The Emergence of New types of Powertrain and the Impact on the Insurance Industry

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Introduction

The 'Green' movement within International motor shows for the past three years have developed to the point that it is now seen that no global vehicle manufacturer dare not take this important factor into account. An example of this movement was the recent 2008 London Motor Show (July 23 to August 3) the major theme was "Green, Green and Green" [1]. This year, British Prime Minister Gordon Brown pledged £90m of government money to help make Britain "the European capital for electric cars", and he also said that money would be available over five years to support (full) electric, (electric/internal combustion) 'hybrid' and other environmentally clean car projects [2]. The move reflects the deals under discussion with Norway, Portugal, Greece and Israel. The two economic drivers of reducing CO_2 emissions and as well as reducing the risk of oil price increases are pushing vehicle manufacturers to make new powertrains such as full electric, electric/internal combustion engine 'hybrids', alternative internal combustion engine fuels, engines which can combust via compression as well as spark, and fuel cells.

In the last ten years, whilst Toyota has sold more than one million Prius 'hybrid' cars – a contrast to the position taken with GM's lease only EV1 electric car experiment, which was abandoned. The global Green movement as well as the prevailing legislation in key markets such as California – where sale of a zero emission vehicle is a requirement in order to sell any conventionally powered cars - has spurred GM to rework plans. Now GM has announced plans to begin making a plug-in 'hybrid', the Chevrolet Volt [3]. This reflects what the majority of vehicle manufacturers have doing, which has required large R&D investments, as well as use of support offered by regional / national governments. The latter have been supporting this by cutting taxes and investing in new infrastructure.

In the near future it is apparent that the successful development of new powertrain variations will acquire higher priority for manufacturers, since the consumer base is very willing to accept reduced running costs – as long as fuel costs are high and tax incentives are available. So, what will be the impact on the insurance and repair industries? Since 2000 the revolution of new materials and joining technologies, introduced into vehicle body structures in order to make cars lighter & stronger, has resulted in some confusion in the repair industry. This has been in the main due to poor promotion of methods documentation, training of staff, objective analysis of available equipment and the very business model itself which has traditionally used by body shops.

This phenomenon is accelerating and is a critical subject in the new standards dialogue between insurers and the repair industry. In this paper, we will take a look at which vehicle manufacturers are particularly active in developing new powertrains, what type of technology is being employed, and what will be the challenges to the insurance and repair industries.

Global Warming & Environmental Challenges

The widely agreed phenomenon of global warming is assumed to be mainly caused by CO_2 emissions from the burning of fossil fuels, although this has been a controversial view internationally. According to research by GISS, the global mean temperature has increased 7C° in 100 years [4], and this is blamed on poorly controlled CO_2 emissions as a result of the industrialisation of the developed and developing world.

Following on from and in accord with the Kyoto Protocol (1997) which is an international treaty on global warming for reducing CO_2 emissions, there was an undertaking for the automotive industry to continue to play its part. Specifically in Europe, thirteen major European vehicle manufacturers represented by ACEA (the Association des Constructeurs Europeens d'Automobiles) have agreed with the EU Commission to reduce CO_2 emissions for new passenger cars by 25% by 2008, which is an average of 140g/km [5]. More recently this target was reduced further to 120g/km by 2012.

The importance of CO_2 legislation is significant. Broadly both in Europe and the USA vehicle emissions for hydrocarbons, CO and oxides of Nitrogen have fallen year on year – made possible by new emission technologies. The 'free' pollutant until now has been CO_2, which was not seen as being as harmful when the current emission legislation was started back in the 1960s. Given the movement to cut all emissions including those incurred during vehicle manufacture, vehicle manufacturers have been confronted with a completely new challenge. With strong support from government through measures such as tax benefits and exemption from local taxation (for example, the London congestion charge), many kinds of new powertrain are being developed for future generation vehicles, as it is the powertrain which is the emitter of the CO_2 during the service life of the vehicle – a prime target for reduction.

Oil price Volatility and Scarcity

Within recent years oil price volatility and scarcity have become recognised as major threats to world economic growth. In the first half of 2008 the oil price soared, then stabilised and at the end of 2008 fell back, but the long-term trend toward increased cost and extreme political volatility is clear. Energy economists refer to 'peak oil', i.e. that the world has already reached or is about to reach a point at which there will be a long term decline in oil output. Supply and demand economics dictate that developing countries such as China are using more oil than before, and, while the supply continues to be limited it is to be expected that the oil price will both fluctuate wildly and experience net year on year cost gain.

In addition politically unstable countries which have large reserves of oil such as Iraq, Iran and Nigeria add to general supply and demand volatility, thus creating a very difficult energy economy. It is very difficult to predict how much oil is left and when it will eventually run out. But, as all acknowledge that there are finite limits on oil production in a rapidly developing world economy, vehicle manufacturers have no other choice to prepare for 'peak oil' and its impact on the products they make. This has also accelerated the development of new powertrains which use less fuel to deliver the same effect as well as alternative. However, Bosch manager, Rolf Leonhard predicted that internal combustion engine with direct injection will continue to dominate the automotive market place for the next 20 years [6]. Most commentators agree with this view, on the grounds that several themes are likely to emerge rather than one overall type of powertrain – depending on the economics of the target economy.

