of the car – great though these have been in social transformation over the last 125 years – to the exclusion of all else. This book attempts to take a balanced view on the benefits and threats associated with the 20th century rise of motoring and to anticipate how the historian of the 21st century may view the evolution of this most disruptive of technologies. In particular, the approach adopted is one that focuses on the vehicle owner, what are his or her responsibilities? What can we do to ensure that this convenient, ingrained method of transport can survive without threatening the future wellbeing of our children and grandchildren and, in the extreme, even the planet that we share with the rest of the natural world?

Staff and Friends of the Cotswold Motoring Museum

Aim of the book

In 1886 Karl Benz was granted a patent for the world's first four-stroke, internal combustion engine powered car. Meanwhile, in Britain, the restrictive "Red Flag" Road Acts of 1861 and 1865 killed off any development of engine propelled road vehicles, whilst development in Continental Europe and in the USA surged ahead.

In 1895 Hon. Evelyn Ellis MP imported a French Panhard et Levassor, the first commercially available petrol engine car to run in Britain. This car is currently in the London Science Museum. By the end of 1895 there were 14 or 15 cars on the UK roads. By 1905, nine years after the repeal of the "Red Flag" Acts, things had changed. There were 221 UK motor manufacturers, the majority in the Coventry area and 15,895 cars (and 9,000 trucks) were registered under the Motor Car Act in that year[1]. Today there are over 35 million registered vehicles, including over 29 million cars.

These are some of the most basic facts around the early years of motoring in the UK. To summarise the impact that motoring has had on our mobility, prosperity, environment and technology over the last 125 years is an exercise in deciding what to omit. Whilst the impact of the railways in the decades preceding the appearance of the car in this country would have changed aspects of life from time keeping to social mobility, arguably their effect was surpassed by that of the car.

The car has provided the freedom to travel independently for work and pleasure changing the nature of rural, suburban and urban life. Commuting to work via 30 miles of 'A' and 'B' roads may, at one point in time, have been deemed unfeasible but with the arrival of the motorways, a 30-mile journey is not uncommon. The car has required and initiated an associated infrastructure, from road networks to fuel supply to sales and repair outlets in order to support its relentless progress. Toys, clothing, publications and all manner of leisure goods have followed the progress of the car. From a technological point of view, the car of today would leave a 1960s motorist open-mouthed in amazement. The rise of services around the car-centric society – maintenance, insurance, accessories - could not have been imagined 125 years ago.

Globally, the impact of the car, its operating environment and our requirements for fuel and raw manufacturing materials, such as rubber, have led to corresponding global phenomena ranging from converging global legislation on new car performance, to new political alliances, to war.

This book has been structured to address the consequences of our ownership and use of the car as they flow from the personal decisions that we all make as we go through our motoring lives. The focus is on the impact of motoring and the responsibility that we have, as motorists, to mitigate that impact on our planet. It includes, but is not limited to, the technology we adopt, the environmental implications of our choices and the usage that we choose to make of our chosen transport.

[1] Figures from SMMT Centenary publication 1896-1996

The specific topic of air pollution, arising from industrialisation and the rise of motoring throughout the twentieth century, is addressed later in this book. Whilst, in the minds of some scientists, the jury may still be out in the debate over the effect of increasing levels of atmospheric carbon dioxide (CO_2) on global warming and ocean acidification, there are a few undisputed facts that are relevant to that particular debate. Firstly, today the average concentration of atmospheric CO_2 has reached a level of 400 parts per million (ppm). By comparison, pre-industrial levels were around 280ppm. Secondly, in road transport as well as other energy consuming sectors, the Earth's natural resources of minerals and fossil fuels are being irreversibly consumed. These facts beg many questions but two of the most salient are:

"Is this morally defensible behaviour on the part of a few generations of the population of the world's most developed countries?"

and, closely related,

"Is this a fair legacy to bequeath to our grandchildren and those in less developed parts of the world?"

It is easy to assume that the response to such fundamental questions must lie with the governments of the developed world but, in fact, there are actions that we as individuals can take which, if widely adopted, can make a significant difference.

