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The automotive industry and the environment

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A technical, business and social future

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Abbreviations and glossary

ABS brakes	anti-lock braking system which prevents the wheels from locking up under severe braking, thus retains the tyres' grip on the road for enhanced safety. The term comes from the German 'Anti-Blockier System'
ACEA	Association des Constructeurs Européens d'Automobiles – the representative body of EU vehicle manufacturers, based in Brussels
biodiesel	a diesel fuel alternative made of organic matter such as rapeseed oil
Buddism	the system whereby the core technology of the car industry is centred on the innovations of E G Budd, who pioneered the all-steel welded body
CAIR	Centre for Automotive Industry Research at Cardiff University, Wales, UK
car-sharing schemes	increasingly popular arrangements, whereby people forgo car ownership in return for membership of a club that runs cars for its members to use for a fee as and when required
CARB	California Air Resources Board – body responsible for monitoring air quality in the State of California and for proposing regulations to improve it

CEO	Chief Executive Officer – the top manager in a business
CKD	completely knocked down – the term for a kit of parts that can be assembled into a complete car at a location other than the originating factory. This is commonly used to assemble cars in markets where a complete car factory would not be viable. A variant is *SKD* (semi-knocked down), which is a kit closer to completion, thus requiring less assembly input, aimed at even less sophisticated markets
CNG	compressed natural gas – a popular alternative fuel
coachbuilt	a coachbuilt car body uses the traditional technique of metal panels on a wooden frame; a technology replaced by Buddism, but which is still used by car manufacturers such as Morgan
CO	carbon monoxide – a gas that occurs in vehicle exhausts as a result of the incomplete combustion of petrol or diesel. It is eventually oxidised into CO_2 (carbon dioxide), but until then is highly toxic
CO_2	carbon dioxide – a harmless gas produced by humans and animals and other natural processes, which is associated with control of the Earth's climate. Too much being produced leads to global warming
CSR	corporate social responsibility – a concept whereby a company looks beyond making money to its wider role in society
CVT	continuously variable transmission – an arrangement whereby the transmission that links a car's engine to the wheels is achieved not by means of fixed steps, but by a continuously changing range of ratios. This is normally achieved through a belt driving over pulleys of variable diameter. In automated form the system was pioneered by the Dutch Daf company in 1958. The key technologies are controlled by German suppliers Bosch (who own the Dutch manufacturer of the belts) and ZF. An alternative is the IVT (infinitely

	variable transmission) developed by Torotrak in the UK
die(-set)	the very large and heavy tools used in a press to form metal 'blanks' into pressed panels for assembly by means of welding into a modern mass-produced car body
DME	Dimethyl Ether, an alternative fuel that replaces diesel
EC	European Commission
ELV	end-of-life vehicle – a vehicle that is no longer wanted and has therefore become hazardous waste and subject to the EU ELV Directive
EPA	US Environmental Protection Agency
(Volvo) EPD	Volvo's Environmental Product Declaration system, which provides a listing of the environmental impacts of each model in the Volvo range – an industry first
EU	the European Union
FDI	Foreign Direct Investment – when a company spends a large amount of money to build a facility in another country
FEV	fuel cell electric vehicle
Fordism	a set of practices, particularly in terms of work and process organisation, which were introduced by Ford and have become associated with mass production in general
FP6	the EU's Framework Programme 6 for organising EU-funded research
fuel cell	a chemical device that generates electricity as a by-product of a chemical reaction
FV	Foresight Vehicle – a UK government- and industry-supported research programme aimed at preparing the UK automotive sector for a competitive future
GHG	greenhouse gas emissions
GM	General Motors Corporation
GRP	glass-fibre reinforced plastic – a thermoset composite material using thin strands of glass for reinforcement encased in a synthetic resin. It can be moulded in very cheap and simple moulds
HC	hydrocarbons – in the context of vehicle emissions this refers to various

	hydrocarbon constituents of petrol or diesel that leave the engine without being burnt. Many of these are toxic
HPV	human-powered vehicle; a bicycle or tricycle not officially sanctioned by the international cycling union (UCI) and thus unable to participate in its events. The human-powered world speed record is held by an HPV and not by a conventional bicycle, as HPVs tend to be more efficient, particularly in terms of aerodynamics
HEV	hybrid-electric vehicle – a vehicle that uses an engine of some sort to generate electricity, which is then used to drive the wheels via electric motors
IC engine	internal combustion engine, the current mainstream car engine technology most commonly powered by petrol or diesel
ICDP	International Car Distribution Programme – an international collaborative research programme into the future of car retail and distribution
ICE	in-car entertainment; the various technologies used in a car for entertainment and information such as radio, CD player, TV and DVD
JAMA	Japan Automobile Manufacturers' Association (Nihon Jidosha Kogyo Kai), the Japanese vehicle producers' representative body, based in Tokyo
KAMA	Korean Automobile Manufacturers' Association, the Korean vehicle producers' representative body, based in Seoul
kit car	a car supplied in the form of a set of parts, to be built up by the buyer, who often has to add key components from an existing mainstream car for completion
LCA	life cycle analysis – a technique which tries to assess the environmental impact of a product or service throughout its entire life cycle, including raw material extraction, production, use and end-of-life processing
LNG	liquefied natural gas – a means of keeping and handling natural gas by liquefaction,

	which makes it more compact. It is used to some extent as a vehicle fuel
LPG	liquefied or liquid petroleum gas – a popular alternative vehicle fuel normally produced as a by-product of the oil refining process
MCC	Micro Compact Car – the DaimlerChrysler company that makes the Smart city car
MFR	micro factory retailing – an alternative car production and distribution model that features a dispersed network of small local facilities that assemble, sell and service cars
modularisation	a trend whereby suppliers to the car industry are expected to supply larger and larger sub-assemblies, called 'modules', which are then assembled by the car manufacturer. This reduces the complexity of the final assembly process for the vehicle manufacturer
monocoque or unibody	a means of building cars that integrates the body and chassis into a single steel box, to which all other components are attached. This was largely made possible by the introduction of Budd's all-steel body technology
MPV	multi-purpose vehicle, or people carrier
NELV	natural ELV – a car that reaches the end of its life by needing repairs that exceed the value of the car, as opposed to a car that is written off in an accident, which would be a premature ELV (PELV)
NGO	non-government organisation – these are organisations that are not linked to government: they include consumer organisations, environmental pressure groups and other campaigning groups
niche	a small part of the market, smaller than a market segment, often discovered by the introduction of a new product variant
NOx	catch-all term for the various oxides of nitrogen, some of which are harmful pollutants whose emissions are controlled by legislation

OEMS	original equipment manufacturers – used in the automotive industry to refer to vehicle assemblers; the companies whose badges appear on the cars
parc	automotive industry term for the total number of vehicles in use in a particular market
platform	the basic elements of a monocoque which carry all the key powertrain elements. The meaning of the term has been extended to include a basic set of parts that can be shared by a number of models made by a manufacturer, or even several manufacturers
PM	particulate matter – very small particles of varying composition produced by various processes, including internal combustion. Research has found them to be carcinogens and, when originating in car engines, they are controlled by emissions legislation
PNVG	Partnership for a New Generation of Vehicles – an initiative of the Clinton–Gore Administration in the US, to develop a more environmentally optimised type of car for the US market
powertrain	a term used to refer to the combination of major components that make the car go: engine, gearbox, axles (depending on layout of the car also propshaft), but not the wheels or fuel system
R&D	research and development
scrappage incentives	schemes whereby car owners are encouraged, usually through financial inducements, to replace an old car with a newer one and where the old car is scrapped
segment	a section of the market at which a particular product is aimed
SMC	sheet moulding compound or composite – a type of thermoset sheet material that can be moulded to shape in heated moulds
SMMT	Society of Motor Manufacturers and Traders – the representative body of car

	makers and importers in the UK, based in London
SNM	strategic niche management – a system for introducing new technologies via temporarily protected small local markets
stewardship	normally product stewardship – an approach whereby the originator or manufacturer of a product accepts responsibility for it throughout its useful life and takes it back once that useful life has come to an end
SULEV	super ultra low emissions vehicle
SUV	sport utility vehicle – American term for a four-wheel drive off-road style vehicle
systems integration	manufacturing approach whereby the final manufacturer limits himself to putting together large components and sub-assemblies (systems) made elsewhere
TDC	top dead centre – an automotive engineering term, used to describe when the piston is in its highest position in the cylinder and has stopped moving up and has not yet started to move down
Th!nk	a small Norwegian manufacturer of battery electric vehicles, bought, then sold by Ford
TNS	The Natural Step – a practical system for implementing sustainable practices developed in Sweden
Toyotism	approaches to manufacturing based on the Toyota Production System (TPS), which centres on the concept of the elimination of waste in all processes – hence also described as 'lean production'
Type Approval	a process that each new car model has to go through to ensure it complies with the legal and regulatory standards of the market in which it is to be sold
ULEV	ultra low emissions vehicle
ULSAB	the Ultra-Light Steel Auto Body programme of 32 of the world's leading steel makers in the 1990s to show steel bodies could be made lighter than had been customary until then

US Big 3	a term used to refer to the main three US car manufacturers – General Motors, Ford and Chrysler
US87	a set of vehicle emissions standards which made the US world leaders in this area and which formed the basis for vehicle emissions legislation in many parts of the world
VOC emissions	emissions of volatile organic compounds – substances released through evaporation, such as petrol fumes and paint plant emissions of paint solvents
VSP	voiture sans permis – a type of lightweight vehicle popular in France, where it benefits from protective regulation. Also known as voiturettes (cyclecars)
VW	Volkswagen AG
WTO	World Trade Organisation
ZEV	zero emissions vehicle – a category of vehicle defined by CARB under California legislation, which has no harmful emissions

1

Introduction

> *The years pass and the buyers become no longer interested in technical advance and turn their attention to the externals and details of comfort. The last stage, that of indifference, has been attained*.
> (Grégoire, 1954: 106)

1.1 Background

It is early 2002 and reports are coming in that several of the first few owners of BMW's new 7-Series have found themselves stranded (Kuijpers, 2002). The problem: the car's battery cannot power the monumentally complex – but landmark – electric and electronic systems. Only with the engine running can owners access the mind-boggling array of functions the car provides. The auxiliary fuel cell under development for this task is not yet ready for production. A survey by the German magazine *Auto Motor und Sport* (König, 2002) indicates that out of 50 buyers of BMW's 7-series and Mercedes' SL, 28 % of the Mercedes buyers and 17 % of the BMW owners had been delivered faulty cars.

We find ourselves with an automobility culture where cars are further and further removed from their basic function as an enjoyable and/or practical driving machine. Cars have become over-complex and heavy. They have become baroque technology – rather than people – carriers and many buyers have been convinced by the industry that this is what they want. To make these decadent devices we have created an industry consisting of large centralised assembly plants which source supplies from global supplier networks and distribute their products through widely dispersed dealer networks (see Chapter 2). Just as we have become further and further removed from our roots as natural creatures, thus the car – one of our most spectacular technological and cultural creations – has become far removed from its roots as a plaything as well as a simple robust mode of motorized personal transport.

Ironically those cars which still retain those basic qualities – the 'plaything' Lotus Elise, Fiat Barchetta, or Caterham 7, for example – are also considered particularly desirable. On the practical side, the Fiat Panda refuses to die and in 2002 was the cheapest car sold in Italy. Also on the practical side, the Russians are refusing to let the old Lada die, buying it in record numbers as a classic design. The argument is that they would rather break down by the side of the road miles from anywhere at –40°C in a car they know they can fix, than in a modern car they know they probably cannot; the difference could be one of life and death (Nowill, 2000: 44). Perhaps there is still hope, and a chance to turn things around.

The authors have been looking into issues of sustainability and automobility for some time, and refer the reader to *The Green Car Guide* (Nieuwenhuis *et al*., 1992) and *Motor Vehicles in the Environment* (Nieuwenhuis and Wells, 1994). *The Death of Motoring?* (Nieuwenhuis and Wells, 1997) took a broader perspective, taking environmental pressures as one – albeit important – pressure facing the car industry. *The Automotive Industry and the Environment* continues this broader perspective but updates it and focuses more on the sustainability issue, including some proposals for possible solutions. One of these is the micro factory retailing concept (Chapter 17); a more sustainable way of making and looking after cars within a product stewardship approach. Some of these ideas have already been touched on in the authors' conference papers over recent years, as well as regular articles in *Automotive Environment Analyst* and other publications.

The authors are informed by their work in the Centre for Automotive Industry Research (CAIR) at Cardiff University, Wales, UK. This is one of the few academic centres in the EU that focuses on economic and strategic aspects of the world automotive sector, from a broad overview perspective. This self-funding centre carries out work for the car industry in the widest sense, as well as other stakeholders such as governments and non-government organisations (NGOs). More recently the authors have also incorporated an increasing proportion of this work in the newly formed Economic and Social Research Council-funded centre for Business Relationships, Accountability, Sustainability and Society (BRASS), also based at Cardiff University.

1.2 Change and complexity – can business really afford to keep things simple?

On the whole, people have difficulty coping with complexity. This is reflected in the way that – despite over a century of development – a complex product such as the car can still suffer fundamental flaws. This will get worse as cars become more complex. Often this new technological complexity is introduced because it is believed to be possible, believed to be profitable in an industry where basic cars do not make money, or believed to be desired by customers. New technologies are normally introduced because they are possible and driven by their creators, or because new optional technologies can still be sold at a profit, thus compensating for the lack of profits made on the basic car.

An area where business and industry often cannot deal with complexity is social and political trends. History is full of examples where corporate executives have mis-read the social and political mood. They have usually achieved their status in the organisation because they fit the current, established way of doing things. If this way of doing things changes because the world changes, these individuals are often ill-prepared and in many cases incapable of formulating the right response. In some cases they are removed as in the Nasser case at Ford discussed in Chapter 2. In a world of increasingly rapid change, the ability to identify and adapt to emerging trends that may affect the business is becoming a vital skill. It is important for industry decision-makers to acquire these skills themselves, rather than rely totally on the often simplistic solutions of outside consultants or populist management 'gurus' (see Chapter 5). There are, then, essentially three key levels of complexity: technical, company and society. On the technical level the industry has tended to increasingly baroque solutions, at the level of the company the industry has moved to globalisation and multi-brand constellations. Society, on the other hand, opposes many of these forces in that it generally favours fragmentation and diversity.

In this book the authors have identified a number of technological, economic and especially social, environmental and political trends. In considering the latter, the focus will range from the deep green, anti-roads and anti-capitalist movements to concerns about the North–South wealth gap and globalisation. Their likely effect on the world's largest manufacturing sector, the motor industry, and on the wider issue of the way its products are used and perceived, automobility, will be assessed. Automobility refers to the cultural, social, legal and infrastructural systems put in place to support the car. The average motor industry executive is likely to regard anti-roads and anti-capitalism protestors as anti-social and marginal elements. He (for it still usually is) will also regard deep green environmentalists as at best irrelevant, at worst a dangerous menace. However, history has shown that yesterday's cranks become today's corporate and government advisors. Similarly, today's tree-huggers and anti-globalisation 'anarchists' will become tomorrow's corporate advisors and political decision-makers.

Opening corporate minds to identify and respond to such trends before it is too late is one of the aims of this book. This ability to spot trends that will have an impact on the business in future is increasingly important and is something rarely addressed in corporate training, let alone at business schools. It is important because business and industry are the key to moving society towards more sustainable economic activity. Conversely, if they get it wrong they can be left behind; and out of business. Chapter 13 shows the importance of a vision in guiding future strategy, while Chapter 16 gives an indication of how to set out to achieve this vision.

1.3 Identifying the problem

The existing automobility system is not sustainable, as will be shown in this book. Two major factors will determine developments in the car industry in the early decades of the twenty-first century:

- how to overcome the chronic lack of profitability in volume car making;
- how to cope with the increasing environmental pressures on the industry, especially mandated or agreed reductions in CO_2 emissions.

These two factors seem obvious drivers on the face of it, yet few observers appear to have acknowledged that they have the potential of fundamentally changing the car industry – for ever.

1.3.1 Lack of profitability

Despite impressive headline profit figures, once the costs of car making are taken into account, the industry survives on very thin margins, as will be shown in Chapter 2. Apparently healthy returns made in the good years have to sustain a growing product development budget and help the company survive through the lean years that inevitably follow. The economics of the industry are such that even a relatively small decline in demand can take the production system below its break even point and losses rapidly follow.

The common response by the industry is to keep feeding the production system with production and then to force its products into the market at a discount. The idea that the car industry is market driven is still largely a fallacy. In practice, given the current way of making cars, the demands of the market and those of the car production system are difficult to reconcile.

The reason for this tension between production and market lies in the technology used for mass car production. The all-steel welded body that forms the core of the modern car was first developed by E G Budd in the US between 1910 and 1920. It requires high initial investments in press technology (including tooling), body build and paint plants, but, once installed, allows cars to be made in high volumes at a relatively low unit cost (see Chapter 8). Alternatives only exist on the margins of the industry. Some of these are reviewed in Chapter 9.

Although Ford believed that his Model T would fulfil all automotive needs, other manufacturers soon realised that the market was made up of subdivisions with different requirements. This market segmentation created a level of differentiation that clashed with the standardisation favoured by Ford and Budd-style body-making. Since the 1970s market demands for differentiation have increased, leaving many car makers with a proliferation of model platforms.

Market demand for visible differentiation is expected to increase further (see Chapter 3). This will lead to lower volumes of each variant being produced, which in turn jeopardises the return per model. It is already the case that many, if not most, models in a volume car maker's range are not contributing to profits. In fact, recent data for the high volume US car producers suggest that money is only made on light trucks (pick-ups, sport utility vehicles (SUVs), multi-purpose vehicles (MPVs) etc.) and upmarket saloons. European and Japanese volume car producers only make money on their high volume products, while the specialists also cross-subsidise much of their range. The smallest of the volume specialists, Saab, has consistently been unable to make a profit on volumes of around 80 000–100 000 a year. In this context, low volume car makers are of some interest and some of the technologies they use are analysed in Chapter 9.

Another cost area has grown rapidly to add to the problems of body technology. Waves of ever tighter emissions and fuel economy demands have meant that engine generations which once lasted several decades now have rapidly shortening product cycles. Not only are engines more complex than in the past – featuring multi-valve heads, variable valve actuation and tighter tolerances – but they also need to be replaced more frequently to meet new demands. In addition, manufacturers who traditionally relied on petrol engines alone now have to offer diesel options, particularly in Europe. More petrol variants such as lean-burn and hybrids, as well as alternative fuel variants, further complicate matters and add cost as illustrated in Chapter 6. As a result, the costs of engine development and production have mushroomed to add to the industry's cost pressures. New powertrain technologies such as the fuel cell, discussed in Chapter 7, will add a new dimension to this rising cost picture.

The current trend, therefore, shows low profitability with declining per-model volumes and rising product development costs. It is clear that the industry is facing problems. The current strategy to deal with these centres around a number of approaches:

- globalisation to increase per-model volumes and recapture economies of scale;
- reducing the number of platforms in order to reduce cost and complexity;
- 'leaning' the industry by reducing perceived waste of all types in the system.

Part of the last approach involves forcing suppliers to cut costs to the bone. 'Leaning' of the industry has also meant that car manufacturers have attempted to devolve more and more product development responsibility down the supply chain to so-called tier 1 (or even tier 0.5) suppliers, making them responsible for developing and supplying large sections of a car, in the form of modules. Many of these suppliers had no or little expertise in this area. These pressures on the supply chain have forced consolidation in that sector which to some extent mirrors the restructuring among car assemblers themselves. Fewer but larger car making groupings face ever larger and more powerful suppliers now offering a widening portfolio of products and technologies (Chapter 2). Some of these are key technologies essential for shaping the cars of the future, such as electronics.

As a result of these developments, a shift in the balance of power in the industry may be seen over the next few years, whereby more powerful suppliers may determine future technologies rather than their car making clients. Thus, the shape of the industry could change, possibly to one of the types outlined in Chapter 15. This would be a radical change in the industry and could lead to a situation previously termed the 'mountain bike scenario'. In that industry a few large suppliers, such as Shimano, dominate. Bicycles are designed by small high value-added companies responsible also for marketing – their name appears on the frame. These frames themselves are often also made by large suppliers in China or Taiwan, many of whom even assemble the mass production versions of other firms' branded bikes. These are fitted with components by named suppliers whose brand names contribute to the image of the whole bike. This is one possible future shape reviewed in Chapter 15. Related to it in some respects is the micro factory retailing concept outlined in Chapter 17, made more feasible by the introduction of fuel cell technology as discussed in Chapter 7.

However, before analysing where the automotive industry is going, first we need to understand where it came from and how it ended up being as it is today. More importantly, we need to understand how its product came to be perceived as an environmental problem – an unsustainable transport mode – from being a desirable and welcomed plaything for the rich. A brief outline of this history will follow.

1.4 Roots of the problem

The origins of the car lie in an innovative cluster centred on Germany, France and the UK, where a number of key enabling technologies were first developed. Car mass production then developed in the US (see Chapter 8). The key enabling technologies centre around such innovations as the bicycle, begun in Germany as Baron von Drais' hobby horse or 'draisine', via Kirkpatrick MacMillan's crank driven bicycle in Scotland, Michaut's series produced velocipede of the 1860s and, finally, perhaps Starling's

Rover safety bicycle of 1886, by which time car and bicycle were developing side by side. Stinnes' seamless tube technology was a typical enabling technology, allowing new lighter and stronger frames to be made, as well as other advances in metallurgy. The high speed lightweight internal combustion engine was also an important development, which should probably be traced back to Lenoir in France, via Otto in Cologne, mentor to both Daimler and Benz.

1.4.1 History of environmental concern: horse vs. car

Perhaps surprisingly, environmental arguments have surrounded the car from the very beginning. In the early days, the negative environmental impact of the car was clearly limited; one isolated car motoring through the countryside has an insignificant effect on the environment. Nonetheless, at this time both positive and negative environmental effects were attributed to the car. Many welcomed the opportunity of reducing or even eliminating the growing urban problem of horse manure, while dead horses in the street were not uncommon either. The horse problem had come about as a result of growing urbanisation in the wake of the Industrial Revolution. Expanding cities saw an increasing need for public transport. New transport links were also required to interface with the spreading rail network. Much of this need was met by horse-drawn omnibuses, cabs and trams. The growth of the middle class meant that an increasing number of people could afford to keep a carriage. Each of these horses consumed the produce of around two hectares of land per year, enough to feed six to eight people.

The railway never replaced the horse, instead it stimulated the growth in the horse economy. However, attempts to stretch the horse system to its limits rapidly led to widespread protest about the treatment of horses among the influential middle classes. In several cities, bus and tram travellers were requested not to make the vehicle stop more often than absolutely necessary in order to spare the horses the damaging stop–start phase. The car lobby was often in the forefront of these horse protection movements. Horse-drawn vehicles were also increasingly blamed for the growing congestion problem in Europe's larger cities. In the end it was lack of efficiency that killed the horse economy: low speed, low power and limited range as well as the space requirement both of a horse-drawn vehicle and the number of horses kept and stabled to keep one vehicle on the road.

Contemporary environmental arguments centred around the then fashionable concepts of 'hygiene' and fresh air. The cities, with their deteriorating air and water quality, as well as the side effects of the horse economy, did not have much to offer in this respect and were considered major sources of bad 'miasma'. Like the train and bicycle before it, the car provided a means of escaping the 'bad' air of the city in favour of clean country air, with all its perceived health benefits (Murphy, 1908).

Clearly, the new ability for city-dwellers to become aware of the countryside and nature in general did much to promote a love and understanding of the natural environment. This trend started with the bicycle, the first mechanical mode of individual transport, and was picked up by the car. The car was promoted with the same arguments of health and freedom as the bicycle and many wealthy cyclists quickly transferred their allegiance to the new vehicle, which could take them much further afield than its non-motorised counterpart. The sportsman image of the bicycle was also transferred to the car, which meant that it had a head-start in being associated with healthy outdoor pursuits and in adopting a positive and healthy aura. If this seems ironic to the modern observer, it must be remembered that environmentalism itself would probably not have developed without the car and its ability to take people to areas of nature they might otherwise have been largely unaware, let alone appreciative, of.

On the other hand, even at that time many saw the potential for negative effects from the car. The most immediate impact was the dust generated by cars on the often unmade roads of the period. The Dutch firm Spyker was one of the first to try and address this problem by providing a fully enclosed undertray for its chassis from 1905, thus improving airflow under the car and reducing turbulence. This 'Dustless Spyker' concept was widely used in the company's advertising in the first decade of the twentieth century and may have been one of the first attempts by a car producer to address an environmental problem through a product engineering solution (Oude Weernink, 1998: 27).

The more perceptive also saw the potential harm in exhaust emissions from petrol engines and for this reason, even in the 1890s, some rated the prospects for electric cars more highly than those for petrol-engined cars, especially in an urban context. At an international hygiene conference in Berlin in 1907, petrol fumes were identified as particularly damaging to health. At this time, soot, carbon monoxide and unburnt hydrocarbons were singled out as the harmful substances and their toxicity had already been shown by animal experiments. However, accidents were identified as the greatest danger to health.

As car use grew, the impact on the countryside was further exacerbated by the growing infrastructural requirements of the new technology. Cyclists first started lobbying for improved roads, with organisations such as the Cyclists' Touring Club in the UK and the ANWB (Algemene Nederlandse Wielrijdersbond/General Netherlands Cyclists' Club) in The Netherlands initially regarding lobbying for better roads as their primary objective. The State of California set up its Bureau of Highways in 1895 as a direct response to lobbying by cyclists in the year when the first car was seen in Los Angeles. One of its founders stated that 'the influence of the bicycle upon this agitation for improved highways cannot be overestimated . . . this agitation for better roads is due more directly to the efforts of the wheelmen than to any other cause' (Irvine, in Brilliant, 1989: 15).

Table 1.1 Car ownership levels in 1910 and 1938 (cars/1000 inhabitants)

Country	1910	1938
US	1.5 (est.)	205
UK	1.25	52
France	0.95	52
Germany	0.32	22
Belgium	0.8	27
The Netherlands	0.34	17
Ireland	–	21
Italy	–	10

Source: adapted from Bos, van Groningen, Mom and Vinne (1996).

Nevertheless, the real impetus for better highways came with the car and the advent of motoring. The dust problem generated by car use was significantly worse than the impact of cyclists. This meant that it was not just the road users who benefited, but also those who lived or worked near the roads. Thus, road improvement became a social good. Road improvement in California often included the spraying of oil on the road surface in order to reduce dust generation. Fruit growers were particularly worried about the effect of car-generated dust on their crops and strongly supported this means of dust control.

1.4.2 The rise of motoring

Like the bicycle, the car was initially marketed as an adventurous machine for the sports enthusiast. Gradually, practical considerations were introduced and it also became a means of transport. Various professions saw the business opportunities offered by the car. Taxi firms were the first user of the car purely as a means of transport, while commercial vehicles, often based on standard car chassis, also developed. Commercial travellers, doctors and veterinary practitioners were also among the first to adopt the car for professional reasons.

By 1907, France, the UK and the US had become the world's most motorised countries, with 1 car per 640 people in the UK, 1 per 608 in the US and 1 per 981 in France (see Table 1.1). By comparison, Germany had only 1 car per 3824 people. By 1910, Belgium – another country which motorised early on – had 1 per 1180. Japan had fewer than 200 cars in total. Ashleigh Brilliant, in *The Great Car Craze* (1989), explains how it was Southern California that first saw the development of a mass motorisation phenomenon. In doing so it established many of the values and problems now associated with automobility as a mass phenomenon. The craze soon spread across the US, but the rest of the world took longer to follow. By 1930 car

Table 1.2 Car use in selected countries (1995)

Country	Cars in use	No. persons/car	Total vehicles	No. persons/ vehicle
US	139 000 000	1.9	208 000 000	1.2
Italy	30 000 000	1.9	32 806 500	1.7
Canada	13 800 000	2.1	17 545 000	1.7
Australia	8 391 500	2.1	10 638 200	1.7
Germany	40 499 443	2.0	43 561 316	1.9
New Zealand	1 652 556	2.1	2 005 191	1.8
France	25 100 000	2.3	30 295 000	1.9
EU	161 348 724	2.3	182 951 643	2.0
UK	24 962 263	2.3	28 170 924	2.1
Belgium	4 239 051	2.4	4 276 388	2.1
Japan	44 680 037	2.8	66 853 500	1.9
The Netherlands	5 632 891	2.7	6 290 863	2.4
Ireland	990 384	3.6	1 145 537	3.1
S. Korea	6 006 290	7.3	8 468 901	5.2
Brazil	12 500 000	12.5	15 020 000	10.4
CIS	18 000 000	16.3	27 500 000	10.7
India	3 446 330	245.6	5 846 382	144.8
China	2 400 000	500.0	7 120 000	168.5
Bangladesh	48 000	2250.0	108 500	995.4
World	492 731 463	11.0	665 844 845	12.2

Source: SMMT (1996).

ownership in Germany had risen to 10.6 per 1000 people, compared to 31 per thousand in France.

Even at the start of the twenty-first century, car ownership in the US is still higher than anywhere else, although Italy beat Canada, Australia and Germany for second place during the middle of the 1990s (see Table 1.2). Nevertheless, mass motorisation was still largely confined to the developed industrialised countries. In most developing countries the number of commercial vehicles exceeds the number of cars as the need to transport basic goods develops long before a demand for luxuries such as personal transport. In fact, at the end of the twentieth century it was still the case that, worldwide, more passenger miles were carried out by bicycle than by car.

By 1950 the worldwide car and truck population had reached some 50 million, which worked out at roughly 2 vehicles for every 100 people. However, by the middle of the 1990s that figure had risen to over 600 million, or 12.2 vehicles per 100 people. If this trend continues, then by 2050 there could be over 3 billion cars and trucks worldwide. This equates to around 20 per 100 people and is still well short of the 1990s US ratio of 70 vehicles per 100 people. The question really arises of whether this is sustainable (see Chapters 10 and 11).

After the initial environmental concerns surrounding the motor car, the spread of motorisation largely marginalised the critics. Environmental

Table 1.3 Growth in US sales of Japanese makes, 1970–79 ('000s)

Make of car	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
Colt*	–***	26	33	35	43	60	48	70	44	63
Datsun**	100	182	184	229	184	253	270	388	338	472
Honda	–	–	–	–	42	102	151	224	275	353
Mazda	–	–	48	104	55	65	35	51	75	156
Sapporo*	–	–	–	–	–	–	–	1	12	12
Subaru	–	–	–	–	–	41	49	81	103	128
Toyota	185	207	273	277	231	284	347	493	442	508

* Mitsubishi cars were marketed under both names in the US at this time.
** Nissan cars were sold under this name at the time.
*** Until 1974 these statistics only list top 10 registrations – does not mean 0 registrations.
Source: adapted from *Automotive News*, various issues.

concerns resurfaced in a different form at times of crisis. Shortages of cars and fuel during the Second World War led to various alternative solutions. Conventional cars were converted to run on gas generated from coal or wood via a heavy apparatus fitted to the front or rear of the vehicle. A limited revival of electric vehicles also occurred as these were less dependent on imported oil, while others opted for human power. Aircraft pioneer and luxury car maker Gabriel Voisin produced a pedal car for his own use during the German occupation, which even carried a smaller version of the 'cocotte' radiator mascot of his cars.

A second wave of renewed interest in the environment came in the wake of the 'hippy' era of the late 1960s. Social movements at this time generally rejected the established value system. Rachel Carson's landmark book *Silent Spring*, an indictment of the over-use of harmful chemicals in agriculture, as well as the growing air pollution problem, sparked new concern for the way human activity impacts on our natural environment. At the same time, new concerns about traffic congestion led to a series of experimental 'city' cars. Many of these, such as Ford's Comuta of 1967, were powered by electricity. This period saw the first wave of environmental legislation affecting the car.

The next wave of environmental concern was probably more of a reinforcement of trends started in the previous decade. The energy crises of 1973–74 and 1979 really concentrated the minds of industry and government. The psychological effect was perhaps greatest in the US, where energy use had never really been an issue. Real petrol shortages at the pumps and the realisation that America's mobility was largely in the hands of minor Middle Eastern powers led to real change. Firstly, the market share of more fuel-efficient Japanese products increased markedly (Table 1.3). Secondly, the US car makers rapidly introduced a product-downsizing programme to develop smaller, lighter cars throughout all segments. Early downsizing attempts, such as American Motors' Pacer, still turned out smaller but no lighter than their predecessors. However, by the end of the century, US cars were markedly smaller and lighter than their ancestors of the early 1970s, which were by then regarded as 'dinosaurs'. Instead, US buyers had turned to light trucks, much heavier than cars, thus largely negating the gains made in more efficient car design.

The spread of mass motorisation created essentially two classes of motorist; the genuine car enthusiasts – continuing, perhaps, the sportsman motorist tradition – and the mass of car users who regard the car as 'a means for getting from A to B', a status symbol, a fashion accessory or a mobile drawing room cum office. This development has marginalised the genuine enthusiast to some extent, prompting the development of cars which, though more reliable, are often less enjoyable and less involving as driving machines. Ironically, environmental pressure may well rectify this; an energy-efficient lightweight car also tends to be environmentally optimised. The Lotus Elise is a good example.

During the twentieth century, the focus of environmental lobbying and regulation was on air pollution and vehicle emissions. Within this narrow perspective one fact has often been overlooked, namely that the environmental impact of the car is much greater than emissions alone. At the end of the twentieth century these other aspects began to receive greater attention as we moved towards a life cycle approach to environmental impact analysis (see Chapter 12).This has the potential to dramatically change the car as the need for drastic weight reduction will force the use of alternative materials and alternative construction methods.The possibility of dwindling oil reserves and continuing concern over air pollution will lead to far-reaching changes in powertrain by the middle of the twenty-first century at the latest. The main concern of car manufacturers will be the cost of such changes and the risks involved in selling radical new technologies to sceptical consumers (see Chapter 3). Engineering and product development strategies are already geared towards preparing for this revolution, and prototypes of such environmentally benign and more sustainable vehicles have been built. Several of these have been shown as concept cars.

With the steady rise of consumerism, informing the consumer is increasingly important. From the 1970s we can discern the development of a 'green' consumer – someone who takes environmental criteria into account in a purchasing decision. Although still rare at the start of the twenty-first century, the green consumer is more apparent in some countries than in others. In practice, a growing number of consumers have started to take environmental considerations into account in their purchasing decisions, although other elements often override a purely environmental choice (see Chapter 12).

One problem is the general lack of information available to the consumer. The complex problems surrounding the car's impact on our environment still baffle many within the industry, let alone the car buyer. In response, a growing number of environmental rating systems have appeared, although, as seen in Chapter 12, few of these take a true life cycle view. In fact, the information needed to carry out a life cycle analysis of a car is rarely available even inside the industry. The European Commission is trying to introduce such a system. If a meaningful eco-rating emerges from this process, consumers will for the first time be able to make a truly informed choice.

At the same time, however, car makers and other companies have started to develop a new awareness of their responsibility to society (see Chapter 4). Some firms now feel that corporate social responsibility, closely linked with corporate environmental responsibility, is the key to commercial success in the future, as well as being of value in its own right (see Chapter 4). We are witnessing a gradual move away from the emphasis on shareholder value that developed during the 1980s, to an increasing recognition of the importance of stakeholders.

1.5 The CO_2 issue – agenda for change

The perceived need to reduce emissions of carbon dioxide in order to avert global warming is now the main agenda driving the car industry in Europe and the Far East. Over the next ten years this will begin to change the nature of the cars we drive. The most influential force is the voluntary agreement between the European Commission and the European vehicle manufacturers' association, ACEA. The agreement stipulates that by 2008 the average emissions of CO_2 should be down to 140 g/km, while by 2012 they should have reached 120 g/km. This is from a late 1990s average of around 170 g/km. The agreement has also been accepted by the vehicle producers of Japan and South Korea, through their representative bodies, respectively JAMA and KAMA.

This issue has also further widened the gap between the US and the rest of the world. It emphasises America's automotive insularity; the so-called Big 3 of General Motors, Ford and Chrysler make cars for the US, but the few exports they achieve is a bonus, rather than essential. Conventional economic wisdom holds that exports are the key to success for any country and any industry; a large home market may compensate for this although the Big 3 do of course operate global production networks. At least as important are the possible implications of growing automobility in newly emerging economies, particularly the more populous ones such as Indonesia, India and China. Even relatively limited automobility in these countries could enable them to rapidly eclipse the US as principal automotive CO_2 emitter.

This first chapter has set the scene for some dramatic changes to the world's largest manufacturing sector, and explained how it came to be where it is today. Some of these issues will be explored in greater depth and pointers will be given to the nature of the changes expected in the near future, as well as some possible future automobility models.

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2

The structure of the automotive industry

Ne nous y trompons pas, l'automobile est l'empire de l'artisanat, le royaume du bricolage et le paradis de l'esbrouffe

(Make no mistake about it, the motor industry is the empire of craftiness, the kingdom of the tinkerer and a paradise for the show-off).
(Gabriel Voisin, 1930)

2.1 The automotive industry: a profile

The global automotive industry has developed over a period of more than 100 years to become a vast entity of many inter-connected parts. While even an entire book could not do full justice in providing an account, this chapter is intended to give an outline description of the industry, its structure, the main forces for change acting upon it, the most important recent changes to the industry, and the current trajectory of change.

In many respects it is an industry standing on the threshold of dramatic upheavals, possibly even reinvention as an industrial sector. Yet, paradoxically, it is an industry that retains characteristics and a form that would have been recognised by some of the founding companies and leading individuals from the very earliest years. This overlapping of huge change and stubborn continuity is not unique to the automotive industry, but it is often easy to overlook continuity when the gospel of academia (and consultants and management) is one of change.

2.2 The vehicle manufacturers

Of all the players in the automotive value chain, the vehicle manufacturers are the most important. Traditionally it was possible to distinguish three broad types of manufacturer:

1. High volume, full range producers. Typified by Ford, VW, Fiat, Toyota, Nissan and GM. These companies are in the centre of the market, producing at the highest volumes and lowest prices with a range of general purpose cars of various sizes and capabilities to appeal to the broad mass of consumers. These compete on the basis of cost reduction.
2. Specialist producers. Typified by Mercedes, Volvo, Audi, BMW and Lancia. These companies occupy the upper market reaches, with larger or higher performance cars that demand higher prices. They compete on the basis of differentiation and cost recovery, offering a compromise between exclusivity, quality and utility.
3. Niche producers. Typified by Lotus, Alpine, TVR and Ferrari. These companies offer exclusivity and extremes of performance, particularly in sports cars, but often at the cost of uneven quality, limited practicality and considerable financial burden.

Note the basic distinction between cost reduction and cost recovery strategies. In cost reduction the premise is that economies of scale allow unit costs to be reduced, and the size of the market expanded. In a fully competitive market, prices are set by supply and demand rather than any one vehicle manufacturer, so profitability will be contingent upon reducing costs rather than increasing prices. In cost recovery strategies vehicle manufacturers compete on the basis of exclusivity and product differentiation, and are able to some extent to pass on increased costs to the customer. Cost recovery is largely confined to Europe these days, where a small number of specialised producers are able to offset the higher costs resulting from their less favourable economies of scale in higher prices. Consumers are willing to pay this premium because of the company's reputation and image in the market, as well as a perceived quality advantage over the true volume producers who practise cost reduction as they compete primarily on price (Williams *et al*., 1994).

However, as Fig. 2.1 shows (along with Table 2.1 on the leading vehicle manufacturers) the last few years of the twentieth century were witness to the disintegration of the traditional structure. What have emerged instead are multi-brand constellations with a few outlying independents. The financial structure of relationships between the vehicle manufacturers is shown in Fig. 2.1.

The process of globalisation in the automotive industry has been evident in two main forms: mergers and acquisitions; and direct investment in non-domestic locations (so-called Foreign Direct Investment or FDI). By no means can all recent FDI decisions be characterised by a movement away

Table 2.1 Leading vehicle manufacturers (2001)

Group	Brands	Total production
General Motors	Buick, Cadillac, Chevrolet, GMC, GM, Pontiac, Saturn, Holden, Saab, Opel, Vauxhall, Hummer	7786000
Ford Motor Co.	Ford, Lincoln, Mercury, Jaguar, Volvo, Aston Martin, Land Rover	6991000
Toyota Motor Corp.	Toyota, Lexus, Daihatsu	5848000
Renault-Nissan	Renault, Dacia, Samsung, Nissan, Infiniti	5841000
Volkswagen AG	VW, Audi, SEAT, Skoda, Bentley, Bugatti, Lamborghini	5201000
DaimlerChrysler	Mercedes, Smart, Chrysler, Jeep, Dodge	4424000
PSA	Peugeot, Citroën, Talbot	3136000
Honda Motor Co.	Honda, Acura	2653000
Hyundai	Hyundai, Kia, Asia Motors	2548000
Fiat Auto SpA	Fiat, Alfa Romeo, Lancia, Ferrari, Maserati, IVECO	2391000
Mitsubishi Motors Corp.	Mitsubishi	1668000
Suzuki Motor Co.	Suzuki	1619000
BMW	BMW, Rolls-Royce, MINI	946000
Mazda	Mazda	868000

Note: DaimlerChrysler and Fiat includes commercial vehicles.
Source: derived from *Automotive News Europe* (2002b:5).

from traditional vehicle manufacturing countries, though it is more accurate to say that new locations within those countries are being explored. Equally, there remain important levels of reinvestment in existing plants. Indeed, while globalisation is often thought to involve a process whereby companies from existing industrialised nations open up new markets and new production locations elsewhere in the world, in the automotive industry at least there is an even more important dimension – the interpenetration of the primary markets through both sales and new investment. The waves of investment by Japanese vehicle manufacturers into North America and Europe from the 1980s onward are prime examples of this process, as are the new plants established in North America by Mercedes and BMW in the 1990s.

As Table 2.2 shows, the vehicle production process is one in which as value is added so the increasingly complete vehicle moves more quickly through the production system. Indeed, the fastest rate of order completion is from the suppliers of sequenced sub-assemblies (such as seat sets) who have proximate plants and can deliver to the final assembly line within 30

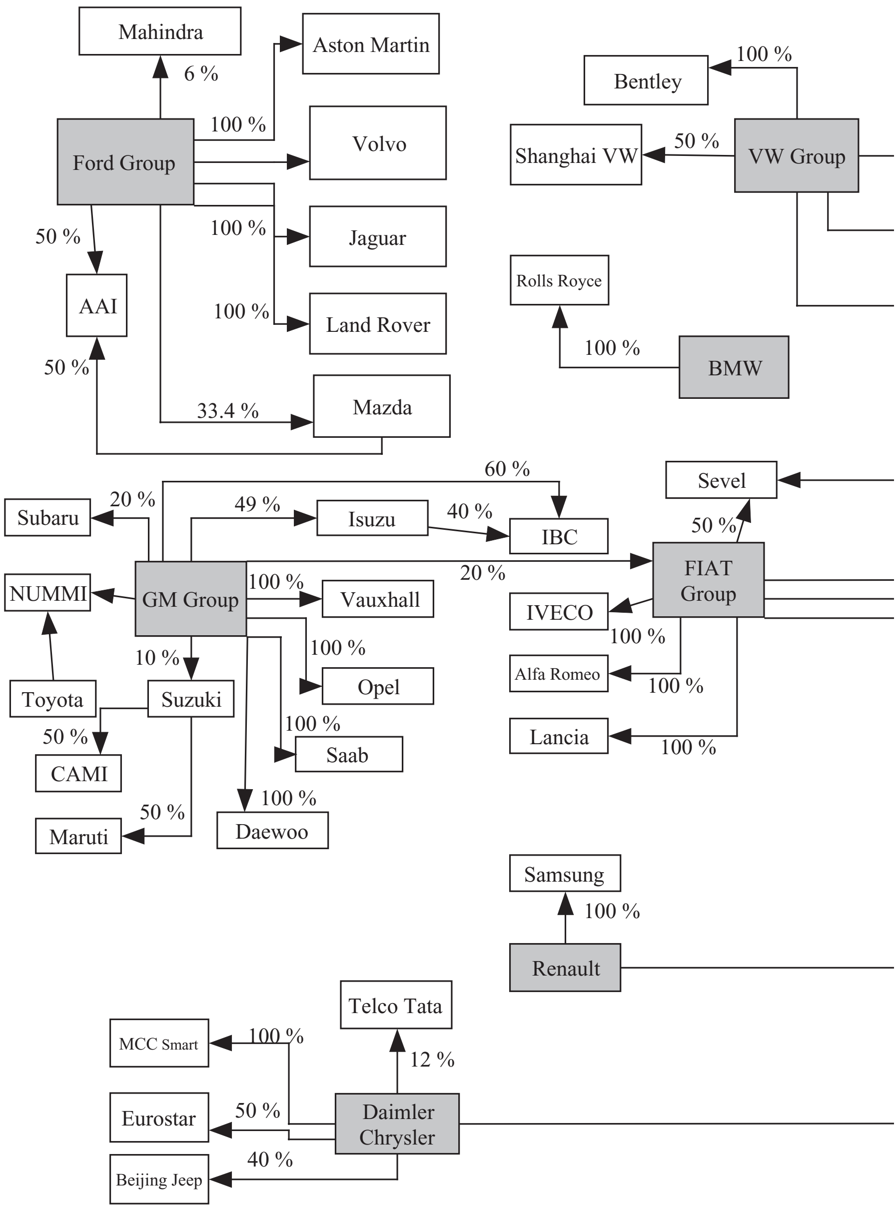

Fig. 2.1 The financial structure of relationships in the global automotive industry (2003).
Source: derived from Wells and Nieuwenhuis (2001).

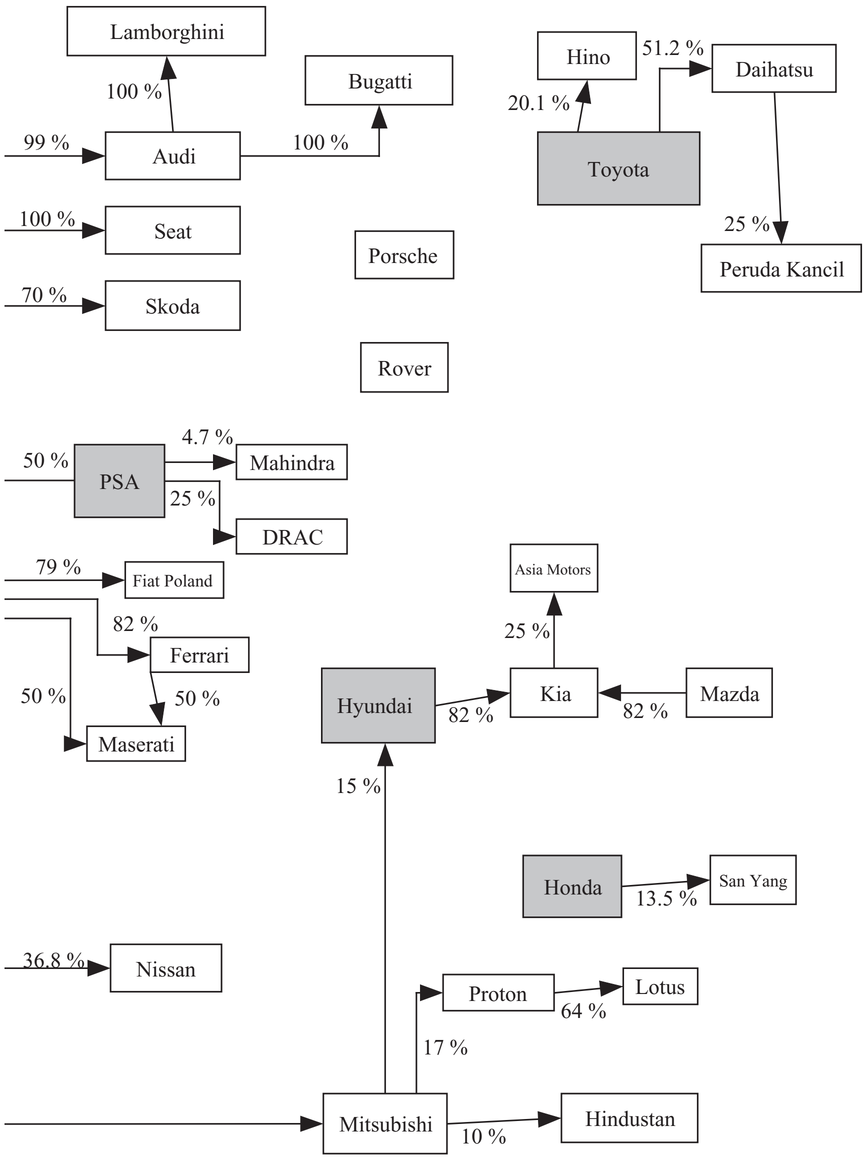
Lamborghini
100 %
Bugatti
99 %
Audi
100 %
100 %
Seat
70 %
Skoda
Porsche
Rover
Hino
51.2 %
Daihatsu
20.1 %
Toyota
25 %
Peruda Kancil
4.7 %
50 %
PSA
Mahindra
25 %
DRAC
79 %
Fiat Poland
82 %
Ferrari
50 %
50 %
Maserati
Asia Motors
25 %
Hyundai
Kia
Mazda
82 %
82 %
15 %
Honda
San Yang
13.5 %
36.8 %
Nissan
Proton
Lotus
64 %
17 %
Mitsubishi
Hindustan
10 %

Table 2.2 The value funnel

Phase	Time taken at each phase, order to delivery
Iron ore extraction Crude petroleum production Silica mining, etc.	90–300 days
Alumina production Iron/steel production Aluminium production Polymers	11–26 days
Semi-manufactured materials Sheet, bar, ingots, granules, etc.	3–26 days
Components	1–21 days
Modules	30–180 minutes
CAR ASSEMBLY	12–18 hours
Franchised dealers / sales	40–70 days

Source: Wells and Nieuwenhuis (2001).

and 180 minutes. However, once the vehicle is fully assembled the embodied value added is not realised immediately by the vehicle manufacturers. On the contrary, in many markets the distribution and stock system can hold vehicles for weeks. Reduction of this time is a key target for the vehicle manufacturers.

Consider the position of the vehicle manufacturer with a mainstream product in a high volume segment exemplified by the Ford Focus. The market essentially sets the price obtainable, in this case around £11.50/kg for the UK market in 2002 (Wells and Nieuwenhuis, 2002). In effect, this price also sets the scope for value added down the material transformation chain. In the case of steel, the value-added chain could be as shown in Fig. 2.2.

The material value chain, as Fig. 2.2 shows, often results in large increments in value added with each major process step. Put another way, there is a large multiplier effect as the material progresses through the manufacturing and distribution system. Hot rolled coil steel in Fig. 2.2 has an indicative price of £0.25/kg, but this is multiplied many times by the time it reaches the ultimate consumer in the form of a car in the market. If the starting price of hot rolled coil steel was £1.00/kg the same multiplier would result in a market price for the car of about £45/kg, or sufficient to make a Ford Focus cost £48 870. This helps to explain why there is such powerful pressure on the material suppliers to reduce the cost of their material. Indeed, any examination of the long run real cost of materials such as steel would

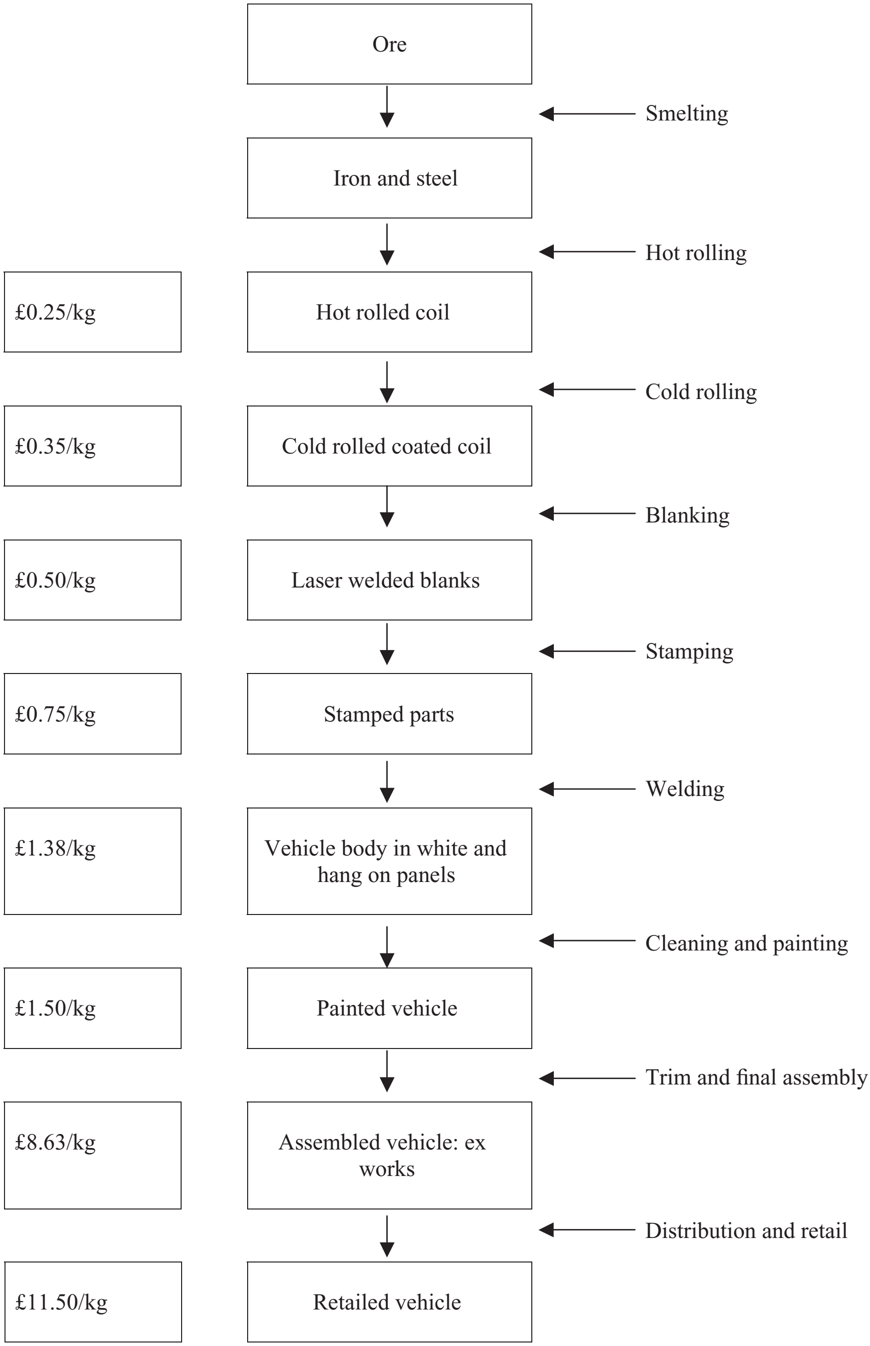

Fig. 2.2 The value-added chain.
Source: Wells and Nieuwenhuis (2002).

show there has been a reduction in price. Steel is a commodity material. Therefore, one response from material suppliers has been to increase the value of their material through what might be termed de-commodification. In the case of steel, this has taken the form of new substrates and new coatings that offer enhanced performance from the material. Equally, the addition of new intermediary processes such as laser welded blanks can be seen as a reaction of material and other suppliers to the vehicle manufacturers' squeezes on cost. In effect, the material suppliers are offering increased functionality from their material, but at some added cost. Note, however, that items such as laser welded blanks may ultimately save cost (results in a lower cost per vehicle) by consolidating the number of parts required.

Seen from a vehicle manufacturer's marketing perspective, basic economics mean that reduced prices for finished vehicles will result in increased sales – all other things being equal. Hence, again this is a starting point for cost reduction pressures throughout the material value-added chain. Of course, consumers do not buy cars on the basis of weight. Few new car buyers would know the weight of the vehicle they purchase. Rather, in a broad sense the very existence of vehicle segments suggests that consumers purchase on the basis of size and cost, with performance a further consideration. Weight is really an indirect issue unless it features in the vehicle classification and taxation regime, as is the case in some countries. Herein lies a basic dilemma – it is difficult for vehicle manufacturers to translate weight reduction per se into premium prices. This is a vital issue for material suppliers, as discussed below.

2.3 Material and component suppliers

Vehicles are comprised of many individual components (such as aluminium radiator cooling fins), aggregated up into sub-systems (such as radiator assemblies) or systems (such as the cooling system including pipes, controls, sensors, etc.). Aside from the core items of the vehicle body structure and the engine, independent companies supply the materials and components that constitute the vehicle. The contemporary competitive context for suppliers is shaped by:

- vehicle manufacturers' sourcing strategies;
- cost, weight and size reduction pressures;
- globalisation: following the vehicle manufacturers wherever they may go;
- localisation: putting satellite plants alongside vehicle assembly plants;
- modularisation: putting together complex sub-assemblies.

In trying to reconcile these pressures the automotive components industry has been through incessant rounds of restructuring and consolidation. In effect, each company has been seeking to put together a portfolio of capa-

Table 2.3 Transitions in vehicle manufacturers' sourcing strategies

Item	Traditional	Lean	Extended enterprise
No. of suppliers per model or plant	2–3000	2–300	20–30
Geographic scope of supply base	Local	Regional	Global
R&D capacity of suppliers	Work to drawing	Design to fit	Innovative solutions
Contracts to suppliers	Short term; awarded on quoted cost basis	Model term; awarded on cost, quality, delivery basis	Model or platform term; awarded on 'shared destiny' basis
Management of supply base	Remote; piece price focus	Interventionist; quality, price, delivery focus; supplier performance optimisation	Outsourced; value mapping; chain optimisation; strategic focus
Structure of supply side	Fragmented; national focus	Tiered hierarchy; regional focus	Supply chain; global focus
Vertical integration in the vehicle manufacturers	High; captive suppliers for main sub-assemblies	Reduced; captive suppliers seek external business	Selective integration in strategic technologies; reduced integration elsewhere

bilities, customers and geographic presence that will ensure survival into the future. The major impetus for change is coming from the shift in vehicle manufacturers' sourcing strategies, as shown in Table 2.3.