The Emergence of New Powertrains

The work by vehicle manufacturers in terms of reducing CO_2 emissions & developing new powertrains has been carried out predominantly through the last decade or so, driven by increasing demands of legislation (Euro II, III, IV, V and now VI in Europe – all in the last 10 years). The Vehicle manufacturer's business model is to sell more cars in the market whilst combating market competition. Therefore the consumers' preference is all important. A higher and more volatile oil price and its impact on fuel prices is starting to persuade consumers once again to consider more economical cars – just as during the last oil crisis. Thus vehicle manufacturers will be forced to develop more economical vehicles which meet this new consumer preference. But its not just the powertrain which is changing - overall vehicle design is changing quickly to solve these problems.

One measure to increase fuel economy would be to reduce the vehicle mass - the most powerful single factor given most emissions occur during acceleration – by halving body weight overall fuel consumption could be cut by 25 to 30%. This target ignores the significant NVH issues that would be raised, or that the consequent vehicle would by demonstrably smaller than the class average. In order to reduce overall vehicle weight decreasing the weight of the body shell is necessary – thus producing a car with thinner materials. But doing this increases safety risks, which could in part be recovered by use of higher strength materials. This trend toward different vehicle body materials and joining technologies has been made possible by a revolution in design and manufacture, and is invisible to consumers, but from the perspective of insurers & repairers this change is presenting a huge challenge; one which eventually might lead to increase premiums.

Toyota's success – the 'hybrid' Prius I & II

Toyota announced that worldwide cumulative sales of the first two generations of Toyota Prius – the world's first mass-produced petrol/electric 'hybrid' vehicle – had passed the 1 million mark in April 2008. The first generation Pruis sold more than 130,0000 around the globe. Prius has been sold in more than 40 countries, including over 100,000 cumulative sales in Europe of which 23,893 have been in the UK. The Prius was launched in Japan in 1997 and began selling in Europe, North America and elsewhere in 2000 [7]. Toyota is continuing this success with the second-generation Prius II. This was launched in 2003, equipped with the Toyota Hybrid System II, and was introduced with improved environmental performance and power.

Figure 1: Toyota Prius II

Toyota plans to add optional solar panels on the roof to Prius III, its next generation 'hybrid' in 2009, in order to power the vehicle's air conditioning whilst parked [8]. Combining a two high voltage electric motors, an 'Atkinson' cycle internal combustion engine (very low emission), and a complex energy management system, the drive system can switch the powertrain between electric and internal combustion motors (or even both) depending on the prevailing motive requirements dictated by the driver and energy requirements dictated by the control system. The vehicle has a range of around 5km on battery charge alone, and uses one electric motor to reverse power the singe epicyclical gear train to achieve maximum road speed with the engine. The whole product strategy was developed for low speed urban congestion, and does not work as well at higher road speeds compared to other forms of hybrid product strategy.

This has been a stunning achievement by Toyota, to produce prototype cars fit for use in the mass markets across the globe, which they have done with almost no competition from other vehicle manufacturers. Further the Prius 2 had classic aerodynamic features (a 2 volume body design with Kamm tail), electric power brake system, electric powered AC, touch screen control and much more. Thus, through this great technical and market success from the world's largest manufacturer the development of new powertrains has now become an inevitable challenge for all vehicle manufacturers as they work to survive fierce market competition with a new factor – the demand for a low carbon footprint.

Toyota Continue to Develop their Challenge to the Auto Industry

After the success of Prius, Toyota has continued to release new Hybrid cars into the market through their Lexus brand - the RX 400h (SUV), GS 450h (Saloon) and LS 600h (Luxury sedan). Toyota implemented this new 'hybrid' technology in the typically high Lexus specification with the usual options for enhanced safety features as well as multimedia and entertainment systems, a complete high technology package. This has contributed to higher performance, high fuel efficiency and lower emissions - all benefits of the Lexus Hybrid Drive.

This innovative and market leading Toyota hybrid technology could be regarded as a trasnsition for powertrain design. It contributes to decreased CO_2 emissions - even though the vehicle still uses oil and emits CO_2 from an internal combustion engine, this 'hybrid' is a very serious step forward in dealing with the world's concerns in the area of global warming. If one ignores the energy investment to create the system in the first place.

While the existing Prius needs to continually recharge its batteries through on-board generation of power using internal combustion engine, the next generation of 'hybrid's are likely to have higher battery capacity with the option of direct charging from the electricity grid. These are the so-called "Plug-in Hybrid" [9].

