FUEL, ENVIRONMENT AND THE ECONOMY: AUTOMOBILES AND THE VOICE OF SOCIETY

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Today's automobile industry is one of the most important and dynamic sectors that contribute to wealth creation in the leading industrialised economies. It does this not only by generating a high level of technical innovation, but by creating and sustaining high value employment for an ever-changing group of assemblers, suppliers and vehicle distributors. However, individual producers within the industry are now facing new competitive threats to their independence and survival due to the crisis of global overcapacity, trade frictions with Japan and increased competition from South East Asian producers. In Europe internal competition is forcing the industry to rationalise production capacity through joint ventures and take-overs to meet the challenge of Japanese assemblers operating from the United Kingdom. These Japanese plants have demonstrated that by adapting 'lean production techniques', to a western context they can outperform their competitors. A two to one gap in productivity, quality and design capability between the leading Japanese producers and established European mass producers is forcing the industry to reassess its future.

In response to this crisis of punctured profits, overproduction and dynamic competition, Western producers have focused upon responding to the 'voice of the customer' when developing and delivering new products to the market place. However, the industry now faces a new set of demands. The two powerful externalities of environmental pollution and road traffic congestion will, for the first time in its hundred year history, force the automobile to respond to the 'voice of society'. This means it must radically rethink its relationship to other industrial sectors and to Government. Societal concerns with regard to road traffic congestion and mobility will require automobile, commercial vehicle, telecommunication, IT and construction companies to collaborate in order to develop the motor vehicle as part of an intelligent integrated transport system. These telematic systems have the capacity to enhance safety and rationalise energy utilisation and land management which has traditionally suffered from the fragmented approach of industry and Government to mobility. At the present time, many transport ministries in Western governments are little more than departments for road building. It is now clear that the faster roads are built - the faster they will fill up with traffic. A new relationship between Industry and Government is therefore vital to ensure mobility into the twenty-first century. It is now vital to balance the need for mobility and economic growth on the one hand and fragile environmental considerations, on the other.

Environment - a Global Problem

Apart from the need to harmonise future intelligent vehicle technologies and protocols across national boundaries, the issue of road traffic congestion remains largely a national one. However, environmental issues need to be

considered not only on a local, but also on a regional and global basis. Nearly all pollution is related to the burning of fossil fuels.

Gasoline is the primary fuel utilised in the internal combustion engine and approximately 600 million tonnes is consumed by the OECD countries. Of this total, 57% is used by the US alone, with Western Europe using 26% and Japan 8%. The rest of the world (excluding the ex-Soviet block) accounts for about 130 million tonnes.

Table 1 shows the primary pollutants from the burning of gasoline that contribute to both local and global pollution.

TABLE 1

PARTICULATE MATTER (PM)	Comprising organic and inorganic particles and largely represent the fraction of gasoline unburned in the combustion process. Dust particles generated during the vehicle's operation can also attract Polynuclear Aromatic Hydrocarbons (PAHs) which can affect the respiratory system. Considered to be carcinogenic
VOLATILE ORGANIC COMPOUNDS (VOCs)	Organic compounds released into the atmosphere during refuelling or vented from service station fuel tanks including benzene and formaldehyde. Vapour lock refuelling nozzles obligatory in the US.
NITROGEN OXIDES (NOX)	Formed by oxidation of nitrogen present in air during combustion
NITRIC OXIDE (NO)	Emitted from the vehicle exhaust and converted into the more toxic Nitrogen Dioxide (NO_2) when oxidised. Nitrous Oxide (N_20) is also a by-product of combustion. Contributes to formation of acid rain and the photochemical production of ground level tropospheric ozone (as distinct from stratospheric ozone at higher levels forming protection against ultra violet radiation). Nitrogen Oxides also contribute to respiratory diseases in humans and growth reduction in plants
CARBON MONOXIDE (CO)	The amount of CO emitted from a vehicle is largely dependant upon the air/fuel ratio and temperature in the combustion chamber. Carbon Monoxide rapidly oxidises to Carbon Dioxide (CO_2), a major 'Greenhouse Gas'. Carbon Monoxide can impair human blood oxygen levels, leading to fatigue, impaired perception and cardiovascular complaints
SULPHUR DIOXIDE (SO_2)	A major contributor to acid rain and a pollutant from the combustion of diesel fuel