Year on year price reduction has become the norm in the automotive industry, and is built into all long-term contracts. When preparing quotations, suppliers will be expected to give a detailed breakdown of costs in arriving at their prices. However, the vehicle manufacturers are not in a position to evaluate the true costs of all of the components and materials they purchase. The target pricing system enables the vehicle manufacturers to calculate the amount of savings over a notional price. In recent years the vehicle manufacturers have sought to use internet marketplaces to reduce costs. The most established example is that of COVISINT, a trading platform owned by some of the leading vehicle manufacturers (though others such as VW have preferred to go their own way). Suppliers have been resistant to this approach, not least because of the prevalence of reverse auctions – techniques such as this amount to financial engineering by the vehicle manufacturers whereby short-term costs are reduced but at the long-term cost of supplier viability.

The vehicle manufacturers, particularly when under financial pressure themselves, may well resort to more basic measures to reduce costs on purchased parts. Typically, a new management regime and a new piece of jargon will accompany demands for lower costs. A good recent example is the practice of 'team value management' (or TVM), introduced by David Thursfield when installed as head of global purchasing at Ford in 2002 (Grant, 2002). With the company recording a loss of $5.4 billion in 2001, his target was to reduce the global purchasing budget of $75 billion by about $5 billion by 2004. The practice of TVM is not being presented as extracting cost savings direct from suppliers, but as generating savings via measures such as increased commonality of parts between different models.

Downsizing and increased complexity in cars combine to bring a further pressure on the supply base; the need to reduce the size of components or to fit them into increasingly complex and congested spaces. The areas most affected are under the bonnet, doors and the dashboard area inside the car. In the case of the dashboard area, for example, the instrument panel has become more complex as more applications become available while other components are being added to that space (e.g., airbags; air conditioning; in-car entertainment or ICE; navigation systems etc.). More generally, internal packaging is also an important sales feature, notably trays, cup-holders, seats that can be removed or reconfigured, storage areas, and so on.

It has become customary to consider the supply base to be arranged in tiers or layers. In this framework, Tier 1 companies supply direct to the vehicle manufacturers and are linked by collaborative R&D, sequenced supply and other measures. Below the Tier 1 suppliers are Tier 2 companies, who supply the Tier 1 companies. Tier 3 companies then supply Tier 2 companies. This structure, if it ever existed outside Japan, is now breaking down. There is an emerging elite of super-suppliers, often called Tier 0.5, Module Suppliers or Full Service suppliers (examples include Magna, Bosch, Lear, Delphi and Denso). These are large multi-location companies, able to supply vehicle manufacturers anywhere in the world at full platform volumes, usually with a portfolio of products. These companies also have advanced technology capabilities and are significant innovators in their own right, able to manage sequenced production flows into the assembly process. However, the supply base as a whole is much more turbulent and fluid than the archetypal characterisations suggest.

Suppliers are expected to meet three key requirements

- continuously drive down costs;
- provide innovative product features;
- manage the sub-supply base on behalf of the vehicle manufacturers.

The suppliers are themselves increasingly turning to internet supply systems (an emerging example is the German supplier-formed company SupplyOn)

Table 2.4 Market shares for the leading companies supplying anti-lock brakes and power steering systems (2000)

Item	Market share (%)
Antilock brakes	
Bosch (Germany)	55
Continental Teves (Germany)	37
Lucas Varity (now TRW) (US)	3
WABCO (US)	1
Other	4
Power steering	
Delphi (US)	21
ZF (Germany)	18
TRW (US)	20
Koyo Seiko (Japan)	16
Other	25

Note: TRW is currently undergoing a further round of restructuring.
Source: derived from *Automotive News Europe* (2002a:18).

while reducing the number of sub-suppliers with whom they conduct business. In aggregate, large numbers of independent suppliers are being squeezed out of the supply chain. However, new suppliers are drawn into the industry at all levels because of the process of new technology introduction. For example, companies involved in electronics, sensors, computers, communications, switches, etc., have all become much more important. In many product areas, particularly the more mature products, the automotive component market is rapidly becoming dominated by three or four companies. Table 2.4 demonstrates this trend in the market for ABS brakes and power steering systems.

2.4 Distribution and retailing

Distribution and retailing (including marketing costs) can account for between 20 and 40 % of the final price of a new car in the market. Much depends upon the source location of the plant and the type of customer. It is customary in many markets for discounts on the retail price to be offered to various types of customer. Table 2.5 shows a typical example.

Table 2.5 shows that different categories of the market are used to manage the vehicle production and order process. The 'three day car' concept (wherein a specific car is delivered against a specific customer order direct from production within three days) can only apply to a small proportion of the total output, a sub-set of private retail consumers, with other

Table 2.5 Typical order segmentation for a high volume vehicle producer in the UK

Customer segment	Volume (%)	Discount (%)	Adjustable delivery
Private retail	40	0–10	Yes, with discounts
Retail fleet	20	10–20	Variable
Direct fleet	25	30–40	Negotiable but limited
Demonstrators	5	Not applicable	Yes
Employees	10	15–20	Yes

Source: ICDP, personal communication (2001).

categories providing the base load of demand. Volvo, for example, uses exports to North America as the buffer against which customer orders can be balanced – a strategy long used by Toyota in Japan. Although customers may be prepared to wait a few days for delivery of their car, in Europe the average order-to-delivery time for volume vehicle manufacturers is around 48 days, and for specialist brands it can be substantially longer. In North America, customers are often not prepared to wait, so cars have to be sold from stock. As a result, it is normal for 60–80 days' worth of production to be held in inventory.

Throughout the logistics chain there is a combination of vehicle manufacturers' owned companies and independents. In shipping, for example, some vehicle manufacturers have traditionally run their own fleets (Nissan, VW, Hyundai). Other manufacturers have relied largely upon independents for particular routes. Smaller independents have picked up residual business on less high volume routes. This has resulted in a characteristic structure (Beresford *et al.*, 2002). This pattern of vehicle manufacturers' owned subsidiaries, large (high volume) independents and niche specialists is replicated through the logistics and distribution system, from ports to car transporters. Two broad trends are evident:

- the vehicle manufacturers are ceding direct control over some or all of these operations to escape the fixed costs of ownership;
- the independents are consolidating and offering a greater range of integrated value-added services, linking together the factory with the dealership.

In terms of distribution systems there is considerable variety on a country to country basis, certainly more so than in manufacturing. Equally, there are no independent car importers or retailers of an equivalent stature to the component suppliers. There are several 'models' of retailing in operation:

- *US model*. Large sites selling over 500 new cars per annum, mostly from stock. Independent retailers. No manufacturer owned retailers, no second tier. Price and incentive based retailing.

Table 2.6 Main dealers and service outlets in Europe (1999)

Main dealers		Service outlets	
Manufacturer	Number	Manufacturer	Number
VW	4218	Renault	13135
Opel/Vauxhall	4191	Citroën	9132
Ford	3789	Peugeot	8981
Audi	3325	Ford	8351
Peugeot	3221	Fiat	8095
Renault	2998	Volkswagen	7261
Nissan	2855	Opel/Vauxhall	6902
Toyota	2494	Audi	4677
Citroën	2481	Nissan	4237
Mazda	2367	Toyota	3316

Source: compiled from ICDP (1999).

- *Japanese model*. Small sites, owned by vehicle manufacturers. Weak market for used cars (many exported). Distinct channels with similar product. Specification based retailing.
- *UK model*. Large dealer groups, multi-franchise and multi-location. Some vehicle manufacturer owned sites. No second tier. Used cars vital for profitability. Many solo sites selling under 300 new cars per annum. New car sales dominated by corporate sector.
- *Mediterranean model*. High levels of manufacturer owned sites, forming the backbone of the network. Many small independents, single site and single franchise. Significant second tier of sales only or service only sites. Strong residual loyalty to domestic brands.
- *German model*. Multi-site single-franchise and regional dealer groups, along with some vehicle manufacturer owned sites and many smaller independents. Dense networks with low sales per outlet. Specification dominated market with long customer order delivery times.

Table 2.6 shows the number of main dealers in Europe for ten vehicle manufacturers and the number of service outlets including sub-dealers (i.e., second tier dealers). Clearly, sales per dealer are considerably higher for VW than for Mazda. Equally, it is possible to get a very different picture of dealer structures depending upon what is counted.

Internet sales have been constrained by the nature of legislation and the characteristics of the car market. In general, new car purchases are a high cost and relatively complex transaction, unsuited to internet approaches. Independents and some vehicle manufacturers in Europe have sought to offer reduced choice and lower prices. However, the transaction also often involves a trade-in vehicle (used car) to be valued, finance package, test drive and other features. Generally there are 'internet assisted' purchases, beyond which consumers are directed to the nearest physical dealership. It is important to realise that many vehicle manufacturers make a far larger profit on finance for new car sales than on the cars themselves. Again, this is a competitive area; dealers may use independent sources of finance, or consumers may get finance from another source.

2.5 Financial performance, structure and the future

The history of the automotive industry is one of waves or periods of consolidation and merger, resulting in fewer companies dominating an ever-greater share of the global market. Over time, new companies have sought to enter the market, or have become established in countries that have been isolated from international trade and competition. With the growing influence of the World Trade Organisation there are fewer such enclaves left, with major countries such as China and India becoming part of the international business world.

Profitability in the industry as a whole over the long term remains linked to growth in market volumes. It is an industry characterised by high fixed costs in factories and in product development, with almost endemic levels of over-capacity, so any downturn in the market can quickly result in factories running below break-even volumes. At an individual company level the automotive industry remains one that is strongly product-driven; that is, a 'good' product range can make all the difference between success and failure. Thus, for example, Renault enjoyed huge success with the first-generation Mégane Scénic in the mid-1990s because it created a new market segment with an innovative product.

Throughout the 'working life' of the car it generates revenues through spending on fuel, insurance, servicing, spare parts, etc. Indeed, it is partly in order to capture a greater share of this model lifetime earning stream that the vehicle manufacturers are shifting into retail and service activities. Research by Knibb, Gormezano and Partners, echoing that undertaken in North America by Booz-Allen and Hamilton (all quoted in Proctor, 2000), shows that building and wholesaling a car accounts for about one per cent of the ten year profit stream associated with that car (Proctor, 2000). Table 2.7 shows the distribution of profits generated by the average vehicle over ten years. Booz-Allen and Hamilton calculated that, for a Dodge Intrepid, repairs and parts provision accounted for profits of $1925 per unit over ten years or 160 000 km. Across the industry as a whole it is apparent that the largest share of total profits made globally lies in aftersales (i.e., all service and sales activity beyond new car sales). Table 2.8 illustrates this point.

Table 2.7 The automotive profits pool (% share of profits generated over ten years)

Item	Proportion of profits generated (%)
Parts distribution	18
Car financing	14
Bodyshop	13
Automotive insurance	13
Mechanical repairs	11
Used car sales	10
OEM parts	9
New car retailing	3
Vehicle manufacturer car sales	1

Source: Knibb, Gormezano and partners, in Proctor (2000).

Table 2.8 Annual global profits ($ billion) in the automotive industry value chain (2000)

Category	Profit ($ billion)	Share of total (%)
Suppliers	28	20.2
Original equipment manufacturers (OEMs)	24	17.4
Retailers (new cars)	7	5.1
Aftersales	79	57.3
Total	138	100.0

Source: McKinsey and Company, press release (2000).

2.6 The direction of the industry: the case of Ford

At an individual company level the automotive industry shows exactly the same volatility of strategic direction that is evident in many other sectors. Perhaps there are structural reasons for this phenomenon related to the nature of financial markets and the ways that individuals are rewarded at senior management levels. New strategies are often announced with considerable flourish, often when new senior management arrive. However, the record of success and failure of these strategies is perhaps debatable. Table 2.9 summarises some examples.

Table 2.9 provides a simple general account of some major restructuring moves in the late 1990s. As a further illustration it is worthwhile to consider the case of Ford in more detail. This is not to imply that Ford is particularly badly run or mismanaged, as similar accounts could be constructed for

Table 2.9 Decisions over strategic direction and the outcome of such decisions for selected vehicle manufacturers in the late 1990s

Company	Strategy / decision	Result
BMW	Purchase of Rover	Sold off after continuous losses; retained useful Mini brand, renamed MINI
VW	Platform strategy to support multiple brands	Some success in 1990s, especially for 'lesser' brands. Problems for core VW brand
VW	Shift upmarket for VW brand and inclusion of others in the portfolio (Bentley; Bugatti)	Abandoned the 'supercar' project. Not able to form brands into coherent groups
Mercedes	Merger (effective takeover) with Chrysler	Caused long run decline in the share price. No obvious synergies. Cost savings slow to emerge
Ford	Creation of so-called Premier Automotive Group (PAG) with Volvo, Lincoln, Land Rover, Aston Martin, Jaguar	Strategy collapsed with departure of key executive. Lincoln could not escape the US market, later removed from PAG. Jaguar volumes could not be grown fast enough
Ford	Purchase of TH!NK, small company in Norway manufacturing electric vehicles	Invested large sums but never generated sufficient sales. Abandoned after CEO left Ford
Renault	Purchase of controlling share in Nissan	Generally considered a success. Nissan restored to profitability, though at cost of plant closures and redundancies
FIAT	Joint venture and cross-shareholding with GM	Failed to stem collapse of FIAT sales and consequential heavy losses. Left FIAT without clear direction

many of the leading vehicle manufacturers (Golding, 2001; Mercer *et al.*, 2000; Mateyka, 2000). However, the case does illustrate the sheer complexity and difficulty of trying to create coherent strategies for companies of a global stature (Wells, 2002).

On Tuesday 30 October 2001 it was announced by Ford Motor Company that Jac Nasser had retired, effective immediately, from his position as CEO after only 34 months in the job. With the departure of Nasser, along with a substantial number of senior managers associated with the fallen CEO, Ford Motor Company then embraced a 'back to basics' strategy. This apparently conflicted with the much-vaunted corporate social responsibility espoused by Nasser. In fact, Jac Nasser paid the price for the usual failings. Prior to his departure:

- the share price fell from $35.61 in January 1999 to $15.34 by September 2001;
- losses of $1.53 billion were incurred in North America for the first nine months of 2001 compared with $4.28 billion profit in the same period in 2000;
- ongoing losses in Europe were not halted;
- significant reductions in available cash reserves resulted;
- the dividend paid to shareholders for the fourth quarter in 2001 was cut – the first such cut in a decade;
- Ford lost market share in the crucial (and hitherto highly profitable) US light truck segment.

However, it could be argued that the core problem was not that of short-term financial performance, even though that performance provided more than sufficient justification for the removal of Jac Nasser. Possibly, the problem was that Nasser did not have sufficient support in his drive to take Ford away from mainstream manufacturing and into being a consumer service company founded on the principle of corporate social responsibility, although the latter element is certainly also espoused by Bill Ford and may itself have been an area of disagreement between them.

If one single issue highlighted the problem it was with the Firestone tyres fitted to the bestselling Explorer light truck vehicle. As is now documented, tread separation on those tyres caused at least 270 deaths and precipitated a series of damaging legal and political proceedings in the USA. Firestone was not only a long-term Ford supplier, but Bill Ford's wife is related to the Firestone family that founded the firm. In the event, Jac Nasser took the brave decision that consumer interests must be protected above all others, and ultimately ordered the recall of 19.5 million tyres at a probable cost of around $3 billion. Of course, Nasser had upset core interest groups such as US dealers and manufacturing workers previously. The Firestone situation undermined his position and allowed those who wanted to remove him the opportunity to do so.

There had been relatively little concern expressed at the expansion of the Ford company into the premium brands via the acquisitions of Jaguar and then, under Nasser, of Volvo and Land Rover. However, there had been disquiet over the shift in the centre of gravity of the company as it moved downstream into the retail and service arena. This entailed the acquisition of companies such as Kwik Fit in the UK, car dismantling operations in North America, moves into retailing (again in the UK as well as the US and New Zealand) and attempted but unsuccessful moves in North America, increasing control over Hertz, and the development of the Ford ConsumerConnect operation. Ford sold off both Kwik Fit and TH!NK at considerable loss. Ford had paid about £1 billion for Kwik Fit, but received less than half that value when the company was sold again.

It also appears that there was disquiet at the core of the company and at a very senior level with the entire strategic direction being pursued. Nasser clearly believed that Ford needed to do more than make decent cars in order to survive. He wanted to position Ford as a caring company. At a time when product was increasingly unable to act as a differentiator, Nasser sought that market edge through changing the corporate culture. It is that strategic direction that is now under threat from the new regime.

2.7 Conclusions

This chapter has given a small insight into the turbulence and confusion within the automotive industry, mainly at the level of the vehicle manufacturers. In reality, that turbulence continues throughout the industry, and does not appear to be stemmed by the creation of ever-larger corporate entities. Part of the search for a sustainable industry must therefore address the problem of sector turbulence, because the shifting sands of the corporate edifice have a huge human cost in lost jobs and decimated communities.

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3

Markets and the demand for cars

> *What Sloan chose to call 'constant upgrading of product' is more accurately described as planned obsolescence through cosmetic changes. In diametric opposition to the Ford Model T product philosophy of a single, static model at an ever decreasing unit price, GM attempted to produce 'a car for every purse and purpose'. Sloanism called for blanketing the market with a car at the top of every price range and encouraging the consumer to trade up . . .* (Flink, 1988: 234)

3.1 Introduction

The opening quote marks the birth of the car market as we know it today, as a deliberate creation, which needs constant management in order to function properly. Traditionally, market growth has been closely associated with two issues: economic conditions and social change. Hence, economic growth generally along with, for example, the proliferation of households, would combine to generate growth in new car sales and, ultimately, the size of the stock of cars in circulation (known in the industry as the parc).

This chapter seeks to highlight the interplay between markets and manufacturing; the issues of saturation in established markets and the rather non-emerging emerging markets. The market for cars is both dynamic and multi-faceted. The themes touched upon here, such as market segmentation and fragmentation, new versus used cars; the international used car trade; lifetime revenues generated from the sale and use of cars; are by no means all that could be covered. However, the key theme is the tension between the capability of the production system, and the demands of the market. In brief, the logic of consolidation, globalisation and manufacturing economies of scale is countered by the logic of market differentiation. The reconciliation of this basic tension between manufacturing and markets is a pervasive and enduring theme in the automotive industry, but one that has been given a new twist with the emergence of alternative automotive technologies and the demands of sustainability.

3.2 The structure of production and markets

The simple contention is that the capital structure of the automotive industry results in mass production. If markets are no longer growing fast enough, this structure rapidly results in over-capacity, over-supply and high levels of depreciation for new cars. Therefore, the market for new cars overall is shaped by some key features in the automotive industry:

- the extent of overall saturation in established markets;
- the opportunities for growth outside established markets;
- the extent of market fragmentation;
- segment shift;
- vehicle prices.

3.2.1 Market growth

Table 3.1 provides a forecast for vehicle sales to the year 2020 in the major regions of the world, as envisaged in current industry thinking. It can be seen that the growth is mainly expected outside the traditional market regions. Table 3.2 shows how the global parc has expanded to nearly 800 million vehicles in 2000. In mature markets such as those in Europe, the US and Japan, demand and supply are mediated by the stock of cars in use and the rate of attrition of that stock. In the UK, for example, a parc of about 24 million cars gives rise to 1.8 million End of Life Vehicles per annum

Table 3.1 Market growth forecasts (million units), global scale/key regions

Region	2001	2005	2010	2020
North America	19.6	21.5	23.0	25.0
Western Europe	16.6	15.0	13.0	13.0
Asia Pacific	12.4	18.5	21.7	27.0
Central/Eastern Europe	2.5	3.0	4.5	6.0
South America	2.4	3.0	4.0	7.0
Middle East	1.3	2.0	3.0	3.0
Africa	0.8	1.0	5.0	10.0
Total	55.6	64.0	74.2	91.0

Table 3.2 The expansion of vehicles in use: the global parc (millions)

Year	Cars	Commercial vehicles	Total
1930	29.9	5.9	35.8
1950	53.0	17.3	70.3
1960	98.3	28.5	126.8
1970	193.4	52.8	246.2
1980	320.3	90.5	410.8
1990	444.8	138.0	582.8
2000*	620.0	150.0	770.0

* 2000 estimated.
Source: SMMT (1999).

(SMMT, 2002). With new car sales of about 2 million per annum it would take 10–12 years to completely change the parc, in which time it will slowly expand.

With the expansion of the parc comes the concern of market saturation. In terms of vehicle ownership rates, by the year 2000 there were 1.7 people per car in the US, 1.9 in Italy, 2.3 in the UK and 2.9 in Japan. This can be compared with 157 people per car in China. If we compare these figures even with Table 1.2 in Chapter 1, which gave 1995 figures, a considerable expansion in countries like China can be seen, which explains why many consider such markets to offer huge potential. However, that potential could at least in part be met by the export of used cars rather than new – in fact, this trade is already surprisingly developed.

In 1998, Japan exported around 420 000 used vehicles according to official figures. Unofficial figures put it closer to 700 000, with many Russian trawlers and seiners spotted loaded with cars up to, if not above, the gunwales leaving ports in Hokkaido and northern Honshu. South Korea added another 87 000 vehicle exports to world markets, while it is estimated that over 300 000 were shipped from Western Europe. This last figure does not include the considerable overland trade to Eastern Europe and North and West Africa – a trade that could account for a further 700 000 vehicles per year. Used exports from North America are also on the increase (Beresford *et al.*, 2002).

Among the largest recipient markets are Jamaica, Peru, Sri Lanka, Cyprus and Russia. However the largest taker worldwide (at least according to available official data on Japanese used car exports) is New Zealand, while Ireland leads Europe as a used vehicle importer. The latter has also become a conduit for used vehicles into the UK, particularly vehicles at the prestige end of the market. It is primarily in the relatively advanced markets of New Zealand and Ireland that critics have suggested that their markets are merely victims of environmental dumping by sophisticated producer

Table 3.3 New Zealand registrations, 1981–98 ('000s)

Year	New cars	Used imports	Used as % of new
1981	91	2	2.0
1985	81	3	3.6
1990	74	85	114.6
1995	66	81	123.3
1996	64	111	173.5
1997	58	92	158.0
1998	54	100	185.2

Source: estimated from various trade and registrations data; Beresford *et al.* (2002).

markets, notably Japan (Nieuwenhuis and Wells, 1999). Of greater concern are the developing markets, lacking in the support infrastructure to ensure vehicle maintenance, that accept used cars older than those shipped to New Zealand and Ireland. Used vehicle exports in this sense represent an unequal trade, an extension of the waste, toxic or otherwise, that is shipped from the industrial North to less demanding developing countries in the South whose often corrupt regimes readily accept it for cash.

New Zealand is by far the largest single recipient of Japanese used vehicles, including both cars and trucks. A relatively easy sea journey away and with no true local assembly left, this prosperous market has seen a growing used Japanese import share. As Table 3.3 shows, in the early 1980s used car imports were marginal in the market, yet by 1998 they were nearly twice the level of new car registrations. This large used car segment in certain markets adds yet another element to the increasing complexity of car markets. Diversity or fragmentation creates growing problems for the industry, which has a natural preference for standardisation and uniformity.

3.3 Fragmentation

Market fragmentation makes prediction of sales volumes for any particular model more difficult. The vehicle manufacturers and their suppliers have to make investment and tooling decisions based upon anticipated volumes. If the volumes actually achieved are too low, profit margins will come under severe pressure. This has been the case with the MCC Smart for example. If the model is more successful than anticipated, as has happened with the first-generation Renault Mégane Scénic in Europe, then profit-making opportunities are lost. Market fragmentation therefore underlines the importance of agility in manufacturing processes all the way through the supply chain. In saturated markets the chances of any one model failing are much higher.

Despite attempts at globalisation, the automotive industry faces markets that remain stubbornly different from each other. There are many dimensions over which markets differ, causing market fragmentation at the global scale. Some examples of these differences include:

- In Japan, the Kei class (a unique category of very small vehicles) accounts for 25 % of the market whereas in the US light trucks account for almost 50 % of the market.
- In Korea, imports account for less than one per cent of the market.
- In Europe, the share of diesel engine cars has grown rapidly to over 30 % whereas diesel sales in Japan and the US are negligible.
- In Europe, the mini-MPV segment (typified by the Renault Scénic) has been the growth area of recent years, yet this segment hardly exists outside Europe.
- In Japan, the emphasis is on vehicle features such as navigation systems; in the US on comfort features such as air-conditioning, automatics and compliant ride; and in Europe on taut handling and vehicle dynamics.
- In emerging markets such as Thailand the share of pick-ups is particularly high.

There is always tension between the need for simplicity from the manufacturing system, and the need for variety from the market. Market segments vary across the major regional markets, but are also changing rapidly within markets. Fragmentation in terms of market share is also under way in individual markets, for example with the long-term loss of market share by the dominant producer in most markets (e.g., GM in the USA; Fiat in Italy; Renault in France). Generally, those markets without locally dominant producers (such as Switzerland and The Netherlands) tend to have a smaller proportion of the market accounted for by the leading models. Table 3.4 illustrates these themes more fully for the leading markets in Europe.

3.3.1 Market fragmentation: a UK example

The UK is but one market among many, yet in some respects it is unique. Of relevance to the data presented here, the UK has a relatively rich endowment of small, specialist vehicle manufacturers present on the market. It is also a right-hand drive market. This means that some models and variants produced in and for left-hand drive markets do not make it to the UK. It also means that 'grey' imports of models and variants from Japan do occur, but these do not feature in official UK price lists from the vehicle manufacturers concerned and hence are not captured by the data. Table 3.5 summarises the changes in the UK market over the period 1994 to 2002 in terms of the number of brands, models and variants available. The data are taken from the price lists published in the consumer journal *Autocar* for July of each year in question.

Table 3.4 Market share for the top ten models and leading model in selected markets (1994 and 2000)

Market	1994		2000	
	Top 10 share (%)	Leading model share (%)	Top 10 share (%)	Leading model share (%)
The Netherlands	34.7	6.8	34.5	5.2
Spain	49.4	6.0	45.6	7.2
UK	47.6	7.5	35.4	5.1
Sweden	59.1	14.2	43.3	10.2
Switzerland	33.9	4.7	27.6	5.1
France	51.0	9.8	52.9	9.6
Italy	50.9	16.2	41.6	11.2
Germany	48.2	12.1	38.5	9.3

Source: adapted from *SMMT Yearbook* (1995, 2001).

Table 3.5 Brands, models and variants in the UK market (1994–2002)

Year	Brand names	Models	Body styles	Variants
1994	54	205	300	1303
1995	56	211	309	1580
1996	57	218	321	1624
1997	53	225	318	1611
1998	54	231	382	1637
1999	52	240	332	1759
2000	57	262	357	1931
2001	58	260	351	2042
2002	57	263	387	2472

Source: Wells and Morreau (2002).

It is inevitable that any market will undergo a dynamic process of change, and, indeed, this in itself is some measure of the health of the market. The UK market has been no exception. There have been exits from the market (e.g., Lada in the latter 1990s) just as there have been entrants (e.g., Smart in 2001). Equally, individual vehicle manufacturers may be expected to add or delete models from their ranges, and adjust trim levels and options packages. Nevertheless, Table 3.5 illustrates some key long-term trends.

3.3.2 Number of brands

In an era of multi-brand conglomerates there is a distinction to be drawn between independent brands and those of large groups. In this sense, the proportion of the market accounted for by large groups has clearly increased since 1994. In some cases, perhaps most overtly with respect to MINI and Smart, new brands have emerged in the market even though none is actually independent from the existing vehicle manufacturers. Whether this amounts to a reduction in choice for consumers is less clear, particularly where there is no sharing of platforms or components between distinct brands held within the portfolio of one vehicle manufacturer. In other instances there have been genuine new entrants, the UK sports car maker Noble for example.

3.3.3 Number of models

The definition of models used for Table 3.5 separates different body styles. Hence, four-door (booted) and five-door (hatchback) versions of the same vehicle are counted as different models. One of the marketing benefits of platform strategies is that, in theory, more model types can be created from one platform: as shown in the case of the Renault Mégane range. Ironically, the Scénic has since become a model in its own right.

Since 1994 the concept of range extension has become popular, with some vehicle manufacturers seeking to create a wider range of models to capture new segments in the market. Hence, the Mercedes market extension into the A Class, Audi into the A2 and Ford into Ka. Global integration has tempted some vehicle manufacturers to import models aimed at other markets, because the marginal costs of doing so are low (Ford Probe might be an example, designed for the US market but also imported into Europe). New segments have been created, most obviously the small MPV segment, and these new segments compel other vehicle manufacturers to supply models into these segments, hence the number of models continues to grow.

3.3.4 Number of variants

During the 1990s one strategy adopted by some vehicle manufacturers was to increase the number of options packs in an attempt to create less complexity in the vehicle assembly process. The growing popularity of diesel engines has resulted in an increase in the number of variants available within a model range. In some cases the growth in variants is indeed impressive. The mainstream Vauxhall Astra 5-door, for example, had 14 variants in 1996, and 20 by 2002, an increase of 43 % in only 6 years. Taking all the Astra body styles into account there are 53 variants available, compared with 35 in 1996. Locally dominant models are likely to be offered with a wider range of variants than those with a marginal market share.

In the period between 1994 and 2001 the UK market grew in volume terms from 1.91 million units to 2.25 million units, while the number of variants grew from 1303 to 2042. If registrations were equally divided among all the models this would mean an average of 1465 sales per variant in 1994, falling to 1101 sales per variant by 2001.

Of course, measuring the number of variants does not capture the true level of choice offered to consumers via the options list. For some vehicle manufacturers their ability to meet consumer wishes is very much dependent upon the scope of options offered. It is also the case that without true build-to-order the apparent choice offered by the price lists of the vehicle manufacturers may not actually be realised in the market. Despite these comments, the extension of the scope of each model with the addition of further body styles and variants does not appear to have halted the fragmentation of markets. Out of all the countries listed in Table 3.4, only France did not see the share of its top ten models fall between 1994 and 2000. Similarly, only Spain and Switzerland have not experienced the share of their leading model fall. The anomalous position of France might be explained by the recent resurgence in both Renault and PSA, with class-leading models and striking styles enabling a growth in domestic market domination. Elsewhere the decline in the share accounted for by the leading models is quite marked. In the UK, for example, the share fell from 47.6 % to 35.4 %. However, in general terms the data in Table 3.4 suggest that local market dominance has been eroded, and with this erosion has come a decline in volumes for core models. A clear example is Sweden where the leading model in 1994 (the Volvo 800) claimed 14.2 % of the market, while in 2000 the Volvo S/V/C 70 claimed only 10.2 %. Only Toyota in Japan and Hyundai-Kia in South Korea have managed to retain a truly dominant share of the domestic market. In all other cases there appears to be a slow but steady erosion of the link between a vehicle manufacturer brand and a particular national market. The situation in Japan and Korea is also likely to change over time, while developments in new technology will add further turmoil.

3.4 Brands and the market for alternative technology vehicles

There is a notion in other product areas of eco-brands, more environmentally benign products aimed at more environmentally concerned consumers. Thus far, the impact of this approach has been limited in the car industry. However, new technologies may well make such an approach more feasible, and Ford, briefly, pursued this with its Th!nk brand.

There can be two key elements to the claims made in an eco-brand strategy: that the product itself is environmentally superior to that offered by competitors; or that the provider of the product is somewhat more acceptable in a social or political sense. In the latter, the product or service itself may not be ‘better’ than the un-ecological competitor products, but consumers are encouraged to sacrifice a degree of performance in exchange for the ‘correctness’ of the company itself. For example, ‘Fair Trade’ coffee is arguably no better than any other coffee, and usually more expensive, but it is supplied by co-operative farms that some consumers prefer to support. An organic option, if not standard, is also at least available. In both cases, the danger is that the brand is undermined by a very public failure – particularly when that failure could be construed as deliberate deception or double standards.

Yet it is apparent that the leading vehicle manufacturers have adopted a range of strategies with respect to the treatment of environmental and ethical issues generally, and specifically in terms of the development of an eco-brand. Two features are critical as the vehicle manufacturers develop their strategies in this area:

- the entire ecology and ethical market is still in the early stages of development, particularly for automotive products;
- brands, once developed, tend to have relatively enduring characteristics – indeed it could be argued that this is the key purpose of having a brand at all.

Given the complex nature of the environmental issues that surround vehicle design, it is hardly surprising that it has been very difficult for vehicle manufacturers to pursue an ecological strategy for all their operations. The differences between an organic carrot and an inorganic carrot are relatively simple. It is a quite different task to say that one model of car is 'greener' than another model (see Chapter 12 for a fuller discussion of this issue). Additionally, corporate leadership on environmental issues may be difficult to reconcile with commercial reality: some vehicle manufacturers such as Ford have explicitly recognised the tension between their stated corporate aims to achieve good corporate citizenship, and the reality of market demands. All too often the most profitable vehicles are also the least environmentally sustainable: the best current example being the SUVs sold by Ford, Jeep and GM in North America.

Traditionally, the vehicle manufacturers have sought to adopt a full range strategy or be niche specialists. After the rounds of consolidation that have so altered the industry's traditional structure, that distinction has almost been eroded. In effect, there are few niche specialists left. Yet this has already posed problems for certain vehicle manufacturers in terms of their brand management strategy. A classic example is Mercedes with the A Class, seen by many observers as stretching the brand too far 'downmarket' and thereby having a negative impact on the equity of the Mercedes brand as a whole. The question of how to deal with the eco-brand is, in this respect, therefore a special case of how to deal with brand extension generally.

Table 3.6 shows how selected vehicle manufacturers have sought to introduce environmentally friendly designs into the market. It is immediately apparent that there is no consensus on the correct approach. The same models as shown in Table 3.6 are usefully shown in contrast with each other

Table 3.6 A comparison of eco-brand strategies

Vehicle manufacturer	Model	Comments
MCC (DaimlerChrysler)	Smart. A 2 seat compact car with small internal combustion engines, petrol and diesel. Unusual design	Positioned as a 'city car' rather than eco-brand, but very low CO_2 emissions. Very isolated from the group
Toyota	Prius. 4 seat small saloon with unexciting design but highly innovative drivetrain	Petrol–electric hybrid presented as an (eco) efficient Toyota, fits with overall utility / reliability image
GM	EV-1. Electric powered with aluminium body. 2 seat, sports car styling	Only GM-badged car ever. Very isolated from the group. Leased, not sold.
Ford	Th!nk City. Unusual design electric vehicle, 2 seats	Positioned as an eco-brand within a multi-brand portfolio. Not mainstream technology. Related eco-products
Volkswagen	Eco-versions. Special version of models with VW badge, e.g. Lupo 3L. Not a radical technical departure	Small extension to the VW / Golf brand, treated in similar manner to GTI versions
Audi	A8, A2. Radical body design and material, otherwise conventional	Significant market differentiation not pursued

Source: Wells (2001).

in terms of market differentiation and technical differentiation in Fig. 3.1. Figure 3.1 indicates that no vehicle manufacturer has made the mistake of making strong environmental claims for a new brand without a substantive technical basis for such claims. Perhaps the most outstanding vehicle is the Toyota Prius, the first petrol–electric hybrid widely available on the market, but clearly presented as a Toyota rather than isolated within a separate brand.

Some vehicle manufacturers have remained outside the eco-brand debate by simply not contributing a product in this manner directly to consumers. This is not to say, however, that these vehicle manufacturers have no strategy per se, but rather that they have sought to integrate environmental concerns into all aspects of their existing products and operations. The danger with this strategy is that it is not particularly visible to consumers, or indeed that the efforts made are simply not sufficiently substantive.

High market differentiation/Low technical differentiation	High market differentiation/High technical differentiation EV-1 Th!nk City Smart
VW Eco versions Other bi-fuel cars Low market differentiation/Low technical differentiation	Toyota Prius Audi A8 Audi A2 Low market differentiation/High technical differentiation

Fig. 3.1 Market and technical differentiation for selected eco-models. Note: horizontal axis represents technical differentiation; vertical axis represents market differentiation.

Figure 3.1 also shows a basic rule in operation: the more esoteric the technology, the more likely it is to be separated from the existing brands – with the notable exception of Toyota. The Eco versions of various VW models have some unusual features, but are otherwise similar to the mainstream model. On the Lupo 3L, for example, some lighter body closures are used. On some Eco versions the engine cuts out while the car is coasting or at rest and then restarts when the accelerator is applied. Other manufacturers have also used the 'eco' label on engines or specific versions of their models, generally applied to the most fuel-efficient version in the range. Similar comments apply to the use of alternative fuels in cars, liquefied petroleum gas (LPG) and compressed natural gas (CNG) being the main examples. This sort of usage dilutes the message. While radical alternative technologies are scarce and infrequently applied, the strategy of creating a distinct brand makes some sense. However, it is clear to any observer of the automotive industry that there are a host of technologies becoming available in the near to medium-term future. These include, for example, fuel cells (however actually powered), various types of hybrid, and several competing alternative fuels from LPG to Bio-diesel (see also Chapter 6 and Chapter 7). Beyond these technologies, there remains scope for pure battery drive, super-capacitors and flywheels. In the world of the automotive industry it is likely that many, if not all, of the models within the range of a large vehicle manufacturer will have several choices of powertrain in the future. Each type of powertrain will be able to make distinct claims as to ecological performance.

3.5 Environment, technology and the creation of new market segments: the example of the TH!NK @bout London project

Electric vehicles have been on the threshold of market acceptance since the 1920s, when they were finally displaced as viable automotive technology by the internal combustion-engined vehicle. In the early years of the automotive industry, particularly in the US, electric vehicles offered real advantages over the internal combustion engine, but this was not destined to last. In those early days the noise, unreliability and difficulty of starting petrol engine cars made them unattractive, especially for women drivers in urban America. Even Henry Ford's wife drove an electric vehicle! In some niche markets pure electric vehicles remained competitive: US golf carts and UK milk delivery vehicles for example. Since the 1920s, however, electric vehicles have not been an attractive technology (see Chapter 6). One of the main reasons for this is because the technical limitations of batteries have meant that the electric vehicle has been little more than a battery on wheels, barely able to transport its own weight over anything other than an extremely modest range, let alone people and their possessions.

In Europe, the most notable experiments with electric vehicles have probably been those of Peugeot at La Rochelle, France and Coventry, UK as well as that of the Swiss town of Mendrisio. However, the Peugeot experiments took the financially expedient route of utilising existing mainstream vehicle bodies and fitting them with electric powertrain systems. Such an approach provides a platform for learning about driver usage of electric vehicles, and about the performance of electric vehicles in 'normal' use, but cannot be said to advance the market as such. Unfortunately, lightweight vehicles and advanced battery technology only serve to further increase costs.

Herein lies the basic problem for electric vehicles to date. While the technologies behind electric vehicles have improved, and while body structures have become lighter to allow greater payload (or better performance) relative to vehicle weight, market expectations are fundamentally shaped by two factors that need to be faced:

- The market context within which electric vehicles might be deployed, including features such as climate, topography, road infrastructure, regulatory regime, etc.
- The embedded expectations and prejudices of consumers, both private and corporate, with respect to electric vehicles and in the light of their mainstream experience with internal combustion engine vehicles.

In other words, technology itself is not enough. What is required is a viable business plan, a marketing strategy that matches the technologies of the electric vehicle to market conditions and expectations. The question is, does the Ford TH!NK @bout London project achieve this? The TH!NK @bout

London project was launched, somewhat unfortunately in terms of attracting media attention, on 11 September 2001. It represents a significant initiative by Ford that appears to combine market testing with public relations.

In all, 15 TH!NK City cars have been made available by Ford to selected users in London. TH!NK @bout London has two levels of partnership. First are those organisations involved in setting up and running the project for the 36 month anticipated duration. Second are the participating partners selected to have the vehicles in their fleets. The primary partnership is one involving Ford, Kwik Fit, Hertz (all Ford companies), Energy Savings Trust, TransportAction PowerShift (a UK government agency to promote the use of alternative fuels in vehicles) and London Electricity. In addition the TH!NK @bout London project was developed from the outset in consultation with Friends of the Earth, the NGO concerned with lobbying on environmental matters, the Greater London Authority, London Mayor and Transport for London, and with participating London boroughs. As such, the project demonstrates many of the attributes of strategic niche management (SNM) advocated by some proponents to provide a nurturing context for innovative technologies (see Chapter 16).

In this framework, Hertz (a major car rental company) provides the vehicle management expertise, while PowerShift provides grants to enable some of the costs of the vehicle to be offset. London Electricity will provide fully certified, matched 'green' energy for the electricity used by the cars during the project: hence Ford is able to claim the project is carbon neutral.

What is particularly interesting about the TH!NK @bout London project is the manner in which Ford has sought to be inclusive, to gain the support of key stakeholders in advance of putting the cars onto the streets of London. This strategy is also reflected in the choice of organisations to run the vehicles. These 'partner' companies were selected from an initial list of 50 applicants with the choice based on vehicle usage patterns and overall environmental credentials. These partner companies include British Telecommunications, Sainsbury's, The Body Shop and the BBC as well as several smaller companies. A key partner is the Government Car and Despatch Agency (GCDA), an executive agency of the Cabinet Office that is the primary supplier of transport and mail services to government departments. As a result of this approach, Ford has been adept at obtaining the endorsement of key figures and opinion formers of enormous benefit to the company as a whole – above and beyond the information gained by running electric vehicles in the real world. Such endorsements include: 'TH!NK @bout London shows how a leading motor manufacturer can contribute by introducing cleaner, more efficient vehicles. Friends of the Earth congratulates Ford on this initiative which we hope will be a blueprint for similar schemes throughout the UK and Europe' from Roger Higman, Friends of the Earth (Verstappen, 2002), whilst Ken Livingstone, Mayor of London stated 'What we've seen here, what Ford has done, is I think an example of how we should tackle all the difficult potentially divisive issues of the environment . . .' (Verstappen, 2002). Chris Leslie, Parliamentary Secretary, said 'It will have an immediate impact on the local environment in Westminster by replacing a diesel powered van used to provide deliveries of official documents to government buildings . . . the TH!NK vehicle is an innovative solution to the needs of city-based organisations such as the Cabinet Office' (ENN, 2001).

The TH!NK @bout London project illustrates quite clearly how markets are shaped, and even designed. With a new product concept such as the TH!NK City this shaping is more overt, and more obvious than usual as the market is created. In particular, it is evident that the product needs a supportive context in order to overcome perceived performance disadvantages and that the building of political and business coalitions is vital in the creation of that context. It is no accident, therefore, that: the TH!NK City attracts central government support from the PowerShift programme; qualifies for zero road fund licence; has exemption from the London Congestion Tax (at £5 per day); and qualifies for free car parking in the central London area. Participating companies such as Kwik Fit and Sainsbury also provide recharging sites (twelve and four respectively), thus marking the first steps in the creation of an electric vehicle infrastructure. Furthermore, the participating companies, government organisations and others are all able to present their participation as their contribution to meeting environmental pressures, which enhances their credibility. This makes it a typical example of the concept of strategic niche management (SNM) discussed earlier and in Chapter 16.

This explains the combination of marketing and public relations. It is not surprising therefore that within Ford the TH!NK @bout London project was promoted by staff from Governmental Affairs. This is an important lesson for any company that desires to promote an alternative automotive technology. It is insufficient simply to place such a vehicle on the forecourt, in the manner of the 'better mouse trap' and expect consumers to beat a path to the door. On the contrary, the important task is to build a political consensus behind the technology, to create the conditions or the context that will make the marketing possible. The timing of the two phases (political context building followed by real marketing), is of course difficult. Ford initially envisaged the TH!NK @bout London project to last 36 months (but in two 18 month periods, hence allowing the possibility of early termination). Ford expected to take the project to other urban areas in the UK and Europe, and it may be the case that cities such as Rome and Barcelona are better suited to electric vehicle use than (the relatively cold and dark) London as battery performance declines rapidly at lower temperatures.

Given the poor publicity Ford generated over the ending of car assembly at the Dagenham plant near London, the positive image generated by the TH!NK @bout London project was most useful to the company. It was a bold move, but also an astute attempt to create the market for electric vehicles. The numbers of vehicles concerned are tiny: 15 electric vehicles do not a sales boom make. It is interesting that Ford quoted its Chief Executive as saying: 'Ford once provided the world with mobility by making it affordable, we want to continue to provide mobility by making it sustainable' (Bill Ford, quoted by Verstappen, 2002).

This is a laudable aim, one that the automotive industry as a whole has to embrace. Yet within weeks of this statement it was announced that Ford was to sell the TH!NK factory in Norway (though it might keep the brand name). Rather than marking a new beginning in the story of the battery electric vehicle, TH!NK has become another false dawn – or possibly an illustration of the inability of the established automotive industry to create a viable new business model.

3.6 Conclusions

Market characteristics in the automotive industry are obviously vital to the future of the industry as a whole. This chapter has demonstrated that at a global level, market growth has not been as strong as anticipated, though future prospects for growth remain reasonable. In addition, in the established markets there is clear evidence of fragmentation as more models and variants are added. Market stagnation and fragmentation pose significant challenges to traditional vehicle manufacturing. This process is likely to continue with the addition of new technologies and, probably, new brands. Given the example of TH!NK discussed above, it is clear that the industry faces many challenges in the introduction of new technologies to meet environmental concerns.

3.7 References

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4

From manufacturers to responsible mobility providers

> *Like it or not, the responsibility for ensuring a sustainable world falls largely on the shoulders of the world's enterprises . . . corporations can and should lead the way, helping to shape public policy and driving change in consumers' behavior.* (Hart, 1997)

4.1 Background

Traditionally, car manufacturers have had little interest in what happens to a vehicle once it has left the factory gate. This has been changing, due to new types of legislation and to a change in the expectations of consumers, citizens and regulators. The relationship with dealers forced a limited interest in post factory gate issues, followed by the need to provide ever longer warranties. Next, mandated recalls forced manufacturers to take a deeper interest in their cars once in the market. After-market sales of parts have always provided a steady income stream; however, after a few years, manufacturers rarely considered their products of much interest, and few had museums to house their oldest products. Companies moved on, new models superseded old ones and the next generation was under development.

To be fair, some manufacturers had already expressed greater interest in in-use issues. Declining profitability at the manufacturing end of the business prompted many car makers to look for profits downstream. Finance, insurance and recovery services all provided such opportunities. By the late 1980s and early 1990s some manufacturers had begun to state publicly that they were beginning to think of their business as that of 'mobility provision', rather than just making cars. However, practice still lagged well behind, and although boardroom thinking may have moved in this direction, the message rarely moved to the frontline of the customer interface. In this context, the European End-of-Life Vehicles (ELV) Directive is a more dramatic departure than is perhaps appreciated.

4.2 The EU ELV directive – forcing manufacturers to take a whole-life view

The driving force behind the ELV directive is environmental concern. Initial German enthusiasm for producer responsibility for end-of-life vehicles in the early 1990s was prompted by the fact that Germany expected to run out of landfill capacity by the year 2000. The German Government did appear to get cold feet when the implications for its crucial vehicle manufacturing sector became clear, especially as by that stage a former VW supervisory board member had been elected chancellor. The landfill pressure still exists and has only been relieved by exports of waste to other countries, waste dumping at sea and, to some extent, exports of used cars from Germany. Nonetheless, waste taxes and restrictions within Germany are among the strictest in the EU. In many towns and cities, families and businesses pay a waste tax in proportion to the amount of waste produced. As a result, consumer pressure on shops and manufacturers to reduce unnecessary packaging is considerable.

Although officially classified as hazardous waste since the early 1990s, cars are already among the most recyclable and recycled of consumer products. However, their sheer size and bulk as well as their relatively short lifespan compared to other complex machines (e.g., machine tools, aircraft, ships) has created a steady waste stream of considerable proportions. Whilst in the past this consisted mainly of easily recycled ferrous metals, technical developments have changed this. On the one hand, the aluminium content has increased, making recovery more lucrative. On the other hand, the content of plastics, glass, rubber and coated steel has also increased considerably and this has made the extraction of valuable and recyclable material more onerous. In addition, factors such as the dumping of cheap steel by the former USSR and others has depressed the value of ferrous scrap so much that metal recovery has become less profitable. As the business becomes less profitable it also becomes more of a test of manufacturers' commitment to ELVs and 'product stewardship' – the concept whereby a manufacturer remains responsible for his products during their entire useful life, and beyond.

4.3 Selling the package: a wider view of costs

The motor industry's business model, as currently defined, is far removed from product stewardship, focusing as it does on the sales of new cars. Over the years, various other elements have been added to this, notably car finance, insurance, accessories and replacement parts. These can all be controlled to some extent by the manufacturer. Via its dealers – usually, though not always, separate, independent businesses – the industry has been able to offer service, repair, body repair, used car sales and trade-in. As the ties between manufacturers and their dealers are gradually loosened by the EU Commission via the 'bloc exemption' regime (now regulation CE nr. 1400/2002 of 31 July 2002), manufacturers have less control over these aspects of the business. More recently, however, the industry has also increasingly used a leasing type model, rather than outright sale. This format was first used by businesses needing vehicles but reluctant to take on the overhead implications. In the UK, many individuals benefit from company cars provided by their employers, thus separating ownership from use for many families. Most of the UK new car market involves cars sold to businesses for this purpose. In recent years this type of package has been made available to private customers as a personal lease.

In the US, personal leasing is now the most common type of new car ownership package. The 'buyer' does not become the owner of the car at any point, but, at the end of the lease, can use the car as down-payment for another lease. Alternatively he or she can buy the car for a previously agreed sum. More recently, some firms have been considering a pay-per-drive type of package whereby the user would pay only for time/miles actually driven, whilst otherwise having full access to the car. This can be compared with car sharing schemes (see below). These systems make the costs of car use far more visible than conventional ownership, whereby the cost of any drive is marginal to the cost of ownership, which is incurred anyway, however many miles are driven. If introduced, such a package would be a further step on the route to mobility service provision.

Consumers tend to regard the purchase cost of a car (particularly a used car) as a sunk cost. Rarely is depreciation an explicit factor in the cost-per-mile calculation, at least in the mind of the private consumer. The consumer regards the cost of insurance, vehicle recovery, repairs for passing periodic testing, etc. in a similar manner. The cost of a trip is then regarded purely in terms of the marginal cost of petrol. Recently, however, changes in the nature of the company car market in the UK, along with shifts in consumer attitudes, have helped to create a different view of costs – at least among some consumers. This change in attitude is reflected in the notion of selling the 'package' or the 'bundle' of the car and associated services, usually for an all-in single price. The extent of the bundling can vary, but can include:

- finance for the vehicle, often with attractive packages such as zero interest or deferred payment;
- roadside recovery and breakdown assistance;
- 'free' servicing for three years;

Table 4.1 Cost comparison of privately-owned cars vs. car sharing schemes in The Netherlands

Costs	Private car (Dfl)	%	Car sharing (Dfl)	%
Fixed				
Depreciation	230	30	–	–
Interest	90	12	–	–
Insurance	145	19	–	–
Taxes	45	6	–	–
Other	25	3	–	–
Subscription	–	–	10	2
Variable				
Fuel	140	18	125	28
Maintenance and repair	95	12	–	–
Additional kms charge	–	–	55	12
Rental costs	–	–	260	58
Total	770	100	450	100

Source: The Netherlands Consumer Association, as quoted in Meijkamp (2000: 47).

- extended warranty;
- road tax for a defined period;
- insurance for a defined period.

This concept of bundling can also apply to car-clubs or car-sharing schemes. Such schemes are already reasonably well-established in continental Europe, particularly in urban areas of Germany and Switzerland, and are spreading into The Netherlands, Austria and Scandinavia (Meijkamp, 2000). Some now also exist in the UK and the US. Meijkamp has made a detailed study of such schemes as they operate in The Netherlands, as set out in Table 4.1. Meijkamp's analysis is based on actual data derived from real people's use of a number of car sharing schemes and can thus be regarded as realistic, at least within the Dutch context. This makes clear that these schemes give relatively cheap access to motoring. In the UK, fleet or corporate buyers are more used to buying 'bundled' motoring services, and are also more used to basing such decisions on the all-in cost per mile. There is no doubt that the original equipment manufacturers (OEMs) themselves have been moving in the direction of offering a transport provision package, although none of them is quite there yet.

Across the industry as a whole, it is apparent that the largest share of total profits made globally lies in aftersales (i.e., all service and sales activity beyond new car sales). Another way of looking at this is to consider the new car almost as a loss leader. The car then generates revenues as it is in the market. The car might be recovering the basic fixed and variable costs of production, no more. This is an approach commonly taken on the truck side. It is also worth considering the turnover and profit generated at the dealership level in the automotive industry. Table 4.2 illustrates the relative

Table 4.2 Turnover and profit flows for the average car and average dealership (UK)

Item	Turnover (£)	Profit (£)
Purchase	13 000	400
Bonus		500
Finance		300
Accessories	200	70
Yr1 service	150	100
Yr2 service	250	200
Yr3 service	300	250
Body shop	200	150
Mechanical repairs	400	200
Total	14 500	2170

Source: CAIR.

profitability of the car in use as opposed to the sale of the new car itself (the aspect of the used car trade-in is not considered here).

In other sectors there are already well-established models of totally service-based product access. One example is the photocopier market, where corporate users rarely buy the machines outright. Instead they lease them under a total maintenance package. The machine remains the property of the manufacturer or a service and leasing company. This highlights the fact that what the user seeks is access to a particular use of the machine, rather than the machine itself.

Leasing is becoming increasingly popular as a means of having access to capital goods. According to Seidel and Richter (2001: 221–2), in Germany in 1998, around 20 % of all investment in equipment by business was in the form of lease; for the UK the figure was 29 % and for the US 31 %. Since then, these figures have only grown. In the UK, 90 % of company vehicles are leased under a full-service contract, compared with 75 % in France and only 18 % in Germany (Seidel and Richter, 2001: 223). They see this trend as essential for the future of the industry: 'Making total mobility available will be the characteristic for differentiation. This includes the transfer of use of the vehicles and their integration into a total mobility concept' (Seidel and Richter, 2001: 226).

However, these Arthur D Little employees still have a quite limited concept of the future of the car industry, far removed from the product stewardship approach advocated by Deutsch and others. Deutsch (1994) highlights the move from product to service provision and puts it in an environmental perspective. His NEC case study (Deutsch, 1994: 142) explains that one of the advantages is that of manufacturer responsibility for the end-of-life process; the know-how thus gained can be used for new product development and can ultimately give the manufacturer a competitive advantage. The re-use of old equipment advocated by Deutsch is still rare in the automotive sector; this issue is discussed in Chapter 11.

Clearly the move towards full service provision, even a pay-per-mile transport service provision embodying a range of transport modes is one aspect of a future automobility. The MCC Smart is innovative not only as a product, but also as a package offered in some markets. In Germany and Switzerland, for example, ownership of a Smart also buys free or cheap parking at railway stations and cheap rental of another Smart at the owner's destination. In the UK, some train operators have also introduced special low rates for parking Smarts at stations. These are first tentative steps towards an integrated mobility provision package. It is a response not only to perceived customer needs, but also to social pressures on the car and the industry that makes it.

4.4 The car industry responds to the new agenda

In the 1980s, corporate boardrooms were often dominated by the concept of shareholder value – optimising the return on investment of the firm's direct financial stockholders. Although this thinking still persists in some companies, more and more are beginning to develop a broader perspective and to take a 'stakeholder' approach (see Section 4.5). To be fair, there are companies that have always had this policy, but most have not. Initially, the driver for change was the need to cope with growing environmental pressure, while more recently the social considerations have grown in importance, in line with the growing importance of the sustainability agenda. In some countries such as Japan and also many European countries, firms have always been aware of their place in society and consequently of their responsibility towards it. The individuals within a firm are all members of that society.

Japanese companies have always attempted to be good corporate citizens in whatever community they choose to settle; this came to the fore with the establishment of Japanese 'transplant' operations in North America and Europe. It is interesting that although Toyota's practices in manufacturing – the Toyota Production System – have found a ready audience in the West through 'lean production', its activities as a responsible corporate citizen have not had the same impact. Yet by many measures Toyota should be regarded as one of the world's most successful car makers. Though it is not the biggest, it is certainly the wealthiest. This success must be due to the totality of its approach to business, rather than merely its manufacturing prowess. It is perhaps typical of a western way of looking at things that we have taken a reductionist approach to analysing the success of the Japanese, rather than trying to understand the totality; the whole.

Although the product quality and manufacturing efficiency improvements over the past few decades can largely be attributed to our study of the Japanese car makers, the origin of the new interest in corporate social and environmental responsibility is probably due more to home-grown pressures. It became clear over time that merely complying with environmental regulation did not silence many of the industry's critics. More was needed to achieve this. Frankel (1998) distinguishes three phases in corporate environmentalism, as follows:

1. First era: compliance – meet regulatory requirements;
2. Second era: corporate environmentalism – large environmental incidents, particularly affecting the chemical industry, made firms realise compliance was not enough;
3. Third era: beyond compliance – to qualify as forward thinking, companies had to exceed regulatory requirements.

Many such typologies exist and most are of limited value, however the term 'eco-efficiency' is then associated with this third phase (e.g., Mauser, 2001: 12). This term was introduced by the World Business Council on Sustainable Development. This was associated with the win–win concept; greener business practices were not a cost, but could be beneficial for the bottom line. A classic example is more efficient use of energy, which reduces the need for fossil fuel, reduces pollution and reduces costs for the business at the same time; the environment wins, as does the company. However this is not the answer either, as once the easier targets are achieved, further progress may be less obviously or less immediately profitable.

The automotive sector is close behind the chemical industry in terms of visibility and impact. The petro-chemical industry is closely linked with the automotive as well. These sectors have therefore been among those in the forefront of these developments. In this study we focus on the vehicle manufacturers primarily, but it must be remembered that incidents such as the *Exxon Valdez*, Brent Spar and other issues linked with the oil sector are also closely linked with our desire for automobility.

4.4.1 Environmental and social reporting

On the car side, tentative moves to a more proactive approach to the environment emerged during the 1980s. Some early environmental reports and statements appeared at this time, prompting Volvo, famously, to admit that its products pollute. Volvo has long been a leader in this field, due to a combination of factors, among them its Swedish base and its history in passenger safety. It is often assumed that environmental improvements are concerned only with human health, rather than the health of the planet, and safety and environment can thus easily be linked.

In the late 1990s, Volvo took the radical step of publishing environmental product declarations or EPDs for its new products (Volvo, 1998). These gave a fairly detailed account of the environmental impact of each of its models. The declarations are informed by Volvo's own EPS (Environmental Priority Strategy) system, which is based on a life cycle approach to assessing materials and processes. The product declarations are independently certified by Lloyd's Register Quality Assurance and stand close scrutiny, complying with all relevant environmental standards.