The way in which the developed world uses our natural resources such as water, minerals, forests and even the Earth's atmosphere and oceans can be critically debated across many aspects of modern life; especially in the context of a so called 'throwaway society'. Arguments could be made in many fields:

- fashion, in which goods may be produced in poor, third world conditions by people who are paid a barely living wage

- food production processes high in water usage, animal feed requirements and wasteful human consumption habits

- consumer goods where rare minerals – some from conflict zones of the world - form intrinsic components of modern mobile phones and televisions which can frequently be regarded as 'fashion' items with a life not necessarily determined by continued, fault-free operation.

Inevitably, counter-arguments exist to each of the above bullet points. These include benefits such as employment opportunities, individual and national prosperity, improved health, better cross-cultural understanding, to name but a few. Common themes are readily spotted between these aspects of modern life and the world of motoring but it is motoring that is the focus of this book. Experience and lessons learned from the world of the car may well carry over into wider aspects of human behaviour and the pros and cons of more than a century of motoring will be presented, as far as possible, as a balanced view.

What influences our decision when we go out to buy a new car? It is generally true that once make, model, performance, colour, comfort and affordability are selected, rationalising a choice of new car based on carbon dioxide (CO_2) emission will not figure too highly in our priority list. If the model 'A' produces 160g/km[2] of CO_2 whilst model 'B' produces 140g/km of CO_2, but 'A' has alloy wheels and a docking port, chances are 'A' is going to win our hard-earned cash. Even if the question fleetingly passes through our mind, then a balanced view to 'put this into perspective' would run something like:

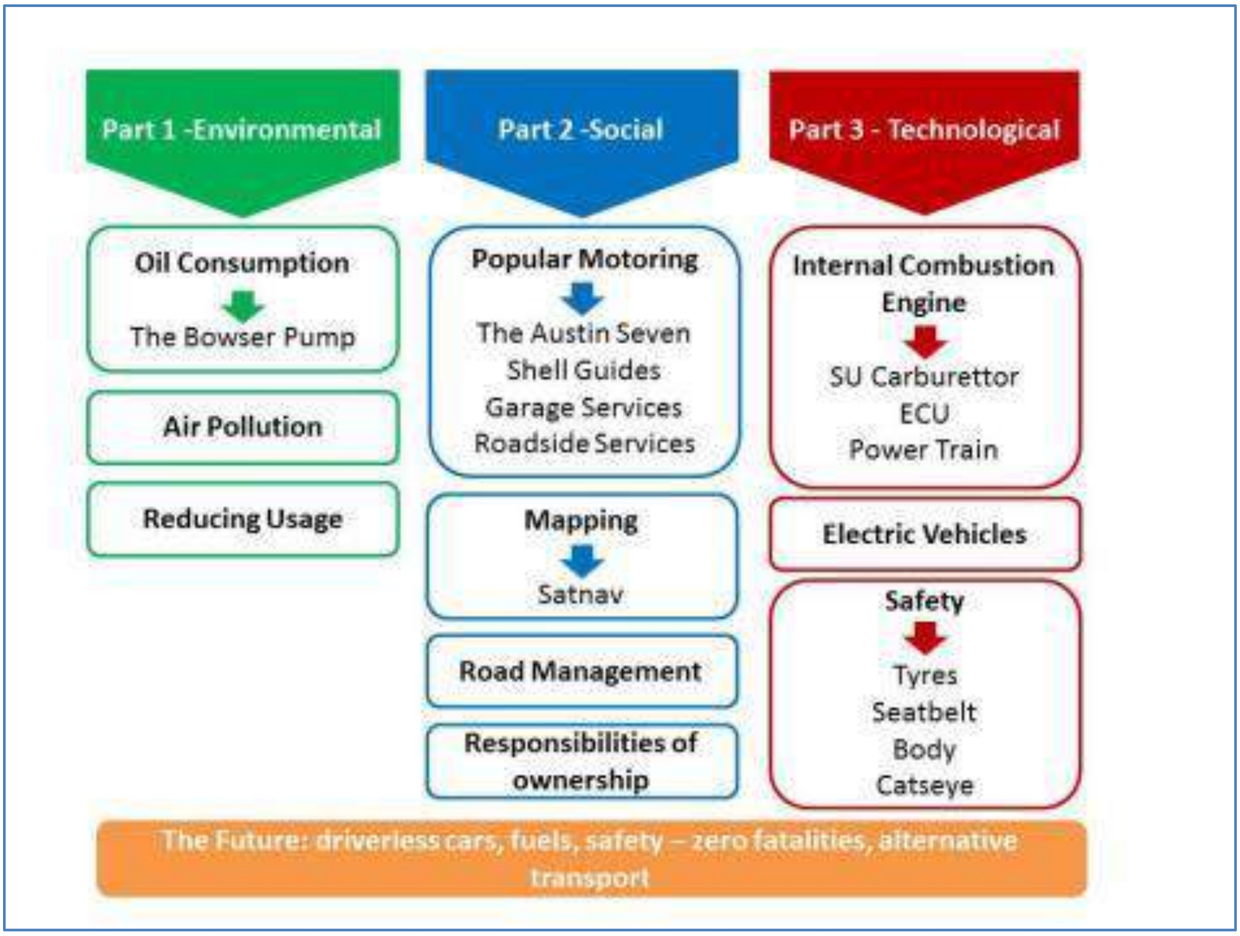
- my decision isn't going to make much difference
- anyhow, in the transport sector, car transport isn't the biggest polluter, what about all those lorries?
- and the transport sector isn't even the biggest polluter, how about manufacturing[3], power generation, agriculture?
- western Europe has targets for reducing pollution; it *is* going down, what about developing countries aren't they much worse offenders?
- if man-made CO_2 is one cause of global warming, this isn't all bad news. A little bit of warming will bring benefits
- and so on