TRACE METALS	Lead is the primary trace metal found in gasoline and is an additive to protect exhaust valve recession and an anti-knock agent. It has a toxic effect on the human nervous system and is gradually being phased out in the Western World. Now virtually unobtainable in the US. Other trace metals include - cadmium, arsenic, nickel, chromium, manganese and beryllium
CHLOROFLOURO CARBONS (CFCs)	CFCs are found in vehicle air-conditioning and vehicle manufacture. Approximately half of all new vehicles are equipped with air conditioning and about 120,000 tonnes of CFCs are used in new and used vehicles. CFCs act as stratospheric ozone depletion agents and CFC 11 and 12 contribute to global warming. A global effort is now underway to replace CFCs with HFCs which do not destroy the ozone layer, although may contribute to global warming. The Montreal Protocol (1987) targeted CFCs as a key contributor to ozone depletion and aims to eliminate their use by the year 2000
WATER VAPOUR	Water vapour is also considered to be a 'greenhouse gas' and research is continuing into its relative importance.

The global effects of CFCs, Carbon Dioxide, Water Vapour and possibly Sulphur Dioxide give rise to global warming and contribute to stratospheric ozone depletion, whilst the local impact of Nitrogen Oxides, Hydrocarbon and Carbon Monoxide leads to damage to humans, plants and animals. In Europe road traffic accounts for approximately 20% of all CO_2 produced, the remainder being generated by industry, electric power generation and households. At the same time, road traffic in Europe releases into the atmosphere 80% of carbon monoxide, 61% of Hydrocarbons and 58% of Nitrogen Oxides. As passenger car registrations have risen in Europe from 4.7 million in 1950 to 145 million in 1992, and from 50 million to more than 500 million world-wide over the same period, and are expected to double in the next 20 years, then it becomes clear that significant action is required on behalf of industry and Government so as to avoid this increase in traffic becoming both environmentally damaging and economically counter-productive.

What is to be done?: There are several approaches to this problem, all of which are being researched and, to an extent, being implemented. These are:-

- o Improved regulation
- o Integrated Transport Policy
- o Alternative fuels and vehicles
- o Reduction of non-auto emissions
- o Improve new and used automobile efficiency

Improved Regulation: Historically the United States has led emission regulation, followed by Japan and Europe. In particular, California has set rigorous standards for both new and existing vehicles. The European Union first introduced a directive on motor vehicle emissions in 1970 focusing upon restricting Carbon Monoxide and Hydrocarbon emissions within cities. This directive has since been revised six times to include other pollutants (NO_X/PM). By 1993 a new vehicle purchased in Europe will emit approximately 93% less CO and 85% less HC and NOX than a vehicle bought in 1970. Although traffic has significantly increased over the period of 1985-1992, pollutant emissions have stayed at a constant level. Between 1992 and 2010 it is predicted that in tons/yr this will decrease approximately by 70% for HC and NOX and 80% for CO, due to three way catalysts and improved engine efficiency. By 1996 the Commission is proposing to tighten regulation further, making Europe the leading world regulator for both petrol and diesel emissions.

Whilst these initiatives address local and regional pollution, they do little to address global problems of CO_2 emissions. The Rio Earth Summit in June 1992 ratified a proposal to stabilise emissions at 1990 levels by the end of the century. However, California has drafted regulations that will require 2% of all new automobiles to be Zero Emission Vehicles (ZEVs) by 1998. These will have to be either fuel cell or electric vehicles. Legislation also being

considered covers pollution taxes to car-sharing and road pricing policies. The problem now facing industry is that much of this legislation is fragmented and ill-informed with regard to available technology, and may only be accomplished through escalating costs.

Integrated Transport Policy: The automobile can no longer be viewed in isolation from a nation's transport system. Policies to encourage the improvement of urban traffic management through the development of Intelligent Vehicles and Highway Systems utilising advanced telematics technologies, need to be integrated into a public transport policy focused upon the movement of large numbers of people between central and peripheral locations. High loading factors are the key to a successful public transport structure. These solutions are site specific, offering different solutions for different cities.

Alternative Fuels and Vehicles: Alternative fuels and propulsion systems are now being investigated by the industry. Leading technologies include: Gas Turbines; Electric Vehicles; Hybrid (e.g. Diesel/Electric); and Alternative Fuels (Hydrogen, Compressed Natural Gas (CNG), Liquefied Petroleum Gas (LPG), Biofuels, Methanol, Ethanol). Of these, only electric and hydrogen power can make significant contributions towards a zero emission vehicle. Electric vehicle technology is still in its infancy and present battery technology restricts their usage. In addition, the life-cycle implications of such technology raises severe doubts about its overall effectiveness at reducing CO_2 emissions. As electric power loss is high between source and vehicle and battery packs are relatively inefficient (both in life span and durability), then only by generating the power from an emission-free power plant (geothermal/hydroelectric/solar/wind/wave power) can there be savings.