Table 1: Toyota and Lexus Hybrid Model specification

Model	Launch year	Body type	Engine	Max power	Top speed	Fuel consumption	CO_2 Emissions
Prius 1	1997	4 Door saloon	1.5 Petrol	71PS	151km/h	4.9 l/100km	114 g/km
Prius 2	2003	5dr hatch	1.5 Petrol	76HP	170km/h	4.3 l/100km	104 g/km
RX400h	2005	4*4 SUV	3.3 Petrol	268HP	200km/h	8.1 l/100km	192 g/km
GS450h	2006	4 Door Sedan	3.5 V6 Petrol	354HP	250km/h	7.9 l/100km	186 g/km
LS600h	2007	4 Door Sedan	5.0 V8 Petrol	445HP	250km/h	9.3 l/100km	219 g/km

The key to 'Hybrid' Technology: Lithium-ion battery

Major concepts shown in Geneva and Detroit during 2008 could included the 'Plug-in Hybrid' from Toyota, the 'Blue Hybrid' from Mercedes, and the 'Plug-in Chevrolet Volt' from GM. The next major variation of powertrain is likely to be the 'hybrid' car – as is already evident in the USA. Until now, most 'hybrid' cars have adopted nickel metal-hydride (Ni-MH) batteries. However, these have a relatively low energy density. In order to move toward higher energy density a new battery technology is being introduced - the Lithium-ion battery. Without this the next step toward the development of a high performance, environmental friendly vehicle will not be possible. In both cases management of heat during charge and discharge is critical – even more so for Li-Ion.

Table 2: Comparison Ni-MH & Lithium-ion Battery

	Nickel metal-hydride	Lithium-ion
Energy Density	1000W/kg	2000W/kg
Durability	5 Year	10 Year
Safety	Relatively safe	Safety strategy required
Relative cost	1	3

The success of future electric battery powered and hybrid vehicles will be related to battery capacity (energy density) – thus providing much further mileage range with one 'plug-in' charge. In this perspective, as shown table 2, Lithium-ion has twice the energy capacity of Ni-MH. It also has another advantage - durability - it is estimated that Lithium-ion batteries can be used for almost 10 years, which is double that of Ni-MH. According to the forecast of the

IIT (Institute of Information Technology), the market share of Lithium-ion fuel cells used in vehicles in 2017 will reach 86% [10]. In short, Lithium-ion batteries are seen as key to the electrification of the automobile. The industry is still working to ensure that the batteries can be mass produced and can withstand daily use by motorists. But there are also other obstacles to overcome, the first is their cost - which is prohibitive, and the second is safety.

Battery systems have the characteristic that the higher the energy density the greater the risks of uncontrolled energy dissipation – which can potentially lead to fires and worse. This is not such a big issue with current battery technology, but as the energy density increases so do these risks. Because of this the vehicle manufacturers are co-operating with each another and present large scale users of the technology – such as computer and mobile phone manufacturers - to progress the next generation ‘hybrid’ batteries.

The Mitsubishi’s new ‘i’ City Car (i-MiEV) was unveiled in Japan during 2006 as a prototype and is based on the petrol powered iCar sold in the UK in 2007. The ‘i-MiEV’ city car has a Lithium-ion battery, is driven by a rear-mid powertrain and has four-seats.

Table 3: Mitsubishi ‘i’ City car and ‘i-MiEV’ specification

Launch year	body type	Engine	Max power	Top speed	Fuel consumption	CO_2 Emissions
2007(UK)	City car (5 Door)	660cc 3 cylinder petrol	57HP	135km/h	5.2 l/100km	114 g/km
2008 (Japan)	City car (5 doors)	Li-Ion battery pack and electric motor	47 kW	130 km/h	7 hours charge at 3kW	‘Zero’ for the vehicle

The ‘i’ has a tall narrow mono space body with a relatively small frontal area. Aluminum is used for the front subframe and the rear de Dion suspension. In manufacturing Mitsubishi have adopted MIG and TIG welding, and have employed innovative ‘hybrid’ laser welding (a type of welding that combines laser welding and arc welding) in order to ensure joint strength and body dimensional precision[11]. Unfortunately there have been many instances of new manufacturing joining technology being introduced by vehicle manufacturers without consideration of the impact of them in the repair sector. It remains to be seen as to how much Mitsubishi has considered the problems that this new vehicle body technology might introduce in vehicle repair.

Figure 2: Mitsubishi i-MiEV

Partnership between Vehicle Manufacturers for Next Generation Vehicles

Developing a new vehicle technology such as the Lithium-ion battery demands tremendous investment by the vehicle manufacturers and their suppliers. New battery development technologies are especially outside vehicle manufacturers' normal field of technical development. Thus many vehicle manufacturers are cooperating with other companies which have the know-how of battery, fuel cell and energy management technology.

Volkswagen announced that it would work with Sanyo - one of the world's leading developers of rechargeable batteries - on high-performance energy-storage system and Lithium-ion technology which has the potential to meet the automotive requirements for a drive system[12]. However, below are the current types of product on offer from Volkswagen, centred around optimized diesel engine calibration, stop start technology and improved aerodynamics:

Table 4: VW's new powertrain models

Model	Launch year	Body type	Engine	Max power	Fuel consumption	CO_2 Emissions
Polo BlueMotion	2006	Hatchback	1.4 TDI Diesel	80PS	3.3l/100km	102 g/km
Passat BlueMotion	2007	Estate(Wagon)	1.9DPF Diesel	105PS	5.1l/100km	136 g/km
Golf VI TDI Hybrid(Concept)	2008	Hatchback	1.2 TDI Diesel	75PS	2.9l/100km	89 g/km

Volkswagen has researched ways of increasing diesel engine energy efficiency with BlueMotion technology applications designed to lower fuel consumption and CO_2 emissions whilst countering the onset of particulates. Volkswagen has also incorporated their BlueMotion technology into Passat and Polo as shown Table 4 as well as a diesel electric hybrid concept shown on Golf VI. The Volkswagen Group luxury brand Audi also unveiled the A1 at last year's Tokyo motor show, with a diesel hybrid power train using Lithium-ion technology. PSA (Peugeot Citroen) and Mitsubishi Motors Corporation (MMC) have announced that both companies have agreed to start a feasibility study on an extended technical collaboration in the field of electric powertrains [13]. Mitsubishi Motors has chosen to centre its development of next-generation electric vehicle technology on in-wheel motors and on the Lithium-ion batteries that the company has been working on for several years.