So, model 'A' it is then!

The above is just one, slightly flippant, example of a choice that the motorist may make at one or more points in their life. Individual choices in motoring are much more extensive and frequent than this. Is it possible that responsible choices on the part of the motorist *can* contribute to mitigating the effect of modern motoring on our environment and if so, is it enough to warrant the effort? Does exercising such choices just make us feel virtuous, like flicking the light switch off, or can it really make a difference? If so, then what are the areas where we as consumers can make that difference? Lots of questions! This book attempts to have a stab at some answers.

[2] Grams of carbon dioxide per kilometre driven

[3] Manufacture of steel, aluminium, cement, plastic and paper represent around half of the CO_2 emissions in the manufacturing sector



Topics from the Contents diagram, shown above, form chapter headings throughout the book.

Looking at the contents of the book, there are clearly many topics that could have been selected for a debate on the Impact of Motoring but the three main parts of the book, Environmental, Social and Technological are almost guaranteed to feature in any debate. The associated topics (shown below the arrows) are not essential to the continuity of the book but provided an extra insight into a main theme, such as the Internal Combustion Engine.

The Cotswold Motoring Museum and Toy Collection is not just about cars. Toys that our parents and grandparents played with as children, everyday artefacts from the Victorian and Edwardian era plus an insight into the social history of the village of Bourton-on-the-Water and much more can be found in the Old Mill, alongside the River Windrush.

The Impact of Motoring

The Future & Epilogue

Disclaimer

Whilst every effort has been made to ensure the accuracy of the content of this book, in a world where technology moves so rapidly, it is inevitable that some content will be out of date very soon after publication. Cotswold Motoring Museum & Toy Collection can accept no liability for any errors or omissions or any consequences of such errors or omissions.

For those accessing this book in electronic form, all web links were functioning at the time the book was prepared but Cotswold Motoring Museum & Toy Collection can accept no responsibility for content hosted on third party systems that may have been removed or updated.

Cover images: The Old Mill, Bourton-on-the-Water, today home to the Cotswold Motoring Museum and Toy Collection and cars associated with the museum.