However, these sources of power may also be associated with other types of environmental damage. If electricity is generated by existing coal power plants, then emission levels could be higher than existing lean burn petrol engines and present day diesels. Ironically, only an increase in investment in nuclear power generation may meet the challenge of electric powered ZEVs with foreseeable technology. This of course raises other key environmental issues.

Industrial Research is being undertaken in Japan, the US and Europe on hydrogen powered vehicles. Hydrogen can either be stored as a liquid or generated by utilizing a metal-hydride such as magnesium-nickel or titanium-iron. These metal powders absorb hydrogen which is released when the hydride tank is heated. Hydrogen is an attractive fuel as it does not emit CO2, CO, HCs, or particulates, but only water vapour and small amounts of NOX (easily cleaned by end-of-pipe technology). However, hydrogen does introduce other technological problems of varying significance. It is not compatible with present day lubricating oils; it causes hydrogen embrittlement of steel alloy engine parts; it is difficult to store or refuel and has a low octane rating. The generation of hydrogen on a large scale is hampered by the production and distribution infrastructure required. Hydrogen can be produced from Natural Gas, but about 30% of the calorific value, also CO_2 is produced as a by-product. Gasification of biomass crops is possible but costly and politically sensitive. The electrolysis of water is the favoured method, but again this relies upon a source of electrical power such as photovoltaics for a zero emission source. As a long term solution to reducing emissions, a hydrogen fuel cell powering a hybrid electric engine may be the optimal solution. However, extensive R & D will be required to deliver such a system with acceptable performance, at a realistic price, and with convenient re-fuelling.

Reduction of Non-auto Emissions: Whilst local pollutants such as CO, NOX, SO_2, PM and VOCs are key concerns to the automobile industry, it is the debate surrounding the 'greenhouse gases' and in particular CO_2, that needs to be addressed on a global scale. However, many regulations that decrease local pollutants tend to increase CO_2 due to 'end-of-pipe' technologies which increase fuel consumption. In addition, the automobile has become the primary target for environmental groups to "out-green" each other and for Governments, particularly in Europe, to extract taxation on a regular ad-hoc basis to solve their fiscal crisis. In Europe, for example, more than ECU 200 billion/year is collected in taxes from motor vehicles, three times their direct costs. Table 2 clearly illustrates that whilst motor vehicles are a significant contributor to CO_2 emissions, they are only one of the industries responsible.

TABLE 2

CO_2 EMISSIONS (World-wide - 30b tons)	**%**	**CO_2 EMISSIONS (Germany 1987)**	**%**
COAL	32	PROCESSING INDUSTRY	36 ¨
BIOMASS	25	TRANSPORT	20 _
OIL	21	INDUSTRY	18
NATURAL GAS	15	HOUSEHOLDS	16
MOTOR VEHICLES	7	SMALL CONSUMERS	10
FN. ¨ 32% due to Power Generation _ 75% due to automobiles		Source: ACEA	

On a global basis only 7% of man-made CO_2 is produced by motor vehicles and in Germany, one of the key countries driving regulatory change, the automobile contributes about 15%. Significant reductions in CO_2 from other industrial sectors need to be vigorously addressed if the total amount of CO_2 emitted into the atmosphere is to be reduced.

Improved New and Used Automobile Efficiency: Whilst radical new solutions will be required over the long-term, societal environmental concerns have obligated automobile manufacturers to take a highly pro-active stance to reducing emissions from the one billion existing engines operating in the global market place. The most dynamic firms now see producing a vehicle that not only meets but exceeds proposed legislation, as putting them at a competitive advantage. This in many ways mirrors the debate of the 1970's and 80's when manufacturers had to respond to the 'voice of society' regarding safety. It took a relatively short period of time for customers to demand increased safety from new models.

Rapid technical change is therefore occurring with regard to key performance characteristics of the overall vehicle in response to consumer demand. In particular, the use of new materials for lightweight structures and improved aerodynamic performance has greatly increased vehicle performance leading to reduced fuel usage and consequent lower emissions. Similarly, engine and drive train research has yielded significant gains in performance and hence reduced emissions. Research in North America has shown that one poorly serviced vehicle pollutes to the same degree as forty new vehicles. It becomes clear therefore, that regular diagnostic testing is needed to repair (or remove) many of these vehicles. In particular, buses, trucks and motorcycles need the same level of testing as automobiles. Mandatory annual inspection of vehicles leading to improved maintenance is therefore essential to reduce emissions. This already occurs in the UK, during the annual MOT test, but needs to be tightened incrementally over the next few years.