As the sustainable development agenda developed, car companies started to incorporate social elements in their reporting. This trend received a further boost from CERES, the Coalition of Environmentally Responsible Economies. This is a US-based association of companies and organisations that want to be proactive in their environmental and social management. In the late 1990s, CERES proposed a set of guidelines for companies to follow in their environmental and social reporting, the Global Reporting Initiative (GRI). The GRI is now administered – separately from CERES – from a base in Amsterdam. Environmental and social reporting is a first step, it does not in itself make a company green or socially responsible. However, it sets targets and standards, which make it easier for individuals and departments in the company to move forward their own agendas for greater environmental and social awareness throughout the organisation.

A couple of reports can be used as examples of the nature of such reports emanating from the modern automotive sector. First of these is Vauxhall's 1999 environmental and social report (Vauxhall, 2000). This UK branch of General Motors has long ploughed a lone furrow in environmental terms within GM, particularly under its charismatic CEO Nick Reilly, who left Vauxhall in 2002 and was put in charge of reviving GM's new acquisition, Daewoo Motors, in South Korea. The report includes the basic financial and operating data found in a conventional company annual report and accounts. In addition, it covers a range of sustainability parameters. Among these are sections on engagement with stakeholders, various environmental indicators, and GM's adoption of the Global Sullivan Principles. The Rev. Louis Sullivan is a former GM director and his principles act as a guide for companies in the areas of human rights, workers' rights and other social and environmental aspects of the global business.

The sections on the environmental impact of Vauxhall's products and processes contain considerable levels of detail, including a table (Vauxhall, 2000: 76) similar to Volvo's environmental product declarations. Although the report is not independently audited in the manner of the Volvo EPD, it does contain an insert with reviews and assessments from three independent authorities, namely: motor industry academic Prof. Garel Rhys, director of the Centre for Automotive Industry Research at Cardiff University; John Monks, General Secretary of the Trades Union Congress; and environmental consultant John Elkington, chairman of SustainAbility.

Probably the most significant of recent reports is Ford Motor Company's *Connecting with Society* (Ford, 2000). Ford describes it as 'its first corporate citizenship report'. This goes much further than any previous social or environmental reports in its broadness of approach and, to some extent, its honesty and openness. Illustrative for the latter is the paragraph on alleged racial harassment at Ford's Dagenham plant in the UK, covered in the report's Diversity section. Another example of this openness is Bill Ford's widely publicised criticism of sport utility vehicles. These light trucks now make up over half of new private sales in the US, but have been widely criticised for their weight and aggressiveness leading to high fuel consumption and high fatality rates. The issue is mentioned in an interview with Bill Ford incorporated in the report, as well as being given a dedicated 'case study' (Ford, 2000: 81–2). The case study highlights Ford's dilemma: 'SUVs are a competitive strength for Ford . . . and on a per unit basis, SUVs contribute more than many other vehicles to the Company's bottom line . . . However, sustainability concerns associated with SUVs raise issues relative to Ford's corporate citizenship commitment . . .' (Ford, 2000: 81).

Ford's solution is to offer SUVs that are better, more fuel efficient, more recyclable and with lower emissions. In addition, Ford is looking for systems to reduce their impact on other road users. It urges customers looking for an SUV to choose the Ford over the competition, in view of this better performance. The report also highlights stakeholder engagement, Ford's efforts in alternative fuels and powertrain, as well as the limits of automobility – all a far cry from most documents emanating from Detroit in the past. Something is changing in corporate America.

4.5 Corporate social and environmental responsibility

The strategy of companies to look beyond the factory gates and the boardroom and consider their wider place in society has become known as 'corporate social responsibility' (CSR), whereby the social also captures the environmental. The definition 'Social responsibility in business refers to an organisation's obligation to maximise its positive impact on stakeholders (customers, owners, employers, community, suppliers, and the government) and to minimise its negative impact' is given by Ferrell *et al*. (2000: 71).

Carroll (1991) proposed the so-called pyramid of CSR, since used in most texts on the subject. This identifies the different levels at which a company can engage with society, as follows:

1. Economic: the basis of the pyramid; responsibilities: to be profitable;
2. Legal: obey the law;
3. Ethical: do what is right;
4. Philanthropic: the top of the pyramid: be a good corporate citizen.

Carroll (1991: 43) then goes on to define CSR as '. . . the total corporate social responsibility of business entails the simultaneous fulfilment of the firm's economic, legal, ethical and philanthropic responsibilities'. However, the elements of the pyramid can very much be seen as degrees of social engagement along a continuum. What Carroll emphasises through his pyramid is that firms should not forget about the basic requirement to make money and obey the law – these form the foundation of the pyramid. Beyond this the company has greater flexibility, although to be socially acceptable it needs to take into account at least its ethical responsibilities, which Carroll (1991: 41) outlines as follows: 'Ethical responsibilities embody those standards, norms, or expectations that reflect a concern for what consumers, employees, shareholders, and the community regard as fair, just, or in keeping with the respect for and protection of stakeholders' moral rights.'

None of this is rocket science; most people in a corporate environment will be at least passively ethical in their approach to life. Yet, we have seen that other elements such as greed or corporate survival can often override these fundamental ethical concerns. As Frentrop (Meeus and Ramaer, 2002) points out, the habit of management to mislead shareholders for personal or corporate gain dates back to at least the early seventeenth century. Thus, business has to actively try and take on board the CSR agenda, something it will do if the threat of not doing so is too high. Press, public opinion and NGO activity are the key to this through their ability to affect the market position and, hence, sales of a company and its ability to raise money. However, ethical businesses are probably able to operate at a lower cost as well – corruption can be expensive and inefficient.

Another area of contention is the definition of a stakeholder. Chryssides and Kaler (1996: 71) argue that '. . . a company exists for the benefit of all those who have a "stake" in it.' This seems of limited use. We could define a stakeholder as any individual or group in some way affected by the activities of the company, and who therefore can be said to have an interest or 'stake' in those activities. The quote from Ferrell *et al*. (2000) given above already outlines some of these groups. However, a trawl through the literature will rapidly expand this group to suppliers, customers, employees, shareholders, management, local government, neighbours and local community, people living downstream or downwind. We could also include consumer and environmental NGOs, trade unions, insurance companies, local media, national governments, people affected by the transport of goods to and from the site, etc.

The number of potential stakeholder groups can easily proliferate, but to what extent could and should a company accommodate this diversity of interests? Should representatives from all these stakeholder groups be represented on the board? Should they be ignored entirely and allow the company to carry on unmolested? Unfortunately, companies cannot ignore pressures from society. They have found that however much one spends on complying with all laws and regulations, a surprise attack can come from regulators or democratic institutions – as when the European Parliament threw out the carefully prepared emissions standards from the Commission in favour of standards based on US87 in the early 1990s (Nieuwenhuis, 1994: 99). Surprise attacks can also come from NGOs or single issue pressure groups. Brent Spar is a classic example, leading to Greenpeace Germany calling for a boycott of Shell petrol stations – an expensive mistake by Shell when they had the law and science on their side.

In practice, companies have responded by engaging in ongoing dialogue with the various stakeholders. This can happen formally and informally and allows problems and potential disputes to be diffused before they become a threat. Alternatively, through such a process of stakeholder engagement, firms can be forewarned of a threat in cases where no agreement is possible. Yet firms can still be caught by surprise, due to the fundamental difference in world view of many corporate decision-makers, compared with those stakeholder groups that can pose a threat. Few companies, for example, have thus far identified the so-called anti-globalisation movement as a threat. Its agenda is explained in Chapters 13, 14 and 18, for those who might want to change their view of this potential threat to their businesses.

4.6 Conclusions

We have tried in this chapter to analyse the process whereby the automotive industry has begun to look beyond the factory gates. It has done this both in order to extend its business and recapture areas of greater potential profit as well as to engage more fully, or in some cases re-engage with society at large and face up to its environmental impact. Although in some cases this may be for idealistic reasons, increasingly it can be seen that by not doing so, management is putting the company in a position where it becomes more vulnerable to threats from various stakeholder groups. Such threats can have a severe impact on the business and its ability to access funds.

Conversely, studying environmental impacts makes corporations more aware of their social responsibilities and at the same time can inform stakeholders as to how business can make a positive contribution to society. Ordinary citizens, particularly in Europe and North America, have developed an increasingly cynical view of business and industry. This form of engagement can draw business and society closer together, whatever the motivation, to the benefit of both. In fact, some companies appear to have conveniently forgotten that they are social institutions, enjoying considerable protection under the law. Therefore, if they fail to serve social needs, as people such as Korten (1995, 1998) have argued, their legitimacy and thus their ability to operate will be lost. Hence there is a functionalist logic to the adoption of CSR that has less to do with stakeholders than with traditional shareholders.

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5

Sector shift, inter-sector dynamics and futures studies

I took the idea of the larger paradigm to mean that the answers we are looking for are not always in the obvious places, as the overall equation is fundamentally influenced by other, often less than obvious, considerations. (Gillespie, 2001, ix)

5.1 Introduction: the question of sector shift

It is often difficult to establish exactly what makes change happen in an industry. There is always a tendency to fall into the trap of post-hoc rationalisation – that the observed outcome was in some sense rational or inevitable. Equally, we can become prisoners of our organising concepts, often used loosely and without clear thought, sometimes used deliberately to delimit the problem. Similarly when change to a sector is considered, particularly in terms of competition, the emphasis is on the internal dynamics. Consideration is given to the realm of microeconomics, the competitive behaviour of firms within the business environment. Yet the 'long wave' school of economic analysis (Schumpeter, 1939; Freeman *et al.*, 1982; Dosi, 1982), while in some respects contentious, at least instructs a distinction between the normal processes of inter-corporate competition within a sector, and the radical upheaval caused by a sector being rendered redundant or transmuting into something qualitatively different.

While the automotive industry appears to represent a relatively cohesive and coherent sector there is plenty of ambiguity at the margins, particularly now that the industry draws more overtly from the realms of electronics, aerospace, financial services, retailing and chemicals. Put simply, car making used to be little more than a particular branch of 'metal-bashing', whereas now the world of the automotive industry is more complex. The history of the automotive industry is one of integrating multiple material and process technologies from other sectors of economic activity such as armaments, bicycle production, railway rolling stock, coach-building and so on (Nieuwenhuis and Wells, 1997). After a protracted period of technological stability it might be the case that the automotive industry is in the process of reinventing itself as a sector, though the characteristics of that reinvention cannot be entirely determined or forecast in advance – they will arise from the interaction of competitive, social and political processes. Much may well depend upon historically and spatially contingent features that create and delimit the boundaries of the possible, bearing in mind that such boundaries may themselves be re-created.

Previous research has demonstrated that the automotive industry technology paradigm is based on two key aspects (Nieuwenhuis and Wells, 1997). While many observers would associate and define the industry in terms of the internal combustion engine, the all-steel body is possibly of greater significance in defining the economic structure of the industry. In particular, the all-steel body is the central factor in determining economies of scale and the capital intensity of production. From this perspective, it is difficult to accept that developments such as the '3 day car' (Kiff, 2000), team-working, or indeed lean production generally (Womack and Jones, 1996) constitute a dramatic change to the industry as a whole. These are the techniques of efficiency enhancement and productivity growth (Holweg *et al.*, 2001; Holweg and Pil, 2001), sometimes of mere financial re-engineering, but they do not in our view constitute a radical shift in the character of the industry.

This is not to deny the competitive significance of the developments noted above or others in a similar vein, but from a historical perspective these are refinements of the essential structure founded on the twin core technologies of the internal combustion engine and the all-steel body. Herein the automotive industry embodies a debate that transcends society; should the existing system or way of doing things be made more efficient, or is the system itself the problem? This chapter therefore considers the future of the automotive industry as a sector from a somewhat broader perspective, grounded in the relationship between production and consumption that is at least in part determined by the fundamental attributes of product and process technology. Ultimately it could be argued that the difference between incremental and radical change is impossible to determine in precise empirical terms. It is at best difficult to decide whether a new event or development constitutes a further step of incrementalism, or the radical start of a new era.

Does the distinction matter? Again, this is a difficult issue for many concerned with environmentalism, ecology and social change. For some, incrementalism is non-disruptive progress towards some desired goal; an improvement of that which exists to something better. This is the argument in support of eco-efficiency. For others that very incrementalism, while it may indeed ameliorate existing problems, does little to challenge the heart of those problems. According to Hukkinen (2001), eco-efficiency assumes that concern for the environment can be de-coupled from material dependency on ecosystems. Indeed, incrementalism may be counter-productive because it delays the ultimate 'day of reckoning'. The conceptualisation of the question of sector shift and of futures studies is therefore important, because the starting point of analysis determines to a large extent how problems are defined and therefore how solutions are elaborated.

A basic contention underlying this book is that those examining the automotive industry in conventional terms will be unable to appreciate the significance of the challenge posed by sustainability. This problem is often evident by those that frame calls for publicly-funded research – the most recent example being the EU FP6 programme. This programme has one stream of research on 'sustainable mobility' but with a narrow emphasis on alternative powertrain and fuels technologies rather than a consideration of the economic, political and business structures that have to emerge around these new technologies. The assumption is that the sector is a sort of vessel into which new technologies can be poured with no change to the economic structures that define this vessel. Even a cursory glance at the global automotive industry would reveal that the structure of the industry has changed much more radically and quickly than the core technologies over the last 50 years, so this assumption of 'non-change' is highly suspect. Significant changes in technology – which have already been proposed – will inevitably lead to significant changes in the structure not only of the industry, but of the wider paradigm of which it forms the principal element.

5.2 Futures and multi-discipline thinking

There is an underlying argument that futures studies, as an area of academic endeavour that is inherently multi-disciplinary and forward-looking, is a 'natural home' for those interested in sustainability. Nowhere is this more important than in the realm of business strategy and management theory where the existing methodologies rooted in an unholy alliance of positivist economics and 'best practice' case studies are unable to provide a radical vision for the relationship between business and society. In some respects this is not a new claim. After all, Schumacher (1973) argued that neoclassical economics was flawed in that it treated 'natural' capital (i.e., natural resources) as free. Many more have followed him and some of their arguments will be reviewed in later chapters. The argument applies to the automotive industry, a sector that exposes the dilemmas of sustainability, and that has also often been the source of 'guru' thinking. In this sense the automotive industry exposes the limitations of traditional management science and business strategy.

There have been many attempts to define the character and boundaries of the activities collectively grouped under the term 'futures studies'. The power of futures studies lies in the scope for these approaches to escape the confines of sector analysis and incrementalism that finds an echo in the structures of academic thought and inquiry. It is in the nature of the evolution of human thought that as new fields of inquiry are created, often at the edge of two or more disciplines, so there is much debate as to whether any one theoretical position or research methodology can be considered within that new field of inquiry. In a review, Niiniluoto (2001: 376) provided the following assessment: 'I conclude that futures studies, when it combines the tasks of exploring probable and preferable futures, is a mixture of theoretical and empirical research, methodology, philosophy and political action. But at its core we find a design science, which attempts to help the rational planning of our future'.

This is a far-reaching definition of futures studies because it absolutely rejects the notion of value-neutral, politically agnostic scientific objectivity. As Niiniluoto argues, because *the* future is not singular when viewed from the present, but in fact a range of possible futures that are to some extent susceptible to choice, futures studies is inevitably political. In this respect, futures studies involves the rational selection of a preferred possible future based on knowledge (of what is possible; of the implications of the future selected; on the extent to which that future can be attained) and on preferences. Thus, there is a combination of scientific rationality and ethical values.

The combination of the multiplicity of futures available, and the notion of choice (a choice aided by the futures studies academic) is supported by other authors such as Malaska (2001) and Bell (1997). However, this does not deny the importance of cognitive understanding: '. . . we perceive and envision reality by our faculty of conceiving, thus attaining that perceptual contingent knowledge and understanding of the future reality' (Malaska, 2001: 227).

Hence, the advocacy of concepts such as micro factory retailing, which we explore in depth in Chapter 17, is more than objective rationality. It reflects a (value-based) desire to change the world in a manner that we believe is better. The cognitive understanding that is contributed in this book is derived from many years of study into all aspects of the automotive industry, from steel mills through vehicle assembly and on to distribution, sales and vehicle recycling. Over the years our research has embraced all aspects of the value chain, but also much of the external business environment in the form of, for example, government regulatory agencies, the insurance industry, consumer lobby groups and others. Equally, our research has embraced many different companies in many countries around the world. Moreover, from a functional or line-management perspective our research has included design, styling, purchasing, production engineering, advertising, strategy, logistics, finance, operations management, dealership management and much more.

5.3 Sustainability and multi-discipline thinking

As with futures studies, sustainability has been seeking a disciplinary shape and content by drawing together various other areas of academic effort. For example, industrial ecology can be seen as an attempt to draw from the natural sciences (biology, ecosystems) and from sociology, politics and economics (theories of the firm, industry and society) in a new and integrative manner (Parto, 2000). It is equally the case that different disciplines, in their own ways, lay claim to the territory of sustainability, with, for example, concepts such as ecological economics (Jordan and Fortin, 2002; Daly, 1992; Tisdell, 2001). Some leading thinkers and philosophers have been able to transcend the narrow confines of academic life to challenge the long-dominant Newtonian–Cartesian dominance of the way in which knowledge is organised, developed and enhanced. These philosophers have drawn attention to the contingent reality that while Newtonian–Cartesian thinking has been very powerful in dissecting the world and allowing knowledge to be created along many channels, the problems of the world today require a qualitatively different kind of knowledge.

Capra (1982: ii) explained: ‘We live today in a globally inter-connected world, in which biological, psychological, social and environmental phenomena are all interdependent. To describe this world appropriately we need an ecological perspective which the Cartesian world view does not offer’. The task of creating an ecological future is almost impossibly complex for any one individual to grasp, yet at the same time the multiplicity of actors in a dynamic interrelationship of change does achieve remarkable things. Some of the leading philosophers from the ecological movement recognise the enormity of the challenge: ‘The new vision of reality we have been talking about is based on awareness of the essential interrelatedness and interdependence of all phenomena – physical, biological, psychological, social and cultural’ (Capra, 1982: 287).

Unfortunately, academia itself is perhaps least well placed to confront the intellectual challenges posed by ecological crisis, social stress and the turbulence of contemporary economic life. Academic life has gradually been undermined by a host of interrelated features. These include the erosion of tenure (and hence the capacity for truly independent thought); the emphasis on ‘ivory tower’ academic life through features such as citation scores and the UK Research Assessment Exercise; the requirement to contribute directly to ‘user communities’ (i.e., those with funds, Government and large businesses); and the retreat into a defensive discipline-based mentality. The result is that, too often, academic output (including our own) is determined by conformism and convention.

Again, the cognitive value that we contribute in this book lies partially in the way in which our research work has, of necessity, tried to transcend traditional academic discipline boundaries. In a sense this is the inevitable result of concentrating on a sector rather than a discipline, or on a school of thought – though of course we too bring all manner of bias to the subject.

5.4 Management science, business strategy and the cult of the guru

The basic premise of management science has been to focus on one particular aspect of the corporation or the business environment. There is usually a combination of the following elements, not all of which need be explicit:

- The analysis is rooted in neo-classical economics with the assumption that market forces work to secure a social optimum distribution of scarce resources;
- Companies and other actors (such as consumers) are held to act in a 'rational' manner, by which it is meant that they pursue a narrow self-interest;
- Some companies (a limited number by necessity) are better at competing than others, and this is attributable to company-specific factors (chiefly management strategy) rather than spatially or historically contingent factors;
- Best practice can be defined, measured, recorded and transferred from one company to another, with the guru as the vector of change;
- Aggregate analysis that compares companies, countries, sectors, etc. assumes meaningful differences can be identified;
- The case study is the preferred means of studying best practice;
- Any competitive advantage so secured is necessarily temporary; management science secures its own existence through the doctrine of continuous change;
- The concept of time (long-term, short-term) is quite different from that employed in futures studies.

These are the basic, usually implicit, assumptions. Thereafter, all a company needs to do in order to ensure salvation is to follow the prescriptions of the guru. A classic example of the business or management fad is that of lean production (Womack *et al.*, 1990; Womack and Jones, 1996), though at least this concept had some substantive basis. There are some key problems with the guru approach to futures thinking in the business and management literature. These problems are embedded in the theoretical basis and methodological approach used; in effect they are endemic to the discipline and to this extent are illustrative of a discipline that has exhausted its usefulness. The very best that can be expected is that 'best practice' can be identified, measured and then implanted in another company or another place – no outright competitive advantage will accrue. This is the value and the limitation of benchmarking. Moreover, this approach is rooted in historical analysis, the post-hoc dissection of why and how company X prospered rather than company Y. It is retrospective and conservative rather than forward-looking. It is therefore not an appropriate methodology to create a genuinely new business model or competitive stance in response to a rapidly changing business environment.

5.5 The automotive industry: an illustration

As noted above, the automotive industry has long been a talisman of management science, not least because of the sheer size of the industry and its impact on the everyday lives of so many people. Henry Ford gave rise to the term 'Fordism' as the definition of standardised mass production and the wider corporatist contract between capital, labour and the state (and indeed the era of 'post-Fordism' that was held to replace this period). The automotive industry was an early example of the applied time and motion studies that came to be known as Taylorism. The industry was also in the forefront of other features of capitalism that have been associated with the twentieth century, including the divisional corporate structure; the use of brands to define the product–consumer relationship; the 'bean-counting' conglomerate in which financial considerations became paramount; the multinational and ultimately the global corporation; and more recently lean production, benchmarking and the ideology of waste reduction.

The contemporary automotive industry, while a source of wealth and employment as well as contributing to the movement of people and goods, generates huge environmental and social burdens. In this respect the industry is likely to again be a leading sector as a harbinger of changes to economic structures in general. The burdens imposed by the industry have been documented at some length (Keolian *et al.*, 1997; Williams *et al.*, 1994; Nieuwenhuis and Wells, 1994, 1997), though new burdens continue to emerge. The industry has exhibited three aspects of the attempt to resolve sustainability problems that are found more widely in other sectors:

- a partial attempt at problem solving, classically with so-called 'tailpipe' solutions;
- an unwillingness to resolve more fundamental structural problems with the industry;
- a tendency to see 'sustainability' problems as essentially environmental and hence resolvable through the technologies the industry employs.

There has been exhaustive life cycle analysis of the industry undertaken (see, for example, the work carried out under the auspices of USCAR to determine the life cycle environmental burden of steel, plastic and aluminium). The industry has been put through successive tightening of emissions regulations, and is increasingly being pressured to meet improvements in CO_2 emissions. As is shown in Chapter 12, there are all manner of 'green' car rating systems, green car taxation systems and other attempts to shift the priorities of the industry. Perhaps the huge attention devoted to the transformational potential of the fuel cell electric vehicle is testimony to the assumption that this single technology will resolve the quest for sustainability (see Chapter 7). On a lesser scale, this is also reflected in the focus on fuels and engines (Comeau and Chapman, 2002); while changes in these may yield substantial environmental benefits, they do not constitute a resolution of all the dilemmas the automotive industry faces (Garling and Thorgersen, 2001; Pascoli *et al.*, 2001). Certain issues and questions remain off the agenda, most notably the primacy of capital (shareholders) over all else and beyond this the economic structure of the industry as a whole. There is an implicit assumption that the business structures of today will be appropriate to the futures of tomorrow, rather than exposing those business structures as part of the problem.

5.6 Micro factory retailing: a futures studies vision of the automotive industry

An alternative approach to mainstream management science is shown in the case of micro factory retailing (MFR). There is growing research that seeks to situate the concept of sustainability in a global–local context; to capture the multiple dimensions of socio-technical systems situated within specific geographic spaces (Roome, 2001). Indeed, within the economics and business literature a key thrust of the debate has been that traditional conceptual focus on the firm as a single entity should be replaced by a focus on networks or groups – a form of systems analysis (Boons and Berends, 2001). In fact, the concept of MFR embodies two distinct aspects of alternative thinking: bounded idealism and whole system analysis. Bounded idealism basically seeks to ask 'What would be the best possible scenario given current or anticipated technologies, social practices, etc.?'. Inevitably this is value-laden in that the answer involves the issue of 'best for whom?'. In the context of sustainability, it means what is the closest we can come to a world that is environmentally, socially and economically sustainable? It forces debate on how far we have to accept the prevailing manner of things. Whole system analysis is a prerequisite for bounded idealism to work. It is necessary, in so far as possible, to understand the totality of the phenomenon under study – in this case the entire automotive industry. This means not just the production chain from iron ore to retailing of complete cars, but also the social, economic and environmental context within which cars are produced and consumed – what might be termed the automobility paradigm. This is a massive undertaking. It is the opposite of *ceteris paribus* conceptualisation wherein complexity is put to one side. Rather, it is the adoption of an approach based on what novelist Douglas Adams (1987) called 'the interconnectedness of all things'. The key lies in identifying exactly which aspects of the phenomenon are indeed bound or constrained, in defining the barriers to change.

The concept of MFR cannot be found anywhere in the existing industry although, as noted in Chapter 17, a new example is emerging. Still, to date MFR does not exist and cannot be measured. There are no benchmarks or case studies with which to convince industrialists and others. Rather, it combines what is technically and economically possible (in, for example, the characteristics of production technologies, materials and product designs) with that which is socially desirable to create a new 'shape' for the industry. The essence of the idea behind MFR is that the attempt is being made to solve multiple problems at once, rather than individual problems one after the other. Still, this is more than a business model or strategy, because it could equally act as a guide to government policy and intervention to create the operating context within which something like MFR could thrive. This takes the debate well beyond areas of our competence, into issues such as 'green' taxation and pricing.

One aspect not considered under this framework is that of ownership, both of capital and of technology. This is clearly a critical issue. The notion of MFR implies a difference in the scale of capital investment, and this is in itself a significant contribution to sustainability in our view. However, the ownership of capital and technology brings self-determination and independence. It also brings the possibility that short-run profit maximisation may be sacrificed against wider social or economic criteria.

5.7 Conclusions

The research agenda for futures studies must have a practical and applied dimension, for it cannot be a repository for idle dreaming. However, it is a hugely challenging agenda because of the complexity of the task, rendered ever more so in a rapidly changing and inter-determinate world. This very complexity, which is unknowable to any one person, also suggests that futures studies must be guided by clear and stated values. Futurologists are not just interested in identifying where and how the world will change, but in contributing to the change process in an emancipatory and democratic way.

5.8 References

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6

Powertrain and fuel

> *The motor car affords expeditious and reasonably sure means of getting over the country – always ready when you are ready, subservient to your whim to visit some inaccessible old ruin, flying over the broad main highways . . . and is a method of locomotion to which the English people have become tolerant if not positively friendly.*
> (Murphy, 1908: 5–6)

6.1 How petrol and diesel came to rule the world

Much of the user-friendliness that Murphy described in 1908 was due to the introduction of the petrol-engined car. In fact, the way our cars are fuelled is so fundamental that we date the origins of the car to the first petrol-powered cars offered for sale. These cars, developed by Benz and Daimler in south western Germany in the 1880s, were in fact preceded by a number of devices that could be described as self-propelling, or 'auto-mobile'. However, these were powered in ways that we would now describe as 'alternative'. Linking the car and internal combustion, particularly petrol (later also diesel and LPG), has to some extent clouded this ancestry of alternatives and thus also our view of possible future options.

The petrol cars of Benz and Daimler that took to the road in Germany in 1886 were possibly preceded by one-off petrol cars by Marcus, a German living in Vienna, and also by Lenoir in France. Both made cars as prototypes and not offered for sale, although there is some suggestion that Marcus built three cars, at least one of which was sold. Although Marcus fitted an engine to a vehicle, this was a non-steering handcart and his first proper car

– innovative in its own right – was probably built around 1888 (Eckermann, 2001: 40–1). Another early claim is that for the vehicle of Edouard Delamare-Deboutteville of Rouen, France, although this is rarely considered outside the country (Brunon, 1926) and was, in any case, also a one-off. These early internal combustion cars were in turn preceded by more than a century of steam-powered vehicles, which were finally phased out as cars in the 1930s and as commercial vehicles in the 1950s (Burgess Wise, 1973; Evans, 1985). The last steam cars offered for sale – primarily in the US – were the Stanleys and the luxury cars of Abner Doble of the 1920s (Walton, 1975), although some experimental steam cars were built in the 1960s and 1970s, particularly in the US (by W Lear of Learjet fame) and Australia. Even earlier, there were clockwork vehicles in the later Middle Ages and Dutch wind-powered vehicles – inspired by much earlier Chinese designs – around 1600.

Powering vehicles directly from natural energy such as wind or solar power always carries with it dependency on the vagaries of the weather. The world's biggest solar powered vehicle event is run in the Australian Outback, although the Swiss Tour de Sol has also been successful (Oesterreicher and Trykowski, 1987). Prince Maurice of The Netherlands' land-yacht, built for him by Simon Stevin, could only be sailed under favourable wind conditions and had to be towed back by horses (Bouman, 1964: 10–14; Wilson McComb, 1974: 12; Leye, 1998: 8). Wind-powered sand-yachts or land-yachts are still confined to leisure use today (Parr, 1991; Leye, 1998), although the British world wind-powered record-holder wind-jet of 2001 shows the potential of this technology with modern materials and aerodynamics expertise (www.windjet).

Although by 1900 there was still strong competition from steam and electric traction, soon the petrol-engined car came to dominate. This was greatly helped by the introduction of the self-starter in 1912, featuring a starter motor which made the dangerous practice of hand crank starting obsolete. By mid-century few non-petrol powered cars were built as the mass car making industry added internal combustion to its portfolio of core technologies, together with the innovations of Ford, Taylor and Budd. At the same time, power output per litre of cubic capacity had multiplied (see Table 6.1).

Diesel cars first arrived in the 1930s when Citroën, Mercedes, Hanomag and Lagonda were among those making tentative steps in this direction. Citroën developed its diesel car with Ricardo in the UK and offered the Type 10 Di for sale from the spring of 1935, while Mercedes offered its 260D from November 1935 (Eckermann, 2001: 138–40). The greater fuel efficiency of diesel engines prompted the French and Italian governments to introduce taxation regimes that favoured them in the post-war period. Thus the diesel share gradually rose in these and other countries following similar policies during the 1950s and 1960s. However, lack of refinement still limited their impact. The energy crises of the 1970s saw another boost for

Table 6.1 Power output per litre for petrol engines (1898–2000)

Car	Year	Horsepower (hp)	Cubic capacity (cc)	Hp/litre
Daimler	1898	23	5295	4.3
Mercedes	1900	35	5918	5.9
Delaunay-Belleville	1912	25	2949	8.4
Ford T	1922	20	2894	6.9
Essex Super Six	1928	45	2511	17.9
Austin Seven	1931	13	750	17.3
Bugatti Type 41	1932	300	12763	23.5
Citroën 7cv	1934	56	1911	29.3
Morris Minor	1948	37	948	39.0
VW	1955	30	1192	25.1
Citroën DS 19	1955	75	1911	39.2
Honda S800	1967	67	791	84.7
VW Golf	1979	37	1093	33.8
BMW 732I	1979	197	3210	61.3
Saab 9000CS 2.3T	1992	200	2290	87.3
Honda Integra Type R	2000	200	1797	111.2

Source: data derived from Eckermann (2001) and Automobil Revue (1979, 1992, 2000).

diesel cars, even reaching the US, where car makers including Cadillac briefly offered diesels. On the whole, the diesel car remained primarily a European technology, however, and by the turn of the twenty-first century, diesels took over half the market in some European countries, making petrol and diesel equivalent engine technologies. Thus, petrol and diesel became the automotive mainstream power sources. Nevertheless, their environmental impact made the industry look again at alternatives.

6.2 The gaseous alternative

In the field of alternative fuels the least costly and most accessible options – apart from diesel – are the gaseous fuels: compressed natural gas (CNG) and liquefied petroleum gas (LPG). Though often grouped together, there are some differences between the two.

6.2.1 Liquefied petroleum gas (LPG)

Liquefied petroleum gas is probably the best established alternative, although the word 'alternative' is quite false as Italian and Dutch drivers have been enjoying its benefits since the 1960s. At times, up to 14 % of the Dutch parc has consisted of cars running on LPG, and in Japan and South Korea most taxis run on this fuel. Worldwide, LPG currently powers between 4 and 9 million vehicles in 38 countries (Table 6.2). It is only in

Table 6.2 No. of LPG vehicles (principal countries and the UK)

Country	No. of LPG vehicles
Japan	3 000 000+
Italy	1 000 000+
USA and Canada	500 000
The Netherlands	400 000
UK	50 000

countries such as the UK, France and Germany, where LPG has been historically rare, that it is seen as an alternative rather than mainstream fuel. The French have recently developed an interest in LPG as an alternative to diesel. This came in response to growing concerns about the impact of diesel particulate emissions on human health. The primary area of interest has been in converting trucks and buses to run on the gas, as LPG is increasingly being seen as a cheap way of reducing diesel use in urban environments. Production of LPG rose by 26 % between 1990 and 1998 (Nieuwenhuis, 1999a).

The gas is a by-product of the oil refining process and has traditionally been flared-off at the refinery. It also occurs in conjunction with oil and natural gas at oil and gas fields. It consists of a varying mixture of propane (C_3H_8)/propylene and butane (C_4H_{10})/butylene, the proportions of which are adjusted through the year to achieve optimum combustion characteristics at different ambient temperatures. Its main environmental advantages lie in clean combustion characteristics due to the simple molecular structure compared with petrol or diesel. The calorific value per litre of LPG is lower than petrol, so fuel consumption tends to increase by about 10–20 %, but the carbon content is lower, leading to lower CO_2 emissions. Toxic emissions of oxides of nitrogen (NOx), hydrocarbons (HC) and carbon monoxide (CO) are also reduced, there are no benzene emissions, and particulate matter (PM) emissions are minimal.

Virtually any petrol engine can be converted to run on LPG. Normally this provides a dual-fuel mode with either petrol or LPG being available at any time. A simple switch on the fascia effects the changeover. A number of manufacturers offer ready-converted cars, among them Volvo, Ford, GM, Toyota and Nissan. Driving an LPG car is no different from driving a petrol car and there is no real hardship in being seen to be more environmentally aware. Disadvantages of LPG include the cost of conversion, the need for an additional fuel tank to store the fuel at around 7–20 bar – which can take up a lot of boot-space – and the remaining emissions. Doughnut-style LPG tanks are now available, which fit into the spare-wheel well and, provided the owner can do without a spare, are a very neat solution although they hold less fuel than conventional LPG tanks. Volvo has started integrating

Table 6.3 No. of CNG vehicles (principal countries and the UK)

Country	No. of CNG vehicles
Italy	300 000
Russia	300 000
Argentina	285 000
Japan	200 000
US	60 000
New Zealand	45 000
Canada	40 000
UK	500

Source: compiled from Powershift; Natural Gas Vehicle Association.

the tanks into the car, making them less intrusive, a policy also adopted by Fiat on the Multipla MPV. However, the lack of regulation of LPG converters in the UK is causing some concern and quality problems which have the potential to harm the whole sector.

6.2.2 Compressed natural gas (CNG)

Natural gas can be used in compressed or liquid form. It consists of between 85 and 99 % of methane (CH_4), the remainder being ethane, propane, butane and pentane in small quantities. Thus, LPG can also be made from these non-methane hydrocarbons when natural gas is purified. Compressed natural gas has a lower energy density and therefore needs a larger additional tank than LPG to do fewer miles, although it has a higher octane rating of up to 130 (petrol is typically 92–98) and a slight emissions advantage over LPG. It is stored at 200 bar (another reason for the bigger tank), burns cleanly and is readily available in many parts of the world, with a more equal distribution than oil. It has proved popular with fleet users in countries such as Canada, Australia, Sweden, Germany, Italy and many others (see Table 6.3).

Liquid natural gas (LNG) requires storage at low temperatures, although more can be carried in the same volume than with CNG. Availability of LNG is more limited as this technique is used mainly for storing longer term reserves for domestic use, while CNG is readily available in many countries from the domestic distribution infrastructure which supplies natural gas for heating and cooking. It is possible to use a compressor to fuel a car from a domestic supply, although this takes about five hours – on a par with recharging electric vehicle batteries.

Volvo was the first to make a factory-converted CNG car commercially available in the UK. Aftermarket conversions start at around £2500; more

Table 6.4 Average emissions of petrol, CNG and LPG (% compared with petrol at 100)

Emission	Petrol	CNG	LPG
CO	100	30	13
HC	100	10 (NMHC)*	60 (THC)**
NOx	100	25–50	45
CO_2	100	80	85

* Non-methane hydrocarbons, a way of measuring CNG emissions, which would be disadvantaged as it is largely methane; as opposed to:
** total hydrocarbons.
Source: Nieuwenhuis (1999a).

than LPG in view of the higher pressure requirements of the whole system. The Volvo is a bi-fuel, capable of running on either petrol or CNG. Alternatives are dedicated CNG vehicles or dual-fuel engines running on a mixture of CNG and diesel – an easy conversion of an existing diesel engine. Dedicated CNG engines have the advantage that the compression ratio can be increased to benefit from the high octane of CNG. This can offset any performance disadvantage compared with petrol.

6.3 Liquefied petroleum gas vs. compressed natural gas

In deciding whether LPG or CNG is the better fuel their advantages and disadvantages must be weighed up. Both are still carbon-based fossil fuels and add to the greenhouse effect. Methane is recognised as one of the greenhouse gases and some is emitted in CNG distribution. In terms of toxic emissions in use, CNG has a slight advantage (Table 6.4). However, there is the penalty of having to use more of the fuel and carry greater amounts to travel the same distance. This means more needs to be extracted and more weight needs to be carried. On the other hand, LPG production requires more energy input, although as long as petrol and diesel are produced, so is LPG as a by-product. The primary purpose of the energy input in refining is to produce petrol and diesel, and much of the LPG currently available would otherwise be burned off, and much is still wasted in this way. Oil refineries, oil fields and gas fields produce more than enough to absorb a significant increase in the demand for both fuels and reserves are better than for oil, although this depends on future demand patterns. Natural gas has a better distribution around the globe than oil and is cheaper and more energy-efficient to transport from source to pump.

6.4 Dimethyl Ether (DME) and biodiesel: diesel's future?

In trying to control the persistent particulate problem, there have been several attempts at developing alternative fuels for diesel engines. Many heavy diesel engines have now been converted to run on gaseous fuels such as CNG and LPG for use in urban areas, in order to reduce emissions. These, however, need to be converted from compression ignition to spark ignition. The most promising real diesel alternatives, therefore, are biodiesel and Dimethyl Ether or DME.

6.4.1 Dimethyl Ether (DME)

Dimethyl Ether (chemical formula CH_3—O—CH_3) is usually derived from natural gas or methanol and is currently used mainly as an 'ozone-friendly' propellant in spray cans. Its usability as a fuel was discovered by accident by an employee working for DME producer Haldor Topsøe in Denmark in 1991 (Nieuwenhuis, 1999b). A diesel engine needs only minor modifications to the engine and injection system in order to use it, but emissions are much improved with little loss of efficiency. Much of the development work on DME is still carried out in Scandinavia. The Norwegian state oil company Statoil has been particularly supportive as it sees a massive potential market for its natural gas reserves in DME.

In terms of emissions, compared with conventional diesel, oxygen-rich DME produces virtually no particulates, no visible smoke, half the NOx and a significant reduction in noise. In terms of CO_2, DME is rated on a par with conventional diesel fuel – i.e., better than petrol – while AVL, the Austrian engine research and development company, has calculated that total end user costs would be only slightly higher than diesel (Nieuwenhuis, 1999b). What is more, power density levels can reach those similar to diesel.

In future, DME could be made from natural gas, coal, heavy refinery residues or from renewable sources such as biomass or wood – the last two options could make it 'carbon-neutral' in use. This ability to generate DME from a range of fossil and renewable sources available worldwide gives it a significant competitive advantage in the alternative fuel battlefield. A single engine type could be fuelled by DME produced from different feedstocks in different parts of the world.

To date, the largest experiment with DME involves the use of Volvo buses, which are eventually to be used to carry passengers in Denmark. The project is jointly funded by Volvo Bus, Volvo Truck, Statoil and the Danish Transport Ministry. Volvo found that by 2000 the bus already met Euro IV emissions levels, which are to be introduced from 2004/5 (Table 6.5). These emissions were achieved in combination with an oxidation catalyst, as would be the case with diesel. Engine noise was reduced by an impressive 15dBA, making it comparable with a petrol engine. Changes to the injec-

Table 6.5 Comparison of Volvo DME emissions (g/kW per hour) with Euro IV recommended emission levels

Pollutant	Volvo DME	Euro IV
NOx	3.0	3.5
PM	0.002	0.002
Total HC	0.12	0.46
CO	0.25	1.5

Source: Nieuwenhuis (1999b).

tion system are needed because DME only requires nozzle pressures of around 300 bar, compared with up to 1500 for some direct injection diesels. Some minor modifications to the compression ratio and cylinder head are also needed. However, the main change is the need for a purging system to collect fuel from the engine after it is stopped, due largely to DME's much lower viscosity compared with diesel oil. The current Volvo system is therefore bulkier and heavier than a conventional diesel installation, although this could be reduced in future. On the plus side, DME is more amenable to being combined with exhaust gas recirculation (EGR) to reduce NOx, and Volvo also reports less contamination of the engine oil.

6.4.2 Biodiesel

Other alternatives to diesel oil are the so-called biodiesels. These are derived from oil-rich crops, such as rapeseed, sunflower, palm, olive or soya beans. Biodiesel can be used with little or no modification to the engine and can be mixed with ordinary diesel oil. Vehicles running on biodiesel produce lower levels of toxic emissions and leakages are less harmful, although the smell can be unpleasant. It can also be carbon-neutral in that the growing plants absorb an equivalent amount of CO_2 to that emitted by the vehicle in use. However, any energy used to transport and process the crops, which in most cases is likely to come from fossil fuels, often negates the biofuels' carbon-neutral claims. On the plus side though, unlike diesel, it is biodegradable. UK-based firm Greenergy has joined with farmers to create a lower carbon life cycle for biodiesel; the first 'carbon-certified' crop was harvested in 2003.

Biodiesel can also be produced in most countries, reducing dependence on imported oil, although at present the cost is higher. Volkswagen was one of the first to make all its diesel engines capable of running on biodiesel from the design phase and Europe has generally been leading in this area. Biodiesel production facilities from rapeseed oil exist in The Netherlands, Austria and Germany, but the largest EU producer is France. Outside the

EU, the Czech Republic has a comprehensive biodiesel sector supported by government initiatives (Overbeek, 2002).

One hectare of oilseed rape can produce 1000 litres of biodiesel. Nevertheless, the Dutch have calculated that their entire crop could produce only enough biodiesel to meet around five per cent of national diesel demand (Nieuwenhuis, 1999b). In the early 1990s the Dutch Government agreed to forgo excise duty on a single batch of 5000 litres of biodiesel for experimental use. In many cases such subsidies are needed in order to make the fuel competitive with diesel at a time of low oil prices. Much research into this fuel has been carried out by Porsche at its Weissach research centre. Experiments have also been carried out in Australia, running a VW Golf and a Peugeot 309 for extended mileages with good results. This research found that CO, HC, NOx and PM emissions were the same as with conventional diesel, but sulphur emissions were much reduced. Mercedes research found fuel consumption to be essentially unaffected.

Biodiesel has been made available in some parts of Europe and North America primarily for agricultural and marine use, although some cars are now also running on it. In the US, biodiesel was approved as an alternative fuel for federal and state fleets on 15 October 1998, which has considerably boosted its market potential as it provides a low-cost alternative to most other options. The main source is soya, with Procter and Gamble the largest producer, although biodiesel derived from aquatic plants such as microalgae is considered particularly promising.

The US agricultural sector is interested in biodiesel as it has found that demand for many of its fats has reduced as a result of health concerns. Potentially, 50% of the US diesel requirements could be met from domestically-produced biodiesel. The US Departments of Energy and Agriculture have launched research programmes to investigate ways of reducing the cost of biodiesel production and to identify the most suitable high oil content crops. According to US costings in 1999, biodiesel from soybeans would cost around $0.66/litre, but larger scale production could reduce this to $0.40 or $0.45/litre. It is hoped that biodiesel made from microalgae could eventually be made for as little as $0.26/litre at 1999 values (Nieuwenhuis, 1999b). As mentioned above, in environmental terms the problem of biodiesel is the cost of fossil fuels to produce the crop in the first place. These are used to power the agricultural machinery and to transport the crop, seeds and pesticides, which themselves have an environmental impact and may be derived from fossil sources. Fossil fuel and energy generally tend to be significantly cheaper in the US than in other industrialised countries, which may distort the cost picture presented here.

Both DME and biodiesel have been described as ‘almost ideal fuels for diesel engines’ and a rosy future seems assured for both. Biodiesel is more immediately usable and has the advantage of being potentially carbon-neutral. The latter is an important consideration while governments try and meet their Kyoto commitments and CO_2 reduction is uppermost in the minds of both politicians and civil servants. However, DME has the potential of much lower overall emissions of toxins such as particulates and hydrocarbons, and this may well prompt engine and fuel makers to overcome the problems that still pose a barrier to the introduction of this fuel. Much will depend on the focus of future rounds of emissions legislation, particularly in Europe and the US.

6.5 Whatever happened to the electric car?

6.5.1 Battery electric vehicles

Electric cars finally disappeared from the market in the US around 1930. However, electric vehicles have seen several revivals; first, on a limited scale, in occupied countries during the Second World War when oil was hard to come by, and next during the 1960s for environmental reasons. The fear of overdependence on imported oil kept up some momentum for the US electric vehicle movement, and during the 1990s more serious attempts were made to reintroduce the electric vehicle as a viable alternative. The main impetus then was the industry's response to the California Air Resources Board's 'Zero Emissions Vehicle' (ZEV) mandate, which prescribes minimum market shares for such vehicles.

It gradually became clear that despite steady improvements in battery efficiency, the breakthrough awaited since the early years of the twentieth century was unlikely to materialise. Thus, the inherent problems of the electric vehicle (EV) of high battery weight, limited battery life, high cost and limited range were unlikely to disappear. Nevertheless, with increasing restrictions on internal combustion in urban areas, a more limited and specialised role for EVs can be envisaged in the future, particularly with many urban use applications where the limited range of battery electric vehicles (BEVs) is not an issue.

In the US, for example, many 'neighbourhood electric vehicles' (NEVs) have been introduced. These are light EVs, often based on golfcarts and restricted in their use to confined residential areas. Much pioneering work in introducing these vehicles was carried out in Palm Desert, California, requiring changes in state law (Sperling, 1995). In California, many car makers are trying to meet at least some of their ZEV mandate quota this way. Battery electric vehicles are likely to grow in number in the future and the reason for this is largely their zero emissions performance at point of use. This makes them highly suited to those applications where vehicles are exclusively used in polluted densely populated urban environments. Street cleaning vehicles, or specialist urban distribution are examples. However, it has become clear that they are not going to be the real answer to the problems of the car. Battery electric vehicles will not replace the mainstream car. Car makers are increasingly abandoning the BEV, as alternatives such as the fuel cell (see Chapter 7) gain in credibility. General Motors' valiant experiment with the very appealing EV-1 electric sports car was a learning experience, now abandoned, while Ford's decision in late 2002 to dispose of its Norwegian Th!nk division, though perhaps rash, reflects the mood in the industry (see Chapter 3).

6.5.2 Hybrids

In many respects hybrids provide the best of both worlds. The internal combustion engine is not particularly well suited to moving a vehicle from standstill as it tends to produce its maximum torque at higher rpm. Internal combustion engines have to be over-specified for acceleration from standstill, therefore for most of the time, a car engine is using only a small part of its performance potential and this leads to inefficiencies. The electric motor, however, is particularly good at moving vehicles from a standstill. It produces its maximum torque from zero rpm and is therefore used to move heavy vehicles such as trains and many of the large dumptrucks used in open-cast mining, both of which are often hybrids.

When applied to a car, a very small engine can be used merely as a generator, while the car is driven by electric motors. On-board electricity generation means a large battery pack is not needed. This can make a very energy efficient package, while modern electronics mean that the optimum combination of electric and internal combustion modes can be used. The first of these modern series hybrids to be offered to the public is the petrol–electric Toyota Prius, launched in Japan in September 1997. Within weeks, demand for this model and the only other hybrid at the time, the Honda Insight, outstripped supply (Fig. 6.1). Toyota decided to launch the vehicle in Europe and North America in 2000.

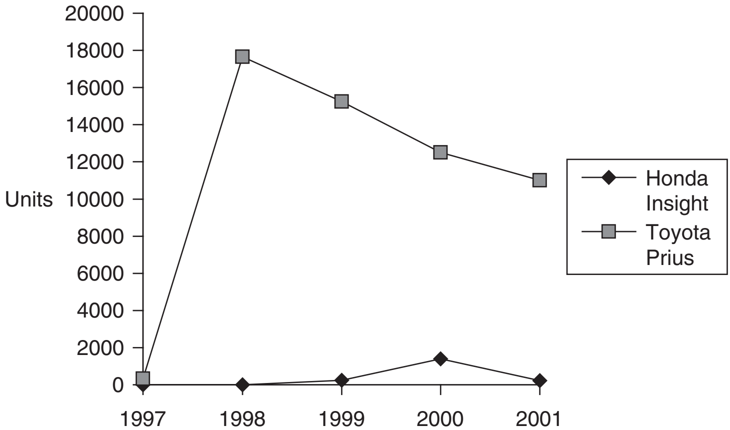

Fig. 6.1 Sales of Toyota Prius and Honda Insight in Japan (1997–2001). Source: adapted from *Japan Automotive News* (2002).

An alternative to the series hybrid is a parallel hybrid. In this variant the car can run either conventionally on the internal combustion engine, or in electric mode as an EV. The idea is that, out of town, the car can run as an internal combustion (IC) petrol, diesel or gas vehicle, while in urban areas it can run as an EV with zero emissions. The disadvantage of this variant is the fact that it carries the weight and complexity penalty of a double powertrain. Both VW and Audi proposed prototypes of parallel hybrids during the 1990s and were announcing production versions before 2000. By 2002 neither had brought any to market. However, on the whole, the series hybrid offers greater advantages. This may well be the most promising technology for the early part of the twenty-first century as it yields very real benefits in fuel consumption and emissions, while retaining the existing fuel supply infrastructure.

A recent development is the 'mild hybrid', called 'mybrid' by some. This involves the integration into the powertrain of a combined generator and starter motor (starter-generator), similar in principle, though not execution, to the 'Dynastar' fitted to Voisin cars in the 1930s. However, the modern iteration can be used as an additional power source, helping the IC engine for acceleration and up inclines. In addition it can recharge the battery through regenerative braking. Most manufacturers are due to introduce these systems in some form. One example is Ricardo's i-MoGen ('intelligent motor-generator) prototype fitted to an Opel Astra car. This concept was launched in 2002 as a practical mild hybrid system as fitted to a car from Europe's most popular, so-called 'Golf', segment (Cropley, 2002).

6.6 The Air Car – a green car at last?

Running a car on compressed air is not new, although the creators of the Air Car make some impressive claims that are yet to be tested. Rudolf Diesel used compressed air on early prototypes of his engine in the 1890s. With tolerances achievable at that time, compressed air was the only viable means of generating the pressures needed to ignite the mixture in Diesel's compression-ignition engine. However, Guy Nègre, the Air Car's creator, was inspired by the pneumatic valve actuation systems and compressed-air powered external starter motors on Formula One racing engines. Nègre was associated with Renault's Formula One programme in the 1980s. In the 1990s he set up Motor Development International (MDI) and registered in Luxembourg with Spanish and French investors (www.mdi.lu).

The engine uses an opposed piston layout and produces around 25 hp at 2000 rpm and 6.3 Nm of torque at 1800 rpm. It works initially like a normal internal combustion engine in that it draws in air. It then mimics a diesel engine by compressing this air. Where it departs from these traditions is that in the next phase air is injected from compressed air tanks stored on board. 200 litres of air is stored at around 300 bar in special carbon fibre tanks and injected at around 30 bar. This small injection of air is enough to move the piston downwards for the power stroke. The process is controlled by using a unique crank layout that allows the piston to spend a quarter of its stroke at top dead centre (TDC), thus allowing for a relatively constant volume into which the air can be injected.

Apart from producing zero pollution, the engine is claimed to be quiet and to work well at low rpm, so it is ideal for an urban or suburban environment. Local delivery vehicles and taxis are two niches targeted by MDI in the initial phase. The styling of the car in its current form is MPV-like to reflect these uses. The engine is also very light and requires no cooling system as no combustion takes place, hence the amount of heat generated is limited. This also impacts on the lubrication system so a mere 0.8 litres of vegetable oil needs to be changed every 50 000 miles. Exhaust emissions consist of clean air at –15°C. According to MDI, the car even filters incoming air to expel air that is cleaner than the ambient urban air taken in.

If successful, the vehicle will compete primarily with battery electric vehicles, or rather fill the niche that has been awaiting the electric vehicle's serious arrival for some time. Both systems use a format whereby primary energy is used off-board to convert into storable energy for use on-board the vehicle. Where the Air Car has the advantage is that compressed air is cheaper, cleaner, lighter, lasts longer and takes less time to compress compared with a traction battery charging system. It is the clean, simple and cheap alternative to battery electric vehicles. While it takes six to eight hours to recharge the batteries of a battery electric vehicle, a home compressor can charge the air tanks in the MDI Air Car in about four hours. Charging from compressed air lines at garages can be achieved in about three minutes according to the manufacturer – comparable to filling up with petrol or diesel. Initial price indications for the vehicle range from about €13 000, which is about half the cost of a comparable electric vehicle including batteries.

If the basic technology works, the critical issue is of course what primary energy is used to compress the air in the first place. Much the same is true for electric vehicles. As with power generation for battery electric vehicles, clean or 'dirty' energy can be used to compress the air. If 'dirty' energy is used we merely displace the pollution from where the car is used to wherever the energy is generated. However, when using clean, renewable energy this technology could take us a long way towards sustainable car use.

When first announced in 1998 the concept met with considerable scepticism from experts, although the Mexican authorities are convinced by the technology and placed an order for 40 000 air powered taxis in 1999. These are intended to replace the elderly petrol and diesel taxis currently in use and blamed for much of Mexico City's spectacular air pollution problem. Another version of the engine has also been developed. This runs in part as an internal combustion engine using CNG as a fuel, although petrol, diesel or LPG can also be used. These are dual-fuel engines in that below 60 kph they run on compressed air, and beyond this they change electronically to the fossil fuel. A form of regeneration is also used, for when the car runs on fuel the air tanks are recharged using a small on-board compressor that is powered by braking and deceleration – much like regenerative braking on an electric vehicle. This engine is aimed at heavier vehicles, particularly urban buses, and produces up to 300 hp. More than 20 patents now protect the Air Car technology. Another novel aspect of the MDI Air Car project is its decentralised manufacturing system. This will be considered in more detail in Chapters 14 and 17.

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7

Fuel cells and the hydrogen economy

There is nothing more difficult to carry out, nor more doubtful of success, nor more dangerous to handle, than to initiate a new order of things. (N. Machiavelli, 1513, cited by Lane, 2002)

7.1 The car industry goes for the hard cell

On the face of it, it is business as usual among the world's car makers. In reality, as we have shown, the sector is going through a period of change. Part of this transformation involves serious strategic positioning among all the major players as to who is going to control some of the key technologies thought to be needed in the future. These technologies could alter radically the way cars are made and powered, so clearly the industry is preparing for major change. One of these key technologies is the fuel cell, which has the attraction of ultra-low or zero emissions and potentially very high levels of efficiency while being cheap to maintain. Making it work economically is currently the holy grail of automotive powertrain development.

Two large consortia have developed over the past decade around two competing, albeit similar, technology systems. The first centres on a small to medium sized company from British Columbia in Canada by the name of Ballard Power Systems. This grouping includes such first rank players as DaimlerChrysler, Ford (hence Jaguar and Volvo) and Renault-Nissan, as well as the oil firm Shell. The other contender is a group centred around Toyota, which was joined by General Motors with its own fuel cell system based on Ballard technology.

The fuel cell first emerged experimentally in the UK and Germany in the 1840s. Welsh-born and Oxford-educated Professor Sir William Grove stated the principle of the fuel cell in 1846, although he had already demonstrated a working fuel cell in 1839. The German scientist Hermann von Helmholtz is also often credited with the fuel cell's invention, though he published in 1847. This has only become an issue in recent years as the fuel cell has become more popular. At the time some thought it would succeed the steam engine as the power source of the twentieth century, but materials technology was lagging too far behind. Its return at the start of the twenty-first century could ultimately make the internal combustion engine no more than a temporary intermediate solution.

A fuel cell uses a reaction between chemicals in order to produce energy. Many organisms, including humans, effectively do the same – we turn food into energy. In a fuel cell, an electrolytic reaction takes place in reverse, so rather than using electricity as an input to separate water into hydrogen and oxygen, the fuel cell splits hydrogen atoms into protons and electrons, thus generating electricity. In a car you then use the electricity to drive one or more electric motors. With hubmotors, for example, two or four wheels could have their individual motors; although unsprung weight would be higher, no 'engine bay' would be needed (see Section 7.4). Efficiencies as high as 73 % have been achieved with fuel cells in the laboratory, although 55 % is a more realistic figure in practical use (Burns *et al.*, 2002: 43). Efficiency losses tend to be confined to heat loss. This compares favourably with the best internal combustion engines – modern direct injection (DI) diesels – which achieve around 45 %.

Fuel cells were developed for the US space programme and first used on Gemini space flights in the mid-1960s. The first vehicle application was in an experimental Allis-Chalmers tractor in the early 1960s, where the cells were used to power a 20 hp DC electric motor. A GM Econovan was converted to fuel cell power in the 1960s, while the first fuel cell car appears to have been a converted DAF 44 with a Shell–Lucas fuel cell in 1975 (Eckermann, 2001: 243). Between 1990 and 1996, despite considerable development efforts in response to the California zero emissions vehicle (ZEV) mandate, battery efficiency showed only minor improvements. During the same period, however, fuel cell efficiencies improved more than fivefold, while also becoming significantly cheaper (see Table 7.1). It is this that has caused the industry's change in focus from batteries to fuel cells in recent years.