Source of right hand image above: Metropolia University of Applied Sciences, Helsinki, Finland.
http://green.autoblog.com/2013/05/30/biofore-concept-car-is-a-plant-laden-sustainable-ride/

The Future

Introduction

Within some of the preceding chapters, a view has been offered of what the future may bring. For example, wearable satnav was the parting shot in the satnav chapter. The 'airless tyre' was one vision of the future. Telematics services were the potential consequence of mandatory Emergency Call (E-call), enabled by widespread car-to-car communications and a suggestion was offered that the second half of the 21st century may herald the widespread adoption of hydrogen as the fuel of choice for our cars.

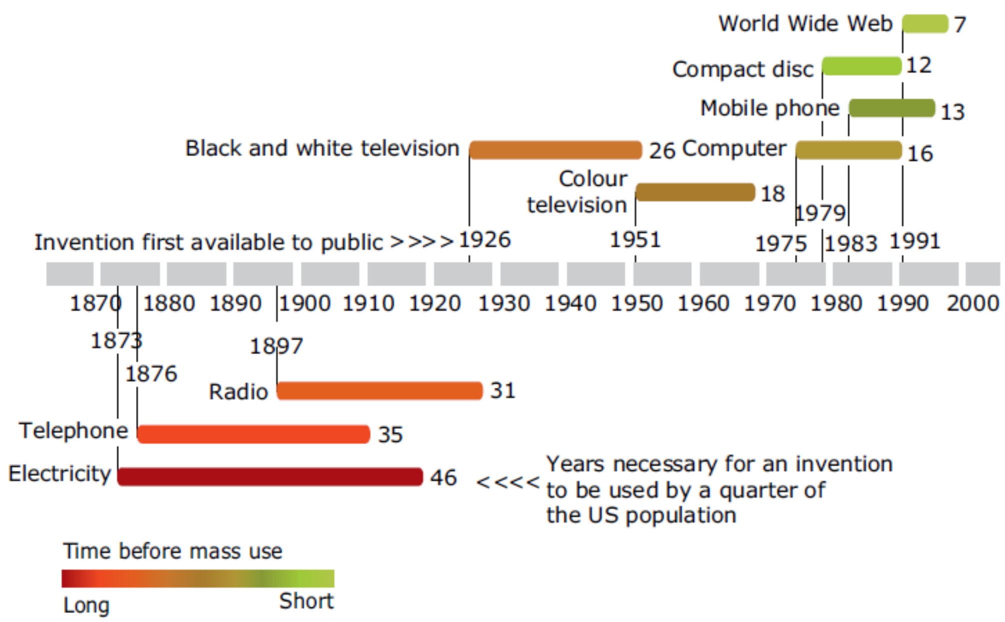
In terms of the car performance, the influence of Formula One Racing has been mentioned in the context of Energy Recovery Systems and their relevance to future hybrid car powertrain design. Formula One also has blazed a trail in terms of vehicle safety with the use of carbon fibre materials capable of withstanding impacts that would otherwise result in death or serious injury to the occupants.

As previously noted, land speed records have been held by both steam and battery powered cars before the records set by internal combustion engine cars powering the road wheels. More recent records have been established by jet and rocket powered cars and the next UK attempt on the record, with a target of 1000mph, is to be made with a car, Bloodhound, powered by internal combustion (to pump fuel), a jet engine and a rocket motor. Whilst the land speed record is one of the objectives of Bloodhound, the main objective is to encourage an enthusiasm of science, technology, engineering and maths amongst the current generation of schoolchildren. Without their skills, none of the possibilities presented in the remainder of this concluding chapter will come to fruition.

Historically, there are occasions when the developed world has been saved from the folly of its own actions through a fortunate change in the direction of technology that conveniently removes a looming problem. It was argued in the chapter on the Internal Combustion Engine that its invention was an example of one such 'disruptive technology'. And the problem it avoided? In 1894, the Times of London estimated that every street in the city would be buried under 9ft of horse manure by 1950! This was not as far-fetched as it may seem today. Urban populations were increasing and rail transport exacerbated the problem as horses were used for the final leg of passenger and goods transport. (Is there a modern day parallel here with internet and white-van deliveries adding to urban pollution of a different sort?). The private car was hailed as an environmental saviour which, in less than two decades removed an urban planning nightmare that, to the majority of the population, had no foreseeable solution. Will hydrogen power be the next such technology? More shortly!