The single most important step to reduce emissions will come from R & D targeted at engine performance. It is here that a more constructive relationship

needs to be built between the automobile and oil companies. Historically the two industries have, not surprisingly, taken different views regarding fuel efficiency. The majority of oil companies focus their marketing on improved sales to gain higher throughput for service stations. The incentive for the customer is usually lower price and other side inducements related to volume. The car company, on the other hand, knows that published data relating to fuel efficiency of their product is a key selling feature. This dichotomy also appears with regard to whether Governments should impose tax upon the vehicle or the fuel. If placed upon the fuel, then consumers may reduce their mileage utilising public transport or car sharing. If taxation is placed upon new vehicle sales, then this may suppress sales of new and more efficient vehicles, artificially ageing the nations car park and limiting emission reductions. This effect, however, is not uniform across countries due to the elasticity of demand for fuel. In the UK for example, the effect may be to dissuade consumers from replacing their existing vehicles. Partly in recognition of the problem some leading oil companies have, over the last decade, invested heavily in higher value added gasolines and oils. As the engine designers develop more sophisticated control systems (e.g. electronic engine management systems/fuel injection) the quality of fuel becomes crucial in optimising performance. The problem is that the engine designer has to develop technology to suit the worst fuel in the market place. Significant progress could be made with regard to controlling emissions if higher grades of fuel were available. The leading oil companies are now investing heavily in R & D to address these environmental issues.

Texaco, for example, have broken new ground in responding to the market challenge for higher value gasoline by introducing a new generation of gasoline, "Clean System3", that reduces carbon deposits in the combustion chamber. These deposits contribute to emissions over time and through their

removal the engine reassumes its original design characteristics. Similarly, new engines retain their intended design performance. Pollution reductions over the lifetime of an engine of up to 20% (CO, HC and NOX) have been shown using this new fuel. It will be interesting to see the effect of this innovation on the oil industry and its customers. If other leading competitors face this technological challenge, and meet or exceed this performance, a new era of competitiveness, similar to the safety arena, will be driven through customer demand. In addition, the oil companies, by adopting a pro-active stance on the environment, may well pre-empt ill informed government regulation in this area. It now becomes essential for the chemical engineer from the oil companies to work more closely with the mechanical engineer from the car companies in order to develop the next generation of gasoline engines and fuels.

CONCLUSIONS

In 1907 the British Prime Minister, Asquith, described the motor car as a "luxury that is apt to degenerate into a nuisance". Since that time the motor car has been transformed from a craft built luxury item to a volume produced utilitarian vehicle that has revolutionised all aspect of society. The economic, social and political freedoms of personal and public mobility and the widespread provision of goods and services has transformed society for the better. However, the issues of environmental damage and road traffic congestion has brought the industry to a crossroads with challenges for both the industry and Government policy-makers.

It is now clear that these challenges cannot be met with technological solutions alone and that 'sustainable mobility' will only be achieved if collaboration

occurs between the automobile manufacturers and suppliers, the oil companies, governments and the consumer. The UK in this respect is uniquely placed to provide a leading role. On policy making, the Government has the responsibility to influence the debate on the globalisation of environmental standards and work within the EU to ensure that greater dialogue occurs between all stakeholders. In particular there is an urgent need for the creation of a trans-european transport network capable of balancing mobility concerns. On the industrial front, Britain is now host to several key multinational producers that have, either through acquisition or by greenfield site, located throughout the country. These include long-standing relationships such as General Motors (Vauxhall) and Ford (Jaguar and Aston Martin) and relative newcomers such as Toyota, Nissan, Honda and BMW (Rover). In addition to these leading manufacturers the UK has a large number of world class suppliers to the industry. Companies such as Alcan, Lucas, Johnson Matthey and Ricardo Consulting Engineers, to name but a few, are at the forefront of environmental technical development with extensive R & D capability in the UK. They contribute knowledge and innovation in such diverse areas as lightweight structures, catalytic converters, engine management systems and lean burn technologies. Together with the manufacturers, the UK supply base could create the critical mass of environmental capability to compete with the best in the world.

Whilst Government can provide leadership and a sound industrial policy, it will ultimately be industry that will develop new technologies and contribute to the success or failure of sustainable mobility. There is currently no industry better placed to meet this challenge than the British Motor Car Industry.