Fuel cells come in a number of different types, but the chosen standard for transport applications is the solid polymer fuel cell (SPFC). A variant of this, the proton exchange membrane fuel cell (PEMFC), is used by both Ballard and Toyota. It uses oxygen extracted from air and needs to be fuelled with hydrogen. It has an operating temperature of between 60 and 100°C. In these fuel cells, a negative and positive electrode are separated by a permeable polymer electrolyte membrane that allows ionised hydro-

Table 7.1 Performance improvements in Ballard fuel cells (1987–97)

Year	kW output
1987	1
1989	2
1991	5
1993	10
1995	28
1997	50

Source: data derived from Koppel (1999: 163).

gen to migrate from the negative to the positive electrode. The hydrogen is ionised by a platinum catalyst generating electrons and is met at the positive electrode by oxygen from air, which binds with the hydrogen ions to form water. On the early prototypes running at present, the moisture content of this incoming air is still a critical issue, leading to some embarrassing failures: Guardian journalist John Vidal's fuel cell Ford Focus ground to a halt on a wet Cornish road (Vidal, 2002). Such problems can be overcome.

One fuel cell produces a limited amount of electricity, in the Toyota case 0.7 V, so fuel cells are combined into so-called 'stacks' to produce higher voltages. Toyota uses 400 cell stacks producing around 300 V and it achieves around 60 % efficiency. One of these units weighs around 120 kg and can power a 45 kW electric motor.

7.2 The role of Ballard

The role of the small Canadian company of Ballard cannot be overestimated in making the industry think of fuel cells as the key to the future. Until Ballard took an interest, the fuel cell had been confined to chemical laboratories. Applications were limited to highly specialised and costly space use. Here they produced energy and water – both rare and valued commodities on a spacecraft. Ballard started applying engineering principles to this esoteric technology.

Geoff Ballard started his project in the 1970s by looking to improve battery technology. His work focused on rechargeable lithium batteries. Only after eight years did he change his allegiance to the fuel cell as an additional area of interest for his company, by now relocated from Arizona to Vancouver (Koppel, 1999). At the time of the 1970s energy crises, Ballard felt that energy conservation in itself was not really the issue as there was plenty of actual energy available from the sun, wind, tidal and hydroelectric power. He felt you could not make people use less energy, as this would not work in the long run, especially with the developing world inevitably increasing energy use (Koppel, 1999: 10). The answer was a better energy conversion device to capture this abundant natural energy in some way.

After spending some time improving lithium battery technology, a request for proposals from the Canadian Department of National Defence prompted a first look at fuel cells (Koppel, 1999: 36). Ballard's small team soon saw the potential of the fuel cell as a means of harnessing natural energy. However, it still took several years to achieve these objectives. Much of the work involved improved and lower cost membranes, reducing the size and precious metal content, whilst improving the energy output. Table 7.1 summarises Ballard's achievements in making the fuel cell a practical proposition.

Despite these advances in energy efficiency, a number of obstacles remain to the widespread introduction of fuel cells. The first of these is the amount of precious metal still required by the fuel cell. Despite Ballard's efforts in reducing the cell's dependence on precious metals, an automotive fuel cell stack currently still requires almost 20 g of platinum per car. This compares with around 6–10 g for a catalyst system. Apart from the cost, as mentioned by Keoleian *et al*. (1997: 92) among others, there simply is not enough platinum in existence to power all cars in current production with fuel cells on this basis, much less accommodate the expected increase in demand for automobility from emerging economies. Much current research in fuel cells by firms such as Ballard and Johnson Matthey is therefore focused on this reduction in precious metal content. Another obstacle involves obtaining and distributing the fuel for the fuel cell.

7.3 Fuelling the cell

Most experimental fuel cell vehicles are fed with pure hydrogen from an on-board hydrogen storage unit. Hydrogen is not a carbon fuel and therefore produces no CO_2 emissions. On the other hand, it is still often produced using carbon fuels, in which case the production process will produce CO_2 and toxic emissions, as is discussed below. Hydrogen storage can also be problematic as it takes up a very large volume in gaseous form and would need to be cooled to –253°C and pressurised to 200 bar, before being turned into liquid form (Keolian *et al*., 1997: 86–8). A heavy cooled tank would be needed to store it in this form. Another route is to use a metal hydride. Here, the hydrogen is chemically bound with a metal for storage. This is the route currently taken by Toyota. It has developed a new alloy that can bind a large amount of hydrogen in a small space. DaimlerChrysler and Ford, on the other hand, use pressurised hydrogen in their Necar4 and P2000 HFC ('hydrogen fuel cell') prototypes.

7.3.1 The problem with hydrogen

On the whole, hydrogen appears to offer the ideal solution. It is also a good fuel for internal combustion (IC) engines and its emissions are essentially water. For this reason, BMW has been advocating this solution as an alternative to fuel cells. It considers IC engines to constitute its core technology advantage and is reluctant to compromise this as would inevitably happen if fuel cells were universally adopted by car makers. BMW argues that the same environmental advantages accrue from hydrogen IC engines as from hydrogen fuel cells. In practice very low levels of hydrocarbons are emitted because of the lubricating oil that is still required by the IC engine, although this is probably insignificant.

More important is that if the oxygen used to burn the hydrogen is derived from ambient air, the higher combustion temperature of hydrogen will inevitably lead to higher NOx emissions, as well as higher thermal losses (Keolian, 1997: 87). This problem would not arise in fuel cells, which operate at much lower temperatures, as well as higher efficiencies. Hydrogen can be burned in existing internal combustion engines with little modification, so a wholesale move away from existing engine technology and production facilities would not be required. BMW also suggests using desert areas for large-scale solar-powered hydrogen production. BMW has, however, been among the first to develop a fuel cell for powering on-board electrical systems in its cars. Mazda reported in the early 1990s that its Wankel rotary IC engines are also particularly suited to running on hydrogen (Hege, 2001: 161).

The new-found hydrogen need ties in well with the desire of some countries to move towards a 'hydrogen economy', which in most cases is an economy based around hydrogen as an energy storage medium generated from renewable energy, rather than fossil fuels. This would then produce an economy based on abundant energy, but with none of the side-effects such as pollution, wars in the Middle East, or global warming. Iceland, with its abundance of geothermal energy, has announced it is on track to achieve this aim within a few decades. Canada believes it can use its hydroelectric energy for hydrogen production. Others have suggested using nuclear energy. US president George Bush has also become a convert to the principle of a hydrogen economy as he regards it as a way of reducing dependence on imported oil and reducing CO_2 output while retaining the energy-intensive US lifestyle. His Freedom Car initiative, which succeeds Clinton's Partnership for a New Generation of Vehicles (PNGV), is part of the implementation strategy.

However, whether one opts for fuel cells or hydrogen IC engines, there are some problems, mainly centring around hydrogen production. Hydrogen (chemical formula: H_2) does not occur naturally in its pure form on Earth and is usually produced from water or some hydrocarbon fuel such as methanol. This process can be quite energy intensive and

Table 7.2 Relative energy densities of fuels (petrol/gasoline = 1)

Fuel	Energy density
Petrol/gasoline	1.00
Diesel oil	1.06
Ethanol	0.74
Methanol	0.54
LPG	0.67
LNG	0.42
CNG	0.23
Compressed hydrogen	0.05

Source: Schuetzle and Glaze (1999).

therefore raises the question of what energy source to use to make hydrogen. This process can itself be polluting, particularly if fossil fuels are used. Currently most hydrogen is produced from natural gas by re-formation and Keolian *et al*. (1997: 86) point out that the efficiency of this process is 70–75 %. The financial cost amounts to two to three times that of the feedstock, albeit at US price levels. Electrolysis of water can be 75 % efficient, although at a high energy cost, while coal gasification at 60–65 % efficiency is the lowest cost in the US. In view of this, the attractions of low cost natural energy sources, such as thermal or hydro are self-evident. On the other hand, as Burns *et al*. (2002: 49) point out, as fuel cell cars are likely to be almost twice as efficient as petrol cars, a considerable price premium for hydrogen could be accommodated, as the cost per mile would be the key to success.

Hydrogen also presents storage problems. Existing storage solutions such as compressed hydrogen tanks or metal hydride are bulky and experimental hydrogen vehicles have often been vans, which can carry these. The problem is that hydrogen has only one-quarter the energy density of petrol, thus more needs to be carried to travel the same distance (Table 7.2). By the late 1990s one strand of thinking therefore moved more towards generating hydrogen on board the vehicle from a hydrocarbon fuel such as methanol or even petrol. This is on-board conversion, whereby hydrogen is extracted by a re-former as and when required from a fuel that is more easily handled and stored in the car, as with IC engines. The debate is still ongoing about whether the best solution is methanol or petrol. The latter was promoted by Chrysler among others in the 1990s as it allows the retention of the existing petrol infrastructure. However, it does not solve the problem of our over-reliance on scarce oil reserves. Nissan's fuel cell vehicle (FCV) uses methanol and water, which react and release hydrogen. Methanol, a form of alcohol, can be extracted from a range of feedstocks.

7.3.2 Methanol

Alcohol-based fuels have been used in automotive applications for a long time, particularly as high-octane fuels for racing cars. They burn more completely and thus produce lower emissions, although they are still hydrocarbon fuels. Two types of alcohol are distinguished: ethanol and methanol. Ethanol is the type of alcohol we drink and it can easily be produced from the fermentation of a range of different crops. In the mid-1970s the Brazilian Government launched the 'Proalcool' programme as an import substitution project. In the wake of the oil crisis of 1973–4 Brazil felt it spent too much on importing oil to run its cars and a means was devised to substitute this with ethanol produced from sugar-cane. Although the heyday of the programme was in the 1980s, cars capable of running on alcohol were still being built in Brazil at the turn of the century. The programme has been revived through the introduction of a new generation of bi-fuel petrol/alcohol vehicles into the Brazilian market (AEA, 2002). Brazilian car makers now regard this technology as marketable elsewhere for compliance with tightening emissions standards.

Ethanol has also proved popular as an oxygenate to add to petrol, particularly in North America. In 1998 the US Post Office ordered 10 000 post vans with ethanol capability from Ford. These vehicles are very durable and should be in use well into the twenty-first century. In practical terms there are limitations to this approach, as vast areas of dedicated crop cultivation would be required to run a significant proportion of the world's cars on this fuel, although where surpluses of crops rich in sugar exist it may be feasible locally.

Methanol is a different product. It is more dangerous to handle than ethanol, or even petrol, and requires a completely different fuel delivery system as it corrodes most existing fuel system materials. Even with the use of stainless steel, a regular replacement of seals in the fuel system is required for methanol-powered vehicles, increasing the cost of maintenance. Nevertheless, it enjoyed some popularity in the US as an alternative fuel. In practice it is usually mixed with petrol in order to control its effects somewhat and make cold starting easier. A usable fuel, M85 (85 % methanol, 15 % petrol) is produced this way. M85 became a popular alternative fuel in parts of the US from the late 1980s onwards. Volvo was among the manufacturers to offer test vehicles capable of running on M85, for evaluation by California's Air Resources Board (CARB) and South Coast Air Quality Management District (SCAQMD). The 1992 Volvo 940 FFV used a modified version of the company's 2.3 litre 4-cylinder engine. When run on M85 rather than pure petrol, power output increased from 120 hp to 130 hp, although range was reduced from 460 km to 325 km. These figures are due to the higher octane level but lower energy density of methanol.

By the late 1990s, California had begun to review its earlier enthusiasm for methanol as an IC fuel and few of the experimental vehicles were still in use. By then, methanol had already come to be regarded as a useful source of hydrogen for feeding fuel cells. In this application it may prove more useful than as a direct fuel for internal combustion engines, although it is still only a hydrogen carrier needing an on-board re-former. A re-former adds weight and complexity, while it needs to do something with the non-hydrogen parts of the methanol; CO_2 emissions at point of use tend to be a by-product of this approach. This does not endear it to regulators aiming to implement the requirements of the Kyoto Protocol.

A methanol version of DaimlerChrysler's Necar4 prototype, based on the A-class, is claimed to return 3.6 l/100 km. Running on pure hydrogen, the fuel consumption is around 3.2 l/100 km. Necar4 uses a stack of 400 cells, which each produce between 1 and 2 V, leading to a maximum 750 V for the stack. The motor only requires 250 V. Fuel cell powered prototypes used to be mostly vans with the powertrain taking up most of the volume, but in the Necar4 the cells fit neatly into the A-class's sandwich floor. Toyota's fuel cell prototypes are based on the RAV-4 compact sport utility vehicle (SUV), where the cells can also be accommodated within the existing structure without interfering too much with the passenger space. Daimler claims a 'well-to-wheel' efficiency of 60 % and 'tank-to-wheel' of 40 % (Nieuwenhuis, 1999). However, developments are moving so fast that analysing the performance of current prototypes is largely irrelevant.

Burns *et al*. (2002: 49) point out that various elements of the hydrogen infrastructure already exist and that these could be built on in various ways. First of all, limited pure hydrogen distribution currently amounts to some 540 billion cubic metres, mainly re-formed from natural gas. This would meet around 10 % of transport demand for a fuel cell powered fleet. It also shows that considerable expertise in hydrogen use and distribution already exists. Alternatively, existing fuel stations could be fitted with re-formers to produce hydrogen on site from existing automotive fuels, while the domestic natural gas distribution infrastructure of many countries could also be used for producing vehicular hydrogen. The type of vehicle this hydrogen may power is also becoming clearer since GM showed the AUTOnomy concept and the Hy-wire running prototype.

7.4 AUTOnomy – reinventing the chassis to fit the cell

AUTOnomy is a concept vehicle shown by General Motors at the 2002 Detroit International Auto Show (www.gm.com; Burns *et al*., 2002; Borroni-Bird, 2002). Few commentators outside GM appear to have appreciated the full significance of this concept, which goes far beyond the fuel cell powertrain itself. However, the GM people responsible know very well what they are trying to achieve. They claim that 'A confluence of factors makes the big change seem increasingly likely. For one, the petroleum-fuelled internal combustion engine . . . is finally reaching its limits' (Burns *et al*., 2002: 42).

General Motors regard the fuel cell as a suitable alternative technology, but move beyond this with their concept car:

> A concept such as that of AUTOnomy . . . could significantly change the current business model. It could conceivably lower vehicle development costs because, with modules able to be produced independently, design changes to the body and chassis modules could be made more easily and cheaply. As with today's truck platform derivatives, it will be possible to design the chassis only once to accommodate various body styles. These derivatives could easily have different front ends, interior layouts and chassis tuning. With perhaps only three chassis needed – compact, midsize and large – production volumes could be much larger than those now, bringing greater economies of scale. (Burns *et al*., 2002: 45)

Essentially, this vehicle consists of a flat base unit, about 15 cm thick, which contains the entire fuel cell powertrain and holds the wheels, suspension and other key items. It is itself an autonomous mobile structure, which the GM engineers in charge call the 'skateboard'. Fuel cell technology and its electric powertrain allow very flexible packaging in a way not possible with conventional internal combustion systems. It is also not made according to Buddist principles, as it uses various lightweight alternative materials in its body and its chassis.

The 'skateboard' has four body attachment points and one central 'docking point' by means of which a separate body structure can be attached to it. This point allows the necessary communications interface between the body and the powertrain module (Robertson, 2002). AUTOnomy is a modular approach to car making, far removed from the monocoque. In a sense, it reintroduces the separate chassis and body structures, as used by Henry Ford on the Model T and, as Burns *et al*. point out, as used on modern US trucks. However, it goes even further. Provided the docking points can be standardised, it should be possible to make a wide range of bodies to interface with a standardised 'skateboard' powertrain unit. The concept car, masterminded by GM's Chris Borroni-Bird and his team, is fitted with a two-seater sports car body. One could envisage saloon, estate, MPV, coupé, roadster and more radical body styles being made by independent small specialists for use with standardised mass produced 'skateboards'. Alternatively, mainstream manufacturers could supply a range of body styles themselves. In fact, GM itself took the next step by presenting a one-box saloon concept on the skateboard platform, called Hy-Wire at the 2002 Paris Motor Show.

On the one hand this spells a potential return to the luxury cars of the past, which were supplied as chassis only to be bodied by the coachbuilder of choice. On the other hand, within the modern idiom it can be compared with exchangeable covers for mobile phones. Space would probably prevent most customers from owning large numbers of bodies, however many people might consider owning one or two spare bodies in addition to their everyday car. For daily commuting – if that still exists when such vehicles become mainstream – a sports car body could be used as in the original AUTOnomy. At the weekend an MPV or estate option could be fitted. Alternatively, dealers or independent body rental firms could provide this service, creating a new subsector. Bodies and 'skateboards' could be updated independently from each other as technology requirements, fashions and offerings change. More efficient powertrain items could be fitted to the skateboard without affecting the bodies, provided the interface could accommodate such an upgrade. Much of this upgrading – as well as tuning to the needs of individual customers – could be done by means of software reconfiguration.

GM's AUTOnomy is the first purpose-designed fuel cell vehicle. It also introduces drive by wire, as all controls actuated by the driver in the body module are communicated to the power module via the electric/electronic docking point from a driver control unit working through a new generation 42 V electrical system. The drive by wire technology is supplied by Swedish firm SKF and it means that conventional pedals and steering wheel or steering column are no longer needed; all mechanical linkages between driver and car are replaced with electronics. More contentiously, perhaps, GM also argues that it could help bring automobility to developing countries in view of low tooling costs and the flexibility of providing dedicated body types for different markets. It claims this could help extend automobility to the 88 % of the world's population who currently do not enjoy its benefits.

AUTOnomy is an attempt to start from first principles. General Motors' CEO Rick Wagoner claims GM started by asking the question 'What if we were inventing the automobile today rather than a century ago? What might we do differently?' (www.gm.com). He was indeed correct when he went on to say that 'AUTOnomy is more than just a new concept car; it's potentially the start of a revolution in how automobiles are designed, built and used'.

All fixed points in the design are within the skateboard. The body can be configured in any way, as long as the connections to the chassis are there. The traditional limitations of engine bay, bulkhead, steering column, pedals are no longer there, allowing the body designer almost total freedom. This will allow a return to true automotive design, centred around people and their needs, rather than the needs of the production system that makes the car, as is the case under the existing Buddist–Fordist system. GM also state that the basic skateboard structure would last for years, '. . . much longer than a conventional vehicle', thereby linking in to that most fundamental of environmental issues: product durability.

7.5 A future for the cell?

In future, more such vehicle structures designed with fuel cells in mind are likely to emerge. Fiat's Multipla is already designed around a multiple fuel capability and this is part of the reason for its space-frame structure. The Multipla is offered with petrol, diesel, CNG and LPG options, while low volume hybrid and battery electric versions also exist. Volvo has also started to integrate its alternative fuel systems within the vehicles' structure, in order to avoid bulky containers taking up valuable luggage space. As we are entering a period when a range of different fuels and powertrains are likely to exist side by side, cars designed purely for internal combustion engines are no longer adequate. These technologies are therefore likely to have an impact well beyond powertrain alone, affecting the whole vehicle structure, the way it is built, marketed and used.

That the industry takes the technology seriously may be illustrated by the money spent so far. Developing the fuel cells used in Necar4 cost Daimler-Benz some $725 m and Ford around $420 m (Nieuwenhuis, 1999). At the time of presenting the Focus FCV Hybrid 2002, Ford claimed it was the result of over $600 million of investment (Vidal, 2002). It is estimated that by 2002 some $7 billion had been invested by car makers, governments and other stakeholders in fuel cell technology, with some 4000 companies worldwide involved in some way (Vidal, 2002).

In the next phase, the unit cost of the cells itself needs to be reduced by developing a way of making them in large volumes. The environmental imperative to do something is compelling. As Lane (2002: 35) argues 'Even with the most intensive (and probably politically unpopular) policies, the greenhouse gas (GHG) emission reduction is one-twentieth of the reduction required to achieve a sustainable road transport system'. Lane (2002: 40–1) calculates that in the case of the UK, a reduction in transport greenhouse gas emissions of some 75 % is required over a baseline of 1990. For NOx the figure is also 75 %, but this time from a baseline of Euro IV for petrol engines. Both are based on a life cycle approach. Hence alternative, non-carbon based automotive energy systems are essential. Burns *et al.* (2002: 49) quote research which suggests that a price premium of around 30 % would make hydrogen competitive for fuel cell use in view of the greater efficiency. Ballard claimed by late 2002 that some of their customers' analyses suggested that the then latest 902 fuel cell system could be made at a cost competitive with internal combustion engines at volumes of at least 200 000 a year (Crosse, 2002).

So, when can we buy fuel cell cars? The timing of the GM–Toyota deal is no coincidence. The collaboration involves the practical testing of a range of electric drive technologies and was clearly put together with the California ZEV mandate in mind. This stipulates that by 2005 10 % of all new cars sold in the state should be ZEVs. All are now agreed that pure battery electric vehicles, such as GM's EV-1 sports car, are not going to appeal to enough customers to achieve the desired percentage. The industry has therefore set its sights on hybrid EVs and fuel cell EVs. This would suggest an introduction date of 2003–4 at the latest, and this is indeed what Toyota and others are officially saying. Toyota launched a small fleet of experimental fuel cell vehicles in Japan in late 2002 in preparation for a limited launch in 2004. The Ballard grouping have also made their technology available to competitors, as they feel it is in their own interest to establish theirs as the principal technology, thus promoting standardisation whilst justifying any infrastructure changes required.

Considering some of the partnerships involved in fuel cell development, it is noted that oil companies are also involved, and for a very good reason. Someone will have to supply the fuel for the cells. This is where the car makers and oil companies part company. The car makers would like to go to market sooner rather than later. This almost forces them to use pure hydrogen as a fuel or, more realistically, methanol. Some of the oil companies are not too keen on this. It would require them to create a completely new methanol supply infrastructure involving significant, and expensive, changes to the existing petrol/diesel infrastructure. They would rather wait until around 2010. By this time they feel that the on-board converter that extracts hydrogen from petrol will be production ready. Alternatively, a future hydrogen distribution system would displace and render obsolete the methanol distribution system so recently introduced at great expense.

Under the petrol re-former scenario no change of infrastructure is required, nor would motorists have to change their perceptions about fuel in any way – they would still fill up with petrol at a normal petrol station. Syntroleum, which makes liquid fuel from natural gas, has already announced that its low sulphur and aromatics content and high hydrogen density makes it particularly suitable for use in fuel cell re-formers. As far as alternative powertrain is concerned, fuel cells are definitely the technology to watch. Their impact could go well beyond changing the way we drive. Environmental commentator Jeremy Rifkin foresees considerable social change as a result of moves to a hydrogen society, bringing about a decentralisation and democratisation process unseen for centuries. He predicts '. . . we will not recognise the future. The hydrogen economy will have massive social repercussions. It will change the world' (Vidal, 2002).

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8

High volume car production: Budd and Ford

> *Up to the introduction of the moving assembly line at the Ford Highland Park plant in 1913–1914, automobiles were made and sold in much the same way on both sides of the Atlantic; that is they were assembled from jobbed-out components by crews of skilled mechanics and unskilled helpers at low rates of labor productivity, and they were sold at high prices and high unit profits through nonexclusive wholesale and retail distributors for cash on delivery.* (Flink, 1988: 40)

8.1 Introduction and background

It is perhaps helpful to start this chapter with a quick summary of the 'Buddist' argument from Nieuwenhuis and Wells (1997), updated with new source material. Although happy to accept the traditional notion that Ford was the first to mass produce cars, the authors noted that the car he mass produced, the Model T, was an 'Edwardian' car, based on a modular approach to car making: separate chassis and separate, wood-framed, or 'composite' body. Modern mass-produced cars are not made like this. They use all-steel 'monocoque' or 'unibody' construction, whereby a structural metal box fulfils the functions of both body and chassis. This technology was made possible by Budd and Ledwinka's invention, around 1912, of the all-steel welded body and the press and jig technology that came with it.

The first all-steel bodied cars were probably made by Eastman of Cleveland, Ohio from 1897–8 onwards (CATJ, 1900: 46; MVR, 1900: 28). From 1901, Eastman decided to concentrate on making steel bodies for others (*The Horseless Age*, 1901: 69; MVR, 1901: 7) and was then absorbed by Benson. Hayes was involved in making these bodies and he later specialised in making fenders or front wings for several car makers. Edward Budd and his chief engineer Joe Ledwinka took a more systematic, missionary and holistic approach to converting the industry to all-steel bodies. They also insisted on welding their bodies; the source of many development problems, but also of the authors' claim to have started car making on its current trajectory. Thus, modern mass car manufacturing in many ways owes more to Budd and Ledwinka than it does to Ford. In a sense it is a complex of Buddist technology overlaid with Fordist, Taylorist and Toyotist approaches to process, although while Fordism was possible without Budd, Toyotism refines Fordism within Buddist technology. Core Toyotist innovations such as rapid die changing are irrelevant without Buddism.

Budd's steel body technology requires very high initial investments, but, once made, these allow low unit costs at high volume production. Budd's innovations constitute the basis for the economics of car making, notably its economies of scale. We can therefore argue that mass car making currently operates within the 'Buddist' paradigm, after having briefly gone through a 'Fordist' phase at Highland Park. The main change was from the manufacture of modular cars from largely in-house components at Ford's Highland Park plant, to the manufacture of steel bodies, assembled into cars from largely outsourced components and sub-assemblies in a typical modern mass production car plant. The in-house manufacture of engines and gearboxes – though not universal (BMW for example makes no gearboxes, while few manufacturers make automatic transmissions) – tends to be common to both.

Although Buddism served the industry well while it was trying to put the world on wheels, in the more developed countries market forces now undermine the Budd paradigm. Markets now expect much shorter product cycles, as well as more visible differentiation, leading to more diverse product ranges. These pressures mean lower volumes per model and thus loss of economies of scale (see Chapter 3). This is one of the primary reasons for the fact that the profitability of mass car making has been declining from a margin – pre-tax – of between 20 and 30 % in the 1920s to between zero and 5 % today, with little sign that this trend will change (Haglund, 2001). Attempts to recapture the economies of scale needed for profitable Buddist car making are behind the industry's efforts to globalise and consolidate. We will investigate the historical basis for our Buddist analysis of mass car making below.

8.2 History

Cars started life as craft-made products. They were made one by one by hand with each being different and each component being different as it was adapted to its neighbours in the sub-assembly – the 'European System'.

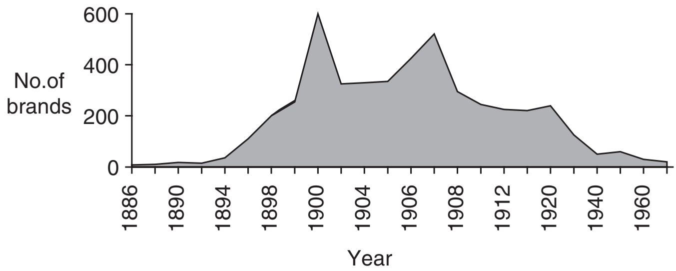

Fig. 8.1 Rise and fall of car companies in France (1886–1960).
Source: data from Pouzet (1996: 137).

Very rapidly, major suppliers were set up, able to supply engines, gearboxes, axles and other key components, allowing the number of brands to greatly increase as the key building blocks of cars were now readily available to all. Figure 8.1 illustrates the rapid rise in the number of car companies in France in the ten years between 1894 and 1904. Many firms assembled cars from bought-in components and limited themselves to fitting their own badge. The modular construction of cars at this time made this possible. Cars were almost invariably built up on a chassis frame, which carried all the components and subassemblies needed to make it move: engine, transmission, axles and wheels. The body was a separate product and many car manufacturers sold their products as running chassis. The owner would then buy a body separately from a specialist coach builder, although many manufacturers could supply bodies or deal with coach builders direct.

Henry Ford combined a number of techniques and technologies to introduce mass production to the car industry. Much has been made of the moving assembly line, which allowed workers to remain stationary while the work passed by them. Ford also applied the concept of standardised interchangeable components – pioneered by arms manufacturers and car makers like Cadillac and Lanchester – on a much larger scale: the 'American System'. In order to do this he had to improve and scale-up casting and machining of key components, as no supplier could keep up with these developments at the time. These were all key innovations, allowing Ford to become very quickly the world's largest car maker by some margin. This happened well before the introduction of the moving assembly line in 1913. Ford designed bodies for the Model T, but these were often outsourced. Certain elements, such as bonnets/hoods and wings/fenders were often made in-house, as few independents had the capacity to supply the numbers Ford needed. Thus Ford achieved very high levels of vertical integration unknown in car making today, owning mines, smelters, shipping companies, forests, etc.

However, if we now look at how cars are made today and the investments required to make them, we see that while there are high investments

Table 8.1 Typical assembly plant investments: the cost of Budd

Process	Typical cost (million £)
Press shop (Budd)	100
+ die sets/tooling per model (Budd)	20–65
Body-in-white (Budd)	50–100
Paint shop (Budd)	200–300
Pre-assembly (Ford)	10–50
Trim/final assembly (Ford)	10–50
Budd v Ford	370–565 v 20–100
TOTAL	390–665

in casting, machining, engine and transmission production, by far the largest area of investment is in making and painting bodies. A car assembly plant's primary activity is the making and painting of car bodies and then assembling them into finished cars by using largely bought-in components. On average, modern car manufacturers outsource some 65–80 % of the ex-works value of their cars. Hence a modern car assembly plant is typically subdivided into the following processes:

1. Press shop – where the sheet steel is pressed into panels;
2. Body shop or Body-in-white – where these panels are welded together to form bodies;
3. Paint shop – where these steel bodies are painted in various stages;
4. Pre-assembly – where wiring and piping and other components are fitted to the body;
5. Trim or Final assembly – after fitting the powertrain (engine and transmission) the car can be put on its wheels and finished inside and out.

The principal investments in an assembly plant involve the first three processes – the making of steel bodies (Table 8.1). As bodies tend to change far more often than castings or powertrain components, these body-related investments have to be repeated regularly, with those elements if not replaced, at least reconfigured and updated. These investments and the resulting breakeven points are so fundamental to the business of mass car production that these Buddist investments now determine the economics of car making. This is a completely different way of making cars from the Model T Ford. The T was an 'Edwardian' car made in large numbers and, according to Batchelor, '. . . may fairly be described as the first product of mass production. But when the car was conceived of in 1908, it was with prevailing – albeit changing – production methods in mind' (Batchelor, 1994: 66).

As outlined above, how it differed from modern cars is that it was modular: it had a separate chassis, holding all mechanical components, and a separate body. These bodies – the mainstay of modern car making – were on the whole outsourced by Ford at the time of the Model T, often from Budd (see below). Body construction was a major bottleneck in pre-Budd car making. Not only could the paint take several weeks to dry, body construction itself was very time consuming. The timber-framed bodies, usually covered with steel, leathercloth, or – for more expensive cars – aluminium panels, could not be baked.

Courtenay (1987: 6) explains that 'The gluing, planing, staining, varnishing ran into weeks. So long as this pattern prevailed, economies of scale and the potential for mass production would never be realised'. The paint bottleneck was a major problem and initially the ability to bake the all-steel bodies was regarded as the primary advantage of Budd's innovations. 'The feature of these bodies is that they are constructed entirely of metal, which allows them to be placed in large ovens for the purpose of baking on the enamel and drying the various coatings of paint and varnish' observes Palmer (1913).

Apart from the time and labour saved, or because of this, there was also a unit cost advantage. Once the initial capital investment was made, a steel car body could be built for around $45 (Courtenay, 1987: 6). With the Edward G Budd Manufacturing Co. themselves making the initial investments, car makers could limit themselves to paying for tooling and then benefited from cheaper, lighter and stronger bodies. Budd repeated this approach by setting up his own facilities in Germany (Ambi-Budd) and the UK (Pressed Steel), thus also removing the initial investment barrier for many European clients, although others preferred to go it alone. Budd's first major customer, Dodge Brothers, paid the following costs at the time of their first order for 5000 bodies in 1915:

- Bodies: $42 each;
- Fender sets: $2 each;
- Tooling: $25 000 (Courtenay, 1987: 12).

By November 1916, 100 000 Dodge bodies had been made (Courtenay, 1987: 13). That year, Budd and Ledwinka also convinced Dodge to adopt the pressed steel roof, followed by an all-closed steel saloon (Courtenay, 1987: 16; Grayson, 1978: 362); an innovation that would spread very rapidly throughout the car industry. *Automobile Digest* (1926) reported that '. . . the open car is losing ground each year in popularity with the closed type setting a fast lead'. In Europe's leading market, the UK, Ware (1976: 70) pointed out that while in 1927 only 46 % of new cars registered were saloon-bodied, by 1931 this proportion had doubled to 92 %.

The 1920s and 1930s are the key phase for the roll-out of Budd technology. Budd had to increase its workforce regularly during the period as demand increased rapidly (*Automotive Industries*, 1922a, b, c). Economies of scale began to be realized and by 1922, Budd was able to reduce the average price per body by 40 % (*Automotive Industries*, 1922b). In early 1923 the company launched a new share issue in order to finance further expansion (*Automotive Industries*, 1923). By 1925, Budd all-steel technology had a 50 % share of US body production (Courtenay, 1987: 22), although new competition came from the European timber and fabric Weymann body, as well as from aluminium (Blanchard, 1925; Mercer, 1927). At the same time, the timber frame, or 'composite' body was increasing its steel content in order to fight off the threat from Budd. Mercer (1927) states that by then, composite bodies had '. . . less than one-third the amount of wood over the former practice'. From 1925 Budd increased its vertical integration downstream by offering complete bodies to its clients for the first time. This necessitated a new assembly facility away from its Philadelphia base, next to its steel wheel plant in Detroit, so closer to the customer (ATJ, 1925; *Motor Age*, 1925).

Outside the US, the first car maker to recognise the potential of Budd's new body technology was André Citroën. His innovative firm was already the first in Europe to adopt Dupont's quick-drying cellulose paints in 1924 (Loubet, 2001: 104). All-steel body technology is a logical next step as the ability to bake the paint speeds up the drying process even further. That same year, Citroën bought all-steel body technology from Budd in Philadelphia. Loubet explains that even in the US it was still rare due to its very high cost (Loubet, 2001: 104). We must assume that this refers to the initial investment, rather than the unit cost per body. Also, being in Europe, Citroën could not benefit from Budd's own facilities. It is perhaps appropriate that a French manufacturer should be among the first to appreciate Budd and Ledwinka's innovation, as they relied heavily on French acetylene welding technology to develop their all-steel technology (Courtenay, 1987: 10).

Citroën shared Budd's longer-term vision. He could see that the high costs of maintaining forests (or at least access to their products), large stocks of timber, sawmills and the highly skilled craftsmen needed to run the timber frame body system could be phased out overnight. The Ford Motor Company, for example, owned half a million acres of timber land in northern Michigan (Ford Motor Co., 1929: 48). Citroën also realised that without abandoning the timber frame body, mass production was not possible. Daily production rose from between 30 and 50 units a day to between 400 and 500, while production times were cut in half (Schweitzer, 1982: 11–19). By 1926 the cost per body had dropped by FF1000 (Loubet, 2001: 104). Citroën production was up to 250 body sides and 200 chassis per hour and the company envisaged reducing its labour force from 14 000 to 10 000 at a rate of 250 cars a day, while it was calculated that 500 cars a day could be reached with only 15 000 people (Loubet, 2001: 104). However, Citroën did become very reliant on US technology. All its major innovations in production, the all-steel body (1924), monocoque construction (1932), power-assisted brakes (1924) and 'floating' engine mounting (1932) – the need for which is a by-product of Budd technology – relied on US technology and patents. In addition to royalty payments on each car sold, Citroën had to invest some $600 000 in the monocoque system for the Traction Avant (see below). Budd received between $1 and $3 on each body made (Loubet, 2001: 105).

The cost of this body technology was high in terms of investment in machinery as well as the need to source the higher grades of steel needed to make it work from the US (Loubet, 2001: 105). In 1926, these special steels cost FF4.5 per kg, rather than the FF2.6 of standard French automotive steel. Each Budd car body used 500–600 kg of sheet. The cost of this Budd technology must now be regarded as a major contribution to Citroën's bankruptcy in 1934. Setting up its own steel mill in Froncles saved FF1000 per car – 10 % of the materials cost (Loubet, 2001: 105). Nonetheless, Citroën still had to import pressings from Budd in the US. In 1927, this amounted to 20 000 pressings at a total cost of $500 000, to allow a rapid introduction of the crucial B14 model. The French even set up a new purchasing office in Detroit for this purpose. They found that with their rapidly rising production, French suppliers could not keep up with the volumes needed, nor could they supply at the cost of US firms. Ultimately Citroën set up much of this capability back home although the FF8 million spent on steering and clutch production saved only FF200 per car, just 1 % of the ex-factory price (Loubet, 2001: 106).

8.3 Budd and Ford

Initially, for the Model T, Ford tended to outsource bodies. Body construction and especially painting caused a real bottleneck in production, which Ford could ill-afford in his attempts to move to mass production. Increasingly many of Ford's bodies were sourced from the Budd Company and with the creation of the Rouge Plant to build the later version of the T and then the Model A, Buddist body production was largely moved in-house. This happened in 1925. 'In 1925 the Ford Motor Company began building all steel bodies which necessitated many changes in equipment at the Rouge body plant. With the introduction of Model A . . . another complete change was necessary' (Ford Motor Co., 1929: 24).

Ford, the inventor of mass car production, did not have within his factories until 1925 those elements that typify a modern mass production car factory: press shop, body-in-white and paint. These came with the introduction of Budd's all-steel body construction. In fact, even at Rouge, only bodies for the local market were assembled. For other locations, pressed panels were shipped in knocked down form (CKD) for assembly near the recipient market. Even so, by 1929 Ford was still a major consumer of timber with a requirement of 1 million board feet per day (Ford Motor Co., 1929: 48), primarily for body construction. Ford clearly did not heed Budd's dictum that there should not be a wood piece 'as big as a toothpick' in a car body (Grayson, 1978: 353). This emphasises the fact that Ford turned the manufacture of Edwardian vehicles into a mass production process. Whilst this makes Ford highly relevant for students of mass production processes, it makes him rather less central to the study of modern mass car production, as we have argued before (Nieuwenhuis and Wells, 1997: 74).

Budd continued to supply Ford with pressings, tools, chassis frames and even complete bodies for decades. From 1953 until 1960 the Budd Company made the entire body-in-white plus closures of the Ford Thunderbird, supplying them direct to Ford for painting and final assembly. Even by 1971, Budd still made all outer panels for the T-Bird (Courtenay, 1987: 116). Budd also supplied plastic panels for its competitor, Chevrolet's Corvette, for Budd had always been happy to embrace innovation in car bodywork.

8.4 ZIS: Budd goes East

Another relatively early adopter was the still young Soviet Union. With its admiration for industry and Henry Ford in particular the Communist Party was naturally inclined to favouring the type of mass manufacturing made possible by the all-steel body. The establishment of a motor industry was incorporated in Stalin's first Five Year Plan of 1928–1933, although it would appear that the agreement with Ford used to implement this involved some kind of CKD shipment to the Soviet Union with local assembly (Besch, 2002: 46). It is not until the second and third Five Year Plans that volume vehicle production really took off. Besch (2002: 47) uses steel consumption by the sector as an indicator, and this seems valid. He writes that steel usage by the automotive sector grew from 14 200 tonnes in 1932 to 494 000 tonnes in 1938 – a good indicator of Budd technology taking off. We know of Budd's involvement in the prestige ZIS 101 luxury car project (*Automotive Industries*, 1935a, b; *Automobile Topics*, 1936). As Besch (2002: 47) explains 'The bodies themselves . . . were built with dies and presses designed and installed at the Stalin works by the Budd Company of Philadelphia'.

This order was a significant boost to Budd Manufacturing Co. at the time (*Automotive Industries*, 1935a). According to Grayson (1978: 362) Budd also trained Soviet personnel to operate the equipment and Budd experts went to the Soviet Union (*Automotive Industries*, 1935b). Przybylski (2002: 52) adds that the cost of these dies amounted to $1.5 million, a cost that could not be justified for the car's successor, the ZIS 110, which used cast dies of zinc–aluminium alloy; a softer material allowing smaller runs of Budd-style pressings appropriate for the volumes produced of this car.

8.5 Monocoque construction

The history of the monocoque or unibody is initially to some extent separate in that the first Budd applications still use a separate body and chassis

(Nieuwenhuis and Wells, 1997: 72). However, Budd pressed steel technology suddenly made this the obvious next step in vehicle construction. Budd found that by using single body-side stampings, some of the load on the chassis could already be fed into the body, thus allowing an overall weight reduction for chassis and body combined (Thum, 1928). Budd also conducted some early experiments with steel monocoques (Courtenay, 1987: 31) and Ledwinka filed a patent application for a steel unibody in 1927 (Grayson, 1978: 362). However, in terms of production vehicles, the Europeans took this next step, albeit with Budd input. Early examples of all-steel monocoque construction are the Citroën 11 cv/15 cv or 'Traction Avant' of 1934–56 and the 1935 Opel Olympia. The latter's derivative, the 1938 Opel Kadett, was later made in the Soviet Union as a Moskvitch, further committing the Soviets to the Buddist manufacturing introduced with the ZIS 101 (Eckermann, 1989: 88; Besch, 2002: 48–9). Edward Budd himself also saw the monocoque as the logical next step. As *Motor* (1937) explains 'If this new method of body–chassis construction gains ground – and it seems to me probable that it will – . . . there are many advantages to a system of construction which eliminates the separate body and chassis units and combines them into one homogeneous structure, ready for the motive power, spring suspension and rolling equipment'.

However, Budd also saw some disadvantages, among them the need for greater accuracy as well as the problem of assembling the car after the unibody had been built, which requires greater care on the part of assembly workers to avoid damage to the painted body. Budd was also doubtful if there was a cost advantage. 'With regard to cost, we have a more doubtful point. At present, a chassis frame can be produced for $9.00 to $15.00. Can we add from $9.00 to $15.00 to the cost of the present body and produce a combination chassis and body unit? We will have to do some close figuring' (*Motor*, 1937). It is possible that this line of thinking is behind the retention of some sort of vestigial chassis on many US full-size cars until the late twentieth century. On the other hand, he did expect a slight weight advantage and described the move as a radical innovation, which indeed it turned out to be, changing mass car production for a long time to come. The weight advantage was confirmed by the 1935 Opel Olympia, which weighed some 110 kg less than its otherwise equivalent predecessor – a saving of 11 % in vehicle weight (Eckermann, 1989: 69).

Citroën was also hoping to reduce vehicle weight by 100 kg by adopting this technology (Loubet, 2001: 140). The concept of this car – the Traction Avant – was ultimately supplied by a new recruit, rejected by Renault, but highly recommended by his former employer, the maverick aircraft and car manufacturer Gabriel Voisin. André Lefebvre had used his experience at Voisin – which introduced monocoque racing cars in 1923 – to dream up a radical new car concept which involved front wheel drive, torsion bar suspension, hydraulic brakes and monocoque construction for a total weight of no more than 750 kg (Loubet, 2001: 140). Citroën paid $600 000 to install the body system for its monocoque Traction Avant from 1932 onwards. This was offset by a saving of 70 kg in steel per car, at a cost of FF300–500 (Loubet, 2001: 105). Although Citroën was the first to produce a monocoque structure in volume production, it relied heavily on Budd's patents and technologies to do so. Weight reduction was a major motivation, which the Americans lacked.

Renault later copied the Opel Olympia/Kadett for his Juvaquattre and ran into problems with Budd copyrights. However, Renault personnel did find on fact-finding tours of the US after the liberation that Europe had by then overtaken the Americans in exploiting the possibilities of Buddist car design. They took two prototype Renault 11 cvs to Budd in 1945, which Budd, who developed the bodies, calculated would weigh around 1100 kg. In fact, Renault succeeded in making them at 900 kg (Loubet, 2001: 226). The Americans, meanwhile, had focused more on styling and advances in production involving the implementation of Fordist and Buddist ideas, as well as implementing much greater specialisation, such as plants making only a single model line.

In the US, most small craft car makers had not survived the 1930s (Nieuwenhuis and Wells, 1997: 197; Raff, 1991, 1994). Loubet (2001: 228–9) describes how an American fact-finding tour in 1946 was astonished to see almost state-of-the-art mass production at Citroën and Renault, side by side with the anarchic craft production at Delahaye. However, they did conclude that the long cycle times at Renault and Peugeot pointed to 'a modern concept of mass production improperly applied'. They felt there was too much manual input in Sochaux and Billancourt and flows were too erratic (Loubet, 2001: 229).

The effect of the introduction of Buddism – as well as other factors – on the French car industry is illustrated in Fig. 8.1. This shows, as mentioned earlier, a rapid rise in the number of French car makers from the industry's beginnings in the 1880s. After an initial shake-out between 1900 and 1910, a period of stability set in. However, the interwar period saw a major decline with the various economic crises and the introduction of Buddism by some manufacturers taking its toll. The post-Second World War period saw a slight revival as plastics technology made some new small volume producers viable (Alpine, DB, Gordini, etc.) and an increase in demand allowed the luxury craft makes, such as Delahaye, Hotchkiss, Salmson and Talbot a brief stay of execution. From 1950 the final decline set in to the present handful of car makers in France: Renault, PSA Peugeot-Citroën, Matra, Venturi, Mega and a few others.

Some of the reasons for the shake-out of the 1950s are illustrated by Fig. 8.2. This shows a number of French cars available in the early 1950s in the range of 4–15 fiscal horsepower (CV – chevaux vapeur), set against their price in units of FF1000. The cost for coachbuilt cars of the same rating is significantly higher than for a Buddist car. Much of this can be attributed to the unit cost advantages of Buddist technology.

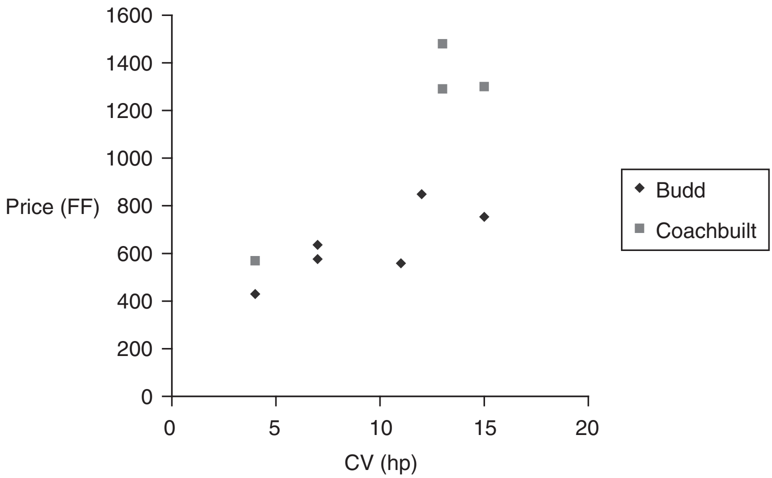

Fig. 8.2 Price comparison of Budd vs. coachbuilt cars in France in 1950 (4–15 CV/FF).
Source: data from Sabatès (1986).
* Models included: Citroën 11cv and 15cv-Six; Renault 4cv; Peugeot 203 7cv; Simca Aronde 7cv; Panhard Dyna 4cv; Ford Vedette 12cv; Salmson G72 13cv; Hotchkiss Anjou 13cv; Talbot Lago Baby 15cv.

8.6 Buddism fraying at the edges

Despite the massive success of Buddism throughout most of the twentieth century, Buddist mass car making can now be said to be in crisis. Profitability has been declining steadily for decades. Buddist steel body making ceased to be profitable for Budd as well. In 1962 and 1963, the Budd Company only achieved 2 % return on sales (Courtenay, 1987: 90). At that time there was still scope for cost reduction through automation and, ultimately, the adoption of lean manufacturing methods, and a decade later Budd was back in real profit. This flexibility has largely gone. The performance of General Motors illustrates this decline in profitability. In the late 1920s GM's net profit margin approached 20 %, yet by the 1960s this had declined to around 10 % – still impressive by modern standards. However, by 2000 this had fallen to only 2.7 % (Haglund, 2001). This is not untypical for the volume end of car making, although specialist producers are still able to maximise their return through cost recovery. Thus in 2000, while GM only managed a profit of £250 per car, Mercedes-Benz managed £1123, BMW £1200 and Porsche a massive £5385 per car.

Car makers have sought solutions to this lack of profitability through several strategies. With increasingly diverse product ranges, few products now reach the minimum economies of scale needed for least cost Buddist car making. As much as 80 % of models from mass car makers may not reach the minimum annual volumes needed to justify the investments in Budd-style car making. With shortening product cycles, the option of keeping these models in production for longer periods – thus recovering their investment costs over a longer time – is also increasingly difficult. Car makers have tried to recapture these economies of scale by forming alliances and take-overs, thereby sharing costs and increasing volumes. This is helped further by platform strategies, whereby the key body and power-train components are shared, thus cutting costs, while visible differentiation is retained. They have also started to abandon pure Buddist technology for various alternatives with lower breakeven volumes. The need for weight reduction, driven by the need to reduce CO_2 emissions under the Kyoto Protocol, has become a new element. This agenda has been focusing attention on body structures generally as a large component with little added value to the customer and thus an area to cut weight as well as cost.

There have been clear signs that the Buddist paradigm is less robust than it once was. Various products have been launched by traditional volume producers which in some aspect or other move away from conventional Buddism. These will be discussed in some detail in Chapter 9, but suffice to say that a number of vehicles can now be regarded as 'signpost' vehicles pointing to a post-Budd future for car production. Examples are outlined in Table 8.2.

8.7 Steel fights back

Just as Budd had to compete in the 1920s with composite structures that mimicked some of the characteristics of his bodies, now the Buddist world is fighting back. The Ultra-Light Steel Auto Body project (ULSAB) has gathered together 35 of the world's steelmakers in order to show that the all-steel welded body is by no means dead yet. Their first demonstration projects, ULSAB I and II, reported in the mid-1990s (Nieuwenhuis and Wells, 1997: 88–94) and showed a body-in-white of lower than average weight. The weight reduction of 36 % over a theoretical benchmark vehicle body was achieved through a number of novel techniques, such as hydroforming for hollow structures, tailor-welded blanking, laser welding, high strength steels and optimised design. The results were flattered by the choice of a body size reflecting a typical US car of the period. The ULSAB project was followed by ULSAC, which added closures (bonnet, boot, front wings and doors) to the body shown earlier. It is important to note, in fact, that one of the key attributes of the all-steel technology has been its inherent capacity for continuous improvements in various areas. Some of these have been to steel itself, but also in joining technology, surface treatment and painting. In addition, the technology has been highly amenable to process improvements such as automation, material yield improvements and labour saving, while also allowing certain improvements in cars themselves, notably greater stiffness, crash safety, cost reduction, etc.

Table 8.2 Some post-Budd signpost vehicles

Manufacturer	Model	Year introduced	Technology
Matra	Renault Espace	1984 (all steel in 2002)	Hot-dip galvanised steel spaceframe with composite body panels
Audi	A8	1994	Aluminium spaceframe with aluminium panels
MCC	Smart City Coupé	1997	Steel spaceframe module with thermoplastic outer panels
Fiat	Multipla	1998	Steel spaceframe combining rolled profiles with pressings
Chevrolet	Corvette	1953 (current generation 1997)	Steel chassis with SMC body
GM	EV-1	1998	Aluminium spaceframe module with composite panels
Audi	A2	1999	Aluminium semi-spaceframe
Honda	Insight	1999	Aluminium monocoque with aluminium and composite panels
Ford	Th!nk City	2000	Folded sheet steel chassis with aluminium framed upper structure and thermoplastic panels
Jaguar	XJ	2002	Aluminium monocoque
Matra	Renault Avantime	2002	Hot-dip galvanised steel and aluminium spaceframe SMC and thermoplastic panels

The steel industry had become increasingly worried by the potential impact of alternative materials, particularly aluminium. The aluminium industry had been working with a number of car makers, such as Ford, Rover and Audi, to show the suitability of aluminium for car bodies. Audi launched the intensively-previewed A8 aluminium luxury car in 1994 and its impact in the industry concentrated the minds of steel companies more than ever. In 2002 ULSAB-AVC (Advanced Vehicle Concepts) were presented to the media (www.ulsab-avc.org). These two concept cars showed in a closer to market form what was now possible with modern steel technology. A two door and a four door car were shown in order to help demonstrate that '. . . steel is the most environmentally optimal and affordable material for future generations of vehicles . . .' (www.ulsab-avc.org).

Not surprisingly, perhaps, the steel industry has focused on material substitution. However, the malaise of the Buddist paradigm is wider and involves high investments and resulting breakeven levels forcing manufacturers into high volume production, whether demand exists or not. The problem is not so much steel as a material, as the chosen technology to process it and turn it into cars in large numbers. Thus, many aluminium technologies suffer the same problem, leading to aluminium being described in automotive materials circles as 'lightweight steel' or 'expensive steel'. A range of technologies are offered by ULSAB that can help in reducing these costs (Berry, 1998). A more radical solution is a move from monocoque construction to a more modular construction – reintroducing the traditional separate body–chassis arrangement in some form. General Motors' AUTOnomy concept is an interesting move in this direction. AUTOnomy consists of a wheeled, driven power module, termed a 'skateboard' by GM. This chassis, powered by fuel cells, then forms the basis on to which various bodies can be fitted (see Chapter 7).

Other initiatives have also given conventional steel technology a new lease of life. The Fiat Multipla is a good example. In this MPV, Fiat used roll-formed steel profiles rather than pressings for those sections that were essentially straight. The tooling costs for these profiles are a fraction of the cost of press dies, thus reducing the tooling costs for the whole vehicle to a level where lower volumes become feasible. Fiat estimated at the time of launch that it could break even on this vehicle at volumes of around 40 000 a year. In addition, derivative variants would be cheaper in terms of tooling. Fiat has since applied this approach to other models and built in this technology on an approach already used by Matra for the steel structure of the Renault Espace. Here too, it allowed lower tooling costs and, hence, breakeven at lower volumes.

One of the keys to the future of Buddism is to develop technologies that enable the profitable manufacturing of cars in the volume range where most of the world's car models now are, i.e., between 10 000 and 100 000 a year, above which existing Budd technology is feasible as economies of scale can be achieved – hence the Espace moving to all-steel in 2002. Experiments with softer tooling (updates of what the Soviets used on their ZIS 110, see above) have already been carried out. While steel technology is experimenting with technologies to move down from 100 000 a year, composites technologies have been moving up and, in the case of SMC, can now compete at the lower levels of steel volumes. In some areas, injection-moulded thermoplastic parts are already out-competing steel, though not on cost.

In addition to the perceived threat from aluminium, plastics and composites have made real inroads since 1990 (Nieuwenhuis and Wells, 1997:

178). There has been a gradual move to increased use of plastic and composite materials in otherwise Buddist body structures, especially for bumpers, spoilers, body-kits, but also increasingly for closures, front wings and roof panels, traditionally made of steel. Within plastics and composite materials there is now also a move from thermoset to thermoplastic materials. This follows an earlier move, still ongoing to some extent, from glass fibre reinforced plastic (GRP) to sheet moulding compound (SMC). The latter has been seen in the history of the Chevrolet Corvette as well as the Matra–Renault Espace, both of which had bodies which were by 2002 made primarily of SMC. The move to thermoplastics is partly motivated by environmental considerations, as thermoplastics are significantly easier to recycle. Recycling problems have often been cited by both steel and aluminium industries as a major problem for composite materials. At Matra, they have also found other advantages in terms of cheaper tooling, shorter cycle times and lower weight due to a density of 1 compared to 1.8 for SMC (Longueville, 2000: 120–1).

It is clear that the Buddist paradigm, which came to dominate car making in the twentieth century, even determining its economics, is under pressure and may give way to an alternative car making system. What this might be will be explored in later chapters, starting with Chapter 9, which reviews currently available alternative car making technology models.

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9

Alternatives to high volume car production

> *One of the most fateful errors of our age is the belief that 'the problem of production' has been solved. Not only is this belief firmly held by people remote from production and therefore professionally unacquainted with the facts – it is held by virtually all the experts, the captains of industry, the economic managers in the governments of the world, the academic and not-so-academic economists, not to mention the economic journalists.* (Schumacher, 1973: 10)

9.1 Introduction

There can be little doubt that traditional, high volume car production, based on the achievement of economies of scale, yields low per-unit costs, all other things being equal. The history of the automotive industry is one in which the smaller companies have eventually succumbed to the larger (Rhys, 1977, 1989). At the same time, car manufacturing has become reduced to high volume plants with products of limited variety. There are exceptions, however. These exceptions are perhaps more prevalent than many would anticipate, and are outlined below in a discussion of alternative approaches to car production. This is followed by an outline of long-standing and recent examples of low volume production, to illustrate the basic premise that mass production is not entirely dominant.

Nevertheless, any observer of the automotive industry would be quick to point out that the highly expensive two-seat sports cars that tend to be the market segment occupied by low volume producers hardly constitute the pinnacle of environmental friendliness. While this chapter demonstrates that low volume production has survived, it does not argue that the product designs and production techniques utilised by those low volume producers can be adapted to affordable and sustainable vehicles. Even the French voiturettes, though aimed at a segment below city cars and quite affordable in absolute terms, are relatively expensive for what they offer, often costing as much as a cheap hatchback from a mainstream Buddist volume manufacturer. The same was to some extent true of Reliant's three-wheeled cars, which sold primarily on the basis of a taxation loophole, rather than price.

9.2 Alternative approaches to car production

It is evident that there are several types of vehicle manufacturing possible. Rhys (1989) identifies five types of car (and, by extension, car maker):

- mass-produced cars;
- quality upmarket cars;
- prestige luxury limousines or grand touring cars;
- sports cars;
- 'London' taxicabs.

Rhys also identifies a distinction between manufacturing processes, in particular between 'factory' sports car makers producing less than 1000 cars a year (including, for example, Morgan, Panther and TVR); utilitarian producers such as Reliant and Carbodies; and the workshop producers such as Marcos making about 1 car per week.

It is insufficiently appreciated that the definition of vehicle manufacturing is actually quite flexible. The characteristics that define different types of vehicle manufacturer are themselves open to debate – at various times the extent of capital intensity, automation, production flexibility, production volumes and labour task cycle times have all been used to characterise vehicle manufacturers. We would contend that also of significance is the character of distribution and sales, in particular whether the vehicle manufacturer relationship with the customer is mediated by third party independents. Sometimes the distinctions to be made are about brands and sub-brands, as for some of these sub-brands the amount of 'manufacturing' undertaken can be minimal. On the basis of the characteristics noted above, the following types of vehicle manufacturing can be identified:

- traditional Fordism;
- contemporary Toyotism;
- systems integrators;
- sub-contract manufacturing and assembly;
- sub-contract body assembly;
- low volume systems integration;
- product performance enhancers;
- kit car manufacturers.