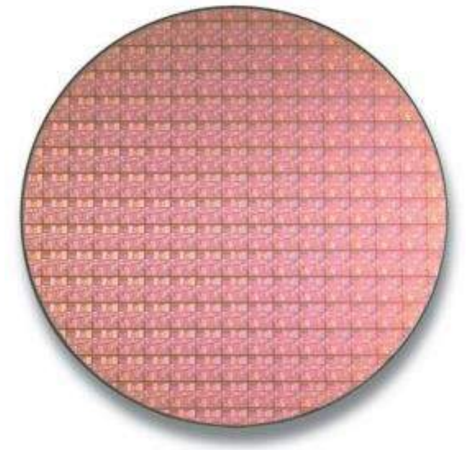
Before looking at specific topics, it is also instructive to look at the evidence that supports what many of us sense; namely that the *rate* of adoption of new technology is increasing. The figure below is based on the talk "The Accelerating Power of Technology" in which Ray Kurzweil suggests that technological advances proceed exponentially and not linearly. His figure below was reproduced in "The European Environment – State and Outlook 2010" and needs little additional explanation.

Figure 4.1 Shortening time lapse before mass adoption of new technologies



So, what else might be waiting around the next technological corner?

Back to basics



As already discussed in the chapter on the Electronic Control Unit, the value of electronics and software in the car is set to increase still further if the legislation on vehicle emissions and 'zero fatality' targets are to be met and the concept of the 'connected car' becomes ever more familiar. Fundamentally, the reason that electronics can be used to achieve these objectives is due to the ever-increasing packing density and power reduction of modern electronics.

In the mid-1980s the target, subsequently the state-of-the-art, lithography in semiconductor processing was to achieve a sub-micron - ie less than 1000 nanometres[1] (nm) - level of detail. This meant that semiconductor masks used in fabricating devices, for example a transistor, on a wafer of silicon would have sub-micron features and this in turn would determine the number of devices that could be grown on a wafer of typically 50mm diameter. Today, the modern home PC and smartphone are running processors with sub-30nm geometry.

At this level of detail, the features of the device are already shorter than the wavelength of the light used to illuminate the photosensitive resist that forms the etch mask overlaying the semiconductor material. Extreme ultraviolet illumination sources may reduce device geometry by a further (small) factor, three dimensional structures may increase packing density and increased use of parallel processing will increase speed. High device density reduces power consumption, improving cooling, enables more powerful and faster processors, results in a high production yield on wafers of up to 300mm diameter and ultimately delivers lower unit cost.

It is possible that the next major breakthrough however will be away from purely mineral-based electronics: germanium, silicon, gallium arsenide, indium phosphide and so on. Biological-based electronics may well provide that next breakthrough.

Researchers working on lithium air batteries have successfully used a bio-engineered virus coating to increase the electrode area of the battery with the potential for increasing capacity and hence the range of electric vehicles, with no associated weight increase. Flow batteries, using an organic electrolyte, are one possible solution to smoothing the flow of renewable energy generators such as solar, wind and wave. With brine as the electrolyte, they may even have a role as a future power source for electric cars. More generally, bioelectronics as the basis of future computers took a step forward when scientists at Stanford University published their results of a transistor based on DNA and RNA dubbed a 'transcriptor'.

Innovation in how the computational power of the day is used is also likely to enhance future vehicle applications. Artificial neural networks have been around for many decades but their affordable implementation has had to await low cost, high-speed processors and vast, affordable memory. Neural networks are particularly good at analysing complex situations. In a facial recognition application, the 'system' is taught to recognise the face of the subject under different lighting, different profiles, with / without glasses, facial hair, headgear etc. When deployed to spot a face in the crowd, identification of the subject is based on the learned knowledge and the identification is typically expressed with an associated probability. Over 97% correct recognition rates have been achieved; virtually equalling the performance of a human being set the same challenge.