The in-wheel motor concept is the placement of an electric motor inside each wheel. Thus the motive parts of the vehicle are contained within the wheels; there is no motive power distribution – no drive shafts. The electric motors act to provide both the drive system and regenerative braking (providing increased energy conservation). This concept has the potential of significantly reducing drive-line energy losses and noise but has a fundamental flaw – the transition of power via two or more electric motors which will require a significantly higher voltage system to minimize power transmission losses. The likely applications are likely to be smaller electric only vehicles, and creates interesting possibilities for innovative vehicle packaging – the 'engine' is effectively moved to the wheels, allowing the space this takes up to be used in other ways – to protect the occupants for example.

A potential problem for the introduction of this technology is that the wheel assembly unsprung weight is increased (the weight of that part of the vehicle which is in contact with the road and which is not 'sitting on springs'). With normal spring/damper suspension systems an increase in unsprung weight is considered a disadvantage because it increases inertia and hence increases response time. During vehicle travel the wheel is designed to follow the road surface in a controlled way, ensuring that the minimal amount of energy possible is transferred to the vehicle body, thus reducing the amount of consequent body movement to a ensure a smooth ride. In-wheel motors increase the wheel hub mass so that during 'bounce' controlling this energy transfer is consequently much more difficult. It may well be that this technology can only be introduced with a computer controlled active spring/damper such as that developed by Lotus engineering and which famously was capable of making a vehicle ride through a corner with no roll whatsoever – and such systems require additional energy to 'place' the wheel relative to the body as the vehicle passes over the road surface.

Not only vehicle manufacturers, but the OEM Tier 1 suppliers are developing new technologies by entering into partnerships. Continental, a major automotive supplier, has contracted with Enax – the Japanese Lithium-ion specialist for the development of high-performance Lithium-ion cells for 'hybrid' and electrical vehicle batteries. Continental will launch first-time volume production of high-performance Lithium-ion battery for the Mercedes-Benz S400 BlueHybrid at the end of 2008 [14].

Bosch GmbH and South Korean company Samsung SDI, plan to manufacture Lithium-ion batteries for use in hybrid vehicles globally [15]. Bosch, Continental and ZF are competing with the OEMs to develop 'hybrid' technology. This kind of partnership will give benefits for all the partner companies and will eventually reduce the vehicle development time.

Electric Sports Car: Tesla Roadster

Unveiled as a prototype in 2006, Tesla Motors (named after the famous electrical inventor), has released the plug in electric Roadster in 2008 with a 220 mile range – however the vehicle is expensive in comparison with a Lotus Elise (US $109,000), which is due to the high development, manufacturing and component costs as well as low projected sales volume. The initial product – the Roadster – will have just 1,000 customers in the US, and Tesla is planning to sell the Roadster in Europe in spring 2009. The company expects to produce 2,000 cars a year (the first phase is sub contracted to Lotus – the vehicle is based on the Elise platform), with final assembly in California. Tesla Motors has also 'inked' a technology deal with Daimler, according to remarks reportedly made by Chairman Elon Musk [16]. The second phase will be a four seat luxury car produced in California. The Roadster has a zero-emission, 248hp 100% electric engine powered by 450kg lithium-ion battery pack giving the vehicle a top speed of 210kph (electronically limited) and a 0-100km/h acceleration of only 4 seconds.

Figure 3: Tesla Roadster

As the Roadster is a 100% electric car, it demands an electric charging infrastructure, which is also an important part of the Tesla Motors vision. With the support from the California Air

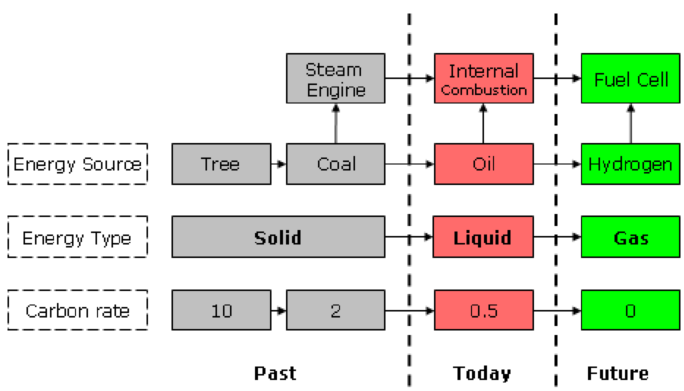
Resources Board (CARB) and the California Energy Commission as well as other related businesses such as Hyatt Hotels, step by step the start of an infrastructure is being established in California [17].