9.2.1 Traditional Fordism

The traditional Fordism approach to production has a high degree of manufacturing integrated into the vehicle company, as embodied in Ford of the 1920s. Activities undertaken directly by the vehicle manufacturer, once the adoption of Budd technology became widespread, included pressing of steel panels, welding of panels into vehicle bodies, painting of bodies, engine machining and assembly, components manufacturing such as gearboxes, seats, radiators, wheels and many electrical components, and material production even including the ownership of rubber plantations. The vehicle manufacturer also undertook virtually all of the vehicle design and the assembly of the vehicle from individual components. Once firmly entrenched, traditional Fordism resulted in very large plants producing up to 800 000 cars per annum, often of a single model. Equally characteristic, Fordism resulted in large franchised dealership networks and a production-push mentality in which the manufacturer was isolated from the customer.

9.2.2 Contemporary Toyotism

The Toyota Production System (TPS) became established in the 1950s in Japan, and was widely emulated in the 1980s and 1990s by Western vehicle manufacturers. The emphasis in the TPS has been on production flexibility and low inventory production organisation. Still, the TPS includes the core manufacturing processes of Fordism. Greater reliance is placed on suppliers, both for component design and for the delivery of more fully assembled systems. Contemporary plant sizes are more likely to be of the order of 400 000 units per annum, with 2, 3 or even 4 models. A standard franchised dealership network is used, but with an emphasis on low inventory, rapid response supply.

9.2.3 Systems integrators

The systems integration approach really derives from other sectors, notably computers, where the vehicle 'manufacturer' actually does very little real production. Rather, the focus of activities is on product research and development, manufacturing system design, and marketing. This approach is not widespread in the automotive industry but does offer the key advantage of reduced capital cost. The nearest example is probably the MCC Smart plant in Hambach, with a capacity of about 200 000 units per annum but with a low degree of product variety. The actual assembly process carried out by MCC itself takes only about 5 hours, rather than the more typical 15–20 hours of a state-of-the-art Toyotist plant.

9.2.4 Sub-contract manufacturing and assembly

Sub-contract manufacturing and assembly has long been a feature of the automotive industry, especially in Europe. This is quite a varied form of vehicle production, but typically exists in order to relieve mainstream vehicle manufacturing plants of the complexity of producing low volume derivative models. Rarely is it done in order to access simple extra capacity. Typically, this scenario applies to the cabriolet versions of some models. In many instances a substantial proportion of the vehicle is built in the mainstream plant and then shipped to the sub-contract assembler. Levels of automation are low, with production volumes typically in the range of 20 000–60 000 units per annum. Vehicles are then supplied and sold through the vehicle manufacturers' own distribution network. Examples include Karmann, Heuliez, Pininfarina, Bertone and Valmet.

9.2.5 Sub-contract body assembly

While not widespread, sub-contract body assembly is a distinct manufacturing approach that appeared in the US in the early years of the adoption of Budd body technology, and is still found in the UK today. In the UK case, the Mayflower company assembles the bodies for the MG Rover MG TF, whereupon they are delivered to the MG Rover plant for painting and final assembly. The German company Karmann builds bodies for a number of clients in a similar fashion. Volumes for this type of activity are also low; usually under 20 000 per annum. Of course, in the days of the separate body and chassis there were many independent body-building companies.

9.2.6 Low volume systems integration

The systems integration approach has often been necessary for low volume vehicle manufacturers. Again, the actual manufacturing content can be quite low, as there is a high degree of bought-in parts, while the focus is on research and development and marketing. There is low capital intensity and low automation, with typically long task cycle times. Still, there is usually a core of expertise that helps define the brand and a tightly defined product type. Very rarely do these companies use Budd technology. Production volumes are typically below 6000 units per annum, but often these companies are close to their customers. A feature, for example, is that of customers often visiting the factory to see their car in production. Examples would be Ferrari, Lotus, Morgan, Panoz or TVR.

9.2.7 Product performance enhancers

Product performance enhancer companies would not usually be considered as vehicle manufacturers by many observers, though some are officially recognised as such. The Germans use the term 'tuner' for such firms, which appear to be more plentiful there than in most other countries. They usually take an existing vehicle and make various adjustments, additions or replacements in order to enhance performance – usually giving the car a more overtly ‘sporty’ feel and look. Examples are Alpina (BMW, MINI), Arden (Jaguar) and Irmscher (GM Opel, Isuzu) in Germany, and Prodrive (Subaru) in the UK. Such firms were more common in the past, yielding legendary names like Gordini, Abarth and Giannini. A trend of recent years has been for mainstream vehicle manufacturers to create their own in-house performance divisions, a notable example being the BMW ‘M’ division. Independent product enhancers have increasingly been brought into the direct control of mainstream vehicle manufacturers, an example being AMG and Mercedes, or Abarth and Fiat. Another model is that of Holden Special Vehicles (HSV) in Australia, an autonomous company set up as a joint venture between GM Holden and TWR of the UK in order to develop high performance variants of mainstream Holden models. The interesting features of these companies, however, are that they operate at low volumes, and confer a brand identity of their own. In this sense the performance enhancers could be said to intervene in the relationship between mainstream manufacturers and customers.

9.2.8 Kit car manufacturers

The kit car industry also exists at the margins of the mainstream automotive industry. Entry costs at this level are very low, with the use of existing high volume vehicles such as the Ford Fiesta to donate engine, gearbox and other components. Sometimes a floorpan is used, but on the whole these kit car makers make or source their own bespoke chassis, while bodies tend to be hand-uplay glass fibre. Still, the concept of the customer building the car should not be entirely dismissed, and again finds parallels in the computer industry. Companies like Quantum and Caterham can also build the vehicles and sell them complete.

Most contemporary cars are built in factories that broadly follow the Toyota Production System (TPS) model, using existing Buddist all-steel technology. However, even within Buddism there is a range of configurations possible for vehicle manufacturing and assembly, while several lower volume producers have never adopted Buddism. Manufacturers such as Lotus, TVR and the kit car manufacturers work outside the Budd paradigm and as a result have breakeven volumes an order of magnitude lower. That is, the number of cars produced per annum in order to be profitable is much smaller. Some kit car makers break even at 20 or 30 cars a year with their cheap tooling, while for firms such as Lotus or TVR the per-model breakeven volume is probably in the range of 300–500 a year.

Sub-contract vehicle production has a very long tradition in Europe. Few purchasers of the Porsche Boxster know that the vehicle has been assembled in Finland by a company called Valmet, rather than in Germany by Porsche itself. Some of the sub-contract assemblers are known in their own right, and their names may appear on some of the vehicles they are responsible for, generally because these companies have contributed some of the design and engineering. Again, this form of sub-branding is interesting because it changes the relationship between the manufacturer and the customer.

It is interesting that so many examples of the low volume vehicle producer are actually in Europe. A number of historic economic and cultural reasons suggest themselves to explain this phenomenon. The characteristics of the European market might provide a more comfortable environment for low volume producers. The market is relatively affluent, structured by class and taste distinctions, fragmented at a national cultural level, and receptive to innovative styles and technologies. In addition there are diverse driving environments caused by differences in climate, topography, road design, traffic laws and support infrastructure. Hence a car designed to hurtle down the German autobahns will be different from one designed to flit down the uneven and sinuous roads of rural Wales. Perhaps the North American market, by virtue of its homogeneity and scale, along with the importance of price rather than dynamic performance, has emphasised the significance of mass production. Conversely, in Japan it is perhaps the nature of government regulation that has made the development of low volume models so expensive while this has been reinforced by a traditional concern for conservative design. While this remains a rather speculative account, it is clear that there is a tradition – still very much alive – for low volume car production in Europe.

9.3 Sports cars: niche vs. mainstream vehicle manufacturers

Much of the tradition in low volume car production lies in sports cars: vehicles that are variously compromised for everyday or family use, but that offer unusual styling and performance. These vehicles, unless built using the kit car approach, tend to be relatively expensive. Thus there has been a simple association between specialised markets and specialised vehicle manufacturers, niche markets and expensive products. Consumers have been willing to pay more for performance and for exclusivity. That pattern has been challenged as mainstream vehicle manufacturers have sought to expand the market and lower prices. At the same time, some mainstream vehicles have once again started to approach the driving experience they once offered. After abandoning volume sports cars and largely leaving that segment to the specialists, volume car makers have rediscovered this segment. Perhaps the definitive car in this respect has been the Mazda MX5 (known as Miata in the US, and Eunos Roadster in Japan), that in 1989 marked the return of volume manufacturers to the two-seat sports car segment. In other markets, Fiat's Barchetta has had a similar effect. The result is much greater pressure on the specialist producers.

Table 9.1 summarises the position for a selection of sports cars from niche and more mainstream vehicle manufacturers. While this is only a

Table 9.1 A comparison of selected sports car models (2002)

Manufacturer	Model	Price (£) on UK market	Production volume (2001)	Comments
Morgan	Aero 8	55 000		Aluminium body
	Plus Eight	35 000		Ash frame body
	4-4	26 000	700 total (all models)	Ash frame body
Jensen	SV-8	42 000	0	Went into administration, July 2002
Westfield	1800	15 000		Open top cars mostly for track use
	Speedsport	18 000		
	Sport	17 000	500 total (all models)	
TVR	Cerbera	41 000		Plastic panels on tubular backbone chassis. TVR make own engines
	Chimaera	35 000		
	Tamora	36 000		
	Tuscan	48 000	1200 total (all models)	
Parradine	525S	na	0	Failed to make it to market
Noble	M12	45 000	150	Recent entrant
Caterham	Super 7	23 000		Open top cars, mostly for track use
Lea Francis	na	na	0	Failed to make it to market
Marcos				Returned from bankruptcy
Strathcarron	SC-5A	na	0	Failed to make it to market
AC	Cobra 212	60 000		Suggestion that AC cars will be built in Malta
	Cobra 302	39 000		
Lotus	Elise	25 000	6000 total (including Esprit and Vauxhall/ Opel models)	Also built as the Opel Speedster / Vauxhall VX220
Porsche	Boxster	35 000		Built by Valmet in Finland
	911	20 000		Bodies outsourced
BMW	Z3	23 000		Built in the US
	Z8	80 000		Aluminium construction
Toyota	MR2	17 000		
Fiat	Barchetta	14 000		Only left-hand drive
Ford	Puma	13 000		Derived from the Fiesta
Rover	MG TF	18 000		Body built by Mayflower
Honda	NSX	62 000		Aluminium construction
	S2000	26 000		

Source: derived from *Autocar* (2002) 'Low volume car producers in the UK', *Autocar* June, 17–19, for price data and estimates; AWKnowledge.com for production data (excludes 'super-cars' such as Ferrari Enzo and Lamborghini Murcielago).

snapshot of the situation, it does illustrate that in broad terms lower volumes mean higher prices. Generally the approach to low volume sports car manufacturing is to use an existing engine and gearbox, not least because this helps with respect to Type Approval. In order to keep costs down these niche assemblers may also use other components from mainstream models, from lights and door handles to glass and pedal boxes. In this sense the low volume vehicle manufacturers are rather similar to the 'systems integrators' in the bicycle sector (see Chapter 15). It is possible that advances in prototyping techniques will migrate to low-volume production and thereby make possible greater levels of differentiation.

Specialist producers in the UK are allowed some dispensation from the provisions of the Type Approval process, chiefly with respect to the requirement to conduct whole-vehicle impact tests to prove crashworthiness. New vehicle manufacturers appear and disappear frequently. In the UK there are (in 2002) several very low volume producers such as Radical (6 road cars per annum), Ronart (6 cars), Trident (17 cars), Grinnall (25 cars) and Ariel (50 cars). Other UK and international specialist producers have been in business for many years, and it is pertinent to consider why this might be so. Much may be attributed to the positioning of the product with respect to supply and demand. Despite the relatively high prices of the cars, it is evident that the annual production capacity of a company such as Morgan is well below the peak of annual demand, and even well below the lowest level of demand at the bottom of the economic cycle. While this means some profitable production opportunities could be lost, the result is that at no point is over-production likely. Fluctuations in demand are then managed through changes in the time to wait for the car to be built. In periods of high demand the waiting period could be five years, whilst at times of low demand it might fall to less than one year. Sports car producers need this approach because the product is much more likely to be a discretionary rather than necessary purchase; a whim or a toy rather than a tool or functional device. In times of economic downturn such discretionary expenditures are more likely to be abandoned or deferred.

A critical problem for the niche specialists is that of new product development, an issue that is also the problem for new entrants. In Table 9.1 a number of instances are noted where the product failed to reach the market. It is frequently the case that a new brand is revealed at a Motor Show or related event, only for the car never to make it to the showroom. The new model needs expenditure in advance of sales, first in terms of design and then much more substantial investments to put the vehicle into production. Having such a narrow product range and such a small customer base, the specialist producers are vulnerable to any mistake. One wrong model can be their downfall, whereas the high-volume vehicle manufacturers can survive such mistakes (see Dansall, 2002 for the case of the Ford Edsel, for example). Ulrich Bez, CEO at Aston Martin (owned by Ford Motor Company) put it thus: 'Aston Martin cannot develop a modern, topflight product without access to global resources. We need the network and synergies that the Ford Group offers us . . . (we cannot) independently and efficiently develop the new materials, sophisticated electronics, complex safety systems or competitive factory processes that form the foundation of modern automobile manufacturing.' (www.automagazine.de).

The mainstream view is clearly that low-volume vehicle manufacturers can only survive underneath the protective umbrella of the global, multi-brand group. As a simple illustration, all the safety simulation and testing done on the new 'baby' Aston Martin has been undertaken at the hugely impressive Volvo Safety Centre (Volvo also being part of the Ford group), a facility that would be unaffordable to Aston Martin as a stand-alone company.

9.4 Examples of low volume car production

Table 9.1 suggests no straightforward correlation between volume and price. Still, the link between low volume and high price is largely reinforced by an examination of new plants being created to produce cars in low volume. Many of these new plants are to produce luxury vehicles rather than overt sports cars. Table 9.2 summarises some of the illustrative plants. The Maybach models cost around £250 000, the Mercedes SLR being in a similar price range, while the Rolls-Royce is projected to sell at about £200 000. In many instances the sports cars noted in Table 9.1 and the luxury vehicles noted in Table 9.2 are not based upon all-steel bodies. Indeed, the Mercedes SLR has a carbon fibre body shell, while the others use varying amounts of aluminium along with degrees of innovative shaping and joining technology. The plants are characterised by long cycle times between the assembly stations, and slow-moving assembly lines that, with low levels of automation, allow the high levels of customisation that distinguish these cars.

All the plants in Table 9.2 are unique establishments that have excited almost as much debate over their architecture as over the models produced. Perhaps the least controversial is the Maybach 'plant within a plant' approach. This has obvious advantages, not least the proximity to the main press shop. On the other hand, because the Maybach is so large a car (the largest version being 6.2 metres long), it is too long to fit into the Sindelfingen paint shop tanks. As a result, the pressed and welded bodies have to be transported to the nearby Mercedes bus plant at Mannheim in order to be painted, and then shipped back to the assembly hall.

The new Rolls-Royce plant arises out of the rather strange agreement between VW and BMW to separate the Rolls-Royce brand from the Bentley brand to which it had been joined since 1931. Previously, both brands were assembled in Crewe. In the separation, VW retained the Bentley brand and the Crewe manufacturing site, and BMW gained the

Table 9.2 Some illustrative new plants manufacturing cars in low volume

Manufacturer	Model	Plant location	Comments
DaimlerChrysler	Maybach	Sindelfingen, Germany	Plant within existing Mercedes Sindelfingen complex. Production started 2002. Up to 1500 cars per annum
Mercedes-McLaren	SLR	Paragon Centre, Woking, UK	Attempt to evoke F1 heritage. Production started 2003. Production of 500 cars per annum. Total investment of € 200 m
Rolls-Royce	All models	Goodwood, UK	Built by BMW. Production started 2003. Staff of 350, making circa 1000 cars pa.
VW	Phaeton, launched 2002	Dresden, Germany	Production started 2003
Spyker	C8	Zeewolde, The Netherlands	Production started 2002
Aston Martin	New 'baby' Aston Martin	Gaydon, UK	Anticipated production of 3000 by 2005

Source: www.daimlerchrysler.com; www.autofieldguide.com; autointel.com; www.mclaren.co.uk.

Rolls-Royce brand from 1 January 2003, but needed a new site. The actualisation of the plan, with a new £60 million factory at Goodwood in the UK, appears sub-optimal from a manufacturing efficiency perspective. Again, complete bodies will be shipped to the plant from Germany. Perhaps the plant that has come closest to being a 'showcase' for the model it produces is the VW operation in Dresden, making the Phaeton. The need to make this effort in part arises out of the attempt by VW to stretch the brand into unfamiliar prestige territory.

9.4.1 The VW Dresden plant

The VW plant at Dresden, termed the Gläserne Manufaktur ('glass workshop' is probably the best rendering) has been given enormous praise for its innovative design and unusual styling: '. . . a cultural monument as much as a car plant. The finished cars are stored, like some gleaming art work, in a 15-storey glazed drum that overlooks the parks, domes and Soviet-style housing blocks of the city' (Glancey, 2002). 'From a distance it appears to be like any other modern city centre office block: a seemingly glass construction that looks airy and spacious . . . A modern art gallery perhaps, or maybe an ultra-modern apartment block? In fact this stunning creation . . . is actually a car plant' (Kimberley, 2002).

The plant, where construction started in 1999, was built at a cost of some US$200 million and at full capacity is expected to employ 800 workers producing 150 cars per day. The vehicle itself is thought to have cost around $700 million in development and engineering (Jackson, 2002). It is further claimed that another 3000 jobs will be created in suppliers and service providers in the Dresden region as a result of the investment, although these claims are difficult to evaluate without further evidence. It is a plant of huge political importance in Germany. Located in former East Germany, the plant symbolises the attempt to integrate the economy of the once-Communist new Länder with that of the Federal Republic. Thus, some $70 million of the total plant cost was met by European Union development aid funding. The appearance of the plant itself, along with the interior layout and décor, is part of an attempt by VW to gain loyalty to the product and the brand, as many customers are expected to visit and see their car being built – final assembly as art. 'The cars are being assembled in airy, timber-floored halls that feel like a cross between the galleries of Tate Modern, the Guggenheim, Bilbao and the Foster terminal at Stansted Airport' (Glancey, 2002).

It is an extension of the thinking behind the VW Autostadt theme park at the main factory in Wolfsburg, Germany – designed by the same architects and intended to convey the qualities of the various brands held by VW Group – and of the customer collection centres run by Audi at Ingolstadt and Mercedes at Sindelfingen. Materials and components are delivered by special freight-only trams, rather than the more usual trains or trucks, while internal parts logistics are handled by a form of automatic guided vehicle termed a 'Driverless Transportation System'. The special trams are 60 m long and linked to the Friedrichstadt logistics centre on the city outskirts, from which all components except the bodies are delivered. The two special trams cost €1.8 million each, and run at 50 km per hour from the distribution centre to the plant. Still, the plant is essentially an assembly rather than a manufacturing operation. Even the body shells are brought in (by truck), fully constructed from the VW plant at Mosel. Levels of automation appear to be very low, with only three robots in the plant (installation of spare wheel, front and rear glazing). However, in line with contemporary thinking on car plants, there is considerable emphasis on providing a light and quiet working environment. For example, the use of wooden floors and moving wooden track (rather than the usual conveyor tracks) provides a warmer surface than the usual steel plate and helps to reduce noise. There are none of the pneumatic tools usually found in car plants, while the plant also employs a variety of measures to reduce the physical stress of the assembly operation for the workers. As when the Nissan plant was established at Sunderland in the UK, jobs in the VW Dresden plant have been well oversubscribed. For example, there were 1200 applicants for the 14 customer manager positions (Jacksonville.com, 2002).

It is perhaps ironic that this palace of modern automotive manufacturing technology is employed to produce the largest and most expensive VW vehicle ever manufactured. The VW Phaeton has three engine choices: 3.2 litre V6; 6.0 litre W12; and 5.0 litre V10 diesel. It is 5.06 metres long and 1.9 metres wide. The car is intended to compete in the US 'luxury sedan' or European 'luxury saloon' segment that includes the BMW 7 Series, Mercedes S Class, Jaguar XJ and Audi A8 but at $50 000 is somewhat cheaper than the rivals. The customers also benefit from an impressive lifetime customer support promise which can be transferred when the car is sold until the car is scrapped. In this, VW is mirroring other vehicle manufacturers that have sought to stretch the service support offered to customers. For example, BMW MINI customers can purchase a 'TLC' package to cover service, warranty and parts over five years. Similar offers are available from Audi for the A8, while Maybach offers a Personal Customer Manager at the end of a mobile telephone, 24 hours a day for the life of the car.

While the VW Phaeton and the factory can be criticised on environmental or sustainability grounds, the car does illustrate quite clearly the linkage between production process, product and marketing concept. While the car itself is a technical showcase, enormous effort has been put into allowing customers to feel special, from the five-star restaurant to the international Technical Service Centre. This reinforces a central theme within this book, that any alternatives to the traditional mainstream practice of production and sales will need to consider the entire production–consumption equation through the whole life of the vehicle, and may well need to embrace a radical business model in order for success to be achieved.

9.5 Conclusions

Two relatively enduring 'truisms' emerge from this chapter. The production of low volume cars remains an element of the total automotive industry, but, equally, cars produced in low volume – even those aimed at cheaper segments – tend to be relatively expensive. Still, in total it is perhaps the case that the low volume plants offer some insights into either the future for the mass industry, or perhaps the features that all customers (not just the very rich) would appreciate if they had the chance. Features such as the opportunity to watch the car being built and then collect it from the factory; to decide in great detail on the finish of the vehicle in terms of options and trim; to have support for the lifetime of the car whether or not the car is sold on to another person – these are all denied to the mass consumer. Thus, one question remains: Can the character of mass production be changed so that the opportunity to provide these additional features can be realised?

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10

Sustainability

Let us not . . . flatter ourselves on account of our human victories over nature. For each such victory takes its revenge on us.
(Friedrich Engels, in Attfield, 1991)

10.1 The sustainability concept

Looking back over the history of environmental concern surrounding the motor car, some distinct phases can be distinguished (Fig. 10.1). In the early phases air quality was the prime concern, leading to regulation of toxic emissions from cars. Initially, from the 1950s, the technical problem of crank-case blowby was the main concern, rapidly followed by tailpipe emissions during the 1960s and 1970s, and then during the 1980s and early 1990s, evaporative emissions of toxic volatile organic compounds (VOCs). The 1990s were dominated by the CO_2 debate, which, in 2003, is still a major concern, and will dominate the agenda of the motor industry over the next ten years at least. However, governments have increasingly adopted elements of the sustainability concept. This concept is by no means clearly defined, although some clarity has emerged in recent years. However, what has been less appreciated is that this trajectory has also taken legislators from relatively superficial concerns into areas of much deeper ecology and this is the focus of this chapter.

Sustainability is the most fundamental of environmental concepts in that it defines any practice that we cannot indulge in indefinitely without lasting environmental damage or impact as 'unsustainable'. Increasing evidence is coming to light from archaeology that a number of quite sophisticated

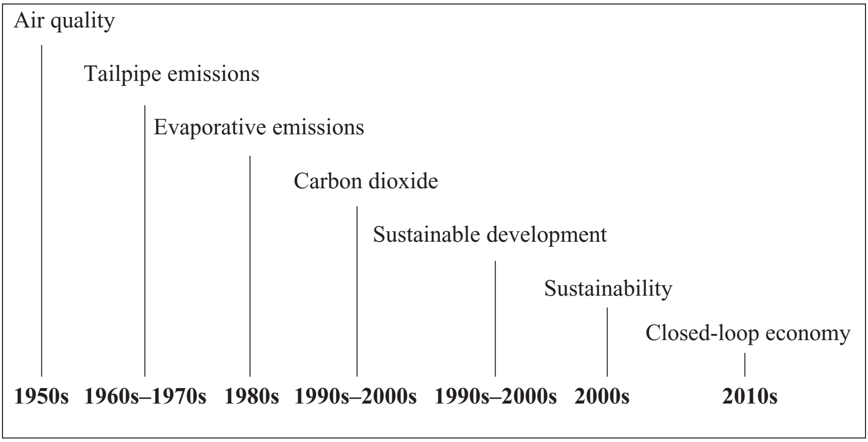

Fig. 10.1 History of primary environmental regulatory concerns.

civilisations have disappeared because they were ultimately unsustainable. Examples are the people of Easter Island and the Anasazi of the American Southwest. In most cases their unsustainability was environmental and lessons appear to have been learned as the present native residents of the Southwestern US, such as the Hopi, for example, are known for their environmental sensitivity (Waters, 1969). It is important for our own civilisation to face up to this issue, therefore, or we could also face oblivion. What this means for the automotive sector will be investigated in Chapter 11.

Unlike much emissions-based concern, environmental sustainability is not about the here and now, and instead looks into the future implications of our current actions and of the continuation of our current practices into the future. Our activities may not damage us in our lifetime, but may damage future generations. This makes it difficult for our short-term focused society and its politicians to handle. It also makes it difficult for conventional economics to handle as the market does not begin to work until a commodity has become too scarce, by which time it is usually too late. Our ability to foresee a crisis and act in a precautionary manner cannot easily be captured by the market without decisive intervention. Common sense, rather than economics, may therefore be required – the precautionary principle.

Some historic legal systems have enshrined sustainability in law. In this context, the Great Binding Law, or Gayanashagowa, of the native American Iroquois Confederacy has generated interest among environmentalists. It survived for some 300 years in the Eastern US and inspired the Founding Fathers and the US constitution itself. It tells its chief legal officers to 'Look and listen for the welfare of the whole people and have always in view not only the present, but also the coming generations' (Murphy, 1999).

Another version that has emerged from the oral tradition specifies that whatever resources are available to the present generation should also be available to the seventh generation. We are that seventh generation since the Great Law was last used.

The Founding Fathers of the United States of America chose not to incorporate this particular clause into their constitution. Today, however, many governments are producing strategy documents for sustainable development and as a basic concept it is firmly moving onto the agenda of government and industry. More recent legal systems, such as the Government of Wales Act, effectively Wales' devolved constitution regulating the responsibilities of the National Assembly for Wales, have started to incorporate a sustainability element: 'The Assembly shall make a scheme setting out how it proposes, in the exercise of its functions, to promote sustainable development . . .' (HMSO, 1998).

But what does it mean in practice? An environmentally sustainable motor industry would not use finite resources and would not cause pollution that could not be easily absorbed by nature. At first this appears an impossible task, yet it is technically possible to operate in this way. The first requirement, however, would be a closed-loop economy (see below). Given the secondary materials currently in the world economies, with judicious recycling a car could be made without extracting additional raw materials, but merely using what has already been extracted in the past and recycling it. There are some problems with this, which will be explored in Chapter 11, but for our present purposes this principle will be used. Energy used in this process would need to be moved onto a sustainable footing. It should not use non-renewable resources nor cause pollution that could not be readily absorbed. This would also apply to the transport of these secondary materials. Clearly, all this is not easy at present.

Using renewable energy sources would be the key. Again, the technology exists, but it is not widespread enough to make an impact. It may never, in fact, meet our current requirements, so a closed-loop sustainable system would also imply a dramatic cut in our energy use, as well as reduced overall consumption levels. Again, this is technically possible, and von Weizsäcker *et al.* (1997), as well as Hawken *et al.* (1999), have analysed how and given best practice examples, but not yet on the required scale. Despite the apparently fanciful nature of these concepts, they are becoming mainstream in various forms and to varying degrees among environmentalists and some regulators and in the longer term will be unavoidable. This means that any longer-term strategies devised at the moment need to keep these concepts in mind.

For several years, the new, more comprehensive, environmental sustainability concept was largely confined to the environmental and academic communities, although an award-winning paper in the *Harvard Business Review* by International Greening of Industry Network member Stuart Hart (1997) brought it to the attention of the wider business community.

Hart asserts that sustainability should not be confused with mere pollution prevention or waste reduction, as it requires a fundamentally different mind set. Hart (1997) writes that '. . . in meeting our needs, we are destroying the ability of future generations to meet theirs'.

Hart foresees the development of completely new technologies and completely new types of businesses, developed in order to meet the sustainability needs. He predicts that in developed economies the demand for virgin materials will decline as re-use and recycling become more common, hence over the next decade or so Hart believes that sustainable development will become one of the biggest opportunities in the history of commerce. Businesses will have to decide whether they are part of the problem or part of the solution. Hart does not ignore the car sector and states that 'Although the auto industry has made progress, it falls far short of sustainability'. Hart extends the responsibility of producers further than ever before, when he asserts that 'Companies can and must change the way customers think by creating preferences for products and services consistent with sustainability'.

This is a new concept, as industry has traditionally blamed the consumer for not demanding greener goods. In fact, consumer choice is always limited by what suppliers choose to supply. Hart recognises this and therefore transfers the responsibility to the supply side and declares it up to them to educate consumers in changing their buying behaviour. Car makers have always tried to influence buyer behaviour through marketing and advertising, but have often been reluctant to actively market on the basis of environmental criteria. Hart concludes by saying that although changes in policy and consumer behaviour are essential, business can no longer hide behind these 'figleaves'. They must actively work to change consumer behaviour through education. We could add that they should also try and involve regulators in an active dialogue to gain their support in this.

Currently, the concept of 'sustainable development' rather than sustainability is preferred by government and industry (Pearce, 1993). This is normally perceived as operating at the intersection between environmental, economic and social considerations and was first defined in the so-called Brundtland Report (World Commission on Environment and Development, 1987). Gro Harlem Brundtland herself in 1986 (Pearce *et al*., 1989: 175) emphasised the following four points as defining principles for sustainable development:

1. It requires the elimination of poverty and deprivation;
2. It requires the conservation and enhancement of the resources base which alone can ensure that the elimination of the poverty is permanent;
3. It requires a broadening of the concept of development so that it covers not only economic growth but also social and cultural development;
4. Most important, it requires the unification of economics and ecology in decision-making at all levels.

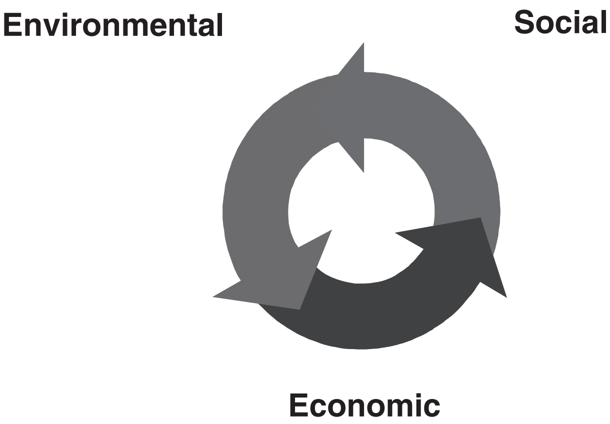

Fig. 10.2 The sustainable development trigram.

The thinking behind this definition is that moving to a purely environmental sustainability agenda would have unacceptable economic and social consequences in the short term. Therefore, a balancing of these three areas of concern may be more realistic. In practice, we now have a situation where business and industry tend to focus on the economic aspects, even proposing the concept of 'sustainable growth'. This is something they understand and can comprehend, although most environmentalists, such as Daly who describes such a concept as 'an oxymoron' (1999: 50) are less inclined to feel the same. Nonetheless, environmental thinking on sustainability continues to inform the rolling definitions of sustainability and thus continues to underpin them with a more radical environmental agenda. The essence, though, is that the three elements are equal and that they interact dynamically (Fig. 10.2).

Environmental thinking has moved on since these ideas were enshrined in the 1980s. A greater sense of urgency now informs environmental thinking and it is likely that less proactive firms throughout industry and business will have a rude awakening, as government and NGOs will increasingly give at least equal weight to the social and environmental elements. They will also find that some of their competitors are already there.

There are other concepts that should also be considered. One of these is diversity. This principle is enshrined in Agenda 21 and the Rio international agreement on biodiversity. However, there is a growing feeling that diversity generally is of value. It reduces risk – as a threat to one element does not necessarily threaten the system – and allows greater creativity and hence more rapid and more flexible progress. Thus in their own way, linguistic diversity and cultural diversity, for example, have been promoted as valuable. We could perhaps add to this economic diversity, and also technological diversity, both of which can be expressed in many different ways. This issue will be returned to in Chapter 14.

One of the key concepts of sustainability is that of our responsibility for generations yet to come. This is actually quite a complex concept, which requires a bit of analysis; something for which we have no capacity in this book. However, those readers wishing to explore this concept further could consult Daly (1999: 51–6), and particularly Chapter 6 of Attfield (1991).

10.2 An ethical and spiritual dimension

It was assumed until quite recently that the concept of sustainability was somehow self-evident and naturally understood by all people. However, this does not appear to be the case. Although steeped in the business of car making and globalising industrial concerns, the authors are by nature quite 'green', and in some respects verging on the dark green of so-called 'deep' ecology, if not always in practice, certainly often in sympathies. Both of us tend to cycle to work, for example, although both of us also own cars. Neither of us has much difficulty understanding the fundamentals of the basic mindset of native peoples who regard themselves as an integral part of the wider natural ecosystem or biosphere.

We now know this affinity with nature is no longer universal among 'civilised' humans. Although we have met a surprising number of deep ecology sympathisers in the motor industry, we have also met many who do not feel this affinity. Most surprising perhaps is the fact that we have found these people on both sides of the ecological divide, with some environmental practitioners apparently merely that: practitioners, but not believers. These people worship at the shrine of environmentalism by practising its rituals – such as environmental auditing, ecodesign, environmental reporting – but they apparently lack an appreciation of that higher, spiritual relationship with nature. This is probably what distinguishes 'deep' ecologists from what we could call – not disparagingly; we need all supporters – the 'shallow' type. It is a theme that enjoys a growing support from movements such as Creation Spirituality (Anderson, 1998) and which is explored so eloquently by McIntosh (2001) and also Abram (1996), who himself draws heavily on the work of the phenomenologists. Anderson (1998: 20) argues that 'It is important to see that capitalism is not purely an economic phenomenon. It is also a psychological and cultural phenomenon, because its amazing transformation of the world would not have been possible without a particular attitude towards the world. It would have been impossible in a culture which saw nature as sacred'.

Abram proposes an interesting theory in that he traces back our Western separation from nature to the invention of the alphabetic writing system, or rather its adoption by the Greeks. Here, for the first time, people used a writing system without clear connection to our natural environment. Even in the Middle East, where the Hebrew aleph-beth – on which the Greek alphabet is based – originated, the letters still had a visual link with the meaning of a word which started with that letter. Abram (1996: 101) gives the example of the letter A, which when written upside down looks like an ox. This letter, Aleph in Hebrew, also meant ox. Other writing systems, such as the Chinese, retain in the shape of their characters such direct links with the natural world, thus reminding writers regularly about their place in that world. Even in Korea, where the 25 character hangul alphabet has been in use for some 700 years, Chinese characters are still used for certain key concepts and places, thus retaining the link with nature. The arbitrary alphabet became a new focus for human attention. Whereas previously – and in more integrated societies still – people had 'read' signs in the natural environment in order to understand the world, now people could focus on the written word, which to a large extent replaced it. Significantly, Lao Zi also warns against book-learning as being against the Tao, and the way of nature: 'Usually, people read because they want to know – but the more you study the Tao, the less you want knowledge' (Kwok *et al*., 1993: 122). The alphabet was widely introduced in Athens around the time of Socrates, who was barely literate, and Plato, who was highly literate. Their work still forms the basis of Western philosophy. This may therefore be one of the reasons for our Western concept of separateness from the rest of creation.

For some time, environmental thinkers in both East and West, as well as North and South, have attempted to re-engage with the spiritual dimension of our relationship with the natural environment. Some, such as Abram (1996), have sought this in more animist societies, whilst others have sought links with Hindu, Buddhist or Taoist thought. Satish Kumar, for example, chair of the UK-based environmental Schumacher Society is a Jain cleric by origin. Johnson (1995) linked modern science with the native religions of the American southwest and also with the local catholicism, while Breton and Largent (1991) highlighted the need for a spiritual dimension in economics: both were concerned to add an ethical element to modern developments. The Tao, China's oldest belief system derived from shamanist animism, also lends itself particularly well to supporting the green agenda, as illustrated by Fritjof Capra's influential book, *The Tao of Physics* (1976) in which he attempts to show links between the Tao and modern particle physics.

Taoism is based on the essential principle of harmony and balance, especially in nature, and in man's relationship with nature. The most famous proponents of the Tao were Zhuang Zi and particularly Lao Zi, born around 570 BCE, whose ideas are captured in the classic *Tao Te Ching*: 'The rule of nature is to be pliant and yielding . . . Man's conduct should follow the rule of nature, and to end the desire to be strong and tough and war-like' (Kwok *et al*., 1993; Chung, 1989, 1999). This concept is symbolised by what we know as the Yin/Yang symbol, which also embodies the dualist aspect of the Tao, where everything is defined only by its opposite, while each half yields to the other; thus apparently weak things can at the same time be strong. 'In a hurricane it is the strong trees that fall, the weak and yielding grass returns to its upright position and survives' (Chung, 1989: 90), and 'Nothing in the world is softer than water . . . but we know it can wear away the hardest of things' (Kwok *et al.*, 1993: 185).

Other western observers have sought a spiritual basis for environmentalism closer to home in the Judaeo-Christian tradition. Notable among these is Robin Attfield, whose book *The Ethics of Environmental Concern* (1991) is a particularly valuable contribution. Attfield reviews various authors' work who see the roots of Western disrespect for our environment as lying in the Judaeo-Christian tradition and in particular its notion that humans are somehow superior to and separate from the rest of creation. He refutes this explanation and finds many examples in both Old and New Testament that support a more environmentalist view of the world. He gives many examples, such as from the author of Ecclesiastes that 'a man has no pre-eminence above a beast', as man and beast die alike and return to their native dust (Attfield, 1991: 53). Attfield finds support for his thesis particularly in the concept of stewardship which deems that humans have a duty of care over the rest of creation:

> Thus there has been a strong tradition in Europe and lands of European settlement, a tradition of Judaeo-Christian origins but not confined to adherents of Judaism and Christianity, of belief that people are stewards of the earth, and responsible for its conservation, for its lasting improvement, and also for the care of our fellow-creatures, its non-human inhabitants. This tradition, far from being merely modern, has been a continuous one, at any rate among Christians, from the Bible, via Basil, Chrysostom, Ambrose, Theodoret and Bernard of Clervaux, to Calvin, Hale and Ray and to modern writers like Black and Montefiore. (Attfield, 1991: 45)

He asserts that the Western tradition therefore already provides the basis for environmental ethics, although, as he also points out, in reality a purely selfish motive would yield the same results as '. . . there is no decision to make between humans and the biosphere: the reason for preserving the latter lies in the interests of humans and of other creatures – and there could hardly be a stronger one' (Attfield, 1991: 193).

Daly (1999: 47–56) has also been confronted by the fundamental lack of understanding of sustainability concepts among otherwise intelligent people and economists in particular. He uses a more prosaic economic analysis to explain this basic difference in viewpoint among experts. Daly argues that the difference in people's 'pre-analytic vision' – a term he sources from Schumpeter, who used this term before settling on the word 'paradigm' – is the cause for the fundamental misunderstanding. In his context of economics he distinguishes between those who regard the environment as a subsystem of the economic system and those who regard the economic system as a subsystem of the environment. The two views are irreconcilable and adherents of each view cannot understand arguments put forward by adherents of the other view. As Daly (1999: 49–50) explains:

> Unless one has the pre-analytic vision of the economy as subsystem, the very idea of sustainable development – of a subsystem being sustained by a larger system whose carrying capacity it must respect – makes no sense. The pre-analytic vision of the economy as a box floating in infinite space allows people to speak of 'sustainable growth' – a clear oxymoron to those who see the economy as a subsystem.

For this reason, Daly argues that the environmentalist concept of anti-economic growth 'seems to economists an empty box – theoretically definable, but empirically irrelevant'. On the other hand, Daly argues, micro-economics is perfectly at ease with this concept. Here, the idea of expanding activity of production or consumption to an optimum level is fundamental:

> All micro activities reach a point beyond which further growth raises costs more than benefits. Microeconomics seeks to discover the optimum scale of an activity, the point at which its growth should stop. But when we move to macroeconomics (growth in GNP), we find no concept of an optimum scale for the macroeconomy . . . How is it possible that each micro activity has an optimal scale while the aggregate of activities does not? (Daly, 1999: 47–8)

In the automotive sector the microeconomic concept of limits to growth is familiar. However, it is a cause for concern that decisions at macro-level are informed by a model that, as Daly points out, is so clearly nonsensical. The implications of this are clear: educating decision-makers, as well as the public, will be a key concern in rolling out the sustainability agenda. At the same time, economics will have to change some of its fundamental concepts if it is to retain its role as a source for government advice at all levels in the future. We should remind ourselves that this role was once fulfilled by astrologers and geomancers, and other professionals who ultimately became discredited in the West. Daly ends up comparing economists' neo-classical production function unfavourably with alchemy (1999: 91). Unfortunately this is one area where compromise is difficult – our economies are either sustainable or they are not – although the precise nature of a sustainable economy can probably take on different forms. This does not mean that sustainability is necessarily a static condition, and that within the confines of environmental sustainability a certain dynamic is possible. In fact, considerable dynamism may be possible given a break with reliance on fossil carbon fuels.

10.3 Nature and the closed-loop economy

The concept of a closed-loop economy, where everything is recycled into new and useful products thus minimising the need for raw materials, has come to the fore in environmental circles recently. Its origins are clearly very old and can be traced back to natural processes, where the waste of one organism is often the food for another.

10.3.1 Definitions

In the theoretical closed-loop economy, no new raw materials are added, only the existing pool of secondary materials is used, re-used and recycled. Any energy used in re-using and recycling has to come from renewable non-fossil sources. In addition, no net increase in emissions is allowed, i.e., only emissions which can be readily absorbed by, for example, growing crops, can be tolerated. The term 'dematerialised' economy has also been used in this context, although this has been discredited by its use for the idea of a total transfer from a manufacturing to a service economy is not realistic.

Given the secondary materials currently in the world economies, with judicious recycling and re-use a car could be made without extracting additional raw materials, but merely using what has already been extracted in the past and recycling it. The term 'closed-loop' is used here in a wider sense, reflecting a situation whereby the whole of the economy would close the loop, rather than an individual sector. Macquet and Sweet (2002) challenge the latter view of 'closed-loop' recycling as unworkable in practice beyond less complex sectors such as the newsprint industry, although regulators still often adhere to this narrow view. We should also decide to what extent there are geographical limits to the economy, as the Earth is itself to a large extent a closed-loop system, albeit one dependent on energy input from the Sun.

Macquet and Sweet highlight a number of issues that make it unworkable in many cases. In the automotive context the degradation of many materials during repeated reprocessing is a major issue, as will be discussed in Chapter 11. Thus, viewing the 'closed-loop' as applying to the wider ecosystem or economic system is more realistic. Jones (1998) would describe such systems as 'open-loop', although, taking a wider macroeconomic view, and applying it to an entire economy, one could still argue in favour of the term 'closed-loop'.

In practice we are far removed from a closed-loop economy in most of the developed world, whilst many developing countries come much closer. Ignoring the environmental cost and limiting ourselves to the economic cost in our calculations makes raw material extraction and transport cheaper than recycling and re-use in many cases. Although apparently utopian at present, in the longer term such a move seems inevitable. By most current calculations, many key raw materials are set to run out or become uneconomic to recover during the course of the twenty-first century. This will make the recycling and re-use options more economic, even for currently uneconomic materials and probably even without fiscal measures. In fact, landfill sites may well be mined in years to come for their valuable content.

The concept of a closed-loop economy is not new. Marx, and particularly Engels, regarded the predatory exploitation of nature as characteristic of capitalism. In fact, they advocated recycling of industrial waste and as Attfield (1991: 79–80) argues, Marx's work includes:

> . . . a surprisingly modern stress on the need to take account of side-effects and long-term consequences. Thus Marx holds that 'all progress in capitalistic agriculture is a progress in the art, not only of robbing the labourer, but of robbing the soil; all progress in increasing the fertility of the soil for a given time, is a progress towards ruining the lasting sources of that fertility'. Capitalism, by concentrating people in large towns, prevents the return to the soil of human waste products, and thus further 'violates the conditions necessary to lasting fertility of the soil' and 'disturbs the circulation of matter between man and soil'.

This line of thinking was not altogether lost in the thinking of the Soviet Union. Attfield (1991: 80) refers to Fyodorov and Novik (1977), who advocate 'new wasteless production based on closed-cycle technology' as one of the long-term methods of production without pollution. More recently, in the West, one of the leading proponents of a different basis for our economy is the American academic and former World Bank economist, H E Daly. His concept of 'steady-state economics' (1999) has become popular with many environmental thinkers. This, and the closed-loop economy, will be explored in greater detail in Chapter 11.

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11

Sustainable mobility

> *We want to construct some kind of machine that will last forever . . . We want a man who buys one of our products never to have to buy another.* (Henry Ford, quoted in Batchelor, 1994: 53)

11.1 Making cars sustainable: a blueprint

Some car makers have already tried to tackle sustainability issues, Henry Ford being a prime example. Apart from experimenting with soya bean plastics, he believed in product durability, as the opening quote testifies. However, the modern car industry is very far removed from being sustainable, as has been pointed out. The question is: could car making and use ever be sustainable, and if so how? In order to analyse this question, we need to establish some basic principles as to what requirements would need to be met, in theory, to make a sustainable automobility system.

Taking inspiration from The Natural Step (e.g. Nattrass and Altomare, 1999), as well as from work carried out by the German Federal parliament, the authors have developed a model for sustainable car making and sustainable automobility (Nieuwenhuis, 2002a). The Natural Step is a practical model for business sustainability, originally developed in Sweden and in use by a number of companies. It recognises a number of basic principles, or 'system conditions', as outlined in Box 11.1. The German Federal parliamentary commission on Protection of Humanity and the Environment has proposed a very similar set of basic rules, as set out in Box 11.2. In Nieuwenhuis (2002a) these two sets of guidelines were adapted for automotive use, as set out in Table 11.1.

Box 11.1 The four Natural Step system conditions

In the sustainable society, nature is not subject to systematically increasing:

- concentrations of substances extracted from the Earth's crust;
- concentrations of substances produced by society;
- degradation by physical means.

In that society

- human needs are met worldwide.

Source: Nattrass and Altomare (1999).

Box 11.2 German Federal parliamentary commission guidelines

1. Use of a resource may not permanently exceed its regeneration capacity or the rate at which all of its functions can be substituted.
2. Release of materials of all kinds may not permanently exceed the capacity of the environmental media to absorb or assimilate them.
3. Dangers and unjustifiable risks for humanity and the environment due to anthropogenic effects must be avoided.
4. The timescale of anthropogenic interference in the environment needs to stabilise itself.

Source: Knell (2001).

Table 11.1 A model for sustainable automotive use

Sustainable car making: the CAIR model
1. Use only secondary materials already in the economy – re-use and recycle. 2. Energy used in this process for manufacturing and transport would need to be sustainable = renewable. 3. Processes cannot cause pollution that cannot readily be absorbed by nature. 4. Products have to be designed and built for maximum durability to avoid unnecessary production.
Sustainable car use: the CAIR model
1. Cars can only be powered by renewable energy sources. 2. In-use disposables would be designed for re-use or recycling. 3. Society encourages citizens to choose the optimum mode for each journey.

Source: Nieuwenhuis (2002a).

Clearly these simple statements paint a picture that is far removed from the way things are currently done. However, having established this set of desirable outcomes, and a vision of a sustainable automotive future, how would we actually get there? One key element is the so-called closed-loop economy – a concept briefly outlined in Chapter 10. Providing a full blueprint for sustainable automobility is probably overambitious at this point. Instead a few pointers will be given to elements that could take us in that direction. A few issues that should be part of our considerations will be singled out: notably product durability, exploring new vehicle niches, and the problem of closed-loop recycling.

11.2 Product durability and scrappage incentives

The case for product durability has been well argued (Cooper, 1994; Deutsch, 1994; Kostecki, 1998; Nieuwenhuis, 1994a, 1994b, 2002b). Making products – in this case cars – last as long as possible has a whole range of environmental advantages, as well as economic ones. However, despite Henry Ford's efforts, the mainstream car industry has consistently resisted this agenda. The industry has even enjoyed government support in various countries, culminating in various scrappage incentives.

11.2.1 Making cars last longer

Cars last longer now than they did in the past. This is an incidental result of various product improvements, rather than a deliberate strategy on the part of manufacturers. However, in the 1970s, there were a number of projects which looked into the possibility of extending the lifespan of the average car, and some of these have indeed influenced car makers to make more durable products. A project by Porsche (Porsche, 1976 and Nieuwenhuis, 1994b) proved that this was at least technically feasible. As a result of this programme, first Porsche then Audi opted for fully galvanised bodies. Others followed, while Audi's aluminium body project that led to the A8 and A2 was also informed by this study. Mercedes now guarantees its cars against corrosion for 30 years.

The environmental advantages of extending the useful lifespan of cars are clear. If we move towards a useful life of 20 instead of 10 years, the number of times a new car has to be produced and dismantled could be roughly halved. This means a saving in the energy consumed and pollution created during the production and dismantling processes, as well as reducing the number of natural end-of-life vehicles (NELVs) and hence the waste burden from ELVs (NELVs are cars that reach the end of their lives for reasons other than an accident or vandalism). This will reduce the overall life cycle impact that a car has on the environment in the production and dismantling stages, though not in its use. However, as the main purpose of a car is in its use, this must be desirable, however small the

Table 11.2 Environmental impact of cars: use vs. non-use phase

Phase	Impact		
	Summers (1992) (CO_2)	Volvo (1992) (energy use)	Teufel *et al*. (1993) (energy use)
Non-use phase (production/dismantling)	29%	15–20%	28.9%
Use phase	71%	80–85%	71.1%

Source: adapted from Nieuwenhuis (1994b).

impact. The proportion of this impact in relation to that of a car's use varies somewhat, as Table 11.2 illustrates. Volvo's (1992) figures are flattered by the fact that they already assumed a longer lifespan than other manufacturers. The figures produced by Teufel *et al*. (1993) are probably the most comprehensive. Only their energy figure is presented in Table 11.2, although they take a full life cycle approach starting with the raw materials extraction stage.

However, none of these calculations considers the impact of the waste stream created by the scrapping of 12–13 million vehicles in the EU annually, nor the issue of sustainability problems concerned with unfettered raw material extraction. Rethinking some of these calculations would significantly change the balance allocated between in-use and non-use phases when considered from a pure energy or emissions perspective. Doubling a car's life expectancy could drastically reduce the vehicle element of the waste burden. Over the past 20 years or so there has been a significant improvement in the quality of cars. This is due to the dual pressures of increasing competition within Europe and the increase in competition from Japan. Japanese manufacturers especially have emphasised particular aspects of product quality. In practice these quality improvements have led, among other things, to greater reliability and longer product life as both key mechanical components – engine and gearbox – and also bodywork last longer. Improved steel types and rust preventative measures in production have rendered modern cars far more rust-resistant than their ancestors.

The implications of this in the context of the ELV Directive are also clear. As the manufacturer incurs an additional cost at some stage in the future, it must be attractive to minimise this cost by increasing the car's life expectancy and postponing the point at which that ELV cost is incurred. Another implication is that whilst primarily geared towards selling new cars the industry may have to devise a way of keeping track of its products throughout their useful life. The need for this has increased with the increasingly stringent rules on product recalls in various countries, notably the US. Once this tracking system is in place, the required database can be used for customer relationship marketing and extending post-factory gate marketing activities, thus encouraging new income streams that are currently underdeveloped (see Chapter 4). The need for product tracking came to the fore in the recent Ford–Firestone debacle. In response to this the industry is now introducing an electronic tracking system for tyres. By such moves the industry is gradually moving towards a 'product stewardship' model, by which producer responsibility would exist as long as the product.

In practice, there are a number of environments where cars already routinely exceed the normal life expectancy of around 12–13 years typical for the UK. This is certainly true for Third-World countries and it was also true for Eastern Europe before de-Sovietisation. Car life expectancy also varies considerably in the industrialised countries of Western Europe. There is a clear correlation between car purchase price and life expectancy. Cars last longer in Denmark, where taxes keep prices high, than in Luxembourg, where cars are cheap. Similarly, Rolls-Royces have a very long life expectancy, while Ladas have all but disappeared from the UK parc. However, overall, useful lifespans are on the increase. The first decade in which these quality improvements became apparent was the 1980s, the decade when most cars currently classed as natural ELVs (NELVs) were built. Environmental considerations make it increasingly attractive to take action to accelerate this trend. The increasing sophistication of various alternative technologies also makes this more realistic. Modern materials such as galvanised or stainless steel, carbon fibre, magnesium, metal matrix composites or even aluminium – as introduced for mass-producing a complete car bodyshell by Audi and Alcoa on the Audi A8 and A2 – could easily be used to build cars whose basic structure would outlast its first owner. GM spokesmen suggested that the long-life technology used on the Impact and EV-1 electric car would allow the car to be '. . . passed on from generation to generation' (GM, 1992).

The latest powertrain items and other new technologies could be fitted at various points during the car's life. This would require a different, more modular, approach to building cars than that which is mainstream at present. However, retrofitting of certain items such as catalytic converters and airbags is already possible, though not encouraged by car makers. Many new technological innovations can thus be fitted to existing vehicles, avoiding the need to scrap the vehicle. Only occasionally does a technological improvement come along that cannot be retrofitted. The safety 'cage' or 'cell' with crumple zones is an example, as this is integrated into the design of the bodyshell. In those cases there may be an excuse for accelerated scrappage.

In the UK, the Morris Minor Centre in Bath has shown that extending the life expectancy of an existing, even obsolete, car is cheap and viable, especially if it is updated in the process. Its founder, Charles Ware, set out the basic philosophy of the venture in his book *Durable Car Ownership: a New Approach to Low Cost Motoring* (Ware, 1982). Ware argued that new car depreciation wastes consumers' money and leads to premature scrapping of many cars when the low residual value of the car renders repair uneconomical. The oversupply created by the current car making model leads to a rapid decline in residual values for most cars, resulting in a direct loss of capital for consumers and businesses buying cars. Ware argues that, like houses, cars should be seen as a long-term investment, rather than a short-term consumer 'durable'. Experience in Sweden shows that – quite apart from the environmental advantages – a long-life car regime can save car buyers significant amounts of money. The Swedish vehicle testing agency, AB Svensk Bilprovning (Nieuwenhuis, 1994b), estimated that Swedish consumers had since 1965 saved between SEK 3200 and 4000 million (£230–285 million) per year in new cars they did not need to buy.

Product stewardship can be used to the manufacturers' advantage. However, it would require a significant shift in culture. At present, the industry is still geared up to selling new cars. Issues affecting the parc, or vehicles in use, are of limited interest. Other industries have already made the move from selling products to selling services based around those products. Leasing is gaining in popularity, with personal leasing now the dominant way Americans purchase automobility. This trend makes a move to product stewardship easier. If new car sales decline due to greater longevity, used car sales take on much greater importance. With a higher new price, new car sales could become more profitable. Under a 'product stewardship' regime, aftersales in terms of parts, accessories and service would also become more important. Retrofitting of new technologies to cars that last for decades could develop into a new industry. The ELV processing sector could manage the salvage of usable parts and modules from ELVs for re-use in the durable basic vehicle structure.

11.2.2 Scrappage incentives

In the mid-1920s General Motors devised a plan to stimulate new car sales by removing used cars from the parc. Dealers paid $5 into a fund for each new car ordered. The fund was then used to pay the dealer $50 for each older car taken in as a trade-in and scrapped. In the late 1930s, US dealers sought to revive the flagging new car market by suggesting cars older than six years should be scrapped at the same rate as new cars were being produced. Sales soon recovered and the plans discontinued.

However, during the 1990s, there were calls from parts of the UK car manufacturing sector and the Society of Motor Manufacturers and Traders (SMMT) for the introduction of some sort of scrapping incentive for older cars. The plans have also been considered at EU and ACEA level in Brussels. A cut-off date of ten years is usually suggested and examples from other European countries are used to back this up. Scrappage incentives of some sort are, or have been, used in France, Spain, Greece, Denmark, Italy and Ireland.

Arguments in favour of these proposals hinge around two issues. The first of these is environmental, the second is economic. We will here focus on the environmental case. It is argued that by increasing the proportion of cars in the parc fitted with the latest emissions technology, the environment will benefit. Urban air quality might improve as a result, although at some environmental and economic cost. This cost is normally ignored, as the principal proponents of such schemes tend to be the car makers. Such proposals often forget that the impact of cars on the environment consists of considerably more than just exhaust emissions and that unnecessarily scrapping cars, and prematurely disposing of the energy and raw materials invested in them, is hardly a sustainable policy. Neither do claimed environmental improvements nor the effectiveness of such a scheme in reducing the age of the car parc stand up to close scrutiny (Nieuwenhuis *et al.*, 1996; Nieuwenhuis and Wells, 1996). The French trade journal *L'Argus de l'Automobile* reported that while the average age of cars in the French parc was 5.95 years on 1 January 1991, by January 1996, after the 'Balladurette' and 'Jupette' scrappage incentive schemes, this figure had actually increased to 6.8 years (Nieuwenhuis and Wells, 1996).

If emissions are the main target, a far better answer is to promote the retrofitting option. Simple, two-way oxidation catalysts can be retrofitted to most cars built since the 1980s and many considerably older ones designed to run on unleaded petrol. These 'cats' can cut harmful emissions by around 50 %. They do reduce hydrocarbons and carbon monoxide, but – unlike 3-way catalysts – do not tackle nitrogen oxides. However, it is exactly in the case of NOx that the balance of in-use and non-use phases is almost 1 : 1 (Nieuwenhuis and Wells, 1996). In other words, avoiding premature replacement of a car is a most efficient way of reducing NOx output, while retrofitting an oxidation catalyst will reduce the other toxic emissions. We are rapidly moving to a situation in most developed countries where most cars in the parc are fitted with a catalyst, though enforcing and checking its effectiveness is not universal. Johnson Matthey, in conjunction with a German firm, has also been promoting a retrofit three-way catalyst option, which can reduce toxic emissions by up to 90 %. In Germany, half a million cars have already benefited from the technology, thanks to government incentives. This approach can show a rapid improvement in urban air quality.