In the automotive world, the role for artificial neural networks is as one input to an autonomous vehicle navigation application. The images captured from on-board sensors and cameras under different lighting and road conditions, different traffic densities, different lane markings and different weather conditions would all be built into the learning phase with the neural network 'decision' being one input to the navigation system.

[1] A nanometre is one millionth of a millimetre or 10^{-9}m

In short, on-going developments in the world of electronic devices will enable ever more applications, which hitherto may have been unaffordable or impractical to implement, to find their way into the car of the future.

Vehicle trends

As outlined above and in the chapter of the Electronic Control Unit (ECU), electronic hardware and lines of programming code comprising the embedded software, dominate a modern vehicle. In the ever-increasing drive to reduce vehicle weight and hence improve fuel economy, this trend is sure to continue.

For most modern vehicles, depressing the right foot on the throttle pedal no longer moves a heavy metal Bowden cable that owes its origins to the world of early 20th century cycling. The action of depressing the throttle pedal slides a potentiometer providing a variable voltage signal to the appropriate ECU(s) where it is converted into a digital signal. This throttle position sensor is used with other sensor inputs such as air temperature, engine coolant temperature, manifold vacuum, crankshaft position, vehicle speed and emissions related data (and, for an automatic gearbox, selected gear ratio) to control the amount of fuel injected into the cylinders.

Continuing the trend, the abandonment of direct linkages to steering, brakes (including the parking brake / hand brake) and clutch, in the on-going quest to reduce vehicle weight, is simply a continuation of the 'drive-by-wire' theme. The Infiniti Q50 is one of the first cars to adopt electronic steering (although the mechanical steering column remains in the event of an electronic failure). Electronics enables the steering ratio to be adjusted as the car's speed increases and allows feedback from the road surface to be varied to suit the driver's preference. Drive-by-wire is an essential, enabling technology if the process of driving is to become ever more automated.

Electronics used in the aid of improved safety take many forms. Included in the safety enhancement features are:

- the provision of information to make en-route decisions on congestion avoidance
- on-board cameras – potentially reducing ambiguity over insurance claims and maybe reducing premiums - as well as enhancing the drivers view in vehicle blind spots
- lane keeping alerts
- emergency brake assistance
- automatic cruise control – responding to the speed of surrounding traffic – with or without the aid of car-to-car communications.

Technically, the feasibility of an autonomous car has already been demonstrated and, following adoption of relevant legislation, some cars fitted with after-market adaptions could be on US and UK roads by 2015 with Google predicting 2017 to 2020 for mass production.

The Autonomous Vehicle

Already, adaptive cruise control and automatic parallel and perpendicular parking are options on mid-range, mass-market cars such as the 2015 Ford Focus. It is certainly a performance leap to go from these features to a fully autonomous car but, given the hundreds of millions of dollars being invested in the concept, there is little doubt that this will become increasingly common within the next decade or two.

The Institution of Engineering and Technology published one view on autonomous vehicles on UK roads in a submission to the government Transport Select Committee, and states:

"Highly or fully automated road transport will improve traffic safety, reduce congestion and provide both financial and environmental benefits. Vehicle automation will reduce the driver's workload, reduce accidents, increase vehicle density, minimise speed variations in urban areas and on motorways and reduce vehicle emissions and fuel consumption".

In 2013, Rt Hon David Willetts MP identified autonomous vehicles and robotics as one of the eight great technology challenges of the future. Government funding, via the Environmental and Physical Science Research Council has helped the University of Oxford with the Robotcar project. Collaborating with Nissan and MIRA, the focus of the research is on an infrastructure-free solution to vehicle autonomy. Using on-board sensors and a training / learning routine, the car interprets a fusion of data from the sensors to recognise its surroundings and navigate accordingly. Pedestrians, cyclists and other variables in its surroundings are detected up to 50m ahead through video and laser sensors scanning at a rate of 13 times per second.