The Emergence of New Energy Source: Hydrogen

Hydrogen could well be the new energy source for mankind's long term future. Since the industrial revolution the primary energy source has changed from solid (coal) to liquid (oil), and more recently it has evolved into gas – currently carbon based CNG and LPG. But Hydrogen is not only a gas, and therefore considered a 'future' fuel, it also has a carbon neutral containment rate – i.e. it is totally clean from an environmental perspective. On an industrial scale the Fuel cell is widely predicted to be the next generation energy source, which whilst not generating the high levels of energy of nuclear power, can be used in situations in which direct grid connection is not possible, and can be 'scaled' to suit small, medium and large applications.

Fuel cells generate power from the molecular combination of Hydrogen and Oxygen, the ions given off during this process producing electricity. Thus all they produce is electricity and water. So, from a mega-trend perspective the steam engine was powered by coal, the internal combustion engine by oil, and the fuel cell by gas – Hydrogen and Oxygen (Oxygen being drawn from the air in terrestrial applications). Hydrogen can made from 'nature' from the hydrolysis of water – of which the Earth has a very great deal; is storable, has a high latent energy, and will enable the fuel cell to play an important role in the near future [18].

Figure 4: Mega trend of energy source



Honda has launched the Japanese market version of its FCX Clarity fuel cell vehicle. This will be sold through leasing arrangements in Japan, US and some other countries with restricted sales starting at about 200 units/annum within three years. It uses Hydrogen feeding a fuel cell feeding Lithium-ion batteries, emitting nothing more polluting than water, and doing 280 miles on a full tank of Hydrogen [19].

Honda announced that it would be sold only with a three-year lease term, at a price of $600 per month (approx. £400-£500), including maintenance and collision insurance. This Hydrogen car is not designed for mass production & sales because of the lack of infrastructure like hydrogen gas station, the higher car price (if sold) and potential aftermarket maintenance problems. Even so Honda had 40000 people enquire about FCX Clarity when the first lease vehicles were delivered.

Figure 5: Honda FCX Clarity

Table 5: Honda FCX Clarity specification

Body type	Engine(Motor)	Max power	Fuel consumption	CO_2 Emissions
Saloon	AC Synchronous Permanent-Magnet Electric Motor	134HP	3.2 l/100km	ZEV

Another Japanese vehicle manufacturer, Mazda, has been developing a hydrogen car since 1991 – but in this case burning hydrogen directly in an internal combustion engine. They have already released the RX-8 Hydrogen RE in 2006 commercialised through leasing. Whilst the Premacy Hydrogen RE Hybrid was being developed permission was sought from the MLIT (Japan's Ministry of Land Infrastructure and Transport) to test this hybrid minivan on public roads [20]. The Pemacy Hybrid uses a transversely mounted Wankel engine powered by either hydrogen or petrol, in conjunction with a battery pack.

Mazda also signed an agreement to provide 30 RX-8 Hydrogen REs to Hynor, a Norwegian national project. It is hybrid car with dual fuel system, petrol & hydrogen; and uses the hydrogen as a fuel for the internal combustion engine. It could be viewed that the main experiment for a hydrogen power fleet is in Norway, where relatively low cost electricity means industrial scale production of hydrogen in liquefied form could be viable one day, provided the cost of oil rises far enough.

Figure 6: Mazda hydrogen cars

RX-8 Hydrogen RE

Premacy Hydrogen RE Hybrid

BMW has developed a new powertrain car - the Hydrogen 7. It is based on the existing 7 Series and comes equipped with an internal combustion engine capable of running on hydrogen or petrol. In hydrogen mode the car emits nothing more than water vapour. Powered by a 260hp 12-cylinder engine, the Hydrogen 7 accelerates from zero to 62mph in 9.5 seconds before going on to an electronically limited 143mph top speed. BMW continues to develop ultra efficient, yet very dynamic petrol engines that significantly reduce fuel consumption and CO_2 emissions [21]. Like the Prius the technology extends beyond running a V12 on hydrogen – this car uses a special fuel tank which has a wall thickness of just 40mm, and yet can keep liquefied hydrogen at minus 270 C at a pressure of just 4 bar. This technology is key to practical and space efficient hydrogen storage. However Hydrogen 7 has another secret too – the first use of Carbon Fibre in the body side frame for BMW. The vehicle was not built for sale, but lease only.

Figure 7: BMW Hydrogen 7

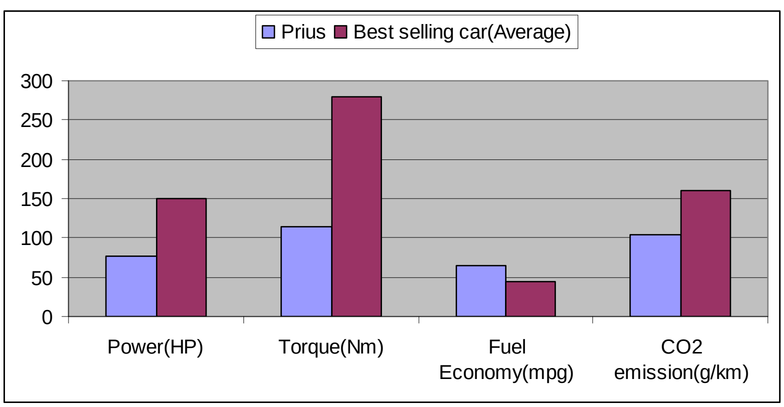
What are the Factors Limiting Market Introduction?