The retrofitting approach could be a considerable boost to dealer profitability. Workshop capacity utilisation would increase. Aftermarket activity is generally more profitable than new car sales for the franchised dealer and the independent sector, including parts sales by vehicle dismantlers. Besides, these retrofitted cats would require regular maintenance. This approach would be more environmentally sound than a scrappage incentive, although it would not boost new car sales. Scrappage incentives boost jobs abroad for car assembly plant workers, while extending car life expectancy boosts local jobs including in the dismantling and used parts sector. Premature scrapping of cars creates unnatural fluctuations in the ELV supply chain, which adversely affect the economics of the dismantling and recycling business, leading to oversupply and lower profitability.

11.3 New product niches

It is almost a given: personal transport equals car. Occasionally a motorbike is mentioned; perhaps a scooter; often public transport; sometimes walking or cycling. But why confine ourselves to these limited and limiting transport categories? Environmental pressures are forcing us to reconsider our transport options. The last thing we want to do is limit these options in some artificial way.

Research suggests that it is easier to coerce people from cars into some other private or personal transport mode, than from cars on to public transport (Ploeger, 1994). One-day car bans only serve to illustrate the inadequacies of existing public transport provision in many areas, as much of the world is essentially designed around the car. This means that rather than trying the conventional response by government of talking motorists on to buses and trains, persuading motorists on to more benign personal transport options is much more feasible. This could include car sharing schemes, a personal public transport mix á la Peugeot-Citroën's TULIP or new and different forms of private transport.

The traditional private transport options are selected from what we could call the car–non-car continuum (Nieuwenhuis and Wells, 1999), which currently offers the following range:

- foot;
- bicycle;
- moped;
- scooter;
- motorbike;
- car.

In certain markets, some of these categories are not separated, while in others the gaps between some of them have already been filled. Some markets do not distinguish in law between mopeds, scooters or motorbikes, for example. More interesting for our purposes is the gap-filling in some markets, such as the 'voiture sans permis' (VSP) or 'voiturette' in France, discussed below. This is a modern attempt to fill the niche once filled by 'cyclecars'.

11.3.1 What is a car?

Cars already fill a range of niches and smaller cars are potentially – though not always – 'greener' than large cars or light trucks. The MCC Smart has extended the concept of what constitutes a car downward in terms of size. In Japan this has been done for some time by the 'kei' or midget car segment. These very small cars are defined in terms of their physical size and engine size. In Japan they are considered quite separate from 'normal' cars, and although they are cheaper, many Japanese would not consider buying a kei car. On the other hand, kei car ownership is encouraged by government and brings with it a number of benefits, such as less onerous parking restrictions in urban areas. It is significant that in Japan's current recession the kei segment is the only car segment showing consistent growth, whilst all other segments are still in decline.

Moving down the size scale one more notch we find the 'voiture sans permis' mentioned earlier. These are very small cars powered by small motorcycle or diesel engines of typically 125–250 cc capacity. In France the smallest versions are classed as if they were mopeds and can be driven without a licence from the age of 14. Their popularity in France has prompted changes in legislation whereby they are now recognised under EU law and can be introduced under various regulatory regimes in other EU member states. Even countries such as the UK, which has traditionally been sceptical about the VSP, now allow them. Reliant has started importing the Ligier Ambra VSP into the UK, although educating potential buyers unused to the VSP concept may be a greater challenge. Other significant builders of VSPs are Aixam and Erad. The cars are usually built on a separate chassis – in some cases an aluminium spaceframe – and are covered with plastic panels. Battery-electric variants are offered and the internal combustion versions frequently use a rubber-belt continuously variable transmission (CVT) for user-friendly operation.

11.3.2 The car–motorcycle interface

Going down another level brings us to the gap between the smallest cars and motorbikes. In recent years a number of vehicles have been inserted into this gap. A small Swiss firm made a novel device in the early 1990s. This was a luxury entrant retailing at a price on a par with an entry level Porsche, but with performance to match. Few buyers succumbed; of those that did, few regretted their choice and a passionate owners' group exists. The vehicle was shaped like a streamlined tandem two-seater fuselage on two wheels, powered by a BMW motorcycle engine. Two stabiliser wheels emerged from the sides when speed fell below a certain minimum. Like a motor scooter with a roof, the BMW C1 is a novel concept, not entirely unlike some Japanese take-away food delivery bikes and trikes. It is designed to appeal to the commuter who is fed up with the limitations of the car in a congested urban setting, but wants to avoid exposure to the elements that is inherent in motorcycle use. Rival Mercedes went one step further with its F300 Life-Jet of 1997, a three-wheeler that leaned into corners like a bike, but there are as yet no plans for production.

There are also a number of sporty powered trikes that could be considered to fill this niche. Several are offered by UK kit car makers, such as Richard Oakes' Citroën 2CV-based Blackjack Avion, the high performance BMW-powered Grinnall Scorpion or the Malone Skunk, which can be based on a number of shaft-driven motorcycles. The Spanish Bandido is similar in concept. Fun, rather than practicality, lies at the heart of these machines, though from an environmental viewpoint it must be said that in terms of fun per litre of fossil fuel these vehicles beat most conventional sports cars, and owners are likely to cherish and preserve them for many decades.

Riley, in his book *Alternative Cars in the Twenty-first Century* (1994), proposes changes in legislation to allow the promotion of such 'sub-cars' for environmental reasons. His case is compelling particularly in the US context, where safety and product liability legislation can act as a barrier to such novel vehicle concepts. These niches frequently attempt to insinuate themselves into the gaps between existing legislative categories, which makes classification difficult. More flexibility on the part of legislators may be required in many markets, as policy-makers have a vital role in creating potentially beneficial shifts to new modal options.

11.3.3 Human-powered vehicles

A further stage down takes us below the motorised two-wheelers into the increasingly varied world of human power. Human-powered vehicles date back to the turn of the nineteenth century and the brief flourishing of Baron von Drais' velocipede and other hobbyhorse derivatives (Street, 1998). After a gap the bicycle was developed and following a brief experimental period the 'safety' design was popularised by Mr Starley's Rover – the basis of the modern British car maker.

Little enduring change was seen after the introduction of the Rover Safety of 1885, until in the 1930s the French firm of Mochet introduced its Velocar. The Velocar was a recumbent bicycle whereby the rider sat as if in a chair operating pedals at the front of the vehicle. This arrangement produces a much smaller frontal area than the conventional upright bicycle where as much as 80 % of the rider's energy may be used to push the vehicle and rider through the air. Some Velocars even had a steering wheel rather than handlebars (Schmitz, 1999). With their performance advantage Velocars began to dominate cycle racing and were duly banned by the International Cycling Union (UCI). The ban stopped any further development until the early 1970s when a number of Californians with an environmental transport interest revived the concept. More recently the same people have advised the US Big 3 (General Motors, Ford, Chrysler) on more environmental car concepts and have built their Solar Challenge racers.

There is now a growing subculture of these vehicles, which due to the continuing UCI ban cannot be classed officially as bicycles and hence are known as 'human-powered vehicles' or HPVs. The vehicles come in many configurations as two-wheelers, three-wheelers or sometimes four-wheelers. The latter are increasingly used as delivery vans in urban environments and courier firms in towns such as Ghent, Amsterdam and London use them. A rickshaw version of the UK-made Brox 4-wheeler also exists, although attempts to employ it for taxi use are often frustrated by motorised taxi interests (Fehlau, 1994; Ballantine, 2000).

Two- and three-wheeled HPVs have been fitted with aerodynamic fairings and in this form have set various world speed records. In 2001 the 130 km/h limit was broken. Notable names are Kingcycle in the UK (now, alas, out of production), the Windcheetah designed by Mike Burrows (who also designed the Lotus bike), Vector from the US and M5 of The Netherlands. A more practical faired three-wheeler recumbent HPV has been built by Leitra in Denmark since 1985 and has found a small but dedicated body of regular users. The Leitra is a single seater, but can be fitted with a child seat. At between £3500 and £4000 it clearly competes directly with a decent used car.

It is clear that there is growing diversity beyond the conventional car in the varied world of personal transport. In essence, three segment 'trees' can be imagined: the 'green'; the powered two- or three-wheeler; and the car (Fig. 11.1). Education of consumers and legislators is now needed to widen the market impact of such vehicles so a more optimised personal transport

Car	SUV
	MPV
	Car (s, m, l, xl)
	Smart
	Kei car
	VSP
2- or 3-wheeled (powered)	Sports trike
	Motorbike
	Scooter
	Moped
	Electric bicycle
Green	Twike
	Velomobile
	HPV
	Bicycle
	Foot

Fig. 11.1 Filling new personal transport niches.

choice becomes available to all, thus making automobility more sustainable. Breaking the monopoly of the traditional car without the motorist having to compromise beyond reason is now technically possible. What is lacking is knowledge and a safe infrastructure to use these alternatives. Some existing modes already mix uneasily and these new modes could make this all the more pertinent. Modern cycling facilities will accommodate many HPVs and velomobiles, while the Dutch have already proposed high speed cycle paths specifically for the faster recumbents and other HPVs. The 'sub-car' categories may need more radical assistance as they do not always mix happily with more substantial conventional cars, let alone trucks (see also Chapter 13).

Another problem is that most of these vehicles are still made in very small numbers by cottage-like craft industries. Volume production would be required before they could make an impact. In some categories this is already happening. After a slow start, Smart sales are beginning to take off; the BMW C1 is proving attractive to a new, though small, group of users, while the recent success of scooters has surprised many, both in the powered two-wheeler and car industries. Conventional motorcycles could also be repositioned away from 'power-tools' to a more environmentally-friendly mode, with the potential to replace the car for many journeys. The technology exists, but what is needed is imagination to put it to better use and move another step closer to a more sustainable multi-mode transport system. Public transport is *not* the only alternative.

11.4 Closed-loop recycling

The issue of recycling has been touched on at various points in this book, and a number of problems have been highlighted (see Chapter 10). With current technology, even coated steel sheet used for bodies (one of the most recyclable of automotive materials) can rarely be economically recycled back to body sheet without adding at least some percentage of virgin material. Similarly, aluminium sheet is normally downgraded and used in castings after recycling, although it is considered to be one of the most recyclable of automotive materials. Many plastics and composites have similar problems, with even thermoplastics being downgraded to less demanding applications. Thermoset materials are notoriously difficult to recycle, although they can be used in other ways. In natural processes too, genuine closed-loops are rare. In practice, several intermediate steps are needed before the same matter can be re-used by its original source.

Nonetheless, there are some areas where a move in this direction has been made for economic reasons. As we know, paper and glass already use recycled material. Similarly, steel bicycle frames, for example, tend to be made from recycled steel sourced from minimills using arc-furnaces, rather than the largely ore-derived steel used for car bodies (Ryan and Durning, 1997: 36–7). The incidence of such examples is increasing and in many cases the technology to bring it about is available. It is the economics that are lagging behind. Taxing raw materials would be a way of moving in the right direction. Other such policy measures using market signals are being discussed by environmentalists, environmental economists and regulators around the world.

One fundamental problem with recycling, highlighted by Herman Daly, is the notion of entropy. *The Concise Oxford Dictionary* defines entropy as the 'measure of the unavailability of a system's thermal energy for conversion into mechanical work; measure of the degradation or disorganisation of the universe'. It is entropy that makes perpetual motion an impossibility and, according to Daly (1992), it also makes full closed-loop recycling impossible. In 1992 Daly wrote a short piece entitled 'Comment: Is the entropy law relevant to the economics of natural resource scarcity? – Yes, of course it is!' (Daly, 1992). In it he accuses many orthodox, 'mainstream' economists – in particular Jeffrey Young – of ignoring natural laws and in effect allowing economic laws to override the laws of nature. Daly argues that total recycling is unrealistic, for 'Our inability to reduce different forms of matter to a common denominator in the way we can do for energy prevents us from determining whether we will eventually use up more matter in the recycling effort than the amount recycled. But it remains clear that complete materials recycling would require ruinous amounts of energy and time'.

Young (paraphrased by Daly, 1992: 101) argues that new human knowledge will expand available matter and energy faster than economic activity will convert it into unavailable matter and energy. There is some historical support for this assessment, although, as Daly (1992: 102) points out, the hole in the ozone layer is also new knowledge, thus new knowledge may also reveal new limits. This is increasingly what new knowledge appears to be doing, in contrast to, for example, the Victorian period when new knowledge almost universally led to new possibilities. 'Modern' economics has its roots in the Georgian and Victorian periods. Daly further bases his attack on the earlier work of Georgescu-Roegen, who claims to have discovered a fourth law of thermodynamics which states that matter will dissipate in a closed system, rendering complete recycling impossible. Young does not necessarily regard this dissipation as a problem and links it with matter for which we have not (yet) found a use. Once human knowledge finds a use for it, it can become available matter, he argues. Daly gives the following quote from Young:

> Is b available matter when there are no known uses for it? If so, then how can we know that dissipated a is unavailable? The absence of a technology for using dissipated a would not mean it is unavailable matter. The point is that available matter is dependent on the existence of appropriate technologies. It is not a purely physical concept.

Daly then counters this by arguing that though dispersed material may be available it is uneconomic to recover in many instances:

> Does the fact that we discovered uses for aluminium imply that we can invent a technology to recycle all the particles of rubber scraped from tyres on kerbs and interstate highways? The difference is that there is a technology for using aluminium that is economic, but the known technologies for recycling rubber particles on highways are not economic. The main reason for that fact is that aluminium deposits are concentrated, and scraped rubber particles are highly dispersed. One recycling technology for rubber particles requires many people on their hands and knees using magnifying glasses and tweezers. That is not likely to be economic. Whether it is inevitable that more matter will be dissipated in the form of worn-out tweezers and skinned knees than will be recycled in the form of gathered rubber particles is a nice question that I cannot answer . . . Since disordered matter requires more energy for processing, and since that extra energy will at some point make the recycling of dispersed matter uneconomic, we need no rigorous law of material entropy with a physical (as opposed to an economic) limit on recycling matter. This economic limit stems from the physical fact that enormous amounts of energy, as well as of other materials, are required to recycle highly dispersed matter. (Daly, 1992; 102–3)

Clearly, any future model that depends on comprehensive automotive recycling would need to consider these issues. Despite increasing levels of efficiency in many of our technological processes, all processes still produce some measure of unused or unusable waste, be it heat, dust, etc. Though we can see a possible model for a sustainable car making system, in practice there are a number of limitations, some of which we have highlighted. However, these limitations should not be used as an excuse for inaction, for it is clear we can actually get very close to a workable sustainable car making system, reducing the environmental impact of the sector by several orders of magnitude without meeting the full requirements of our model.

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12

Practical steps towards sustainability

12.1 Introduction

For anybody interested in statistics concerning the environmental burden of car manufacturing, use and disposal, there is a large range of sources of information. None of these is perfect, many are incomplete, some are deeply flawed, and almost all are unacceptable to the automotive industry and/or government as a basis for regulatory policy. Still, there needs to be a practical translation of environmental aspirations. This chapter explores different approaches to evaluating the environmental burden of cars, culminating in the authors' own highly pragmatic Environmental Rating System, based on the premise that in order to embark on the sustainability process it is helpful to measure current performance.

12.2 Alternative approaches to evaluating the environmental burden of cars

There are many different views on how environmental burdens should be measured. It is not at all clear that the methods employed will necessarily further contribute towards guiding thinking on sustainability. The main approaches are:

- LCA materials: life cycle assessment (LCA) on each major material i.e., steel, aluminium, plastic (Geiser, 1999).
- LCA fuels: some work has been done in this area, especially with the advent of alternative fuel vehicles such as those employing battery elec-

tric or fuel cell electric traction (Sheehan *et al.*, 1998). Energy companies have undertaken 'well to wheel' studies (API, 2000).

- LCA vehicles and components: there have been some discrete studies of particular components, as well as complete vehicles, both by industry and by academics.
- Fuel economy guides: for many years governments have made fuel consumption part of the vehicle type approval process, the results of which have to be displayed when the car is on sale (NRCan, 1999). Fuel economy listings are available from government agencies such as the US Environmental Protection Agency (EPA, 2000) and the UK Department of Environment, Transport and the Regions (DETR, 1999).
- Vehicle emission guides: as with fuel economy guides, official organisations such as the EPA and DETR provide Type Approval data.
- Corporate environmental reports: all the major vehicle manufacturers produce these reports (see Chapter 4), although they are not necessarily consistent in terms of data and presentation. This means that comparison between companies, and the attribution of environmental manufacturing burdens on a per-model basis, is fraught with hazard.
- Environmental product declarations: Volvo has pioneered the use of the environmental product declaration (EPD) on a per-model basis (Volvo, 1999). Scania also provides an EPD (Scania, 2000), but in this case in the form of the 'average' Scania truck.
- Factory emissions guides: in North America a comparative guide to manufacturing emissions has been created using data provided to the EPA under mandatory disclosure laws (Environmental Defense, 2000).
- Environmental Ratings Systems: various independent organisations have sought to introduce comparative assessments of individual models based on a range of environmental criteria.

Considerable effort has gone into so-called eco-ratings schemes for products worldwide, including green labelling. Generally, environmentalists try to take a whole life cycle view of products, and to capture all of the potential or actual impacts of the product on the environment. While such an approach may be feasible for relatively simple products like paper or soap, the more complex the product the more difficult this sort of analysis becomes. The eco-ratings approach tends to be dominated by a sort of 'scientific environmentalism' that has the following key assumptions:

- all environmental impacts can be identified;
- all such impacts can be measured objectively;
- environmental outcomes can be related to causal inputs;
- actions can be taken which will result in environmental improvement;
- there is a single 'best way' to achieve environmental progress;
- the results of such analysis are immediately understood by all parties that may wish to use them e.g., consumers, regulators, etc.

Life cycle assessment measures the environmental impact of products over their entire life from cradle to grave, and derives from two traditions: global modelling studies of resource consumption; and process/systems engineering. This gave rise to the general field of life cycle analysis, which set out to provide an inventory of inputs and outputs. Life cycle assessment extends life cycle analysis through the evaluation of potential environmental impacts, and the interpretation of results. Life cycle assessment, therefore, usually has three elements:

- analysis and measurement of inputs and outputs;
- evaluation of the (relative) magnitude of environmental impacts;
- interpretation of the results of the analysis in the light of policy objectives.

Other terms for LCA include Cradle to Grave Analysis, Eco-balancing, and Material Flow Analysis. A more detailed code of practice for LCA is defined by the Society of Environmental Toxicology and Chemistry (SETAC), in which the methodology has five stages (PRe, 2000). In principle LCA can also be used to allow the comparative evaluation of an alternative process or product, and, more ambitiously, inform governmental regulation (Gaines and Stodolsky, 1997; MSL, 2000).

12.2.1 Product life cycle assessment

For many consumers, LCA only becomes significant when attached to a product. In particular, consumers may want to make comparisons between products, with environmental issues as one of the parameters. Life cycle assessment has been conducted on a wide variety of products including houses, domestic appliances, paper and packaging. In all cases where there are many variables, consideration has to be given to evaluation and 'normalisation'. Product LCA will typically employ assumptions pertaining to various aspects of the whole life cycle. These may include, for example, the energy and other environmental costs of the raw materials used in the product. For many relatively simple household products and domestic appliances, in-use consumption of energy is often the most important single element of the environmental burden imposed by the product. As a consequence, energy consumed in use is a reasonable proxy for eco-efficiency for some products.

12.2.2 Material life cycle assessment

Material LCA has been widely supported by materials suppliers, largely for competitive reasons, in that organisations such as the Aluminum Association (US), the American Plastic Council and the International Iron and Steel Institute have employed LCA to promote the case for 'their' material. Through being arranged in this way, under the umbrella of a trade organisation, the detailed (and commercially sensitive) results of each company are obscured in a more generalised or aggregated summary of the data. It is possible that more 'suspect' methods are used, for example best-practice technology may be used to compile the LCA even though in reality few companies possess this technology. The task of compiling and reconciling the LCA for the three materials groups in the US automotive industry was undertaken by the United States Council for Automotive Research (USCAR) initiative in the late 1990s.

One method to allow inter-material comparison has been to undertake a 'single issue' approach. For example, aluminium suppliers have been keen to exploit the life cycle energy savings that could accrue from aluminium-intensive vehicles (Stodolsky *et al.*, 1995). Studies of this type may indeed conclude that the petroleum energy saved by improved fuel efficiency would be greater than the additional energy required to produce aluminium compared with steel. However, even single issue approaches do not really resolve some key problems. For example, assumptions have to be made about the extent to which secondary aluminium is used on the vehicle and about the energy efficiency of the particular smelting process involved.

Whatever the material, there is a fundamental problem in dealing with the age of capital equipment and the capabilities of process technology. In wide strip steels, for example, continuous casting mills have resulted in large reductions in energy requirements. Equally, aluminium producers have also started to introduce continuous casting technology for wide strip products. At any one time some raw material production facilities will be 'state of the art', some will be average, and some will be technologically backward. When a per-model analysis is required, differences in the environmental performance of the raw material supplier may contribute to a significant difference in the whole life cost of any one model.

12.2.3 Life cycle assessment: conclusions

Life cycle assessment merely measures how much burden is imposed on the environment, and does little to inform the transition to sustainable production. The technique is at its strongest when used to compare relatively similar products, materials or processes within existing industrial structures and practices. The more radical an alternative proposal in terms of product, materials and processes or in terms of innovative industrial structures, the more difficult it is to compare with current practice. The relatively new area of environmental research termed 'industrial ecology' has emerged to explore the vast network of interconnected activities that comprise contemporary economic practices (Keoleian *et al.*, 1997).

Indeed, it may be dangerous to assume that policy measures taken as a result of LCA are going to result in sustainable industry or in a more environmentally benign product, and in this sense are closely aligned to practices such as eco-auditing. For these reasons, any vehicle rating system or attempt to portray one vehicle as 'greener' than another may be regarded by elements of the environmental movement as a palliative measure designed to maintain the status quo rather than a move towards sustainability.

In terms of conducting LCA in the automotive industry, the favoured approach for dealing with the complexity of the contemporary car has been to define 'generic' vehicles as the basis of comparison. Discrete components have been treated in a similar manner (see, for example, USCAR, 1999). The USCAR study described its generic vehicle with 73 different materials comprising 644 parts and components organised into 7 vehicle systems. The life cycle inventory (LCI) model tracked 31 raw materials and 27 environmental data categories. It is worth noting that special software had to be developed for the LCI. However, this was merely an inventory analysis, rather than a full LCA with evaluation. In addition, co-operation between vehicle manufacturers and materials suppliers, as well as others in the production chain, was a pre-requisite to the study. This in itself may have limited the scope of the study to LCI rather than full LCA, which would have exposed politically contentious choices.

While the above discussion has highlighted some technical problems in measuring the current situation, where LCA provides a 'snap-shot' of the state of play, it must be emphasised that LCA in the automotive industry also has an implicit element of forecasting if the in-use phase is to be captured. Studies have compared the relative burden of manufacturing with the in-use phase, and the following shares for material production and car manufacturing (see also Chapter 11) were given by the USCAR study:

- thirteen per cent of consumed energy;
- sixty-five per cent of particulate emissions;
- sixty-eight per cent of solid waste;
- ninety per cent of metal waste to water.

There are virtually no diesel cars in the US market and this fact has influenced the particulate emissions and energy consumption performance figures.

Therefore, in terms of energy the in-use phase is vital. Any attempt to conduct an LCA for a new car today must therefore be based, to some extent, on necessarily arbitrary forecasts. To some extent these forecasts may be informed by historical data on, for example, product longevity, mileage per annum, tyre wear, etc., but this may be a rather inexact guide to the future, particularly for radical technologies such as fuel cells.

12.3 Official and unofficial vehicle emissions and fuel economy guides

Official figures for fuel economy as measured during the Type Approval process are well established. In recent years, more effort has gone into making that information available to consumers. Fuel efficiency has always been a general concern in the automotive industry, particularly in European markets where fuel costs have historically been high compared with North America. The US CAFE (Corporate Average Fuel Economy) system has been in place for many years, along with a 'gas guzzler' tax, but fuel costs are considerably lower.

Guides to fuel economy are available in published form (such as the *Vehicle Certification Agency* booklet covering UK models) and via the internet. The US Department of Energy produces an online guide that allows annual fuel costs to be calculated for any model on the US market (see www.fueleconomy.gov), although the Environmental Protection Agency (EPA) is a better-known source of the same data (EPA, 1999). Other guides include those produced by the Australian Greenhouse Office (AGC, 1999) and the Australian Department of Primary Industries and Energy (DPIE, 1999).

The overall approach is broadly similar in all cases, with the emphasis on the provision of basic information in a manner that consumers might find helpful (e.g., the interactive guides such as those from the EPA allow searches to be made under different market segments or manufacturer brand names). The EPA *Fuel economy guide* also highlights those cars with the highest fuel economy in each vehicle class, as shown in Table 12.1. It is worth noting that the EPA adjusts the official fuel economy statistics to account for the difference between controlled laboratory conditions and actual driving on the road. The figures for fuel economy are reduced by 10 % for city driving and 22 % for highway driving.

Rototest AB is an independent Swedish organisation that conducts emissions tests on cars. The tests are different from the EU test cycle. The results of the leading ten European models for 1999 are summarised in Table 12.2. The three key differences in the Rototest approach are:

Table 12.1 Fuel economy leaders by vehicle class (1999)

Market segment	Leading models
Sub-compact	Chevrolet Metro; Honda Civic HX; VW new Beetle (diesel)
Compact	Toyota Echo; VW Golf/Jetta (diesel)
Midsize	Mazda 626; Saturn LS
Large	Chevrolet Impala; Toyota Avalon
Minivans	Chevrolet Venture; Dodge Caravan; Oldsmobile Silhouette; Plymouth Voyager; Pontiac Montana
Small SUVs	Chevrolet Tracker; Suzuki Vitara; Toyota RAV4
Large SUVs	Jeep Cherokee; Jeep Grand Cherokee
Small pick-up	Chevrolet S10; GMC Sonoma; Isuzu Hombre
Standard pick-up	Ford Ranger; Mazda 2500; Toyota Tacoma

Source: EPA (2000).

Table 12.2 Rototest results: the leading ten models in the European Market (1999)

Rating	Manufacturer	Model	Index score
1	VW	Lupo 1.4 16v	64
2	Toyota	Yaris	66
3	Vauxhall	Corsa Eco 1.0	69
4	VW	Polo 1.6I	70
5	Volvo	S80 2.4	73
6	Mercedes	C200	75
7	Mercedes	A 140	76
8	SEAT	Arosa 1.4	77
9	Mercedes	A 160	78
10	Audi	A6 1.8T	78

Note: Diesel cars were not included. The highest (i.e., worst) score of the 84 models tested was the Chevrolet Camaro, with a rating of 226.
Source: *What Car?* (1999).

- emissions data are collected continuously over the test cycle;
- part of the test cycle tests the engine under full load;
- the test is more than a pass/fail measure, as it records comparative performance.

12.4 The Volvo environmental product declaration (EPD)

The Volvo EPD is particularly noteworthy, not only for the type of information portrayed but also for its manner of presentation. In particular, Volvo have not sought to make comparisons between models but have shown how the model in question compares against some benchmarks, with a format that has some visual appeal. The thinking here is clearly that a schematic representation of the EPD information might help consumers and others make an assessment of the performance of the model. The Volvo EPD is independently audited by Lloyds Register Quality Assurance on an annual basis, and is therefore expensive for Volvo to maintain. Volvo defines four main areas, each comprising three aspects in the EPD approach. These are:

- manufacturing: solvent emissions; material utilisation; energy used per car;
- operation: exhaust emissions; evaporation of hydrocarbons; CO_2 emissions;
- recycling: labelling of plastics; dismantling; use of recycled plastics;
- environmental management: own operations; dealerships; suppliers.

For each aspect, the performance of each Volvo model is rated on a 0–100 scale, where 0 means ‘worst case’ and 100 ‘best case’. This is an interesting approach because it allows a degree of flexibility. The 'best case' can sometimes be improved and hence the 'goalposts' moved. It should be noted that Volvo makes the best case/worst case judgement largely in terms of its own operations or with respect to legislated standards, rather than with other models from other vehicle manufacturers. In this respect the Volvo EPD cannot be used as a basis for comparison between models.

12.5 Vehicle assembly plant rating systems

Only one example has been identified where vehicle manufacturing facilities are rated. This is the 'Pollution Prevention Performance Ranking for Vehicle Assembly Facilities' produced by US Environmental Defense (Environmental Defense, 2000). The ranking is devised for local communities that are interested in the implications of having a vehicle manufacturing facility in their neighbourhood, and therefore concentrates on pollution and waste prevention. In particular, the main concern is with local human health impacts from toxic emissions. The normalised data are presented in the format shown in Table 12.3. Under the Environmental Defense approach, toxic releases of chemicals (Toxic Releases Inventory data) are measured along with transfers (pollutants taken off site), total production of related wastes (TPRW), and volatile organic compounds (VOC). Each record for each facility is adjusted for facility size. Data are also presented, on other pages within the web site, in the form of actual

Table 12.3 Toxic emissions from vehicle manufacturing facilities in the US

Name	Location	Toxic Releases Inventory Data (1996)			Aerometric Information Retrieval System data (1994)
		Releases (lb/vehicle)	Transfers (lb/vehicle)	TPRW (lb/vehicle)	VOC (lb/vehicle)
Auto Alliance	Flat Rock MI	11.11	3.64	14.91	11.60
BMW	Greer SC	1.53	7.03	10.99	na
Chrysler	Newark DE	2.89	4.61	7.62	9.87
Chrysler	Belvedere IL	1.00	0.43	1.60	4.39
Chrysler	Detroit MI	1.46	3.73	6.89	5.62
Chrysler	Sterling Heights MI	1.45	1.34	3.04	4.55

Note: Not all plants shown here.
Source: Environmental Defense (2000).

Table 12.4 Pollution prevention performance ranking for vehicle assembly facilities in USA (2000)

Worst pollution prevention record (bottom 20 %)	Middle of the road pollution prevention record	Best pollution prevention record (top 20 %)
Ford, Avon Lake (OH)	AAI, Flat Rock (MI)	Chrysler, Belvedere (IL)
Ford, Hazelwood (MO)	BMW, Greer (SC)	Chrysler, Fenton (MO)
GM, Arlington (TX)	Chrysler, Detroit (MI)	Chrysler, Sterling Heights (MI)
GM, Bowling Green (KY)	Chrysler, Newark (DE)	GM, Detroit (MI)
GM, Doraville (GA)	Chrysler, Toledo (OH)	GM, Lansing (MI)
GM, Fort Wayne (IN)	Chrysler, Warren (MI)	GM, Linden (NJ)
GM, Pontiac (MI)	Diamond Star, Normal (IL)	GM, Lordstown (OH)
GM, Wentzville (MO)	Ford, Chicago (IL)	Honda, Liberty (OH)
Honda, Marysville (OH)	Ford, Claycomo (MO)	NUMMI, Freemont (CA)

Note: Not all sites shown. Sites are listed alphabetically.
Source: Environmental Defense (2000).

(total) emissions alongside vehicle production figures. A summary table is produced wherein all plants are placed into one of three categories, depending on their pollution prevention record. This is shown in Table 12.4. Environmental Defense does not in fact resolve the emissions data into one index to create the rankings. To obtain the summary ranking, those plants with at least three of the four indicators in the top 25 % of the normalised data (Table 12.3) were accorded the highest category of pollution prevention.

12.6 Car environmental rating systems

12.6.1 Green Guide to Cars and Trucks

In the US market, the American Council for an Energy-Efficient Economy (ACEEE) has produced a *Green Guide to Cars and Trucks* intended explicitly for consumers (ACEEE, 1999, 2002; www.greenercars.com). Results are grouped into segment categories for ease of reference, and the approach is able to include recent hybrid vehicles (i.e., those having both an internal combustion engine and battery electric traction, such as the Honda Insight) as well as conventional vehicles.

The ACEEE guide constructs an index based upon the relative performance of the model compared with the average, with the focus mainly upon exhaust emissions and fuel economy. Weight is also used to construct the index, chiefly as a proxy for manufacturing impacts. These are translated into a cost per mile. It is a highly complex methodology, involving a large

Table 12.5 The 12 greenest vehicles in the US market (1999)

Rating	Make/model	Type	Fuel economy (US gallons per mile – city)	Fuel economy (US gallons per mile – highway)	Green score
1	GM EV1	Electric ZEV	3.3	4.0	57
2	Nissan Altra	Electric ZEV	2.9	3.3	52
3	Toyota RAV4	Electric ZEV	3.2	2.6	50
4	Honda Civic	1.6l CNG ULEV	28	34	46
5	Chevrolet S10	Electric ZEV	2.2	2.4	46
6	Honda EV Plus	Electric ZEV	2.0	2.0	42
7	Ford Ranger	Electric ZEV	2.6	2.3	42
8	Chevrolet Metro	1.0l LEV	41.0	47.0	38
9	Suzuki Swift	1.3l LEV	39.0	43.0	37
10	Mitsubishi Mirage	1.5l LEV	33.0	40.0	34
11	Honda Civic	1.6l LEV	32.0	37.0	33
12	Saturn SC	1.9l LEV	29.0	40.0	33

Source: ACEEE (1999).

number of assumptions, largely informed by previous Life Cycle Analysis studies (see, for example, Keoleian *et al.*, 1997). As a result, the three 'greenest' vehicles for 1999 in the US market, according to ACEEE, were all battery electric. Table 12.5 summarises the vehicles with the highest (i.e., greenest) rating. The scoring system used ranges from 100 points (very green) to 0 points, although very few cars score more than 50 points, thus the entire market is compressed within a small range. In addition, only two diesel models are rated and both do very poorly, reflecting US views on this fuel. The ACEEE also present information in a more complete format, with tables showing per-model fuel and health costs per annum, greenhouse gas emissions per annum, environmental costs per mile, and the green score. These data are shown in Table 12.6.

12.6.2 The VCD system

The Verkehrsclub Deutschland's (VCD) Auto-Umweltliste (auto-environment list) is not unlike the UK Environmental Transport Association's version shown below. The approach is based upon vehicle manufacturers' responses to questionnaires. In the VCD system, the higher the score, the more environmentally friendly a car is considered to be. The parameters scored are as shown in Table 12.7, with ratings for the Volvo 850 2L 10V used as an illustration. In the VCD approach the 'Technical score'

Table 12.6 Green ratings using the ACEEE system

Model	Type	Fuel economy (mpg)		Costs ($ / annum)		Greenhouse gases (tonnes per year)	Environmental Damage Index (cents per mile)	Green score
		City	Highway	Fuel cost	Health cost			
Toyota Corolla	1.8l TLEV	31	38	510	160	8	1.92	30
Nissan Altima	2.4l LEV	24	31	640	150	10	2.07	28
Chevrolet Camaro	3.8l TLEV	19	30	750	190	12	2.46	22
Ford Mustang	3.8l Tier 1	20	29	750	190	12	2.48	22
Ferrari 456 MGT	5.5l Tier 1	10	16	1620	260	21	3.94	11

Selected models only, the source provides details on every model by engine / transmission type.
Source: ACEEE (1999).

Table 12.7 VCD environmental rating: the Volvo 850

Category	Model particulars
Model	850 2.0–10 V
Body type	L/K (saloon/estate)
Price	46 400 DM
Kerb weight (kg)	1 370
Power (kW/PS)	93/126
Engine capacity (cc)	1 984
Top speed (kph)	195
Fuel type	S (Euro95)
Fuel consumption (l/100 km), town	11.9
Fuel consumption (l/100 km), mixed	8.9
CO_2 equivalent (g/km)	276
Noise (dB(A))	73
CO (g/km)	0.81
HC + NOx (g/km)	0.32
Particulates (g/km)	0
Technical score	30
Environmental interest	0
Total points	30

Source: VCD (2000).

starts with 100 basic points, to which are added or subtracted points from the categories: power, top speed, CO_2 equivalent, noise, HC+NOx and particulates. The category 'Environmental interest' seeks to assess to what extent a manufacturer can be said to have a general interest in environmental issues. The VCD also incorporates a manufacturing score. The two sets of points are then added together to provide an overall rating with a maximum of 335. The authors recommend buying cars that rate at least 180 and advise against buying any car with a score of less than 60.

12.6.3 The ETA system

The UK-based Environmental Transport Association (ETA) system takes a much wider view than some – not least because of the advocacy of alternatives to car ownership and use. The ETA (2000) relies on voluntary returns by car manufacturers and importers. As an example, Table 12.8 shows the ETA rating for the Honda Accord. The points scoring system excludes the yes/no categories and the Type Approval-based emissions data. They are based on an average of the models listed so have the sophistication of accommodating an overall improvement over time. Points are then translated into a 'star rating' system. The ETA makes the data available in detail, but also provides a summary table of the best models by market segment. This is shown in Table 12.9.

Table 12.8 ETA environmental rating: the Honda Accord

Category	Model particulars
Make	Honda
Model	Accord
Type	4 door
Transmission	A4
Fuel	P
Engine capacity (cc)	1997
Power (kW)	100
Consumption, urban (l/100 km)	12.6
Consumption at 90 km/h	7.0
Top speed (km/h)	199
Noise dB(A)/50 km/h	70.0
Emissions, soot	–
Emissions CO (g/km)	0.2
Emissions HC (g/km)	0.0
Emissions NOx (g/km)	0.1
Emissions HC + NOx (g/km)	–
Emissions CO_2 (g/km)	215
Plastic parts labelled?	Yes
Dismantling manual available?	Yes
Star rating	***

Source: ETA (2000).

12.6.4 The CAIR system

The system developed by the Centre for Automotive Industry Research (CAIR) is, as with all the ratings systems discussed above, one with both weaknesses and strengths. The index needed to:

- be based on sound environmental principles;
- be based on easily available data;
- include only data that had 'official' status;
- ensure no extra costs were imposed upon the vehicle manufacturers, regulatory authorities or consumers;
- have a clear methodology that resulted in a simple numerical score;
- allow 'good' performance to be identified;
- be applicable to cars on the market now;
- have a methodology that was transparent.

The information used in the system was that created through the official EU Type Approval test cycle used to ensure that any model complies with emissions and other regulations, together with limited basic information on the dimensions of the car. These data are therefore available at no extra cost, cover all cars in the market, and have official status. The methodology used by the regulatory authorities to collect emissions data can be criticised

Table 12.9 The greenest cars in the UK market by segment (2000)

Market segment	1st	2nd	3rd	4th
City car	Daihatsu Cuore	Volkswagen Lupo 1.0 AER	Toyota Yaris 1.0 GS 5 door	Suzuki Alto 1.0 GL
Supermini	Daihatsu Sirion	Suzuki Wagon R+ 1.2 GL	Vauxhall Corsa 1.5 TD Diesel	Renault Clio
Small hatchback	Honda Civic 1.6 3 door	Fiat Brava 80 16 v	Volkswagen Golf 1.9 Tdi AGR	Renault Mégane
Small family car	Suzuki Swift 1.0 GL/GLS	Vauxhall Astra 1.7 TD	Suzuki Swift 1.3 GLX	Proton Persona 1500
Large family car	Vauxhall Vectra 2.0 Tdi 16 v Estate	Audi A4 1.9 Tdi AHU	Skoda Octavia 1.9 D	SEAT Toledo 1.6 AEH
Executive/ luxury car	SEAT Toledo 1.9 Tdi AHF	Audi A6 1.9 Tdi AFN	Vauxhall Omega 2.0 Tdi 16 v	SEAT Toledo 1.6 AEH
Multi-purpose vehicle	Renault Scénic	Vauxhall Zafira 2.0 Dl 16 v	SEAT Alhambra 1.9 Tdi AHU	Volkswagen Sharan 1.9 AFN
Off-road vehicle	Daihatsu Terios	Suzuki Jimny 1.3 JLX	Suzuki Grand Vitara 2.0 TD	Land Rover Freelander 2.0 DL
Sports/coupé	Honda Civic Coupé 1.6 L	BMW Z3 1.8	Lotus Elise	Honda Prelude 2000

Source: ETA (2000).

for being an inaccurate reflection of real-world use, or inappropriate for use in creating an index of environmental performance. Our pragmatic response is that these are the only data available that meet the requirements listed above.

The CAIR approach to environmental ratings for cars has two elements: footprint and performance. The footprint figure is adjusted by a longevity factor. It is determined by measuring the length, width and weight of the vehicle and is used as a crude proxy for the broader (i.e., non-engine emissions) aspects of the car's environmental burden. In this way, the footprint is a measure of both the materials and manufacturing burden of the car (such as emissions from the paint shop) and the in-use costs such as congestion and accidents (note, for example, that heavier vehicles cause more damage in an accident). As argued in Chapter 11, product longevity or durability is an important factor in overall environmental performance. Therefore, the footprint figure is adjusted by a durability factor. The performance element relates to the emissions from the car as measured in the official test cycle. In the examples shown below CO_2, CO, HC and NOx are used but, as will be clear, the method is actually able to use more variables (such as particulates or noise levels) should the data be available or appropriate.

For each of the main regulated emissions (note that CO_2 is not regulated as there is no set standard to be attained) the extent to which, for the car in question, emissions are lower (i.e., better) than required by the standard is calculated. Absolute values are not used, but, rather, the proportion by which the emissions are lower than the standard. If a car has CO emissions that are just 25 % of those permitted under the regulations, the 'better than standard' proportion would be 75 %. Where other variables are available, such as HC and NOx, the CAIR approach is to calculate the average 'better than standard' proportion across all variables to give a single figure. In order to allow direct comparison with diesel, and to reflect health concerns with particulates, petrol-engined cars are also rated in terms of particulate emissions even though they are not tested against such emissions. On this variable, all petrol engines will perform 100 % better than standard.

The durability factor can only be applied in circumstances where a brand name has sufficient history in a market, so cannot be applied on a per-model basis. The available data on longevity are not ideal. For the UK, there are only figures on a per-brand basis (and not for all brands) for those cars registered in 1984 and still in circulation by 1998. Certainly these data show differences in performance for longevity. Thus, the market average is that 42.4 % of the original population is still extant by 1998, but for individual brands the figure is higher or lower. At the extremes, 69.9 % of BMW models are still extant, while the same applies to only 2.8 % of Lada models.

Several alternative methods have been tried to use the available longevity data to adjust the footprint figure, and hence overall performance on the rating system. Again, key considerations have been simplicity, portability, and the plausibility of adjusting the figures in this way. In addition, also in line with the approach taken throughout, the emphasis has been on rewarding best performance, although there is of course no official standard on longevity per se. The footprint is reduced by subtracting a numerical value derived from the longevity data. Thus, for example, the Volvo V70 footprint of 11.77 would be reduced by 2.4 (66.3 minus 42.4 = 23.9, rounded up to 2.4), i.e., 9.37. That is, the average population figure of 42.4 % of all 1984-registered vehicles still in circulation compares with 66.3 % of all 1984-registered Volvo cars still in circulation. Thus, Volvo cars achieve 23.9 % greater longevity. This would amount to a 20 % reduction in the footprint. Intuitively, this value appears about right in that it provides a reasonable allowance for longevity. No attempt is made to penalise those models that have a lifespan shorter than average.

Table 12.10 Sample petrol models: the key variables

Model	CO (g/km)	HC + NOx (g/km)	CO_2 (g/km)	Particulate matter	Length (m)	Width (m)	Weight (t)
Volvo S70 2.0	0.78	0.22	206	0.00	4.66	1.76	1.37
Volvo V70 2.0	0.78	0.22	206	0.00	4.71	1.76	1.42
Audi A4 1.6	1.10	0.19	225	0.00	4.48	1.73	1.22
Peugeot 106 1.0	0.41	0.11	160	0.00	3.56	1.61	0.78
Audi A8 2.8	1.10	0.22	297	0.00	5.03	1.88	1.46
Mercedes E320	0.30	0.15	246	0.00	5.11	1.88	1.89
EU Standard	**2.20**	**0.50**	–	**0.08**	–	–	–

Data on emissions refer to 1996.

Table 12.10 shows the data for some example models using the key variables. It can be seen that, for example, the Volvo S70 model has CO emissions of 0.78 g/km compared with the allowed limit of 2.20 g/km. In this sense, the Volvo S70 CO emissions are 64 % 'better' than the standard. Equally, in terms of HC and NOx emissions, the Volvo S70 is 66 % better than the standard. Note that the petrol models are also assessed against the particulate matter standard used for diesels (0.080 g/km), where the score is 100 % better than standard. The average better than standard performance is therefore 76.7 % (64 + 66 + 100/3). Again using the Volvo S70 as an example, the CO_2 emissions figure of 206 g/km is then divided by 76.7 to give a performance figure of 2.69. The footprint is calculated by multiplying the length (4.66 m) by width (1.76 m) by weight (1.37 t) to give the figure 11.24. This footprint figure is then reduced by the longevity factor (in the case of Volvo –2.4). The adjusted footprint figure becomes the basis for the index calculation of performance multiplied by footprint. The performance and footprint calculations are shown for each model in Table 12.11, with the resulting ratings. In the case of the Volvo S70 the calculation is performance (2.69) multiplied by footprint (11.24 − 2.4 = 8.84) to give a rating of 23.77 in total. The CAIR environmental rating system has only been tried on a sample of models, although the footprint calculation has been made for a range of vehicles including HPVs (see Wells and Nieuwenhuis, 1998).

Table 12.11 Performance, footprint and rating calculations for petrol cars

Model	Performance	Footprint	Longevity adjustment	Rating
Volvo S70 2.0	2.69	11.24	–2.4	**23.77**
Volvo V70 2.0	2.69	11.77	–2.4	**25.20**
Audi A4 1.6	3.18	9.45	–1.0	**27.87**
Peugeot 106 1.0	1.85	4.47	0.0	**8.26**
Audi A8 2.8	4.24	13.80	–1.0	**54.27**
Mercedes E320	2.88	18.15	–2.5	**45.07**

12.7 Conclusion

This chapter has illustrated a burgeoning concern with the measurement of the environmental impact of car production and use, together with techniques to compare performance on a per-model basis. As such these measures may indeed contribute to an understanding of sustainability in the automotive industry, but they do little to guide future strategy – particularly with respect to issues such as capital scale and intensity. These are partial solutions, partial understandings, and should not be mistaken for definitive and absolute answers to the problem of sustainability.

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13

Automobility 2050 – the vision

> *. . . one may well imagine that the motor vehicle of AD2000 will be infinitely more similar to the one of 1950 than today's car is to the model of 1900.* (Grégoire, 1954: 109)

13.1 Introduction

The desire for change arises from a dissatisfaction with the present. What is unsatisfactory about the present? Automobility is so embedded in our societies that any vision will be of a society that is materially different from what most of us enjoy today. Some of the authors' objections have been outlined earlier. Our problems with the present involve both the car and its social context. These issues will be looked at separately below.

As Ruth Brandon (2002: 238) points out 'Nothing is harder to predict than the future; yet on correct prediction business success depends'. Many visionaries and others regularly attempt to predict the future of automobility. A few are reviewed in *The Death of Motoring* (Nieuwenhuis and Wells, 1997), where the authors discuss the visual representations of future transport developed by the Das brothers (Das and Das, 1995). One of the most elaborate future visions was the Futurama model built for General Motors by Norman Bel Geddes in 1938. It created a concrete vision of the world of 1960. Brandon (2002: 294–5) quotes from the voice-over heard by the many visitors to this exhibit at the New York World's Fair:

> Let's travel into the future. What will we see in the wonder world of 1960? This world of tomorrow is a world of beauty – hills and valleys, flowers and flowing streams . . . Over space, man has begun to win

> victory – Space for all! . . . The farmer of 1960 works in greater security! Science and research control the risks of agriculture! Orchards are protected against insects, pollination is controlled – Physics and chemistry have joined hands with the farmer in help and friendship! . . . [in the city] Residential, commercial and industrial uses are separated for greater efficiency and convenience . . . Parks are united to form green strips around each community. Along the banks of the river, landscaped parks replace outworn neighborhoods of an earlier day. Outmoded business sections and slum areas have been replaced where possible. Man always strives to replace the old with the new!

Subsequent Motoramas were used to present to the buying public GM's latest concept cars, or 'dream cars' (Berghoff, 1995). However the value of a visible future vision is clear. The first Futurama had a considerable impact on the expectations of the American public in the post-war period. Earlier, Bel Geddes had developed a range of visions for Shell, using a newspaper article format. Brandon (2002: 287) quotes the following from 1937:

> Tomorrow's Children Won't Play in the Streets says Norman Bel Geddes. 'One half the space of the city of 1960 will be used for parks and playgrounds' predicts Norman Bel Geddes, authority on future trends. 'Pedestrians will move quickly and safely on elevated sidewalks above the traffic level. Streets will be made much wider by eliminating present-day sidewalks . . . Parking, loading and unloading will be done in side buildings. Traffic going 10 blocks or more will use high-speed Express Streets. No stop lights . . . no intersections . . . no stop and go!'.

The emphasis at this time was on technology creating a better future for people, but what we are facing now is the possible limit of such technical solutions. This requires a different mindset. It is very difficult for us to imagine a world where the things we think we have come to rely on are removed. Democratic societies also make it very difficult to forcibly part citizens from their possessions and lifestyles unless faced with a real, immediate and visible crisis. This point is often not appreciated by the more extreme elements in the environmental movement. Running lemming-like to the edge of the cliff may not be prudent, but it can be very democratic. We may have to accept this and instead make the alternative somehow more appealing, not just to deep greens, but to the wider community in developed industrialised countries (many in developing countries already have a sustainable lifestyle, though not necessarily by choice). Attracting people away from the cliff is ultimately more productive than single-handedly trying to stand in their way and stop them as they run towards it.

Particularly interesting in the current context are the scenarios developed by Shell (2002). Shell produces scenarios every few years and this particular pair seem highly relevant for our purposes. The Shell scenarios take a range of political and social factors into account and see two possible trajectories over the following 20 years. In their 'Business Class' scenario (Shell, 2002: 27) the current trend towards globalisation essentially continues, albeit with some attenuations. These include a slowly growing resistance to some aspects of globalisation, as 'Highly interconnected global elites form the cutting edges of almost every area of the world. Their power is disproportionate to their numbers, in part because of their wealth, and in part because the principles with which they agree constitute the operating framework of global institutions such as the World Bank, the IMF, and the WTO' (Shell, 2002: 28).

The trend whereby decentralisation due to the reduction in the central power of the state leads to local communities setting their own global agendas alongside those of states and companies (Shell, 2002: 34) is more prominent in the alternative scenario, entitled 'Prism' (Shell, 2002: 55). In Prism, the pressures of modernisation are the same, but 'people look to their roots, their heritage, and their families as the source of values around which to organise their lives' (Shell, 2002: 56). This creates quite a different world of 'multiple modernities', perhaps surprising many of the ruling elite: 'Those who saw no alternative to the onrush of globalisation consistently underrated the power of two coupled human aspirations: identity and belonging' (Shell, 2002: 58).

13.2 A sustainable world: the context for automobility 2050

It has probably become clear that we feel more at ease with 'Prism' than with 'Business Class'. This book is about sustainable automobility, and as such is within the realm of our expertise. However, underneath the vision for automobility that we outline here there are more fundamental considerations: the views, prejudices, opinions, values, aspirations, dreams, biases, experiences and knowledge that inform our view on automobility. Often such profoundly held beliefs are difficult to articulate clearly, they remain submerged within the subtext just as real meaning often remains between the words rather than in them. Equally, many would baulk at putting such beliefs down in a book of this type because they may appear as arbitrary, irrational, unscientific, emotional or idealistic and thereby undermine the value of the other evidence presented. Of course in part this is a reflection of the traditional and deeply embedded notion of impartial, neutral and dispassionate scientific rationality that is supposed to form the bedrock of knowledge in Western civilisation. As a culture we have tended to suppress the intuitive, the irrational, the spiritual dimensions of the human experience, particularly with respect to science, technology and the economy. Yet humans are not only rational, but also emotional and spiritual, and to ignore this makes for an unbalanced vision of the future.

At its most grandiose, we hope that this book is a contribution towards the creative, inspirational process whereby society as a whole is transformed: the project of sustainable automobility makes little sense in an unjust, unequal and unsustainable society. Our work is hardly prescriptive; rather it is a contribution to a discourse; to a language that challenges the existing bastions of power, reason and legitimacy. What our work does show, however, is that even with respect to something as apparently immutable as the global automotive industry the internal logic and rationality of that industry can be challenged when the conceptual starting point and value system is different. Some of the values we seek to embrace include:

- democratic content and real control over individual and community life, including economic self-determination;
- enriching and fulfilling lives that create a sense of self-worth, of community and belonging, of tolerance and fellowship;
- recognition of both individualism and society;
- connection to and grounding in locality;
- life enhancing work that is both 'good' to do and creates products and services of real value to our communities;
- fostering of diversity, difference and contextual embeddedness;
- fostering of emancipatory creativity and a return to real choice rather than the myth of market choice.

In our view, therefore, the concept of a decentralised economy is not simply one in which a bunch of computers are put together in a network to allow teleworking, but is rather much more complex and all-embracing. It is founded ultimately on the re-creation of economic independence as a form of 'vernacular economy' to ensure that people are no longer the hapless victims of the endless global economic storms that sweep away livelihoods and communities. It is therefore the case that the most profound questions remain those regarding the ownership and concentration of wealth. Alastair McIntosh in his book *Soil and Soul* (2002: 117), puts it thus:

> Just consider what . . . spiritually rich education might look like: it might start with soil structure and why the biochemistry of organic farming sustains biodiversity, and go on to look at how biodiversity equates with an optimal balance of arable crops and animal stock, and that with animal welfare and human health; with awareness of energy alternatives that would mitigate dangers of global warming and keep the old and poor from being cold; with ecological restoration including computer modelling of new techniques and evolutionary processes; with maximising economic linkages and multipliers at bioregional, national and global levels; with business structures that harmonise enterprise with accountability and co-operation; with an economics of 'Fair Trade'; with ecological architecture and clean, efficient public transport systems; with the spiritual ability to see anew why all life is

> providential; with healing skills based on advanced scientific and spiritual principles; with knowing the roots of artistic creativity and inspiration; with poetics and story, and learning how to listen to one another; with a participatory politics of empowerment; with awareness of the psychology of prejudice and the resolution of conflict; with a nonviolent civic-defence strategy and taking away the causes that give rise to war; with cherishing human life from cradle to grave; with extending the erotic into all life, including sexual love; with kids having fun and playing in treehouses; with the discovery of beauty as the touchstone of what is good; in short, with building of community as right relationship between soil and society, powered up by the passion of the heart, steered by the reason of the head, and then applied by the skilled technique of the hand. And remember: this is not a pipe dream. Humankind is already well on the way towards understanding most of these principles. It's just a matter of linking them up and applying them.

The alien rantings of a dreaming deep green ecologist? If that is our response it just shows how far removed we have become from our roots and how far we still have to go to reach the goal of sustainability, for this just about sums up the essential elements of a sustainable society. Translating some of these ideals into our own area of expertise immediately leads to a consideration of how various aspects of automobility are interconnected. It is not enough to design a 'sustainable car' as a piece of disembodied technology, bereft of the culture that created and will use it. If the structure of the industry to build that car is such that a few become inordinately wealthy while most live in constant fear of unemployment while struggling through mundane 'soul destroying' jobs on mediocre pay then that car is not sustainable. To be sure, much of this debate has yet to happen or is in an early phase. But we would reiterate that the debate is about choices rather than absolutes.

For example, it may be held that the decision to build a few large car manufacturing plants is more 'efficient' than many smaller ones. It could be argued that there is less capital investment required, so it is a more efficient use of financial resources. There is higher output per worker, so it is a more efficient use of human resources. Pollution is concentrated on a few sites, so abatement measures are more efficient and more easily monitored. Total usage of items such as land, buildings and machinery may well be lower with a few large car plants. All of these efficiency arguments suggest that the contemporary practice of using large, centralised car plants is the most 'logical' or the 'best', the economic and technical optimum. Alternatively, multiple small plants that both manufacture and support cars in use may help avoid the gross inefficiencies of over-capacity and over-production. Multiple small plants could also offer greater resilience with respect to the erratic fluctuations of the global economy – indeed it is an intriguing thought that a decentralised economy might actually result in an overall reduction in economic turbulence generally. There are massive (social) inefficiencies in actions such as closing large car plants, but these are never put into the economists' calculations.

13.3 Automobility 2050: making cars

With respect to making cars, our vision for 2050 has two broad aspects: the work involved and the shape and structure of the industry. In terms of making cars, it must be admitted that the contemporary automotive industry has made tremendous progress on issues such as working conditions and practices. The interested reader should take themselves to the Detroit Institute of Arts to see the fabulous murals by Diego Rivera partly inspired by the Ford Rouge factory in the 1930s, or consult Linda Bank Downs' in-depth study of them (Downs, 1999). Compare this with a stroll through the BMW plant in South Carolina, or the new MINI plant in Oxford, where the transformation has indeed been dramatic. A modern car plant at its best is light, airy, and surprisingly quiet. Moreover, work tasks have been designed to reduce strain injuries to a minimum, while many onerous tasks have been automated. Compared with many occupations, working in a car assembly plant is relatively well paid.

However, the basic dimensions of working on a car assembly line remain the same. The work typically has very short cycle times, less than one minute in a high volume plant, and is therefore highly repetitive. Furthermore the work is unrelenting, the disciplining power of the assembly track and the prime consideration to keep that track moving creates a potentially high-stress working environment. In addition, the work is not always very fulfilling. Our vision for automobility 2050 therefore includes the notion of job enrichment as a basic target. Workers should have interesting, varied and challenging tasks creating products of which they can feel proud and for which they can feel directly responsible.

Connected to this vision of work in the car industry is a vision for the structure of that industry. We have largely considered the question of structure in terms of the scale and scope of a car plant, irrespective of issues such as ownership or the structure of capital. We implicitly expect that a reduction in scale will result in lower levels of automation, much longer cycle times and thereby greater skill levels for workers. This may prove an erroneous assumption. Equally, we expect that the concept of micro factory retailing (MFR) will create, in any one enterprise, a broader range of potential tasks for workers – from sales, via repair and assembly, to ELV processing. At the same time we expect MFR to create a business which is less dependent on the sale of vehicles alone in order to survive, but can derive a profit from these other activities, as well as the possible management of a transport provision service using its products.