In contrast, the Google project to build a fleet of autonomous cars does take information from the infrastructure, namely GPS information and uses this to map-match the car's location: just as described in the satnav chapter of this book. In addition, scanning laser rangefinders, video cameras and radar for obstacle detection provide other inputs to the steering wheel-free car.

Of the current mainstream motor manufacturers, BMW have a road-going 5-Series prototype capable of autonomously navigating the autobahn whilst recognising and responding to surrounding traffic. Sensors again include map-matched GPS location, stereo video, radar and forward-looking scanning laser rangefinders along with all round ultrasonic sensors: the same technology used on current cars for parking sensors.

Whether known as 'autonomous driving' or, maybe less emotively 'assisted driving', the capabilities outlined above seem certain to become ever more pervasive over the next decade, offering increased mobility to the elderly as well as smoothing traffic flow with the associated environmental benefits and offering a major step towards the 'zero fatalities' target. Legislation and public acceptance may have to catch up with the technical progress.

Motive Power

So, whether autonomous or not, what will be powering the cars of the future?

Adverse effects on human health, including in the extreme, premature death, for which air pollution is responsible, have already been outlined. The corresponding financial cost has been addressed in a report from the Organisation for Economic Cooperation and Development (OECD). It estimates that air pollution costs the OECD countries $1.7 trillion per year in healthcare cost with half of this attributable to road transport. Since the most harmful emissions come from diesel vehicles, the OECD wants governments to remove incentives to buy them. Nitrogen dioxide (NO_2) levels in London's Oxford Street, predominantly from diesel powered buses and taxis, have been recorded at peaks of ten times the recommended average EU safe level.

With this concern over NO_2 levels from diesel taxis, buses and cars, even with ever-finer diesel particulate filters, has the peak of diesel-powered cars been reached? More efficient petrol engine cars come onto the market each year, complying with ever-tougher emissions legislation and reflecting customer demand for more affordable and environmentally friendly cars suitable for predominantly urban use.

This momentum behind the development of the internal combustion engine and progress in recent years however has been spectacular. For example, the entry level 2015 Ford Mondeo will use a turbo-charged one litre, 3-cylinder petrol engine with CO_2 emissions under 130g/km and fuel consumption of around 70 mpg on a motorway. Compared with the 2 litre, 1997 Mondeo, the 2015 model will travel 20 miles further on a gallon of petrol and have a 7% power improvement over the 1997 model.

Soon after the launch of the 2015 model Ford Mondeo, it is reported that Ford will introduce a petrol / electric hybrid, at *around the same price* as the diesel and producing around 100g/km of CO_2. To date, the hybrid has been sufficiently more expensive than its petrol powered equivalent, even with a subsidy, to act as a deterrent to purchasers who like the concept but not the price differential.

It seems highly probable that there will be a long-term role for the battery electric vehicle (BEV). Users who make frequent short trips, who have access to recharging points at home or their place of work and who want to enjoy low running costs (excluding depreciation) would find this an ideal solution. All the while the market remains small however, and prices high, take-up is likely to remain low. Extended-range electric vehicles (E-REV), some of which may also be plug-in, eliminate the anxiety associated with the 100 mile 'fair-weather' range of the BEV, with the on-board charging offering a range similar to many of today's petrol engine cars.

Increasing gas production by fracking is reducing gas prices in those parts of the world where fracking is gaining ground: the USA and China for example. Powering commercial vehicles and possibly cars on liquefied natural gas (LNG) then becomes affordable. The gas however, that holds the greatest hope for the future of low emission motoring is hydrogen. The potential for hydrogen and air used with a fuel cell to generate electricity to power the car has been mentioned in the Electric Vehicle chapter. The challenges facing this potentially carbon-free motive power are associated with the production and distribution of hydrogen. Nonetheless, as a mid-21st century solution, this has to be a strong contender as a replacement for fossil fuel derived motive power.