There are many limits to market introduction of these new technologies. 'Hybrid', hydrogen and electric cars are more expensive than petrol and diesel models, are not so fast and in some cases don't travel as far between fuel top-ups. Hydrogen fuel has a poorer energy density than diesel or petrol, and the infrastructure across Europe is limited to a very, very small network. Further hydrogen fuel is (currently) not cost effective to extract on an industrial scale for use as fuel. In addition the selection of first generation products on offer is poor, and for some of these technologies the essential infrastructure is effectively non-existent.

The median car price of Prius sold in the UK is about £19000. If compared with other models in the top 10 best sellers list last year, in Europe for cars with a similar car price Prius shows 1.46 times better fuel consumption and emits only 65% of the CO_2 compared to other similar models. It also has a benefit of lower car tax in some countries, as well as being exempt of congestion charge in places such as London.

But with the same car price, motorists can on average buy twice the performance (HP) and 2.4 times higher torque (Nm) for an equivalent vehicle. For instance buying the stylish and more powerful base BMW 3-series adds just £2000.

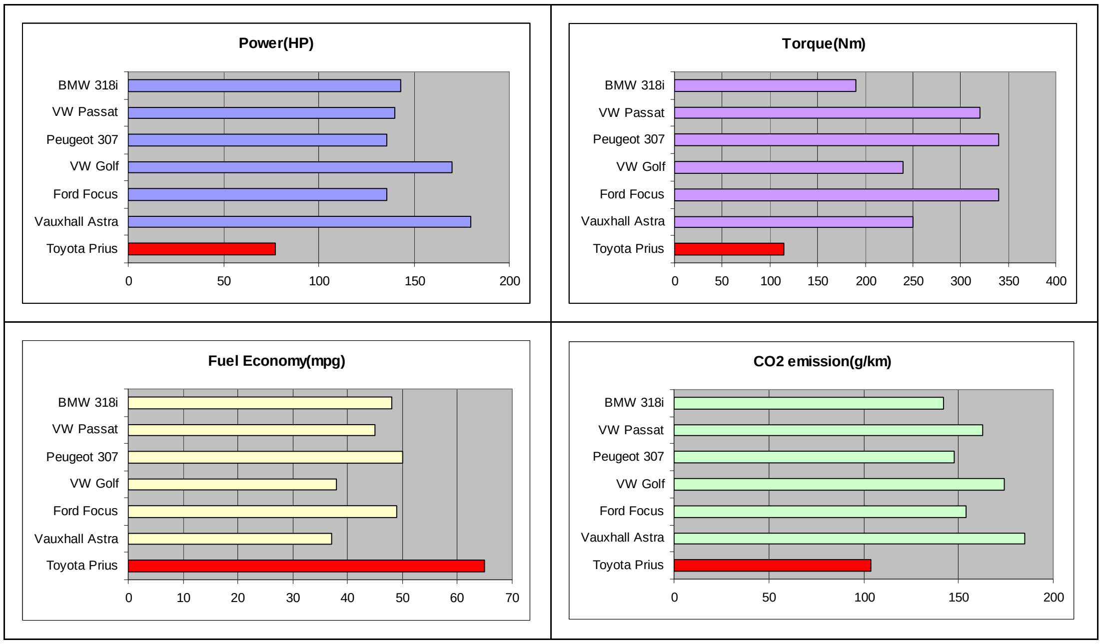
Figure 8: Prius vs. Best selling car comparison (average)



Source: MSN Cars <http://cars.uk.msn.com/News/Top_ten_article.aspx>

Thus most motorists prefer to buy more powerful models for the time being, even though the Prius has many positive attributes such as low maintenance cost, low CO_2 emissions and tax benefits as well as being a new powertrain car and part of the 'future',

Figure 9: Prius comparison with other models



Source: MSN Cars <http://cars.uk.msn.com/News/Top_ten_article.aspx>

Significant Obstacles to the Hydrogen Car

Back to the 1990s car makers proclaimed that the mass production of hydrogen-fuelled cars was only 10 years away. Even today, if we ask the same question of the car makers we get exactly same answer. But the technology has not stood still and every year new prototypes are unveiled [22]. The Hydrogen car which could be refueled in minutes, emit only water vapour and have a driving range that matches conventional cars, would seem to be an excellent solution to the problem of car carbon emissions. In spite of these advantages, why has no manufacturer announced plans to mass-produce hydrogen cars?

Fuel cells have complex membranes which allow the passage of electrons – and are sensitive to impurity. So, fuel cells need a clean source of fuel such as hydrogen. They also have a minimum operating temperature, which means until recently the cell would not produce power below an ambient of minus 10 C. Volkswagan have led the development of membrane technology to overcome this. So, today the operating requirements expected by modern car drivers are not met.