Similarly the concept of multiple small plants is assumed to lead to the better fulfilment of local needs, accounting for geographic, climatic or cultural differences. Again, this is a different sort of efficiency from a narrow consideration of the utility of capital. Our vision for automobility 2050, therefore, includes the notion of an industry characterised by fragmentation, multiple small plants distributed across geographic space creating products that are appropriate to the local communities in which they are placed.

13.4 Automobility 2050: the car itself

Ask any car enthusiast with enough experience of different machinery and enough detachment from marketing and badge hype about his or her favourite 'driving machines' and more often than not the choice is either for a classic car or one of the few remaining contemporary lightweight cars. Light cars are more responsive and more intuitive to drive than heavy cars. The feel of lightness can be achieved to some extent in heavy cars by fitting more powerful engines and power-assisting various functions, thus adding even more weight and adding a level of 'detachment' between the driver and the road. However, despite the dominance of enthusiasts among decision-makers in the industry and those who rate their products, most cars are not bought by car enthusiasts but by people who regard them as transport. This group – the majority – has different criteria, many of which have been addressed in the process of adding weight and detachment. Thus was created the safe, comfortable, reliable, low maintenance, durable device we buy today.

Clearly we would not want to lose those positive elements of today's cars, yet much needs to be changed, both for the sake of driving pleasure and sustainability. We have often highlighted the case of the Lotus Elise, a lightweight, minimalist driving machine designed for pure driving pleasure, but which also scores rather well in our environmental rating system for cars (see Chapter 12). Weight reduction is a key element in making our cars more sustainable. It is brought about by using fewer materials more prudently, thus producing benefits in terms of waste reduction, reduction in raw material requirements, lower toxic emissions, lower fuel consumption, lower CO_2 emissions, reduced transport and logistics needs; and greater driving pleasure. As Lovins has argued on many occasions, once you take out enough weight, you can also take out those devices that compensate for excess weight, such as power-steering, and you can design all components lighter, thus reducing yet more weight (Lovins, 1995; Lovins *et al.*, 1993).

The design brief for our car of the future is therefore not too difficult although executing it may be more challenging. A lightweight structure, powered by a zero emission powertrain, that will also allow us to travel in reasonable comfort with minimal energy input is the aim. We can only move in this direction by encouraging both industry and markets to build this type of vehicle. However, industry has to take the lead, with the help of legislators. Moves such as the CO_2 agreement are key elements in this approach. A broader regulatory approach could be one based on our Environmentally Optimised Vehicle (EOV) concept (Nieuwenhuis and Wells, 1997). This would encourage regulators to develop legislation along a number of parallel tracks, with each tackling one aspect of the car's impact on our environment. A car would be rated on the extent to which it met or exceeded these requirements and taxes would be levied accordingly. The baseline would be calculated from the average of cars currently offered in the market, thus creating a moving target, but ideally one moving in the right direction.

Credits could be given for any cars exceeding the baseline, while penalties would be given to those not meeting it. These could be expressed in terms of taxation of various types. Elements taken into account would include toxic emissions, CO_2 emissions, weight as a proxy for raw materials needs, recyclability, performance of the production process, impact of the distribution system, durability, etc. Thus a manufacturer who had difficulty scoring on one of these parameters could compensate by exceeding the baseline on one or more of the other parameters.

We would also advocate the promotion and development of various types of sub-cars, voiturettes, etc. The gap between these and bicycles would be filled by promotion of human-powered vehicles, such as 'velomobiles' (sophisticated pedal cars) using lightweight materials and advanced production techniques. Cycling on conventional bicycles should also be promoted, particularly where bikes could easily replace the car for certain journeys. Many countries such as Germany, Denmark and The Netherlands are already following such a policy.

Our cars would be assembled by a dispersed network of local micro factories which would also repair, enhance, maintain and upgrade the car and which would take it back for updating, re-use and ultimately dismantling and recycling (see Chapter 17). The micro factories would source standardised powertrain and chassis components from larger supply facilities which could be owned jointly by a group or which could be independent. Other components would be sourced locally to create vehicles optimised for local needs and configured for local tastes. Detailed specifications and variants could be configured for each individual customer.

13.5 Automobility 2050: cars in use

The automobility paradigm has given us urban and suburban environments designed around the car rather than around people. Many such areas are alienating environments for people as pedestrians or cyclists and have become no-go areas for most people when out of their cars. Urban and suburban streets where children once played have also become no-go areas, but this time for the very children who once gave them dynamism. Urban areas in temperate zones have moved imperceptibly from smog zones to toxic air pollution zones from vehicle emissions. The problem of air pollution first emerged in Southern California in the 1940s. By the time the car reached its first century, it had already become implicated in a range of environmental problems, as we saw in Chapter 1. Initially, industry saw the environmental debate as yet another temporary fad that could be addressed by technology and then quietly forgotten about. However, increasingly, people realised that the environment was not some external entity deserving of our benevolent protection. Instead at issue was our own environment – mankind's ability to live on a planet that could survive perfectly well without us. As this realisation spread, and with it social and legislative pressure on the car, the debate became incorporated into motor industry strategy such that the car and its use became increasingly shaped by environmental requirements.

At first the debate focused on toxic emissions from car exhausts and this was reflected in the legislation that followed. Over the years the scope widened to include other issues such as energy use, raw materials use, traffic congestion and greenhouse gas emissions, as well as end-of-life issues such as recycling, re-use and vehicle durability. As a result, a more global assessment of the car's impact on society as a whole became possible leading to a so-called life cycle approach to the problem (see Chapter 12). This approach will guide regulations more and more in the coming decades.

13.6 Conclusions: a vision of the future

The vision outlined above is obviously going to be our vision. Expectations and desires of the future are very personal. Conventional future-gazing techniques do not always acknowledge this. In the case of a Delphi study, for example, the personal views of a number of experts in their field are collected and collated to come up with a view of the future that is usually rather bland and predictable. The numbers involved make this inevitable, although sometimes an original view does emerge. We have deliberately avoided such a formal approach to creating our vision. Our vision represents not so much what we expect, but what we hope will be the future.

13.6.1 The short term

As many in the motor industry take a shorter-term view, we thought we would cover this briefly before moving on. In 2002 many people within the industry in Europe were very interested in the effects of the new bloc exemption regime. We expect the impact to be gradual and perhaps only significant with hindsight. Car distribution will change, but the drivers will go beyond regulatory tightening to such factors as the impact of internet selling of cars, which will become more prevalent. We offer a future vehicle retailing model in our MFR concept, as outlined in Chapter 17.

Another trend will be a gradual decline in the importance of the brand. Brands have already begun to be eroded in the automotive sector. Where once brands such as Citroën offered a significantly different driving experience, now those variations between brands' products have become too small to support the brand differentiation. Platform and component sharing has made this inevitable, as has the pressure to sell sufficient volumes to pay for new investments. Catering for small bands of aficionados is no longer viable, as Citroën, Alfa-Romeo, Saab and Lancia have found to their cost, not to mention the victims already left by the side of the road: Panhard, Bugatti, NSU, Delahaye, Hotchkiss, Packard and many others. As the substance of brands has been eroded, the effort put into boosting brands has increased. The little brand differentiation left has to be optimised in order to compete. In practice many larger cars built by the volume brands now offer the same quality and features as their equivalent offerings from specialist brands. In reality a Ford Mondeo, VW Passat or Opel Vectra are not significantly worse in terms of quality than a BMW 3 Series, Mercedes C-Class or Audi A4. In many respects they may well be better. In order to justify the price premium, therefore, the brand values have to be artificially inflated. At present, enough customers are willing to pay the premium but this is not going to last for ever.

Electronics will allow fine tuning of powertrain and chassis over the next few years and this will allow a relatively cheap way of making products from different brands 'feel' different. However, the traditional stratified segmentation system will give way to more horizontal segmentation. When segmentation started, saloon cars of different size, performance and quality could be found as one moved up the segments from cheaper brands and models to more expensive ones. This has already begun to change. At a given price point of, for example £15 000–20 000, one may now be able to choose from among a group of genuinely different products, such as a large saloon or estate from a volume maker, a small executive from a specialist manufacturer, a small sports car, a well specified compact MPV, a large MPV from a Korean manufacturer, a small SUV, etc. We now have a form of horizontal segmentation, whereby customers have the choice from among a group of functionally and visually distinct vehicle types from a range of different brands and origins within each price band.

This trend is likely to intensify as people become less willing to pay extra for a prestige badge on the bonnet, but may be willing to pay extra for greater differentiation, individuality or functionality. This will allow the development of new brands standing for a new set of product characteristics and values. Similarly, existing brands can reinvent themselves by offering products with a new set of distinctive characteristics, far removed from the pure snob value of many current brands. Renault is a good example.

During the 1990s it reinvented itself around a new set of brand values, based on substantial product differentiation. It started by promoting a new design language through vehicles such as the Twingo, a vehicle that revitalised the city car segment. This has been updated more recently via the style embodied by the Vel Satis, Avantime and Mégane, followed by the 2003 edition of the Scénic. The Scénic itself created a new subsegment, that of the compact MPV, while the Mégane–Scénic range itself is a good example of this horizontal segmentation: a single model range offering quite distinct body types and value propositions. Renault products are now regarded as well-designed, practical and safe family transport for those who have a more progressive outlook. Such real visual and functional differentiation is likely to replace much of the segmentation currently still dominated by brand value thinking, particularly within the mainstream market segments. The prestige specialist brands can either offer similarly horizontally diversified ranges – for example, through platform sharing with volume partners – or move further upmarket chasing lower volumes. Alternatively, the specialist car makers' brand values may become so hollowed out that their brands will become valueless and the ability to charge a premium will disappear. The difference between specialist and volume brands will then effectively disappear from most of the market.

13.6.2 The longer term

This is all likely to happen by around 2020. Our core vision will probably take a lot longer to realise, although the seeds have already been sown. One key element is the Kyoto agenda. This is being implemented through a voluntary agreement between the EU vehicle producers' body, ACEA, and the European Commission to reduce emissions of CO_2 from the average new car sold in the EU by close to 30 %. The Japanese and Korean industries have also agreed to comply. This agenda is beginning to dominate many key decisions in new car design, so much so that weight reduction and improved energy efficiency have become real issues. The longer-term results of this will be far-reaching. Similarly, the implementation of the EU ELV directive will have far-reaching consequences as it forces the industry to move towards a product stewardship model.

Here we move well beyond the superficialities of branding to the essence of automobility and its role in society. What would our world look like? In an urban environment, virtually all motorised transport would be banned – cars do not mix well with pedestrians, and more benign modes such as human power would dominate. Buses do not mix well either, as they still tend to pollute and are often under-used. A more flexible public transport system based on smaller, lower-impact, more benign vehicles would be developed. These could realistically be totally automated. Trams or light rail may be easier to accommodate. Otherwise, urban traffic would be dominated by human-powered modes. The human-powered mass transit system proposed by Skyway of Canada is also a possibility (Kor, 1994). This involves human-powered pods travelling through see-through tubes in which a slight tail-wind is constantly created by fans. This provides a dry, warm, comfortable and low-effort cycling environment. Human-powered monorails have also been proposed.

One of the reasons for taking a car into a city centre is to carry shopping. In future, much more shopping will be done online using the internet and distributed to our homes via more efficient distribution systems, although transport costs would be more indicative of environmental impact. City centre shops would still provide an outlet to sell the kinds of products – such as perfumes, certain foods, tactile products – that are less suitable to be sold through virtual means, and would also sell a range of products that require a personalised sales process for precise product configuration. City centres would also still be used as meeting places, accommodating restaurants, cafés, coffee shops, theatres, cinemas, large-scale virtual experience centres, etc.

The weather is another factor determining modal choice for urban journeys. Providing public transport access or transfer points close to home and destination would be easier in more densely populated urban environments. Where the distance to these hubs or access points is still a deterrent, advanced HPVs could be used in many instances. In rural areas, providing a comprehensive public transport or mass transit system is unlikely to become economically viable even in the future. A form of personal motorised transport may well be the optimal solution, as congestion levels will be low. However these would also be low impact, lightweight, environmentally-optimised vehicles. They could be used to travel to urban areas and left on the outskirts near comfortable, efficient and convenient transfer points to interface with various public transport modes, as well as non-motorised personal modes for entering the city centre. These would be far removed from today's unappealing park and ride schemes, which often involve a long wait in inclement weather for an uncomfortable bus.

Vehicles would be guided by advanced telematics systems, though for personal modes these could still inform rather than drive the vehicle. On the other hand, urban environments are well suited to developing the more robust vehicle guidance systems that would allow the realisation of the telematics dream for the vehicle to be 'driven' by the infrastructure without creating the legal liability problems still widely dominating telematics discussions today.

In order to allow the safe development of lightweight personal and private vehicles, a separation of light vehicles from heavy vehicles will become essential. A separate infrastructure would have to be created for heavy goods vehicles. Much of this could use the principles of the guided bus in order to minimise the space requirement and these would feed urban distribution centres on the outskirts. Further distribution to retail locations and to people's homes would be carried out by lightweight vehicles that could be mixed safely with the more benign modes in cities. Some such vehicles could be human powered. Such HPV vans already exist and are used in cycle-friendly cities such as Ghent and Amsterdam.

It is important, for economic reasons, to separate key goods transport functions from private and personal transport. However, the increasing localisation of economic activity would also reduce the volumes of long-distance transport. International exchange would be in certain high value-added goods reflecting particular local expertise and traditions, as well as in data, information, intellectual property, etc. via the internet. In future, the internet will contain more information for sale, rather than for free. Basic food production would be relocalised as much as possible. The distance goods travel would be reflected in their price, thus making the environmental impact of long-distance shopping more obvious and guiding consumers to more local sources, without making distant goods totally inaccessible.

When you step out of the average front door in 2003 you are greeted by an urban A road with an almost constant flow of cars, trucks, vans, buses and very few bicycles, some pedestrians and a certain amount of pollution and noise only kept at bay via double glazing. Now imagine stepping out of this front door in 2050. You step outside and smell fresh air blowing in from the hills and the not so distant sea. You can hear only the occasional hum of an electric motor, whirring of bicycle gears, the sound of children playing and of adults stopping for a chat. You could cycle to work as in 2003, but in much greater safety and hence less stress. When it is raining you can use an enclosed velomobile, for which a safe infrastructure now exists. However, most days going to work is not necessary; you can interface with people from home and work at home. Essential shopping is done online and delivered by lightweight long-life fuel cell-powered vans; social and recreational shopping is more pleasant, although environmental levies have increased the price of many 'non-essential' goods sourced from further away, while a less pressured working life has reduced the need for compensatory purchases. If you wanted to take your shared hydrogen fuel cell car into the city centre you would need to buy a special permit. Villages and town centres are all pedestrianised and limited to benign transport modes but out of town driving is less restricted. McGurn (1994) gives a vision of a human-powered future, illustrated with a two-page spread of cycle highways. You get the picture, we hope, and can probably add your own elements to this vision.

13.7 References

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14

The distributed economy

Diversity is the characteristic of nature and the basis of ecological stability. Diverse ecosystems give rise to diverse life forms and diverse cultures. The co-evolution of culture, life forms and habitats have conserved the biological diversity of the planet. Cultural diversity and biological diversity go hand in hand.
(Vandana Shiva, quoted in Shrybman, 1999: 30)

14.1 Introduction

A major part of this book is concerned with the details of technologies, materials, markets and government regulation. It seeks to present a critique of existing practice, largely from an economic or business perspective. Environmental concerns provide a second basis for the analysis of the contemporary automotive industry. However, underneath this debate are the more profound philosophical issues about the nature of our society, its organisation and the purpose of the things that we do. This chapter is about the wider philosophical debate. The fact that we have largely concentrated on the narrow business and environmental issues does not deny the significance of these wider questions, but rather reflects a concern to meet the existing priorities of society (chiefly the demand that any activity be 'economic' or profitable) on its own terms while simultaneously proposing a radical agenda for change.

The vision for Automobility 2050 outlined previously (Chapter 13) is far removed from automobility today. In fact, there seem few trends even pointing in that direction. We live in an automotive paradigm predicated upon the growing use of motorised modes, particularly cars, at the expense of more benign modes in many parts of the world. Although, on the whole, individual car emissions have become significantly cleaner, there is still scope for improvement, while in many parts of the world, any improvements in individual cars have been offset by the growth of the parc as a whole.

Another issue is CO_2. As discussed earlier, individual engines are more efficient than ever before and produce more power and torque per cubic centimetre of cubic capacity. However, cubic capacities have increased over time and are used to move much heavier cars so the average modern car is not necessarily more fuel-efficient than one from the 1970s – and has the added disadvantage of emitting more CO_2. Congestion has also not been eased. As more roads are built, there appears to be an inexorable tendency for cars to appear to fill those roads.

On the supply side we have witnessed developments that have given rise to multi-brand global manufacturing groups as a result of mega-mergers, particularly during the 1990s. These groups exert enormous and highly centralised control over their material and component suppliers, and equally over their franchised dealer networks. As with other industries, the automotive industry has given rise to companies of global scale and stature, often to the disquiet and concern of those within the existing industrialised nations (who fear that jobs will be exported to other countries, or that workers in emerging economies will be exploited) and those within the emerging economies that are in this sense the 'recipients' of globalisation and who fear the loss of economic autonomy that global companies may bring. This chapter seeks to situate the 2050 vision for automobility within the social and political framework of the decentralised economy. The chapter starts by examining the linkage between corporate centralisation, globalisation and the antithesis of the decentralised economy.

14.2 Centralisation, economies of scale and globalisation

The authors' proposed vision for 2050 is by comparison radically different from the current structure of multi-brand, multi-location companies founded upon the logic of mass production and economies of scale. How could this dramatic trend change come about? Batchelor (1994: 124) quotes Sabel and Zeitlin, who point out that:

> . . . the persistence and development of manufacturing strategies other than mass production oblige us to review its place in history, as well as how it functions. Rather than habitually ascribing to it the status of an ideal of industrial efficiency, to which all other forms are in various respects inferior, subordinate or anachronistic remnants of some older, soon-to-be outmoded way of thinking, it can be argued that mass

> production was but one of a range of manufacturing strategies, each of comparable technological viability. The decision to pursue mass production at the expense of these alternatives arose, not because of 'an immanent logic of technological change', but because of 'some implicit', collective choice, arrived at in the obscurity of uncountable small conflicts.

We have seen that small-scale non-Budd manufacturers like TVR and Morgan have survived and can survive profitably. We have also seen how Buddist mass car making is in crisis, but is intimately linked with the primacy given to economies of scale and hence to centralisation tendencies within the automotive industry. Consequently, we envisage a manufacturing system based on small local assembly facilities, also responsible for sales, marketing, service and repair, as well as product take-back – micro factory retailing. How do we get there from here, and why would we go that way in the first place?

To find the evidence for smaller, more distributed, assembly or manufacturing, we need to first step outside the automotive sector and look elsewhere. The move towards smaller, more distributed, production units can be found in several other sectors, for example: micro-breweries, steel mini-mills, Michelin's low-volume production system for tyres, the return of local bakeries in countries like the UK, the development of intensive chemicals production systems, and others. The history of the steel wide strip mill is perhaps as good an example as any, for it illustrates the contradictory trends of globalisation and capital centralisation in terms of ownership, alongside a reduction in capital intensity and scale of production at a plant level (see the contributions in Ranieri and Ayling, 2003 for an extended discussion of this history). In general terms the industry can be characterised as having gone through distinct phases. While many of the foundation technologies for wide strip mills originated in Europe, those technologies were elaborated and enlarged in the US, giving rise to ever-larger units of production. At the peak of the US model of steel production in the 1950s mills were constructed with capacities of five million tons per annum (mtpa) but with very low levels of production flexibility or product variety, and an emphasis on volume output rather than quality.

By the 1970s and 1980s this model had been somewhat supplanted by the Japanese model with a much greater emphasis on process control, and hence quality, albeit at lower production volumes. At the same time, again in the US, the rise of the mini-mill accounted for the decline in the commodity elements of the market for strip mill output (so-called long products such as rails). The mini-mills used scrap steel and electric arc furnaces, with output volumes viable at less than one mtpa, but were unable to produce the high value wide strip and coated strip produced by the traditional integrated mills. However, in the 1990s technological leadership in strip mill design once again passed to Europe, with the development of integrated mills able to produce economically at volumes of about two mtpa. These mills, using continuous casting technology, have very diverse output capabilities with a wide range of product types of high quality. In other words, wide strip steel is no longer a market where competition is based only on price reductions and economies of scale, but is one where flexibility and value-added products are the key to success.

There are some clearly discernible trends towards the 'small is beautiful' approach in a range of industrial sectors. However, on a macro level we also have to contend with the WTO agenda of global free trade encouraging ever-larger units of production and business – a clear trend away from micro-factories. This is actually a relatively new phenomenon, as only a few years ago protectionism was still common and even now many so-called barriers to trade are still in place. The recent nature of the WTO agenda is further emphasised by the overall fragility of the system. Recent disputes include those over bananas (the US against the EU); steel (the US against the rest of the world); the Clean Air Act (Brazil and Venezuela against the US); BST hormones in meat (the US against the EU); agricultural subsidies (the EU against the US); GM food (the US against the EU); dolphin-friendly tuna (various against the US) to name but a few. These examples have shown that the instigators of the WTO agenda – the rich countries – have also themselves to some extent been on the receiving end of its more onerous provisions, if not yet become victims of it (Hines, 2000).

Many more countries and trading blocks are likely to become embroiled in the PPM (non-product-related process or production) provisions of the WTO. These countries are likely to be in the rich North as well as the poor South. This is the logical result as the WTO agenda drives economies and legal frameworks to a lowest common denominator of global standards – the 'race to the bottom'. The PPM rules prevent discrimination on the basis not only of the product itself, but also of how it is produced. This means that countries cannot penalise products made by means of environmentally destructive processes or by unacceptable labour practices, such as child labour. As Hines (2000: 235) points out: 'PPMs are not some minor sticking point, but are utterly central to free trade and international competitiveness. Once any country is allowed to ban a product on the basis of how it was made, a floodgate of trade restrictions could result'.

In fact, attempts to use consumer information labelling to get around this problem have also been challenged under WTO rules, such as with the EU–US GM foods dispute. Only narrowly-defined scientific evidence that proves beyond doubt that a product is dangerous can be used to stop it entering a country (Hines, 2000: 222). We saw in the case of BSE in the UK what a complex process this can be. The precautionary principle – invoked by a number of recipient countries to ban UK beef at the time – is not acceptable under WTO rules. Clearly the consumer has lost much of the protection built up over many years of campaigning and much of the protection traditionally provided by democratically elected governments who can now be overruled by unelected WTO officials. Furthermore, the issue of local choice has been trampled under global economic interests.

Job security has also suffered. Even before the WTO, the liberalisation in world trade contributed to a transfer of an estimated nine million person years (in terms of labour) from the North to the South (Wood, 1994). It is not only the developed North that is affected either: China plans for the loss of 4 million civil service jobs, as well as some 150 million jobs from ‘inefficient state enterprises’. This is in addition to the estimated 100 million peasant jobs lost by economic migration within China (Gray, 1998: 3). It is not surprising then that even the WTO itself feels compelled to admit in its 1998 Annual Report that ‘Empirical evidence tends to show that trade liberalisation may entail non-trivial adjustment costs for certain groups’.

The number of trade disputes resulting from the WTO is likely to grow and will increasingly challenge such fundamental cultural factors enshrined in national law. Citizens and consumers in many countries are unlikely to accept this trend for very long and it seems reasonable to predict therefore that opposition even at government level will grow. Such opposition already exists at grassroots level, as illustrated by the seminal Battle of Seattle of 1999. The fact that WTO negotiators were genuinely surprised by the Battle of Seattle shows just how out of touch many of our leaders are, and its resulting shock effect may well ultimately change the political support for the WTO, for Seattle was followed by Prague, Barcelona and others. Though still haphazard and anarchic in nature, these protests do reflect a growing public concern with a system that has shown little or no benefits for ordinary citizens, even as consumers. Further ammunition was provided by popular books challenging many aspects of globalisation, notably Naomi Klein’s *No Logo* (2000). Those wishing to see a reversal of the globalisation agenda may take some comfort from the problems encountered by the talismanic McDonalds empire of fast food restaurants which in the early years of the twenty-first century was forced to rein back expansion plans.

If opposition is building so clearly even at such an early stage of WTO implementation, and if the disbenefits to consumers and employees are evident at such an early stage, how could the WTO regime possibly be sustainable? In a scenario that takes us to 2050, we must therefore consider the demise or radical reshaping of the WTO at some time during the forecast period.

One problem is that many opponents have so far not considered an alternative to the globalisation agenda, which somewhat undermines their effectiveness in gathering wider public support. However, an alternative scenario does exist. Both Korten (1995, 1999) and, particularly, Hines (2000) suggest that a re-emphasis of the local may well provide the answer. Hines sets out a new world trade regime which emphasises relocalisation. The localisation idea is promoted by a growing body of literature with particular emphasis on the revitalising of local communities (Shuman, 1998; Shiva, 1998; Douthwaite, 1996; Hines, 2000). The Rio Earth Summit of 1992 also emphasised the local in its Agenda 21, which encouraged the implementation of local equivalents on the basis of 'think global, act local'. How is this relevant for our MFR concept? Shuman (1998: 6) explains that localisation '. . . means nurturing locally owned businesses which use local resources sustainably, employ local workers at decent wages and serve primarily local customers. It means becoming more self sufficient, and less dependent on imports. Control moves from the boardrooms of distant corporations and back to the community where it belongs'.

The definition of what constitutes 'local' is kept flexible and in practice will differ for different types of economic activity (Hines, 2000: 29–30). The main aim is that any move towards the local '. . . has at its core the aims of providing basic needs sustainably, improving human rights, reducing the power gaps between different groupings and genders, and increasing equity and democratic control over decision-making' (Hines, 2000: 31). In the automotive case it would also enable better response to genuine customer demand, whilst restoring profitability to the sector and thus rendering it economically, as well as socially and environmentally, sustainable.

14.3 The distributed economy: an outline of basic ideas

From an ecological perspective there is a challenge to be made to the predominance of production in both mainstream economics and Marxist thinking. While there have been attempts to produce environmental economics (Pearce, 1989, 1991), radical critics argue that this is a deeply flawed project (Hayward, 1994). Not least, environmental economics remains reductionist, it attempts to reduce all things to a monetary value and hence to remain within the rationality of economics. This is therefore seen by critics as an attempt to put a price on the priceless.

The concepts that underpin the distributed economy are many and varied, and cannot be treated in full within the confines of this chapter. However, the distributed economy is not just a statement of how to do things 'better' from an economic perspective. On the contrary, it is a deliberate attempt to reintegrate economics with the concerns of politics and society. The basic principles outlined here are derived from Schumacher (1973: 26–35):

- material wealth, particularly as measured by metrics such as Gross Domestic Product, has no correlation with individual happiness or peacefulness;
- continued 'growth' on such measures is doomed to meet the physical limitations of the natural world;
- contemporary economics is based upon the non-valuation of natural 'free' goods or the short-term valuation of irreplaceable natural resources;

- the distributed economy is founded on the notion of the economics of permanence;
- science and technology should be orientated towards the peaceful, the non-violent, the gentle, the organic and the non-invasive;
- technologies should be cheap enough to be accessible to everybody, suitable to deployment at a small scale, and able to foster creativity;
- work should be enriching and rewarding, not enslaving humanity to the regimen of the machine;
- wealth and power should not be concentrated into a few hands, in particular the capital cost of a workplace should not be substantially more than the average annual wage.

There is, in the view of the proponents of the distributed economy, as much importance placed on how things are produced as on what is produced. It is an idea that has long been present to a greater or lesser extent in Western society: that work is its own reward if there is autonomy, skill, satisfaction in producing a good that serves real social need, and gives scope for creative input. This is a long way from the reductionist minimalism of the WTO agenda that reduces production to financial cost – consumers benefit from globalisation and free trade in the form of lower prices and therefore the WTO agenda must be good. Other ideas are less well developed, notably that of 'permanence'. Just as the eco-park concept raises the danger of inter-corporate rigidity that could prevent improvement and adaptation over time, so the notion of permanence raises the danger of social stagnation, actually stifling the creativity and innovation that appear integral to the human condition.

It can be seen that thus far the distributed economy concept has, from its philosophical roots, a strong normative content, with value judgements of what is 'best' from a holistic perspective. Yet the core contention of this book is that the hegemony of centralised capitalism is itself under threat on the most basic of economic terms: it is not as profitable as decentralised and flexible production. Therefore, while decentralised production is indeed about resolving socio-spatial inequality; is indeed about closed-loop wealth generation; and is indeed about life enrichment in its broadest sense as a form of moral imperative, the authors would also argue that the distributed economy is simply superior as a mode of organisation over the long term, and it is more sustainable.

14.4 The significance of scale and production

The concept of the distributed economy has many dimensions, not all of which can be captured in this chapter. Perhaps the single dimension that is most relevant to the analysis of the automotive industry is that of scale. The anarchist theorist Murray Bookchin has sought to emphasise that technology per se is insufficient. What is of equal importance is that from an ecological perspective the organisation of economic and social life also needs to approach a human scale. 'Simply put, this means that corporate gigantism with its immense, incomprehensible industrial installations would have to be replaced by small units which people could comprehend and directly manage by themselves' (Bookchin, 1980: 92). As Schumacher (1973: 31) argued, 'Small-scale operations, no matter how numerous, are always less likely to be harmful to the natural environment than large-scale ones, simply because their individual force is small in relation to the recuperative forces of nature.'

The question of scale is intimately bound up with two other issues: technology and ownership. Some technologies are of necessity large-scale undertakings. Although originally intended as a small-scale distributable technology, in practice, huge investments are required, resources have to be found and concentrated to make nuclear power possible compared with distributed energy production with domestic-scale windmills, waterwheels and solar panels. It is an extremely complex technology, the domain of experts, unfathomable to the 'man in the street'. These technologies literally and figuratively allow the centralisation of power. Similarly in the automotive industry huge scale has become the norm. Car plants are impressive installations; apparently miraculous in scale and complexity; in their unrelenting production; in the disciplining power of the assembly line. However, these huge plants embody equally huge financial investments both for corporate capital and for society at large. By virtue of this scale they are also vulnerable to fluctuations in demand.

14.5 Conclusion

It has been shown in this chapter that a number of sectors have sought smaller scale, more distributed and distributable solutions. These are often made possible by technological changes. The number of sectors thus affected is growing so fast that there is a clear trend visible towards the smaller scale; the more localised. The automotive sector is unlikely to be immune from this trend and the remaining chapters will explore how such changes might happen, what the options are and how this links with the wider social, political and economic aspects of automobility.

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15

The shape of the future

> *. . . the present system is destroying itself by destroying its markets. Poor people do not make good customers so, for as long as the polarisation of the world into rich and poor continues, sales to the less well off will shrink, and markets serving the better-off will become increasingly competitive. This is already happening. There is excess production capacity in most manufacturing activities, and prices of items such as shoes, clothing, cars and electrical goods are falling in real terms. It has become very hard indeed to find investment projects involving making tangible goods that can offer a high return.*
> (Meyer, 2000: 31)

15.1 Introduction

It is clear that change is going to happen in the car industry. What is unclear is the extent and the nature and direction of this change. There are a number of possible trajectories along which this change can take place. This chapter explores two key issues: different approaches to vehicle manufacturing and different structures for the automotive industry. The basic contention is that these two issues are closely related. Distinct vehicle manufacturing strategies create the potential for different industrial structures. The examples of vehicle manufacturing and industry structure given are not intended to be exhaustive or definitive, but examples of the direction(s) the industry could take. Indeed, if there is one single expectation it is that there will be co-existing automotive industries in the future. The first half of this chapter accordingly explores several different manufacturing strategies. The second half considers the implications for industry structure as a whole. The latter is much more contentious, involving as it does multiple (and often conflicting) interests.

15.2 Alternative 1: the traditional assembly plant

In 'normal' scenario building it is customary to insert a 'business as usual' case. For the automotive industry, however, the continuation of the traditional assembly plant should not be taken to imply a static situation. In particular, and notwithstanding the comments with respect to the inflexibility and high capital cost of traditional assembly, the automotive industry has been assiduous in its attempts to minimise the problems. It is possible to identify several key areas of operational flexibility and responsiveness in the contemporary automotive industry. Table 15.1 provides a summary of critical features that have changed in the automotive industry since the late 1980s.

Great claims are made for the impact of the above developments on the business performance of the automotive industry. Despite these claims, it is worth noting that the historical pattern of this highly competitive industry is to pass on efficiency gains and cost savings to customers. That is, the aggregate financial performance of the industry – suppliers, vehicle manufacturers and retailers – has hardly changed at all (see Chapter 2). Given events in the wider world – particularly in terms of the catastrophic destruction of value in world stock exchanges – the key pressure on the industry may well be that of raising the finance required to implement these continuous improvements in an era of financial stringency. The measures noted in Table 15.1 can contribute to a reduction in capital intensity in the automotive industry, but it is not clear whether this amounts to a delay of the inevitable, and, if so, for how long.

The developments in product design, factory design, production and logistics are all designed to result in a quantum leap in operational performance. For example, vehicle development times in Europe in the mid-1990s were in the region of 40 months. By around 2005 the average could be as low as 25 months. The cost of some critical stages in the design process, such as crash testing and aerodynamic testing, has been dramatically reduced by computer simulation. In short, some aspects of model development will cost perhaps 50 % less than they did in the mid-1990s on a like-for-like basis. They will be built in factories that cost 50 % less to build. Those factories will deliver customer-specified vehicles in 14 days rather than the contemporary 40 days. Despite this, other aspects of vehicle development show exponential cost increase, not least electronic vehicle integration.

However, the changes and measures outlined above fail to resolve fundamental inflexibility at the core of the automotive industry. That is, the automotive industry has sought to achieve flexibility by refining the exist-

Table 15.1 Major developments in the automotive industry to improve flexibility and responsiveness

Item	Main features	Impact
Digital product development	CAD and CAE, electronic transfer of files, real time design changes	Reduction in product development lead times (10–50%). 3–1 reduction in impact test requirements
Rapid prototyping	Direct use of data to create prototype components	Reduction in product development lead times (10–50%)
Virtual reality suites	Allow vehicles and components to be visualised in a virtual context	Large reduction in modifications made to car after full-size model stage. Full-size models may be omitted
Factory simulation	Simulate layout and design of factory	50% reduction of factory construction times, optimisation of layout
Electronic procurement	Electronic transfer of all purchasing data, from bid to payment	Claimed 90% reduction in transaction administration costs
Electronic supply chain integration	Linkage in real time throughout the supply chain	50–70% reduction in inventory throughout supply chain
Flexible manufacturing cells in suppliers	Rapid tool change, low inventory production	Reduction in inventory, improved quality
Smart logistics	Digital warehousing, internet tracking of stock, JIT	Reduction in transport capacity required, reduction in inventory
Supplier parks and disintegrated vehicle assembly	JIT supply of modules by proximate suppliers, assembly by suppliers	Sequenced, high variety production with low inventory
Customer ordering systems	Dealer to assembler systems to allow direct customer orders for new cars	Reduction in build to stock, reduced discounting, reduced intermediary stock of finished vehicles

Source: Wells (2001b).

ing system rather than via a re-design of the system as a whole. Some key contradictions or unresolved issues include:

- Where to achieve basic manufacturing economies of scale? An example would be gearboxes or stampings. These processes traditionally demand very high volumes of output. Such crucial components become blocks of rigidity in the total manufacturing system.

- How to progress from concept to production? It is still the case that there is a huge chasm between the cost/volume equation for prototype production and that for high volume production of vehicles.
- How to overcome the limitations of existing vehicle body technology? Existing all-steel body technologies define the scale and pace of modern car production, but are still highly limited in terms of product variety. In addition, body technology defines the economics of the industry.
- How to reconcile the different optimum capacities of different processes, all the way back to material production? This is a perennial problem in the automotive industry and provides some logical limits to the attempts to smooth production down the supply chain, quite apart from the problem of variance amplification.

It is still the case that the industry as a whole is driven by attempts to achieve economies of scale. This is most evident in platform strategies, recently re-glossed as 'common architectures'. The leading platforms in use by the industry achieve almost two million units per annum, with lifetime volumes of the order of twelve million units. This is hardly testimony to product variety. Reduced product lead times, even to less than 24 months in some cases, are of less significance if the product is then hardly any different from the model it replaces (because of a high proportion of carry-over parts) or if it is kept in production for 8 years. In the same way, the strategic and operational benefit of a lean and agile manufacturing system is largely wasted if there is one large plant designed to serve geographically extensive markets. Why rush to build a car in Japan if it takes weeks to ship it into Europe?

The vehicle manufacturers have also sought alternative solutions to their problems with respect to the high capital cost of plant. Ford, for example, pioneered an approach that involved 'pay on production' contracts for capital equipment (such as presses), or process steps (such as paint shops). This approach (for capital equipment) was abandoned by Ford after a few years, when it became clear that equipment suppliers were not prepared to co-operate.

15.3 Alternative 2: the modular assembly plant

The modular assembly plant involves the vehicle manufacturers taking even greater steps to pass on financial burdens to their suppliers. There are several prototype factories, possible new models of production for the future, in operation around the world. These factories have received much attention from the industry press because they seem to embody the logical conclusion of the 'mega-trend' in the industry to modular component supply. Examples include 'Blue Macaw' (GM) and Resende (VW) in Brazil, and Smart (DaimlerChrysler) in France.

The Smart plant at Hambach is a good illustration. In essence, the plant has a series of sub-assembly halls in which the key suppliers build up the system component modules. The plant itself is cruciform in layout, rather than the traditional linear pattern. Suppliers are responsible for the assembly and fitting of their component modules, and were required to invest in the site as part of the contract agreement. It is interesting to note that DaimlerChrysler has taken a €536 million charge to free it from supplier contract penalties as a result of over-estimating production of the Smart (the plant got tooled up for 200 000 units pa yet actual output was nearer just 120 000 units pa).

There are several benefits thought to flow from the modular assembly plant approach. These include:

- lower direct investment costs for the vehicle manufacturers;
- reduced assembly complexity, with knock-on benefits for quality;
- reduction in long-range delivery of components and sub-assemblies;
- greater flexibility in production;
- reduced stocks of components and sub-assemblies.

Given the design of the Smart, the plant itself also offered significant environmental benefits compared with traditional manufacturing. In particular, there is no paint shop apart from the facility for powder-coating the Tridion safety structure in either black or silver. The Roadster, introduced in 2003, is assembled in a new building alongside the City Coupé facilities, but follows a more traditional linear assembly process. Table 15.2 shows the module suppliers on the Hambach site, and those more remotely located, when production started in 1996. Although there have been problems with the Smart Hambach approach, the automotive industry as a whole appears committed to the extension of modular supply.

15.4 Alternative 3: the global production network

To a certain extent the global production network approach is already in place with some vehicle manufacturers. The idea is quite simple: the same model is produced in several locations around the world, perhaps with particular variants built in particular locations. As a production approach this is dependent upon the creation of global platforms: models that can be sold in a wide variety of markets around the world. Typically the global production network approach is structured with a lead or mother plant, and subsidiary or daughter plants. In this sense the approach can be seen as a continuation or development of the long tradition in the industry for establishing so-called kit assembly plants in markets that were too small to justify

Table 15.2 Illustrations of module supply: the MCC Smart

Module	Supplier
Suppliers on the Hambach site	
Front end: brakes, steering, suspension	Bosch
Braking control system	Bosch
Plastic body parts	Dynamit Nobel
Paints	Eisenmann
Rear end: suspension, engine mounts	Krupp-Hoesch
Body structure	Magna
Internal logistics	Rhenus
Complete dashboard	VDO
Doors	YMOS
Spare part management	TNT
Suppliers not on the Hambach site	
Heating system	Behr
Seats	EBF
Wheels	Continental
Exhaust system	Eberspaecher
Gas struts	Freudenberg
Gearbox	Getrag
Headlights	Hella
Alternator/starter	Magneti Marelli
Engine	Mercedes
Electric and micro motors	SMH
Windows	PPG
Roof	Rockwell-Golde
Control and stability systems	Schenk
Fuel tank	STMP
Seatbelts and airbags	TRW

Source: *L'Information du Véhicule* (1996), July, 36.

a major plant but which also demanded local value added rather than direct imports of fully built vehicles.

A particularly clear example of the approach, and one that illustrates the difficulties as well as the advantages, is that of the Fiat Palio. Table 15.3 illustrates the spread of production of the Fiat 178 Palio world car in 2000. This concept involved the shipping of components, sub-assemblies and kits around the world in order to assemble a similar range of cars in various locations. Some shipments of Complete Built-up Units (CBU) from these assembly locations can then take place within a regional context. The Palio example is considered in more detail below.

Table 15.3 Production of the Fiat Palio (2000)

Location	Model	Volume
Brazil	Palio	170 000
Brazil	Palio Weekend	43 000
Brazil	Siena	10 000
Poland	Siena	5 000
Poland	Palio Weekend	6 100
South Africa	Palio	4 400
South Africa	Palio Weekend	650
South Africa	Siena	200
Egypt	Siena	3 150
Turkey	Palio	18 500
Turkey	Palio Weekend	18 300
Turkey	Siena	12 100
Argentina	Palio	12 000
Argentina	Siena	13 800
Morocco	Siena	1 100
Morocco	Palio	5 100
India	Siena	2 300
India	Palio Weekend	400

15.4.1 Completely Knocked-Down (CKD)

The term CKD (Completely Knocked-Down) refers to the process by which a plant is supplied with a vehicle in its component form to be assembled on behalf of another plant. The plant which receives these vehicles is thus able to assemble them according to specific, pre-determined technologies which are designed from the outset to suit the level and nature of production facilities at the receiving assembly plant. Within Fiat, CKD kits are identified by the various 'standards' to which they are supplied and which depend upon the specific technology to be used. The extent to which the vehicle body has been assembled is used as a base reference. Thus:

- Standard 2 indicates that the vehicle body comes fully assembled and that the parts for assembly are supplied in sub-groups or as single components;
- Standard 4 indicates that the body is supplied in kit form comprising the basic sub-groups: movable parts, side frames, front floorpan, middle floorpan, rear floorpan, engine compartment frame and sheet metal (complete and ready for assembly). The remaining elements of the vehicle body are supplied as individual components. Parts for assembly are supplied in sub-groups or as single components. A plant receiving these needs no press shop, but does require body welding facilities, paint and final assembly;

- Standard 5 indicates that some elements of the sub-groups described in Standard 4 are supplied as single components;
- Standard 6 indicates that the vehicle body is supplied in the form of single components, to be assembled on site.

Standard 1 would imply a painted body – a format more commonly known as SKD (semi-knocked down) and frequently used for small scale local assembly of commercial vehicles, where a fully painted and trimmed cab is supplied as part of the kit. The exact nature of Standard 3 was not specified by Fiat. There is no fixed choice of standard. It can vary according to the technology and expertise available at the assembly plant. The kits are supplied in batches which normally comprise 96 vehicles each. In plants where the daily production rate is limited, kits are supplied in batches of 48 or 24 units. With a few exceptions, Fiat Auto and its operating companies are accustomed to receiving batches of 96 kits.

For Project 178, Fiat's Palio World Car, two new and fundamental management concepts were introduced, dramatically altering the logic of CKD production. The first of these concerned the organisational structure for managing CKD itself. Fiat has moved from a 'single strand' relationship between manufacturing plant and client plant to a 'multi-strand' relationship between several manufacturing plants and each client plant. This means that the structure for the supply of complete batches has been broken down into several micro-groups, or kits, for each of which it is the sole responsibility of a single manufacturing plant to supply to the client plants. Overall organisation of the various kits, in order to allow their assembly into a complete vehicle, now falls under the management of the client plant. Thus Fiat has moved from a 'push' system to a 'pull' system.

For example, the partner plant in Morocco assembles the Fiat Uno, Palio and Siena models according to CKD processes and the vehicle bodies are supplied to a standard between 4 and 5. For the Uno, the Moroccan plant receives the complete CKD kit from Fiat Auto in Italy. For the Palio, the same firm receives kits from Brazil, Italy and Turkey. For the Siena (a Palio derivative), it also receives a kit from Argentina (see Table 15.4). It is the responsibility of the Moroccan firm to assemble the various containers in which the kits arrive, in order to make up a full CKD kit before customs clearance and dispatch to the assembly areas. Thus, the receiving company plays a more active role than with a conventional integral CKD system involving a single supplier.

The second new concept involves the movement of the kits according to a just-in-time (JIT) production system, i.e., only on specific demand. Suppliers of single components have also been involved in this process by arranging for materials to be delivered pre-packed and labelled for their final destination. Thus Fiat Auto Poland receives components from Brazil, Argentina and Italy for use in its production of the Siena. Suppliers operating in these territories receive a weekly production schedule directly from

Table 15.4 Fiat Palio range and assembly locations

Range	Assembly locations
Palio 3 door hatchback	Argentina, Brazil, Venezuela, South Africa, Morocco, Turkey, India
Palio 5 door hatchback	Argentina, Brazil, Venezuela, South Africa, Morocco, Turkey, India
Siena 4 door saloon	Argentina, Venezuela, South Africa, Morocco, Poland, Turkey, India, Russia
Palio Weekend 5 door estate	Brazil, Poland, Russia, South Africa, India, Turkey
Strada pick-up	Brazil

Poland and deliver components already pre-packed to designated dispatch centres for their own respective countries. These centres are then responsible for delivering the goods to their final destination, in this case Poland.

All packing and containerisation for both CKD and JIT material supplies are now handled by designated collection and packing centres. Two such centres operate in Italy, one in Argentina, one in Brazil and two in Poland. The centres outside Italy fulfil a dual role as they collect and dispatch material for export as well as receiving and organising delivery of imported material to the production line. With the exception of Fiat do Brasil, which operates its own centre, physical management of components for export and import in all of Fiat Auto's other territories is handled by third parties, principally TNT. Fiat departments then manage all those aspects linked directly to the product, the technology, specifications and the inter-plant supplies schedule. Fiat has been able to develop a manufacturing system that fills niches at various points between full assembly and traditional CKD. This could well become a more widespread model for manufacturers wanting to serve a range of disparate smaller markets from optimised manufacturing locations around the world.

15.5 Alternative 4: the eco-park

The eco-park is an established industrial concept pioneered in Denmark, although the ideas have not yet been applied to the automotive industry. The basic principle is straightforward: the 'waste' product of one industrial process can become the input raw material for another such that, in effect, no waste is produced at all over the park as a whole. The entire operation of the park is akin to a living bio-system in which the individual elements hold the entire whole in self-regulating and sustainable balance. Clearly the concept resonates with the systems thinking and network approach favoured by many environmentalists (Roome, 2001). Moreover, in this system the product output of one plant itself can become the input to another. There is, therefore, a series of 'nested' or interrelated businesses all working together. Recycling is embedded into the system as a whole.

As a concept the eco-park is best suited to quasi-biological or chemical processes in which bulk flows of materials pass through various transformation phases. It is less suited to mainstream manufacturing. It would certainly be difficult to apply with existing all-steel vehicles but might be plausible with a 'plastic intensive' vehicle that uses a biological feedstock for the plastic. The eco-park could become quite inflexible, and difficulties in co-ordination could render the park unsustainable (Boons and Berends, 2001).

Certain other problems may also emerge. In terms of logistics the car version of the eco-park would still be a large, centralised facility where geographically extensive markets can only be reached by physically transporting the finished product. In addition, an integrated complex of this type implies a large land area dedicated to this use. In practice, there is a limited supply of suitable land within the majority of industrialised countries, so arable land often has to be sacrificed. There would be technical problems concerning the balance of levels of input and output required by the various stages of production. These problems are not new. In the contemporary car manufacturing system it is already the case that the optimum economic scale of key operations varies widely, with the result that it is difficult to balance the capacities of final assembly, gearbox machining, panel pressing and so forth. However, the problem would be more acute in this type of eco-park, particularly as technical changes to one element or sub-process would threaten to destabilise other elements or sub-processes. The eco-park concept relies upon the notion that it would be more economically and environmentally efficient to process materials on site rather than transport them to some larger, more centralised location. It is not self-evidently clear that this would be the best solution for automotive technologies.

15.6 Alternative 5: decentralised manufacturing

A quite different approach is that of decentralised manufacturing, explored in Chapter 14, which is based on the basic principle of 'small is beautiful' (Schumacher, 1973). In this concept of production the all-steel body would be inappropriate as a product within existing production technologies. However, various alternative, low volume technologies as discussed in Chapter 9 would be appropriate.

The environmental advantages of decentralised production are various. Such facilities would not require large areas of virgin land, or large proximate sources of power. In contrast, they could generally fit into existing light-industrial buildings and 'brownfield' sites. Of course, it might be the case that in total a large number of small production sites would require a larger land area, more concrete, etc., than one contemporary integrated high volume car plant. However, the impact is spread more widely, effectively 'diluted' into the existing industrial infrastructure, rather than consuming virgin arable land or premium locations. Moreover, many of the potential low volume technologies that could be employed in a decentralised manufacturing approach are of an inherently lower environmental impact. Thus, for example, a car constructed with plastic body panels could have in-mould colouring of those panels and so do without the paint shop of contemporary car production. As the paint shop is probably the single most environmentally damaging part of the existing car production process, this is a huge benefit. Equally, thermoplastics are suitable for on-site recycling so material efficiency would be high.

A further area of likely benefit is that of logistics. With decentralised production the car plant is near to the market so the transportation of finished vehicles is relatively limited. The movement of finished vehicles is highly inefficient, as cars are bulky and cannot be packed tightly together for fear of damage. With decentralised production most of the components and materials (which can be more efficiently packed into available space) are transported to the point of final assembly. As such, decentralised manufacturing need not sacrifice economies of scale in core component technologies. Moreover, the approach resonates with the current concept of modular component supply as it is suited to the delivery of sub-assemblies and systems. For example, generic fuel cell cores could be produced at a centralised facility and shipped (tightly packed) to the decentralised assembly operations.

The final potential area of environmental advantage within decentralised manufacturing is less obvious. In contemporary car manufacturing the imperative is to continue production. There is no viable alternative use for the facilities so they must continue to produce cars almost regardless of market conditions. In contrast, decentralised or distributed manufacturing could also be used as sales, service, maintenance and recycling sites. This feature could endow decentralised manufacturing with greater resilience so that sites would be less prone to the chronic over-production that plagues contemporary car production. It should be remembered that over-production is also waste, and often leads to 'dumping' of a product on a market. As a result, labour force stability would also be improved, while job content would be more varied.

15.7 Different shapes to the automotive industry

The above models of manufacturing imply different structures or shapes to the automotive industry. The 'shape' of an industry can be thought of in terms of the size, number, character and power relationships of the various players throughout the value chain, from the creation of a product or service to its delivery in the market. In the case of the automotive industry the ‘traditional’ conceptualisation of the supply chain is that of a pyramid composed of tiers that has as its tip the vehicle manufacturers. First, the industry as a whole is centred on the manufacture of car bodies and engines. This is where the biggest companies are, where the market brands are rooted, and where the largest concentration of economic power is to be found. In other words, it is an industry still based on the continuous production of material objects within a defined set of power relations. Second, observers of the automotive industry would note that recent years have been witness to a shift in the centre of gravity of the industry, away from the aforementioned production realm, downstream into vehicle retail and service provision (see Chapter 4). This shift in the centre of gravity has two dimensions: the largest players (the vehicle manufacturers) are themselves getting more directly involved in downstream activities associated with the sale and use of cars; and the revenue opportunities generated by car production and use are increasingly in these areas.

Clearly this schematic does not capture all the parties to the automotive industry, particularly as considerable revenues are derived from the support of vehicles in use. In essence there is a second pyramid, also centred on the vehicle manufacturers, that leads to the ultimate purchasers and users of vehicles.

The shape of any industry is rarely static. In the case of the automotive industry there has been a long-run process of vertical disintegration by the vehicle manufacturers from at least the 1970s. On the supply side, the fragmented multitude of jobbing component suppliers has been replaced by a consolidated and quasi-tiered structure of multiple competence suppliers. However, while much of the process of industry reshaping has been driven by economics, in the future, the environmental and sustainability dimension will play an ever-greater part. Not least, it can be difficult for vehicle manufacturers to make radical changes to existing structures in existing locations without meeting widespread labour and political resistance. New technologies and processes (and indeed new locations) offer an opportunity to break with the past. The evidence is visible in the case of the Audi A8 where Alcoa played a substantial part and invested in facilities specifically to produce that car. In essence, the A8 body is a joint venture product.

In view of these considerations it is worthwhile contemplating some of the potential future shapes of the industry. Such organisational forms are not necessarily mutually exclusive. Different ways of participating in the industry may co-exist at any one time, especially so in the light of the emerging diversity of product and process technologies. Indeed, it could be argued that fluidity of organisational form, the ability to shift from one shape to another, is to become a key competitive weapon in the automotive industry of the future.

Table 15.5 Summary of alternative shapes for the automotive industry

Structure/role of vehicle manufacturers	Main points	Scope
System integrators	Design and marketing only, manufacturing is sub-contracted, retailing is franchised	Industry already moving this way. Based on new car sales
Mobility providers	Manage use of vehicles in the parc. Cars become a retained asset. Manufacturing not necessary	No strong evidence for this shape, difficult to define the market
Environmentally and socially benign corporate citizens	Material and product stewardship, manufacturing only a small part of activities	Some moves in this direction, but unclear where it leaves existing materials suppliers
Retail and service providers	Ownership of retail and related activities, possible third party branding	Already moves in this direction to shift centre of gravity. Some moves by some manufacturers e.g., Ford, via ownership of companies in downstream activities
Car makers	Focus on manufacturing. Retain existing relationships down the value chain. The current shape	Considerable scope for retention of this current shape. Under threat from the asset cost
Micro Factory Retailing	Combine manufacturing and sales in multiple small sites	Unlikely for existing industry. Possible shape for new entrants or new technologies redefining the terms of competition
Cross-sector consolidation	Links with aerospace and electronics companies	Not been successful in the past. Not clear that automotive industry would dominate such a structure

Source: adapted from Wells and Nieuwenhuis (2001).

Table 15.5 shows some potential shapes for the automotive industry. For example, in the 'system integrator' model it might be similar to the mountain bike industry. Here there are brand owners such as Marin who specify the components content and frame design, and undertake the marketing of the bicycles. There are significant economies of scale in the component supply chain, which is dominated by a few large-scale producers. Retailing is separate from the activity of product supply, and manufacturing is centralised in large factories remote from the target markets. This shape might be most appropriate where the environmental technologies employed require little ongoing service and support.

In product terms, the mountain bike is an excellent example of multiple brands co-existing and reinforcing each other. The very richness of the 'brandscape' invites the consumer into a semi-secret world where only the initiated know the difference between a Hope hub and a Scott hub. At the upper end of the mountain bike market, multi-branding demands, and confers upon the consumer, a level of knowledge that is not required when buying 'off the shelf'. Each individual component has a brand league table, a hierarchy of credibility that only the cognoscenti can fully understand. The following list of desirable mountain bike component brands gives a flavour:

- wheel rims: Mavic (France);
- spokes: ACI (Switzerland);
- groupset: Shimano Deore XTR (Japan);
- front shock absorber: Marzocchi (Italy); Rock Shox (USA);
- rear shock absorber: Fox (USA);
- brake levers: Magura (Germany);
- disc brakes: Hope (USA);
- brake blocks: Aztec; Weinmann (Germany);
- handlebar stems: Raceface (USA);
- saddle: Selle Italia Flite (Italy);
- seat post: Easton (USA);
- handlebars: Easton (USA).

This is a world where the minutiae of specification flow seamlessly from science into pure art; from the substantive into the ephemeral. The price differentials at the upper reaches of each brand league are truly impressive. A commodity steel wheel, with ordinary spokes and unbranded hub costs around €30. A hand-built Mavic wheel with ACI spokes on a Hope hub can cost around €250. There is no single component on a mountain bike that does not have a distinct brand – even 'humble' items such as brake cables and 'commodity' items like tyres can be so branded.

Table 15.5 reflects a view of the automotive industry world from the perspective of those we currently define as vehicle manufacturers. It is interesting to consider that the re-shaping of the industry might in fact involve a challenge to the ascendancy of the vehicle manufacturers or vehicle manufacturing within the industry in total (Wells, 2001a). Such an outcome is most obvious in the case of the environmentally-benign automotive industry. Here the emphasis is on material stewardship and the key task is to be custodian of the resources used to make and use vehicles. Hence, product longevity (and reduced production of new cars) and recycling are the key themes, whilst manufacturing becomes something that is done as little as possible! Perhaps in this situation the materials suppliers will become ascendant. It is equally possible that existing vehicle manufacturers could become subservient to large retail groups.

15.8 Conclusions

The turbulence in the supply chain and in the market occasioned by the introduction of novel environmental technologies will open up competitive space for such shapes to emerge. These new technologies can be thought of as fissures or fault lines that will fragment the existing industrial landscape. This rending apart of the existing structure of industry will provide the opportunity to dismantle and reconstruct corporate capabilities for all participants in the automotive industry.

Ironically, in the context of this book, the most successful attempt at technology-led industrial restructuring has come from the largest and one of the oldest of the vehicle manufacturers – General Motors. This innovation is the GM AUTOnomy project with its so-called 'skateboard' chassis (see Chapter 7). This vehicle concept creates a chassis housing the power source (fuel cell) and drive system (hub motors) upon which a large number of body configurations can be mounted. The concept makes possible small-scale local final assembly of an almost infinite variety of vehicles based upon the ubiquitous and standardised 'skateboard' chassis structure, a concept that opens up many possibilities for rewriting business strategy and industrial structure in the automotive industry. This shows that the existing players may be quite capable of reinventing themselves in order to meet the challenges posed by the impending change. They may themselves be among the drivers of such change.

15.9 References

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16

The roadmap

Without deviation from the norm, progress is not possible.
(Frank Zappa)

In preceding chapters some guidelines have been provided as to how automotive sustainability might be achieved. However, as has been shown, this will require major change from the way things are done today. The role of government is crucial in bringing about such changes. Unfortunately, neither the traditional political left nor right can easily accommodate the sustainability agenda. Both are premised on conventional economic growth. Both state capitalism and private capitalism are based on the same non-sustainable approach, with a heavy emphasis on economic growth. For this reason, environmental politics has rarely been successful within the current system. Daly (1995) identified the basic mindset or 'pre-analytic vision' of the majority of economists as the problem. This does not allow them to accept the sustainability concept (see Chapter 10). As politicians at present rely so heavily on orthodox economic analysis, they too have difficulty reconciling sustainability with their mainstream political agenda.