Picture Captions and Credits

Page 3: Bloodhound. http://www.bloodhoundssc.com/news-events/press-and-media/media-library
Page 4: A wafer of silicon with multiple semiconductor devices prior to being scribed into individual dice. Source unknown.
Page 7: Robotcar. http://www.epsrc.ac.uk/newsevents/news/selfdrivecar/
Page 7: Google Car. http://blog.caranddriver.com/wp-content/uploads/2014/05/Google-Autonomous-Car.png

Epilogue

For the last couple of decades, developing countries such as Brazil, Russia, India and China have aspired to catch up with the living standards of the developed world. Intensified global competition for natural resources has occurred and this trend is unlikely to reverse in the short term. Fossil fuels will remain the most important energy source, at least until 2030, and the use of oil, gas and coal is expected to grow in volume over this period. As the sources of easily accessible oil decrease, production costs rise due to the expanding share of deep-water exploitation and unconventional sources (eg biofuels) in the total supply.

In motoring, as in the wider uses of energy, there are no easy answers but those actions that can be taken include:

- *Use less of the Earth's raw materials*. Ultimately, if we are to keep the effect of manmade air and sea pollution to a level where we ensure future generations can enjoy the quality of life experienced in the developed world at the start of the 21st century, the energy use per head of population has to fall[2].

  Whether driven purely by environmental concerns or economic necessity, in the world of motoring there are encouraging signs. Average annual car mileage in the UK is falling, the number of cars on the road, whilst still rising, appears to be flattening and of those that are being purchased, smaller, lower emission cars predominate. Amongst young people in the UK, Germany, the USA, Australia and Japan, those learning to drive are doing so at a later age and car ownership is seen as less important than good, smartphone internet access. Increased urban living may also be a factor in this age group [3] .

- *Reuse more*. For more than a decade, EU directives have covered the end-of-life disposal of vehicles: they are now built to be recycled rather than sent to landfill. The average age of cars on the UK roads is at its highest for over 20 years but even so, the average life is still just 7.9 years. The CO_2 produced during manufacture and scappage can be a significant percentage of that emitted by a car during its lifetime: anything from 15% to 50%, depending on the age of the car and assumptions made in the calculation, so it makes sense to maximise the use of our cars. One trend that will help is that away from personal ownership to membership of instant sharing schemes: again, particularly relevant in urban areas. Technically, software upgrades to existing hardware are likely to extend the useful life of the ever-more connected car.

- *Innovate alternative solutions*. Europe is relatively resource poor and imports many of the resources it requires. With a dependence on non-European suppliers, with their associated political uncertainties, there is every incentive to develop European solutions to energy generation, transportation and food production. Many areas of innovation in car transport have been covered in this book. One, clearly on the mind of a major manufacturer and highlighted by Bill

[2] David J C MacKay: "Sustainable Energy without the hot air"
[3] Eric Sanderson: "Terra Nova: The New World after Oil, Cars and Suburbs"

Ford, Executive Chairman of the Ford Motor Company, is that of networked cars leading, by 2025, to autonomous cars bringing their benefits of lower emissions, less gridlock and lower casualty figures.

Perhaps the biggest challenge will be that of fuelling the car of the future whilst keeping the harmful emissions of the car, when in use and during manufacture, to levels that produce no further degradation to the planet's atmosphere.

Whilst trying to avoid producing proscriptive lists, a significant part of this book has focused on what the individual motorist can do to minimise his or her impact of motoring on our environment. A discussion of how we might better plan our journeys to avoid congestion, avoid becoming lost, select our new or used car and prolong the life of that car has been presented. It is encouraging that there must be a significant number of motorist who are already changing their habits (or not even going down the route of car ownership) since for reasons of cost, population growth - especially in our cities - or environmental concerns, there are trends that suggest the impact of motoring may yet be something that our planet will survive.

The Cotswold Motoring Museum and Toy Collection is not just about cars. Toys that our parents and grandparents played with as children, everyday artefacts from the Victorian and Edwardian era plus an insight into the social history of the village of Bourton-on-the-Water and much more can be found in the Old Mill, alongside the River Windrush.