The technology to produce hydrogen for either fuel cells or direct burn is far from mature.. Storing hydrogen is also tricky. It has to be compressed or liquefied, which requires significant energy along with high pressures or on-board cryogenic systems. Other technologies that avoid this, such as storing hydrogen in solids like metal hydrides, are yet to emerge from the laboratory. Secondly, even if these problems are overcome, one of the biggest obstacles is the cost of building the infrastructure to deliver hydrogen for the transport sector. It is reported that there are only 150 hydrogen refueling stations worldwide. That is compared with about 10,000 petrol stations in the UK alone. Without filling stations, consumers won't buy hydrogen cars and energy companies have no incentive to invest in building the stations. In order to boost the manufacture and purchase of hydrogen cars like the other environmentally friendly vehicles like electric cars, it is necessary for the governments and energy companies to invest in building the hydrogen manufacturing, storage and delivery infrastructure.

Are New Powertrain Cars Safe Enough?

Vehicle safety is the one of measures used by motorists when they choose a vehicle. So, what about the safety of a new powertrain car? To date there seems to be no societal awareness regarding vehicle safety or other concerns with new powertrain cars.

Table 6: Safety of Hybrid cars (Euro NCAP)

Model	Adult	Child	Pedestrian	ESC Fitment
Toyota Prius 2004	★★★★★	★★★★☆	★★☆☆	
Honda Civic Hybrid 2007	★★★★☆	★★★★☆	★★★☆	

If we see the crash test result conducted by Euro NCAP on vehicles with new powertrains we note that only two have been tested. The Prius is the first hybrid car to be tested by Euro NCAP. It achieved five stars for adult crashworthiness, four stars for child and two stars for pedestrian respectively. Euro NCAP said it had a very strong and stable passenger safety cage and side impact protection was impressive, too, while the recommended child restraints performed very well and they had average protection for pedestrians.

The test results of the Honda Civic Hybrid was similar to the Prius and exactly same as the 'normal' derivative, the Honda Civic (2007) – hardly surprising given the IMA drive line features an integrated flywheel and starter motor. Thus the Civic IMA is not as complex as Prius 2. ESC fitments for both models are 'green', so no real difference can be perceived between the two vehicles.

In comparison with conventional vehicles hydrogen cars have a serious concern as hydrogen is astonishingly explosive. As it is non-carbon gas it burns with an invisible flame. Hydrogen was responsible for the Hindenburg disaster in which the world's largest airship was destroyed within minutes when docking in New York. This well known disaster has a large cultural resonance and will continue to provoke public fears about the danger of Hydrogen as a fuel. At an engineering level it is very difficult to make any container impervious to Hydrogen as it is such a small atom, so on-board management of it is very difficult and expensive. Within an internal combustion engine it can also produce combustion problems. So the safety challenges for Hydrogen cars will remain a very serious problem for the introduction of these vehicles.

Hybrid drive lines are likely to rely on bigger capacity LI-Ion battery technology as well as capacitors. Both devices have critical energy management issues – not least of which is heat – and the bulk of these systems may intrude further into the passenger compartment. This presents potential issues for the emergency services – should they kill the power? As the electrical systems will also be trying to cool the battery pack down this would be very dangerous. There will also be further challenges for the future development of occupant safety.

Electric vehicles can also cause unexpected safety problems. Lotus, the British performance carmaker, has introduced a new device that makes 'hybrid' cars louder. Since 'hybrid' cars first hit the market, concerns have been raised about the potential risk to blind pedestrians — as well as children and cyclists — who may not hear 'hybrids', which can be very quiet. Consumer organisations, such as the National Federation of the Blind, have pushed for legislation to address the issue. The new system, dubbed "Safe and Sound," was designed to generate artificial noise mimicking a gas-powered combustion engine [23]. There are also some concerns about the potential negative health impacts from electromagnetic fields (EMFs) from electric vehicle such as 'hybrid' car [24]. No doubt other unexpected safety issues for new powertrain cars will emerge.

Conclusions

The business of insurance is all about the accurate pricing of risk – as the saying goes 'there is no such thing as a bad risk, just a bad premium price'. With the emergence of the new powertrain car, new and different types of risk may present new challenges for the insurers. The most obvious of these is the higher repair cost caused by more a complicated powertrain which may be difficult to repair. Of course, as in other areas of insurance this is not only a problem for the insurance company as well as the repairer, but will ultimately affect the motorist who will have to pay a higher insurance premium once the insurer reflects the true cost of repair and the risk it represents in the premium charged for insurance. Vehicle manufacturing technology has been developing radically and evidence to date shows that in the changes to the body structure that has been done mostly without considering repairability. The vehicle body has evolved which has high strength, high rigidity and light weight because of the necessity for the automotive industry to improve crashworthiness and reduce CO_2 emissions and this is a problem for the repair industry. This trend will accelerate with the emergence of the new powertrain car resulting in even more complexity in repair.

For example MMC (Mitsubishi Motors Company) has developed and applied on the "i" – a cheap mass market basic car – a steel space-frame body that is highly strong and rigid but with extensive use of aluminium for the subframes, suspension links and the engine [25].

Figure 10 Mitsubishi i aluminum engine

According to Thatcham (The Motor Insurance Repair Research Centre) which did repair methods and repair times research on the Prius II in 2006, when it is repaired it needs more care than conventional vehicles in the workshop for the repair technician in terms of health & safety because of its high voltage battery. In addition the Prius II repair times were higher than for other similar models. To meet the increasing environmental challenge it is inevitable that the vehicle manufacturers must adopt lighter and efficient materials in body repair in combination with an increasing complex powertrain. But how much will they take into account the aspects of repairability when they design these future vehicles?