One answer may be to decentralise and re-localise the political system, creating political diversity, and moving towards more of an issues-based democracy, rather than a party-based democracy. Some trends in this direction are already visible. This could involve greater use of referenda, as a political programme predicting a response to every issue is unrealistic, especially in a period of rapid change. The Swiss system is a possible model, although this has tended towards an inherent conservatism and resistance to change, as well as growing voter apathy. Another approach would be enshrining sustainability principles somehow in a constitution, such that it is taken for granted, becomes axiomatic, before the normal democratic process is even engaged. The example of the Government of Wales Act (see Chapter 10) is too recent at the time of publication and too limited to have had a major impact, but may be a useful first step.

It is clear that the necessary changes involve not just technological measures, but also social, political, organisational or legal and regulatory changes. Once a situation involves such a wide range of players and stakeholders in a change process, a popular tool for bringing them together on a shared trajectory is the so-called roadmap, although it has never been attempted on such an ambitious scale.

16.1 Roadmaps

A number of companies and government agencies, particularly in the US, have in recent years used 'roadmaps' or 'routemaps' as a strategic tool. The process of creating these is known as 'roadmapping'. Whilst traditional roadmaps are used for navigation in space, strategic roadmaps plan a trajectory through time. These roadmaps both forecast what is likely to happen, as well as to some extent influence what is going to happen by putting an organisation on a particular trajectory that will bring about that future (Kappel, 2001: 39). It is often forgotten that the future does not just happen, but is rather influenced, to an extent, by decisions made today. This also means we can shape that future to bring about outcomes we consider desirable – Kappel (2001) calls this 'normative' forecasting. However, it is important not to prejudge too much in our forecast. As Breton and Largent (1991: 106) quote Boulding (1985) on this issue: 'An important source of bad decisions . . . is an illusion of certainty. If our image of the future is certain, there is nothing wrong with making exact plans without flexibility. Under illusions of certainty, however, we make exact plans that can lead to disaster. With realistic images of uncertainty, we stay liquid, flexible, and adaptable'.

The roadmap, therefore, presupposes the Western concept of progress and may well be interpreted as an attempt to impose social and political certainty through technology certainty. Roadmaps have largely come out of the world of technology and are dominated by the product technology type of roadmap (Kappel, 2001). Such roadmaps have been used for some time by firms such as Motorola and Philips. Another typical example is the series of roadmaps produced by the US Aluminum Association. Of the latter, the *Aluminum Industry Roadmap for the Automotive Market* (Energetics Inc., 1999) is of some relevance to this study. This roadmap considers a range of existing and near-market technologies and maps out their future trajectory. This is fairly typical of many product technology type roadmaps. They tend to be driven by what we have today, rather than by what we want tomorrow: the 'illusion of certainty' perhaps. It tries to tie in with the agenda of the US Partnership for a New Generation of Vehicles (PNGV) – since superseded by FreedomCAR – which promised a greater use of aluminium in cars. This roadmap thus '. . . will aid the auto industry in reaching the goals it has set for producing cost-effective, aluminum-intensive vehicles by 2004' (Energetics, 1999). Aluminium still has a number of basic technical problems to overcome before it can be considered competitive with steel. Much of the roadmap considers the key enabling technologies needed to bring this about and assesses their likely trajectory and is therefore to some extent designed to focus research and development (R&D), and government policy (in the context of the PNGV at that time). Whilst interesting in its own right and useful for developing the authors' Environmentally Optimised Vehicle (EOV) product concept for production and distribution via micro factory retailing (Nieuwenhuis and Wells, 1997), it cannot be considered visionary. To be fair, it does not set out to be so, but rather attempts to set all players within the sector on a common trajectory in order to meet the future needs of a specific customer base and fight off competition from other materials solutions.

This approach to forecasting is firmly rooted in the traditions of engineering and technology provision, which is still rarely market-driven. Instead, R&D suppliers tend to develop technologies that are 'possible' or for which considerable support exists within the R&D division. These are then 'sold' internally to management whereupon funding brings them to market readiness. Rarely does market analysis precede the initiation of the development of a particular technology, let alone social need. In truth it is of course very difficult to carry out research into potential consumer demand for as yet non-existent products for which no price or detailed specification and performance parameters are known. Nonetheless, the R&D world increasingly feels the need to target its efforts more precisely to areas of likely future demand. Roadmaps which incorporate realistic demand forecasts can be useful, although, again, these are still rare. One attempt to plan future transport provision to likely future demand was carried out by Elzen *et al.* (1996). Research in five countries was used to identify transport problems and technological solutions, whilst setting these in a social and political context. This report, commissioned by The Netherlands ministry of transport, was a serious attempt to match technology with social and political demand. Elzen *et al.* contrasted the easier option of 'system optimisation' – improving what we have incrementally – with 'system renewal' – a more radical approach, tackling a range of parameters at once. They propose 'strategic niche management' (SNM) as a realistic means of bringing about the latter. This is discussed below.

Kappel (2001) reviewed a number of roadmaps in use by a range of US companies and pointed out that 'Despite the long-term view promised by roadmapping, roadmaps in practice typically gave serious consideration only to the next product generation (beyond the one currently in development)'. This conservatism is to some extent inherent in this approach, but does not allow for the incorporation of discontinuous change: '. . . when a strategic, discontinuous change approaches from the outside, the roadmapping process may not provide early warning'. Kappel (2001) further argues that this is largely due to the use of extrapolation techniques in most roadmapping templates. In view of the fact that a number of paradigm shifts are required to bring about the authors' vision of sustainable automobility – paradigm shifts in the way cars are made, sold, used and powered – this approach appears inadequate. The Aluminum Industry Roadmap (Energetics, 1999) is a good example of this type of short-term extrapolated roadmap but it offers relatively little for our purposes. However, a more strategic roadmap has been produced which could be more useful in this context.

Foresight Vehicle (FV) is the nearest equivalent the UK has to the US PNGV. Foresight Vehicle tries to assess the shape and nature of automobility around 2020–30 and then assesses the types of technologies needed to bring that about. Its primary task is to make sure the UK automotive supply, R&D – including the key UK contract R&D sector – and assembly base are prepared and competitive for that future automotive industry. However, it also considers social, regulatory and market factors. Foresight Vehicle commissioned Cambridge University to develop a roadmap to help devise its strategy along these lines (Foresight Vehicle, 2002). The roadmap's strength is that it sets a number of targets that need to be met and also incorporates some future visions stretching to 2020 and beyond. In addition, it offers individual sub-maps for societal, technological, environmental, economic, political and infrastructural themes, based on a so-called 'STEEPI' approach, from the initials of these headings. Within each of these sub-maps there are three streams for 'Market/industry trends and drivers', 'Uncertainties' and 'Performance measures/targets'.

16.2 The sustainable automobility roadmap: basic principles

In the case of sustainable automobility, a quite elaborate vision of a sustainable automotive world, as outlined in Chapter 13, would have to be created. The elements of this vision would be the desirable outcomes of the strategy (Table 16.1). Rather than planning forward from the present as many existing roadmaps do, the vision would be used to work back from; a process sometimes known as 'back-casting'. If a timescale was added for when the vision would need to become reality – say, 2050 to be realistic – the roadmap would then need to plan backwards to build in various intermediate targets. These targets, milestones or staging posts – depending on their magnitude – would involve technology deadlines, as well as deadlines for enabling legislation, fiscal changes, social changes, planning changes, organisational changes, etc. Once final and intermediate targets have been set, an auditing system for tracking progress towards the desired goals and

Table 16.1 CAIR sustainable automobility roadmap to 2050

Elements	Present (2003)	Present (2003)–2010	2011–2020
Market and social	Markets asking for increasing visible differentiation; environmental concern growing but not translated in buyer behaviour	Growing cost of high CO_2 vehicles boosts demand for low CO_2 vehicles; urban congestion and pollution increasingly unacceptable	Developing countries also demand low CO_2 cars now popular in industrialised countries
Regulation and incentives	Tightening internal combustion (IC) emissions; zero emissions vehicle (ZEV) mandate in California; EU end-of-life vehicle (ELV) directive	Bellagio principles adopted globally; Euro V, VI	Bellagio principles guide regulation; all cars ultra low emissions vehicles (ULEV), super ultra low emissions vehicles (SULEV) or zero emissions vehicles (ZEV)
Product technology	Heavy inefficient IC-engined steel monocoque cars; some niche products non-Budd; some low CO_2 cars	Increasing use of hybrid electric vehicles (HEVs); first fuel cell electric vehicles (FEVs); CO_2 reduction leads to weight reduction	Weight reduction trend continues; on board H_2 storage problem solved
Production technology	Large centralised factories sourcing and supplying globally; some non-Budd plants	Budd system adapted to lower volumes; composites and Al to higher volumes	Growing demand for lightweight cars leads to first volume non-Budd car plants
Infrastructure	Gradual decline in roadbuilding; telematics seen as solution; HCs dominate fuel supply system; cities clogged by motorised vehicles; some car bans	Widespread introduction of telematics; road charging growing rapidly	More and more urban space reclaimed from cars; limited hydrogen network appears

the intermediate targets will also need to be set up. A useful prototype here could be the progress tracking systems set up by the UK Government, and the UK automotive sector via its representative body, the SMMT, for the move towards wider sustainability (DETR, 1999; SMMT, 2000a, 2000b, 2001, 2002).

2021–2030	2031–2040	2041–2050	Vision
Car use demand outstrips car ownership demand in established markets	Car parc hits fundamental structural limits in established markets	Social prestige of car falls rapidly	Environmental optimisation a given; customers use motorised modes responsibly; demand durable products
Bellagio principles implemented; all new cars SULEV, ZEV	ZEV applies to all new cars; life cycle analysis (LCA) guides regulation	Materials become focus of regulation	Environmentally Optimised Vehicle –Zero Emissions Vehicle (EOV–ZEV) for all new cars based on LCA
Number of ZEVs produced exceeds IC	All new cars ZEV; durability up to 25 years; modular refit becomes priority	All new cars EOV; purpose-specific vehicles and/or modular design	Lightweight environmentally-optimised ZEVs; improved human-powered vehicles (HPVs)
Mass production of 'skateboard' structures starts	Rapid prototyping becomes viable production technology	Production-only factories become unviable	Microfactories deal with assembly, sales, service, upgrades, ELVs
Reversal of spatially extensive society; start of decentralised economy	H_2 production 50% from renewables; car use controlled by active telematics	H_2 production 100% from renewables	Only benign modes in urban areas to reduce congestion, pollution; supply of solar/wind power for ZEVs; comprehensive HPV/bike and light rail (LR) networks

Although ambitious, it is precisely such demanding, multi-disciplinary, multi-stakeholder scenarios that are best suited to some kind of roadmap. Roadmaps have not so far been stretched to capture such a major undertaking and no roadmap could encompass all the changes required, but it could certainly highlight the major staging posts along the way. The first set

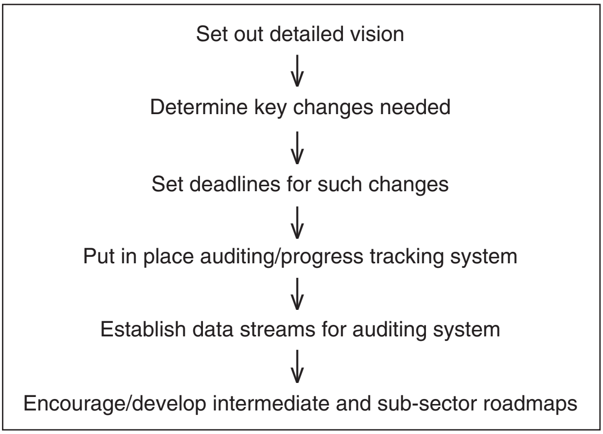

Fig. 16.1 Roadmap building stages.

of milestones or staging posts could then be served by shorter-term product technology roadmaps such as those described earlier (Energetics, 1999); and in fact the latter could fulfil this task in its present form. The first phase would also see the creation of the necessary auditing system and the establishment of the necessary reliable data streams to inform this auditing system. Thus the stages set out in Fig. 16.1 need to be incorporated.

CAIR's vision for a sustainable automotive future was outlined in Chapter 13 and could embody a number of goals in terms of targets to be achieved, as well as a set of technologies. It could ultimately aim for:

- perfect urban air quality;
- near zero fatalities on roads;
- near zero congestion;
- zero consumption of non-renewable resources;
- a genuine democratic structure with localised decision-making;
- rebuilt communities.

As part of this vision, these aims could be brought about by particular technology choices, and political and social changes such as:

- intensive use of human power in the form of bicycles and advanced HPVs;
- use of only benign, zero emission, public transport modes;
- banning of motorised personal transport from urban areas;
- requirement of all transport modes to be ZEV;
- greater use of teleworking;
- more localised service provision;
- other travel need reduction measures.

Moving further into the realm of technology, it could then be decided that some of the ways to deliver this are through FEVs, more advanced telematics, and carbon fibre HPVs, for example. In practice, setting performance targets is more likely to stimulate innovation than prescribing technologies, so such elements of the roadmap would need to be indicative only. Capturing some of the social and political changes as set out in Chapter 13 would require further changes, although some of these would have to flow out of other measures.

Similarly, within the authors' MFR agenda, we could decide that our vision would contain a situation whereby all personal transport products are assembled close to the end user and configured with considerable input from the end user. We could also include that all ELVs are taken back by MFR units and 'depolluted', disassembled on-site, with re-usable parts and sub-assemblies re-used or stored for re-assembly. The remainder could be sent for recycling with minimal transport and environmental impact, for which specific targets could again be set. To enable this to happen, the key supply base of modular elements for powertrain and basic body/chassis structures would also need to be developed. These would require considerable investment in order to deliver the economies of scale needed to make MFR cost-effective. However, such supplies could start with smaller scale production units, during which phase some form of subsidy may well be required, perhaps via a strategic niche management model (see below). Hence impacts would be seen in manufacturing, research and development, legislation and also international trade under some sort of successor, or evolved regime for the WTO. A staged trajectory towards setting up this new supply sector could thus be incorporated in the roadmap.

Fortunately this does not need to be invented from scratch as there are already a number of trends visible within the automotive sector that point in the direction we suggest. The problem is that at current pace we are unlikely to see any meaningful progress towards sustainable automobility for a long time. Some of the existing trends that need to be incorporated are, for example:

- ever-tightening emissions standards;
- carbon dioxide reduction agreement between EC and ACEA;
- moves towards weight reduction;
- technology trends making lower volumes more viable;
- market introduction and take-up of HEVs;
- experimental introduction of FEVs;
- high levels of investment in FEV technology by major players;
- impending safety standards (e.g. pedestrian impact safety).

This listing includes both technological and regulatory trends. One of the sub-sector maps would cover the regulatory agenda. Here a few facts and trends are already known. In fact, the Policy Cycle, as outlined by Marzotto *et al.* (2000: 6), though descriptive, could serve well as the basis for a public policy roadmap. These authors identify the following stages in the policy cycle:

- problem definition;
- agenda setting;
- formulation;
- implementation;
- evaluation;
- change.

Evaluation has a feedback loop back to formulation. Unfortunately there is not enough space here to develop this sub-map in any detail. Another area to incorporate in any regulation sub-map would involve the Bellagio Principles (see below).

16.3 The Bellagio Principles – a known agenda

Bellagio is a town in Italy where in June 2001 a low-key event took place that may well have a significant impact on environmental regulation of the car for many years to come. The event was organised by The Energy Foundation, which invited 18 regulators and emissions experts from a range of countries and institutions, such as the European Commission (EC), Organisation for Economic Co-operation and Development (OECD), California Air Resources Board (CARB), and national government officials from Germany, China, Japan and France. As the organisers explained, they tried to include '. . . representatives of nations at the forefront of motor vehicle production, consumption and regulation' (Energy Foundation, 2002: 16). Their brief was to come up with a set of global, fundamental principles to guide future environmental legislation of motor vehicles. The impetus behind this was the need for global harmonisation in emissions regulation.

Not mentioned specifically, but no doubt also a consideration, is the fact that under WTO rules, any national environmental standards can be challenged as anti-competitive. By moving all countries to a uniform but high standard, an environmental 'race to the bottom' can be avoided – it is hoped – as countries are unlikely to challenge standards in other countries which they themselves have also adopted. This aspect of the WTO agenda – the PPM (Hines, 2000) or non-product related process and production rules – is of growing concern to environmentalists and environmental regulators alike. They prevent any restrictions on trade in products based on the way they are made or harvested, so any official ban on, for example, footballs made by child labour, cheap goods made in highly polluting factories, eggs from battery hens, tuna caught by killing dolphins etc., can be challenged. In fact, aspects of the US Clean Air Act affecting fuel production have already been successfully challenged by Venezuela and Brazil (Hines, 2000:

224). Former World Bank economist Herman Daly (1999: 124) puts the problems of this approach most succinctly:

> A country which internalises environmental costs into its prices will be at a disadvantage in free trade with a country that does not internalise environmental costs. Therefore, national protection of a basic policy of internalisation of environmental costs constitutes a clear justification for tariffs on imports from a country which does not internalise its environmental costs. This is not 'protectionism' in the usual sense of protecting an inefficient industry, but rather it is the protection of an efficient national policy of internalisation of environmental costs!

While such internalisation is embodied in any regulation and legislation that protects people and their environment, such environmental costs can equally be called environmental and social costs. To counter this negative WTO trend, the Bellagio 18 asserted that 'We need to have government recognise that harmonisation . . . allows freer movement in an increasingly more global automotive market. We've found through studies that even if you harmonise standards up, the cost savings and benefits are incredible' (Energy Foundation, 2002: 3). In order to provide the necessary impetus, the group has come up with 43 principles that should guide future policy for motor vehicles and transport fuels. The principles are grouped under five headings:

1. Overarching principles;
2. Fuels;
3. Conventional pollutants and toxics;
4. Greenhouse gases;
5. Advanced technology.

The principles represent a wish-list and reflect areas of frustration with earlier or current regulations and loopholes within them. An example of the latter is the requirement to have clear content standards for alternative fuels, such as LPG and CNG, so all regulators know what these terms actually mean and can agree on their formulation. Other fuel-related principles put forward agreed limits on lead (no leaded fuel), sulphur and benzene levels.

One of the 11 overarching principles is that both air quality and greenhouse gases should be dealt with in parallel, so there are no trade-offs. Another is that vehicles and fuels should be considered together, as a system. In addition, new vehicle standards should be 'fuel neutral'. This last point means that all engines should meet the same standards, whatever the fuel, so there are no different standards for petrol, diesel or LPG. In California, the Air Resources Board has already moved in this direction. The requirement to consider vehicles and fuels together might prevent the type of regulation introduced in some developing countries in recent years whereby catalytic converters are made compulsory, but the requirement to supply unleaded petrol is not. Policies should also be based on life cycle emissions, and should take production, distribution and disposal of vehicles and fuel into account.

On the economic side, the principles highlight the need for cost-effectiveness and for using economic instruments to promote clean vehicles and fuels. Conflicting signals should be avoided – one tax incentive should not be a disincentive to cleaner and greener behaviour elsewhere. The idea that inherently clean technologies should be promoted is also included – if a vehicle is inherently clean, no durability, maintenance or in-use controls are needed. The principles also warn against dumping old, less clean technology on developing countries. In practice many newly industrialised countries, such as China and India, are already closing the gap with more advanced industrialised countries in the West.

The Bellagio principles are an interesting blueprint for the way forward in regulation that could see the world through to about 2020 at least. However, in view of the relative lack of publicity it may be wondered how influential the principles will be globally. Conversely, it probably only takes a strong lead from some key jurisdictions, such as California in the US, the EU and China – all well represented – for the principles to make an impact.

16.4 The mechanics of change

Given that we need dramatic change to achieve our roadmap's agenda, how is this brought about? We should not dismiss existing players as potential agents of change. Contrary to popular belief, the existing car industry has, at times, been surprisingly radical and risk seeking. In 1963 Chrysler Corporation embarked on one of the boldest such experiments, when it produced a run of 55 specially designed turbine cars and put 50 of them in the hands of the public (Dixon, 1980; www.turbinecar.com; www.geocities.com/motorcity). Between 1964 and 1966, some 203 ordinary volunteer drivers in 133 cities in 48 states as well as the District of Columbia used the cars on 3-month trial periods. The feedback was considered extremely useful and fed into subsequent generations of Chrysler turbine engines. The turbine project was finally abandoned in the financial crisis of 1979–80 when Chrysler had to call in government help. Government officials considered the turbine programme frivolous and were unwilling to support it.

Other bold technologies reached the market and actually survive to this day. The Wankel engine was a bold technology from a small German company, NSU, and can be said to have cost the firm its independence. The company is now incorporated into the Audi division of the Volkswagen Group, although the Wankel engine itself survives in Mazda's sports cars such as the RX-7 and RX-8, and a number of other applications (Hege, 2001). More successful was the automatic continuously variable transmission (CVT). Its principles go back to the dawn of motoring with manual CVT systems used by vehicles such as the belt-driven Fouillaron from 1901 (van der Brugghen, 1988: 61) and the friction-wheel driven Turicum from Switzerland (Schmid, 1978: 244).

However, the real breakthrough came in 1958 with the launch of the Dutch DAF 600 small car. This used an automatic CVT system involving rubber belts on variable diameter pulleys controlled by the engine vacuum. This 'Variomatic' system worked well and in addition to providing continuously variable automatic drive, as a side effect it also offered traction control and – up to and including the DAF 55 of 1968–72 – a limited slip differential effect. The system was only available on DAF cars and their derivatives, and after the sale of DAF's car business to Volvo, these were the Volvo 66 and 340. In all, this spanned a production period from 1958 to 1990. However, a specialist transmission company, Van Doorne's Transmissie (VDT) was spun off from the DAF company in the 1970s and this developed a steel-belted version that could be adapted to any powertrain. This system is now fitted to a range of cars, particularly from Japan, and in 2002 over one million belts were produced, prompting the commissioning of a second plant in Japan. Although this represents fitment to just 2 % of global car production, it represents more than 90 % of CVT systems fitted, and around 5 % of automatic transmissions.

By 2002 the system had been fitted to Subaru, Nissan, Honda, Ford, Fiat, Volvo, MG, Rover and Lancia production cars, as well as several experimental cars. Although by that time the VDT company was owned by Bosch of Germany, the technology had become well established. The rubber belt version, meanwhile, became more of a commodity transmission and is now fitted to motorcycles, French 'voitures sans permis' and some offroad vehicles such as quad bikes and skidoos. The high risk DAF took with the CVT technology can be shown by the fact that it remained a niche player and had to sell out to Volvo in the 1970s. Only when Volvo adapted the 340 model to take conventional manual gearboxes and offered these in the market as well did sales of the car take off. However, throughout the production life of the 340, around 15 % were delivered with CVT. The alternative Torotrak infinitely variable transmission (IVT) is also coming close to reaching the market now that most problems have been overcome, and a chain-driven CVT developed by ZF was launched in the Audi A6 in 2001.

In terms of time scale for the introduction of new automotive technologies we can take the adoption of Budd technology itself as an example. With Dodge as an early adopter around 1915 and Citroën around 1923/4, the main roll-out of this technology occurred in the course of the 1920s and 1930s, during which time many of the non-adopters perished. A further boost came with increased car demand after the Second World War, and by the 1960s the system was dominant. In fact, by about 1935 the tide had turned in its favour, meaning a critical roll-out period of some 20 years. The belt-driven CVT was developed in about three years in the late 1950s (van der Brugghen, 1988: 129) and entered the market from 1958. However, true penetration to any significant level was not reached until the late 1990s – hence a 40 year roll-out, or adoption of the technology. The Wankel engine was developed during the 1950s and like DAF's CVT found early adopters in its own products at NSU in the 1960s. Full roll-out never really occurred as it remained a marginal automotive technology, and is now only used by Mazda on one model, since Audi-NSU abandoned it in 1977, having sold over 37 000 RO80s (Sedgwick, 1986: 147).

Using Rogers' (1995: 262) theory of the diffusion of innovations and applying it to firms, it can be argued that Buddism has reached virtually all adopter categories, from Innovators (Dodge, Citroën), via Early Adopters (Ford, Chevrolet, Morris, Fiat), via the Early Majority (Renault, Opel), to the Late Majority (Toyota, Nissan, Alfa-Romeo) and the Laggards, who are those that never adopted it (Aston Martin, Lotus, Ferrari). Wankel technology did not move beyond the innovation stage (NSU, Citroën and Mazda), although several firms experimented with it, among them GM and Mercedes-Benz. Continuously variable transmission has moved from the Innovators (DAF), via Early Adopters (Fiat, Ford, Subaru) to the Early Majority phase. It may be that a truly globalised world would allow a faster roll-out of new technologies than these historical examples illustrate. Even globalisation sceptics regard the free exchange of intellectual capital among nations as desirable. In the current global car industry, fewer larger firms could aid faster adoption of new technologies worldwide.

16.5 Strategic niche management (SNM)

One way of nurturing a desirable and promising new technology through the early, vulnerable phases is through a technique known as 'strategic niche management' (see Weber *et al.*, 1999; Hoogma, 1999, 2000; Lane, 2002: 118). Lane (2002: 122) explains that 'Strategic Niche Management is . . . a deliberate attempt to make the coproduction of technological options, use, policy measures and sustainable development visible and productive'. In essence, SNM identifies a promising, more sustainable technology, and creates a nurturing, uncompetitive and protective environment where it is favoured over the established incumbent technologies. It can be developed to a point where it is either ready for the competitive environment of the real market, or it is considered not viable after a realistic and fair assessment, free from market pressures. One example is the electric vehicle-friendly environment created in the Swiss town of Mendrisio, Ticino. The local authority favoured and promoted electric vehicles from the late 1990s, and assessed how viable a town relying on EVs would be in practice.

This approach also reduces the risk of the innovator in the market and it ensures a minimum market take-up, albeit in a small niche. In California, the Air Resources Board is similarly trying to create experimental fleets for limited periods, ensuring a limited market. However, it has not yet created the protective environments promoted by SNM, where social, political and technological factors combine to see what a system based on such a technology would be like.

16.6 Conclusions

This chapter, of necessity, gives only a brief sketch of a roadmap for a future automotive sector trajectory. It can only hint at routes to implementation and change. We intend to work out the detail of some of this in future years and would invite others to join us in this process. The bottom line is that change is necessary and inevitable – guiding it merely makes it less risky, while ensuring a desirable outcome.

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17

Micro factory retailing

All the indications are that the present structure of large-scale industrial enterprise, in spite of heavy taxation and an endless proliferation of legislation, is not conducive to the public welfare.
(Schumacher, 1973: 245)

17.1 Introduction

The concept of micro factory retailing (MFR) is in essence a business model for the automotive industry in a distributed economy. The MFR concept is not an account of an existing business, but rather an ideal type; a vision; a view of what might be rather than what is. Micro factory retailing is an attempt to provide an individual understanding of how a specific industry could try to meet the many and varied demands of sustainability. As such, MFR represents a radical reshaping of the relationships between product technology, process technology, business organisation, and the purchase and use of cars. If new patterns of production and consumption are to emerge, MFR might be one means of achieving these new patterns. The MFR model is grounded in reality in that parts of the MFR concept are already in evidence in the industry – albeit not in one single place. Moreover, since we started working on the ideas embedded within MFR a new entrant to the automotive industry has emerged. This new entrant, MDI (Motor Development International), had the UK launch of its concept (the Air Car) in September 2002, demonstrating remarkable similarities to the ideas behind MFR. In this chapter a brief account of the MFR concept is provided, followed by a case study of the Air Car (see also Chapter 6). The chapter concludes with some observations on the barriers to MFR and the scope for the concept to become the dominant organisational paradigm in the automotive industry.

17.2 Micro factory retailing: a delineation of the basic idea

The current approach to vehicle manufacturing involves the construction of large car plants able to manufacture and assemble all-steel cars in large numbers. Despite the potential innovations in industry structure discussed in Chapter 15, this is the dominant model. Manufacturing economies of scale are realised and per-unit ex-factory costs are low. In order to sell this many cars, geographically extensive markets are required – which in turn means long logistics chains and dense networks of retail outlets. To date, most vehicle manufacturers have not had to bear a great deal of the investment cost in the dealer network. Neither have they sought to capture a high proportion of the total lifetime revenue stream created by a car in use. Between the manufacturing plant and the customer are stockpiles of cars throughout the system, managed by long customer lead times. The essence of lean production has been to seek compliance from the supply base and the vehicle distribution network to the demands of the vehicle manufacturing process, thereby reducing stock levels in the system, rather than optimizing the system as a whole.

Despite many measures, traditional manufacturing and distribution face problems (Wells and Nieuwenhuis, 2000). The high capital costs and 'lumpy' investment in plant and models inherent in Budd technology are leading to high risk, though many producers regard the situation as normal and inevitable. The resulting over-supply is leading to discounting and rapid erosion of residual values. At the same time, the introduction of a new model can often lead to long delivery times for customer-ordered cars. This inflexibility of manufacturing results in an inability to adjust output to demand and difficulties in switching from one model to another. Responding to increasingly violent market fluctuations is difficult with existing technology. The reliance on continued sales of cars as the main source of revenue is increasingly untenable in developed markets, while costs rise as shorter model lifetimes lead to lower per-model volumes. Thus, high break-even points are leading to over-supply and the need to maintain extensive logistics lines to a large number of sales outlets. Finally, the environmental costs of production, particularly (but not exclusively) with respect to the paint shop, can no longer be ignored.

With micro factory retailing the terms of competition are changed. Rather than seeking to match the high volume, low unit cost approach of traditional manufacturing and distribution, micro factory retailing (MFR) refutes that logic by placing small factories within the markets they serve – and so eliminates the distinction between production and retailing. Rather

Table 17.1 The investment costs of micro factory retailing (MFR) compared with traditional manufacture and distribution

Item	MFR	Traditional
Volume per plant	5000	250 000
No. of plants	50	1
Workers per plant	100	3000
Total staff in production	5000	3000
Investment per plant	£50 m	£1.5 bn
Total investment in production	£2.5 bn	£1.5 bn
Model R&D cost	£100 m	£500 m
Model specific tooling	£250 m	£500 m
Total investment in model	£350 m	£1.0 bn
No. of dealerships	0	500
Staff in distribution	0	5000
Investment per dealer	£0	£1 m
Total investment in distribution	£0	£500 m
Total investment	£2.85 bn	£3.0 bn

Note: Assumes 500 new car sales per dealer, investment cost of £1 million per dealer and 50 staff per dealer for traditional retail. Assumes £5 million per micro factory in model-specific dies, etc.

than having one large plant producing, for example, 250 000 cars per annum, the MFR approach would involve 50 plants, each assembling 5000 cars per annum. There would be no separate distribution channels or sales outlets as the factory is also the sales, maintenance, service and repair location. Powertrain components and other generic items could be centrally produced in conveniently located, highly automated, facilities for distribution to the decentralised assembly plants, thus benefiting from economies of scale. Ironically this would conform to the early Ford dictum of 'Manufacturing near the source of supply and assembling near the point of distribution'. The business model for MFR has many aspects, not all of which can be captured in a like-for-like comparison with traditional manufacture and distribution. However, it is useful to consider the basic investment costs of the two. Table 17.1 provides a comparison of the way in which the two models would produce 250 000 cars per annum.

The MFR concept is not merely Buddist car manufacturing on a small scale as it necessarily involves a radically different product technology and body production process. One of the nearest contemporary examples is TH!NK (see Chapter 3). This is a vehicle built on a folded steel platform on to which is fixed an aluminium body frame which holds thermoplastic outer panels. Virtually any type of non-Budd body/chassis technology is suitable for this type of low volume, modular, low investment devolved assembly. Despite this, the idea of factory retailing itself is not entirely new to the automotive industry and there are parallel lessons to be learned from other sectors (such as steel mini-mills and micro-breweries) that have already experienced some aspects of MFR in action. In other sectors, such as computers (for example, Dell Computers) consumers deal direct with the factory, a practice likely to become more prevalent with internet shopping.

The combined fixed cost of traditional manufacturing and distribution, including the franchised dealer network, is indeed substantial. Compared with this, the fixed costs for MFR are probably an order of magnitude lower. Perhaps more important than the simple investment cost comparison are the many strategic possibilities which are provided by MFR (Wells, 2001). A few potential advantages are listed below:

- Investments in assembly capacity can be incremental, and thereby expand or contract in line with the market. Each MFR unit would have an investment cost well below that of a traditional manufacturing plant – although the cumulative investment cost for the same production capacity may be higher.
- The incremental expansion of capacity can have a geographic component in that new plants can be added to develop new market territories.
- New products can be introduced incrementally on a factory-by-factory basis, and high product variety will become possible. The overall financial risk associated with introducing a new product will be much lower than with contemporary approaches.
- The factory becomes the location for repair, spare parts and in-use modification (e.g., external panel refresh, powertrain upgrades, refitting of interior trim), which allows the manufacturer to benefit directly from profitable after-market activities.
- The factory could become the repository of different vehicle structures or adaptations that existing owners or users could use to change the characteristics of their vehicle.
- The factory becomes the centre for trade-ins, used vehicle sales and end-of-life vehicle recycling and hence becomes the embodiment of product stewardship.
- The factory can undergo a transition over time from an essentially new car production focus, to one more involved in service and repair. That is, the factory does not depend absolutely on the continued sale of new cars. This helps to mitigate the tendency to over-production with all manner of associated environmental and market benefits.
- The consumer will benefit from a reduction in depreciation of the vehicle, as in existing systems this depreciation is created by a combi-

nation of product wear, over-production and the step-change introduction of a new model.

- Customers can be taken around the plant, meet the people who will make their car, and thereby feel ‘closer’ to the product. Information on customer lifestyles, aspirations and mobility needs goes direct to the factory to inform product development.
- There is no conflict of interest between production and retailing. The vehicle manufacturer can have direct control over the retail business and capture a greater share of the downstream value chain.
- The inherent flexibility of MFR is the practical basis upon which new levels of customer care can be built. MFR makes flexible response, shorter lead times, and late configuration possible.
- The MFR concept takes advantage of the possibilities offered by the internet, which becomes the main medium by which customers order vehicles, spares, etc.
- Stronger worker commitment to the product and to customers. These small factories escape from the ‘mass’ culture of traditional high volume manufacturing.
- Micro factory retailing is the best way to take advantage of modular supply strategies, combined with commodity or off-the-shelf purchasing. In transport terms, it is more efficient to move components and sub-assemblies than complete vehicles.
- Products can be customised to local market conditions.
- Manufacturing processes have a lower environmental impact compared with traditional high volume manufacturing and even provide the option of doing without a paint plant.
- Micro factory retailing does not require a large, flat dedicated site with extensive support services. A modern car plant occupies several square kilometres of land. Compared with this, MFR requires a classic ‘light industrial’ facility.
- The MFR concept clearly resonates with social and political objectives in many countries worldwide by creating local employment in high value manufacturing activities. It also embodies the growing desire to increase labour and reduce fixed investment in order to reduce cost, widen flexibility and increase social cohesion.
- The social impact of plant closure would be lower as a smaller plant would be closed in each location.
- A version of the MFR is therefore also ideally suited to investments in emerging markets. In these markets the investment costs of a major plant would be prohibitive. MFR could replace the existing approach of kit-assembly in such locations.
- Through duplication of MFR sites, substantial investment savings could be realised by means of multiple ordering of machines and equipment and the use of a standardised layout.

17.3 Barriers and opportunities for micro factory retailing

There are many varied reasons why some form of MFR will not happen. There are the 'traditional' barriers to entry, features of an existing industry or market that make it difficult for a new entrant company to succeed. These barriers can be financial, technical or market-based in character. Certainly in the automotive industry the financial costs for a new entrant employing mainstream technology to compete in the mass market are huge, as Samsung discovered in its abortive attempt in the 1990s. The technical barriers are hardly trivial either. Beyond the very smallest scale of production all vehicles have to meet extensive government standards for Type Approval. These standards cover a wide range of issues from exhaust emissions and seatbelt performance to the width of the gap between the headlights. The requirement to meet Type Approval standards is one of the reasons why a new model costs so much to engineer. Some of these issues may be compounded if the new entrant employs innovative technology with which there is less experience and knowledge. At a market level, more barriers emerge. New entrants will not have an established brand, and building a new brand image takes time and money. In addition, the established vehicle manufacturers all have extensive distribution networks that reach into the market across geographic space. At a more general level, there is often the comfort factor that consumers may have with a 'tried and trusted' set of technologies, particularly with respect to the all-steel body. This is particularly relevant if consumers are concerned with purchase price alone, rather than the lifetime cost of a vehicle.

Furthermore, many in the industry would argue that the industry has changed greatly over recent years and will continue to do so. Innovations such as water-based paint, lean production and high-strength steels to name but a few all contribute here. The overall thrust of the industry has indeed been to address the financial and environmental critique presented in this book and elsewhere, and for many, if things are getting better there is less incentive for a radical and disruptive change. Others would argue that vehicle manufacturers cannot 'do' retailing. They have already sunk huge costs in presses, welding stations, paint shops, etc.; the exit costs are too high; centralised manufacturing is easier to manage and profits are still being made; and at a political level these giant companies have enough leverage to secure their own futures. All of these forces suggest that the industry itself will not change quickly, nor will new entrants attempting some form of MFR find much room within which to flourish.

An alternative situation could be that the industry and existing companies may not be able to stem the tide of change. If an MFR new entrant does indeed come up with a new product concept; a new market offer; a new way of being profitable in this industry; a different formula to achieve sustainability; then the existing sector may simply collapse under the weight of its own irrelevance. The history of industrial nations is full of once-great sectors that have withered to virtually nothing, often with alarming rapidity and dire social consequences. There is no law that says the automotive industry is immune.

It is certainly possible for MFR to be introduced via a range of alternative business models, that may or may not involve existing vehicle manufacturers. These models might include:

- Single business new entrant. A small company with appropriate financial backing starts essentially as a micro factory without the retail and service content, but builds these in over time and expands the number of sites.
- Franchised concept. The vehicle is designed and engineered centrally but the concept and brand is franchised out to independent entrepreneurs and investors.
- An existing consumer segment such as a city taxi company takes on micro factory car construction and service to support its own needs.
- A local community forms a co-operative to generate local employment and create products for local needs, possibly assisted by government.
- An existing vehicle manufacturer introduces the idea as an alternative to the existing way of doing business, to create a 'sustainable mobility' brand, so underwriting early start-up costs. If the idea is successful it can then be transferred to more locations.
- A newly motorised country wants to start its own car industry.

Ultimately, it is likely that the fundamental force for change in the sector will remain economic, but this too will work in favour of MFR. The existing industry is capital intensive and has a very low rate of return, with high levels of risk associated with correspondingly high investment demands. In the end, global capital will seek out and support better opportunities that offer higher returns and lower risk.

17.4 Case study: the Air Car

Motor Development International (MDI) is the company that has brought to market the compressed air engine. Like many truly powerful ideas, the concept developed by Guy Nègre actually built on existing knowledge and transferred the ideas to a new application. Interestingly, this is precisely what E G Budd did in the early 1900s when he developed the all-steel car body, and transformed the economics of the automotive industry. Compressed air is of course already used in the industry, usually to power hand tools in factories and workshops. It is also used to power starter motors for Formula One cars, the application that Nègre used as his starting point. In essence the idea is very simple. Compressed air is held in a suitable canister. As such, it represents stored energy. The compressed air is then fed into a cylinder and allowed to expand, and in so doing the expansion provides the motive force to push a piston and hence turn the engine. There is no combustion, so there are no emissions at the point of use other than air – although of course overall emissions performance depends upon the energy source used to compress the air.

A useful attribute of the technology is that any sort of dedicated infrastructure would not be technically difficult or expensive to install – air refilling points could easily be added to existing petrol stations, based, for example, on those already offered for inflating tyres. Simple air compressors could be run from domestic electricity to recharge the cylinders overnight. The detailed design of the Air Car is more complex than the above suggests: for example it involves an innovative articulated connecting rod to allow the piston to be positioned at top dead centre for a longer duration in the cycle than is normally the case with an internal combustion engine. The engine develops maximum power at 3500 rpm and maximum torque at just 800–1300 rpm. The slow speed and low temperature of operation (air in the cylinder head reaches 400°C maximum) mean that vegetable oil is sufficient for lubrication, and the oil will last for up to 50 000 km. The vehicle is available in four basic body styles that reflect the urban/commercial vehicle focus of the product: family car, van, taxi and pick-up. The van is a good illustration. The body is constructed from foam-filled plastic panels on a basic steel chassis, and has two sliding doors. Table 17.2 summarises the characteristics of the model.

The core of the MDI approach is to grant licences to third parties that in effect take on an MDI franchise for a defined territory in return for the investment needed to create the factory to serve that territory. The company has designed a standardised or modular factory, and claims that 50 factories have already been allocated in various locations around the world. In addition, the standardised factory includes office space and a showroom, because in the MDI concept the point of manufacturing is also the point of retail and service/maintenance delivery. A prototype factory already exists in Nice in France. The factory includes 4200 m^2 of workshop space, 500 m^2

Table 17.2 Basic characteristics of the MDI van

Item	Characteristic
Seats	2
Features	Airbag; air-conditioning; ABS
Load volume	1.5 m^3
Dimensions	3.84 m long; 1.72 m wide; 1.75 m high
Maximum speed	130 kph
Range	200–300 km
Recharge time	4 hours (electric); 3 minutes (air station)
Air storage	90 m^3 at 300 bar, carbon fibre canister with thermoplastic liner

Source: MDI (2002).

of offices, and 300 m^2 of showroom space. On a single shift basis, with 70 workers, the factory is expected to produce about 2000 vehicles per annum. In terms of operations, the factory would manufacture and assemble engines, car parts and the chassis, and undertake final assembly. The large plastic body panels would be manufactured at the factory as well. In addition the factory would undertake promotion, sales and distribution, sales of spare parts, repairs and service within the zone allocated to them.

Clearly the body technology is vital to the business model developed. The MDI vehicle does not have steel panels and therefore does not require large presses, welding stations or a paint shop. While plastic body panel technology has typically long cycle times, the plastic can be through-coloured and the breakeven volumes are an order of magnitude lower than steel panel technology. There are issues of consumer acceptance of the aesthetic qualities of plastic body panels, though in a more commercial application the operational benefits of plastic may be more of a consideration.

This innovative approach to manufacturing and retailing has several advantages. Most importantly, it greatly reduces the start-up market entry costs of the business. The alternative would be for MDI to mimic the existing industry. That is, MDI would have to commit very large sums of money into building a large factory somewhere in Europe, and then recruit a network of traditional franchised dealers to sell the cars. Using the franchised factory approach MDI can provide participants with economies of scale via the central sourcing of components and materials. Moreover, having a standardised factory concept results in significantly lower unit costs on all aspects of designing and equipping the factory. A secondary advantage is that consumers can see the manufacturing system that will build their car, and can indeed watch their car being built. For a new entrant in particular it is necessary to engender consumer confidence and 'buy in', and this might be one means of doing so. The small scale of operations means that large, expensive sites are not necessary. Indeed, MDI claim that a site of only 15 000 m^2 is needed. These units, similar to the concept of micro factory retail units (see Wells and Nieuwenhuis, 2000) can be located near the main sources of demand, on the urban periphery or existing industrial estates.

It remains to be seen whether the MDI approach is genuinely useful and viable. The core technology may be flawed. The business concept may be unable to attract sufficient support from investors. However, the very fact that MDI has emerged at all suggests that alternatives to the mainstream are under investigation.

17.5 Conclusions

The concept of MFR could be criticised on many grounds, not least that it falls into the trap of business 'guru' thinking discussed in Chapter 5. The intention is not to be so prescriptive. The ideas behind MFR do not suppose that there will be a single 'best' answer, a cookbook recipe for business success. Rather it should be seen as an organising concept, a philosophy or way of thinking about the world that opens up possibilities rather than forecloses them. The concept of MFR is a research agenda: a guiding theme for an exploration of the automotive industry and indeed other sectors. Equally, it is a point of debate that perhaps will allow all participants the opportunity to articulate their view on what sustainability means in the translation from concept to reality.

17.6 References

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18

Conclusions and implications

Nothing makes driving more enjoyable than a car.
(quote from car salesman in *Sabrina the Teenage Witch* TV series by Nickelodeon)

18.1 Summary

It is probably too early to write a conclusion to this book. We should try again in about 2020. What we have tried to do is give our view of the current state of the automotive industry based on many years of working within the industry and studying it at close quarters. To summarise: the industry adopted a technological paradigm which we can call Buddist–Fordist, combining a set of technology choices and practices centred on the all-steel welded body. This suited it well as long as markets were satisfied with large numbers of identical or near identical cars, as its ability to reduce cost was bought at the price of severely reduced flexibility in both volumes made and variants offered. As markets became more differentiated, segmented and 'niched', the minimum per-model volumes became more difficult to achieve. As a result, breakeven points determined by the economies of scale that result from these technology choices are more and more difficult to reach, leading to a lack of profitability. Each manufacturing group has several models in its range that are inherently unprofitable. At the same time, the cost pressures on the industry have increased due to shortening product cycles, increasing competition, increasing product complexity and more and more onerous regulatory pressures.

All this has resulted in a steady downward trend of profit margins since the 1930s. There are no radical proposals in the pipeline that can break this trend. In the not too distant future it will become virtually impossible to make and sell cars in the fashion that has become ‘conventional’, but which is in fact not that old or well-established. The industry has been trying to stem the tide by fleeing into globalisation (resulting in ever larger organisational and production structures through mergers), ‘leaning’ their processes inspired by ‘Toyotism’, and cutting costs wherever possible. More promising perhaps have been the industry’s moves into the post-factory gate elements of the automobility system. However, all these measures must ultimately be merely a stay of execution. The current system will become economically unsustainable, and the current business model unviable.

In addition, it has become clear that our new-found automobility has a considerable adverse effect on health, the natural environment, and society. Automobility can be dangerous and divisive. Making sustainable cars requires a sustainable production system. In moving towards more sustainable automobility, we also need to tackle the unsustainable production system that produces the current, unsustainable car. That the environmental unsustainability of the current car production system becomes apparent at the same time as evidence of its economic unsustainability is growing, is not mere coincidence. We need to look for alternatives.

Given that most people in the developed world have come to expect access to automobility of some sort, we may need to rethink how this demand can be met. There may be alternative ways of fulfilling this need, that differ from our current expectations of what a car is. The car has become rather inefficient in terms of its basic function as a people-carrying device; a function fulfilled rather more efficiently by the bicycle, albeit at some inconvenience. If we rethink the car, we then have the opportunity to also rethink the way it is made, sold, serviced, repaired and used. We can reconfigure the ‘automobility paradigm’. In doing so we can be guided by the growing need to make our activities on this planet more sustainable. This way we can ensure access to some form of automobility far into the future, rather than driving ourselves to the point of no return.

In this book the authors have attempted to present and analyse the basic problems faced by the industry, following up from earlier work, particularly *The Death of Motoring?* (Nieuwenhuis and Wells, 1997). We have also tried to present a basic blueprint for an alternative, more sustainable, automotive system and outlined a roadmap that might get us from where we are today to where we should be, or should want to be, at some point in the future. We have highlighted the fact that many in the industry can also see the revolution coming and are actively trying to accommodate and prepare for radical change. An unprecedented level of investment is being allocated to radical new technologies with no immediate payback, such as fuel cells, hybrid powertrain, and alternative body/chassis construction techniques. In addition, we can see real changes in the types of ownership packages from leasing to car sharing schemes, demonstrating that the conventional ownership concept of cars is being eroded. Relationships between car makers and their suppliers are also changing towards a different power relationship in which suppliers may well become more powerful than car assemblers. Suppliers already dominate some of the key technologies required in the future, from electronic and electric systems, through alternative powertrain to alternative materials.

18.2 Our future

However, we do not just outline the problems, but actually propose a range of possible solutions as well. Our model for the future and the roadmap for getting there have been presented. It has been explained how our cars will be manufactured and sold using the micro factory retailing (MFR) model. This will combine sales with detailed customer-focused configuration, final assembly, repair, maintenance, modular upgrades and end-of-life processing for re-use or ultimate recycling.

18.2.1 Powertrain

In terms of powertrain we see a gradual increase in the efficiency of internal combustion engines. Petrol, diesel and a range of other carbon fuels will dominate until about 2030. However, at the same time a growing number of them will provide the power for a hybrid system which is likely to become the dominant intermediate technology. Like many other observers of the industry we can see the hydrogen fuel cell ultimately becoming the mainstream powertrain choice. This point will probably have been reached by about 2040–50. Another intermediate technology may be hydrogen internal combustion as proposed by BMW. This would allow the establishment of a hydrogen infrastructure without a wholesale move to a radical new powertrain technology, which could be gradually introduced side by side.

However, the problem of economies of scale could thwart the introduction of new technology. It is quite clear that making cheap fuel cells, hydrogen storage tanks, or on-board converters is only feasible if they are produced in sufficient volumes. Without the low cost, demand is unlikely to materialise, while the low cost is not possible without sufficient volumes driven by sufficient demand. Clearly, someone will have to take the risk of generating this demand before the real market can respond. Both industry and government may need to take the initiative here.

18.2.2 Structure

The vehicle structure would be modular. This way the wide range of choices needed to fill the wide range of niches and segments now expected can be most easily accommodated. Modules would give powertrain choices, but also provide choice in vehicle size and shape, number of seats, cargo space, frontal area, etc. Structures could be made as modular monocoque structures out of a single material, without forcing a single shape on the whole vehicle. Alternatively a multi-material solution is possible, such as a spaceframe type structure with external cladding. Such a spaceframe could be an easily recyclable metal structure, with recyclable thermoplastic outer panels. Another possibility is a long-life carbon fibre inner structure with more recyclable outer panels, which could be changed over time. Another type of car that could be made in micro factories is the Hypercar, as developed by Amory Lovins' Rocky Mountain Institute and now managed by a separate company, Hypercar Inc. Although this relies primarily on a carbon fibre monocoque structure, it uses non-aerospace standard carbon fibre technology, requiring much lower levels of investment. A similar approach has been taken by the UK Aerostable Carbon Car project, a Foresight Vehicle project that involves both Lotus Engineering and Cranfield University. This also involves low investment carbon fibre technology.

Another very promising model for future automotive structures is GM's AUTOnomy concept. The 'skateboard' chassis structure analysed in Chapter 7 is without doubt the most significant concept car in recent years. It embodies a new approach to car design made possible by the newly emerging powertrain technology of the fuel cell. It shows how a technological change in one key area suddenly makes it possible, if not inevitable, for change to occur elsewhere: in the vehicle structure, its production system, the way it is marketed, where it is made and how it is used. AUTOnomy could be built in a facility operating within the micro factory retailing model and is, in fact, a perfect example of the type of vehicle MFR could offer.

18.2.3 Relocalisation

Another advantage of the MFR model is that it will capture the new political agenda of relocalisation that is likely to emerge from about 2010 or 2020 onwards. The current globalisation model is not sustainable for various reasons outlined in this book and elsewhere. In its place will come a model whereby information and various types of data and intellectual property rights are global. However, economic activity will increasingly be relocalised, thus reducing energy consumption and pollution whilst increasing democracy. Ultimately this will be followed by the relocalisation of capital, as envisaged by Smith, Ricardo and Maynard Keynes, and others who 'sympathise therefore, with those who would minimise, rather than those who would maximise, economic entanglement between nations. Ideas, knowledge, art, hospitality, travel – these are the things which should of their nature be international. But let goods be homespun whenever it is reasonably and conveniently possible; and above all, let finance be primarily national' (Keynes, as quoted in Daly, 1999: 68).

The regionalisation of economic and industrial activity and particularly of capital will become an increasingly important issue in politics. The trend of a population increasingly alienated by a ruling elite that sides with unelected and unrepresentative corporate leaders out of touch with all except their small global coterie of peers is clearly unsustainable, and not just in democracies. Decision-makers who are out of touch with localities will take no interest in the effects their global decisions have on those localities. However, local communities are where people live. The nation and the nation state in its various forms and varying degrees of decentralisation are still the key building block of national and international law and of international organisations, which is difficult to circumvent entirely.

18.2.4 Use

In terms of use and developments in personal mobility, there seems to be no alternative but to reduce our reliance on motorised personal mobility of all kinds. Cars should probably largely be banned from urban areas, with the possible exception of those belonging to the elderly and disabled. Others can enjoy sophisticated high technology human-powered vehicles of various kinds. Buses would also need to become a lot more benign before they would be acceptable in future urban centres, though light rail or trams would be ideal in many ways. Smaller, lighter, automated carriers for smaller numbers of people on less busy routes could largely replace urban buses on such routes where large buses are inherently inefficient.

Significant social changes can be expected, characterised not only by changing population profiles and different working patterns, but also a growing resistance to the negative aspects of automobility. This would make the exclusion of cars from urban areas more likely, and has already begun.

18.3 The UK – a special case?

In many countries the UK is regarded as, at best, a second rate player in the world motor industry. Over the past few decades, the UK has lost most of its indigenous volume car makers and most of its significant truck makers as well. Although the number of cars built has reached record levels, these are built in factories owned by non-British companies. What is more, much of the product development for the cars made in these factories is now carried out elsewhere. What remains in the UK, and is UK-owned, is one volume producer – MG-Rover – accompanied by a myriad of small specialist firms making cars in limited numbers, as well as a dynamic kit car sector and a flourishing aftermarket sector, particularly to support the classic car and motor racing markets. However, the latter do operate in a global market. Most interesting, though, is the UK's large design engineering sector, a network of small and medium-sized firms that carry out product development work for vehicle producers worldwide. Linked with this sub-sector is the British motor racing industry. In a previous publication these sectors have been called the ‘fringe of gold’ (Wells *et al.*, 1999). The UK boasts a large number of very small specialist producers. An increasing number of these have developed considerable engineering and design expertise over the years and in addition to spicing up the UK car market and several export markets, are able to charge other manufacturers for their consultancy or sub-contracting services (Wells *et al.*, 1999). Lotus is probably the most famous of these, although there are several others that play a significant role in the UK automotive sector.

Although other countries have their own small specialist car makers – Venturi and Aixam in France, Ferrari and Maserati in Italy, Isdera in Germany or Panoz in the US – in terms of the number of these compared to the industry as a whole, the UK is unique. Liberal Type Approval and taxation regimes have historically not sought to restrict the sector as in other countries. Other factors also play a role, notably the solid base of enthusiasts in the UK market as illustrated by the historical love of sports cars, the traditional love of motorsport and the sophisticated engineering skills available in the cradle of the Industrial Revolution. For these reasons the sector is also very dynamic, with new players appearing all the time, while others falter.

If there is any sector of the ‘fringe of gold’ that shows that Britain is still a force to be reckoned with in the automotive world it is the competition car industry. Players here build Formula One racing cars, world class rally cars, group C sports cars, as well as cars for formulae such as the North American IndyCar, not even run in the UK. Such is the influence of the UK in this sector that no Formula One racing cars are made without UK input. In fact, even Ferrari had a UK technical centre for its Formula One racing team for a number of years, although its has now concentrated all its activities in Italy. Rather than being a marginal activity, motor racing is moving towards the core activities of many manufacturers in a way it has not done since the early years of the twentieth century. Hugh Chambers, then marketing director of Prodrive – builders of Subaru’s world championship rally cars in the 1990s – explains:

> In a world where the car is in danger of being an over-engineered commodity product, the one true marketplace differentiator is the brand itself. The role of motorsport is to develop that brand personality and give it meaning and life. As the marketing world moves towards brand experiences . . . so there will be more and more emphasis on motorsport programmes aimed at long-term brand building. (Wells *et al.*, 1999: 112–13)

If he is right, the true potential of this sector of the UK automotive industry is still to be realised. Players in this field range from designers, developers and builders racing their own cars, such as McLaren and Williams, to small specialist suppliers of parts made exclusively in the UK, but used worldwide. What is of interest is that these various sub-sectors that flourish in the UK have developed expertise in a range of technologies that appear to be highly suited to the new types of future car we and others propose. This is particularly true for the low volume technologies increasingly needed to meet the diversified demands of developed markets. This has already been recognised by some and Hypercar Inc., for example, has a base in the UK to try and benefit from this expertise. Foresight Vehicle has also tried to capture this knowledge and experience and move it towards possible future car technologies.

If the existing Buddist–Fordist automotive system is genuinely on the way out then those economies not encumbered by this now 'old' technology will be less affected. If they in addition already have an advantage in the required new technologies they are well placed to benefit. Job losses due to the phasing out of the old system can be absorbed by the growth in the new system. However, though theoretically well placed in this respect, the UK would need to actively prepare for such a change in order to truly benefit and become a dominant player. The UK Government, traditionally reluctant to fully engage in industrial policy of any kind, would have to overcome this reluctance and become fully and actively supportive of the necessary preparation process.

18.4 Conclusions

The motor industry is not alone in facing possibly radical change over the twenty-first century. Other industrial sectors are in a similar position and some have already responded in some way, as seen earlier. In fact, the motor industry, despite being the world's largest manufacturing sector, is merely caught up in a wider trend towards smaller scale manufacturing technologies, leading to a more dispersed pattern of economic activity. This links in with wider social and political trends towards greater diversity and political localisation.

Many of Europe's nation states have opted for more devolved decision-making structures. Since the 1960s greater regionalisation of political power in Italy, Spain, France and the UK has been witnessed, while other countries, such as Germany, Switzerland and the US already had some history in this respect. The fragmentation of nations in Eastern and central Europe, as well as the former Soviet Union, can also be seen as part of this trend. Perhaps it is merely the gradual implementation of democracy, which in truth is still quite young even in Europe. True democracy cannot be said to start until all adult citizens – including women – get the vote. For many European countries this did not happen until the early twentieth century.

Subsequent developments in empowering citizens, including consumerism, protest movements such as those opposing 'the bomb' in the cold war, environmental pressure groups, Amnesty International, as well as the declining status of politicians may well be symptoms of the growing power of real democracy. It is not surprising therefore that those who feel threatened by democracy have sought to move decision-making further and further away from ordinary people. The first few decades of the twenty-first century will decide which side will win. Diversity and localisation are more likely to be sustainable than unfettered, unquestioning globalisation, leading to ever larger entities responsible for all human activity. The automotive sector is well placed to show the way to this better, more efficient, more equitable, more sustainable and more profitable future.

18.5 References

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