As vehicles get more difficult to repair, insurance claims will of necessity rise, and as the complexity increases there could also be a negative impact on the repair industry as a result, as the cost of business grows through increasing requirements for complex repair equipment and training. Thirdly there could be an increased amount of waste handling and recycling from an environmental prospective which will add costs [26].

Thus we can conclude that vehicle repair will probably become more difficult and the emergence of new powertrain vehicles will lead to damage patterns which have not yet been seen. Consequently as a result repair costs may increase, which will be a big challenge for motor insurance companies.

Therefore motor insurance companies as well as related research organisations should monitor closely changes in the vehicle market mix as the new technologies emerge, and should prepare for these changes. As these different kinds of vehicle emerge, it will be necessary to train claim specialists for coping with these more complex claim settlements, and the UK Group Rating system for motor insurance may need to take into account the characteristics of new powertrain cars, thus ensuring that the pricing of premiums is more accurate and through its transparency of assessment bringing some influence on vehicle manufacturers in controlling repair costs.

The repair industry will need to monitor the market introduction of vehicles with new powertrains, and to ensure that information providers such as Thatcham and the VMs can provide appropriate repair information. The repair method and process will become even more important as vehicles become more complex, and the industry must step forward to full engagement with the new quality control standard PAS 125, applied and audited through the industry by the British Standards Institute (BSI); thus creating a strong foundation for managing future technical change.

Executive vice president of Nissan Motor Co., Mitsuhiko Yamashita said “Motor technology is very old and in reality there has been little real change and progress in the basic technology.” But he also admitted that things are changing quickly now as manufacturers prepare more hybrids and electrics for market [27]. This change is not only applied to vehicle manufacturers, but also motor insurance companies, repair industries and related organisations.

From the vehicle perspective the powertrain variations on offer from each OEM globally will increase dramatically, and vary between markets. There will be offerings using not only petrol / diesel fuel, but also bio-fuels, compressed natural gas, the provision of public access mains electricity plug in points, and the longer term provision of a liquefied hydrogen supply network. The related motive technologies will use internal combustion engines (spark ignition, compression ignition and combined process), fuel cells and of course battery technology. The impact of the additional systems - even additional to the current conventional drive line - will create issues for the location of power control modules, DC / AC inverters, battery cooling modules, battery charging modules (for plug ins) and of course the high voltage connection between batteries and electric motors.

Vehicles not originally designed to take these additional parts may be forced to place some of the components in locations vulnerable to low speed accident damage. Further, the systems - especially for hybrids and for vehicles powered by liquefied hydrogen - may encroach on the interior volume for a given external size of car, and induce weight gain. This trend may put further pressure on reducing weight for all other aspects of the vehicle, with the result that this is likely to accelerate the development of fully bonded body structures with a large array of steel alloys. This would be a further revolution in vehicle architecture with all the impacts on the insurers and their repairers previously described.

Future Research

As the number of new powertrain cars is currently quite small there are very few comparative studies, strategic research or case studies about repair issues. However, there will inevitably be different and possibly even controversial repair issues which are brought into the industry as the 'hybrid', electric and hydrogen vehicles get more popular in market, and these may well be a big challenge for insurers and repairers. Recommended areas for future research are as detailed below.

Different Types of Accidents and Other Safety Issues

It is difficult to predict the characteristics of accidents involving the new powertrain vehicles as it is yet to be seen which technologies will become more common. However studies can be done on the new technical features and their architecture such as 'hybrid, electric and hydrogen powertrains, and thus it will be possible to identify specific risk. For examples even in a light crash some cars might be susceptible to energy releases which might cause a fire; and which may not be evident in the damaged vehicle, which would in turn mean that special care must be taken by the repair industry. Until now, safety has not been seen to be a big problem, even though 'hybrid', hydrogen and electric vehicles which have high voltage batteries contain a significant risk. Also vehicle manufacturers must consider the safety of post accident vehicles when they develop them, and it will be necessary for them to keep an eye on this issue as the sales of new powertrain vehicles increases.

Repair Technology

Through the vehicle manufacturers' strategy to make vehicles lighter and stronger the insurance and repair industries now face significant challenges in repair. In some cases it has been found that it is hard or effectively impossible to repair these new body structures in the independent general repair shop because of the lack of appropriate repair tools, lack of training and even lack of appropriate replacement parts. As vehicle technology will become more diverse through the emergence of new powertrain cars, it may become be more difficult for these repairers to repair a range of vehicles. Thus it is important that the insurance and repair sectors engage with the vehicle manufacturers, requesting that their perspectives are considered in future vehicle design and that reparability factors are considered.

Thatcham, in recognizing these issues has recently embarked on an ambitious programme to provide researched repair methods to the repair industry. This programme now sees information provided to the independent repairer on every new vehicle entering the UK market. Thatcham sees this vital service as key to the provision of safely repaired vehicles for the UK consumer, and will continue to develop this service in the future as vehicle complexity grows.

Further research on best-practice repair technology for the new powertrain car must be done. This could be added to the Research Council for Automobile Repairs (RCAR)'s 'Design Guide for Repair' which details best-practice design for vehicle manufacturers. This can be found on the RCAR website at www.rcar.org

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