Automotive Plastics & Composites

Worldwide Markets & Trends to 2007

FROM THE PUBLISHER OF

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Worldwide Markets and Trends to 2007

Second edition

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Executive Summary

In 1994 the global usage of plastics in cars was approximately 4.8 million tonnes, this has grown to an estimated 5.2 million tonnes in 1998.

Our forecast increase to 2003 is 5.6 million tonnes, and to 2007 it is 6.3 million tonnes. The average weight of plastics per car will rise from 108 kg in 1998 to 120 kg in 2007.

In 1998 the value of plastics used in cars worldwide was approximately US$10.5 billion. This is likely to grow by 22.5% to just over US$13 billion.

The two tables at the end of this summary provide an analysis of how the above global tonnages and values are divided between the different regions of the world.

Global car production is forecast to increase by 14.5% between 1998 and 2007. Most of the industry's expansion is expected to come from developing markets including Eastern Europe (86.8%), Asia (25.2%) and Latin America (77.3%). The mature markets of North America and Western Europe are anticipated to grow by 0.7% and 3.2% respectively.

Table A.1 Global car production by region 1997-98 and forecasts for 1999, 2003 and 2007 – (000s)

	1997	1998	1999	2003	2007
Western Europe	14,508	15,030	14,520	15,070	15,510
Eastern Europe	2,040	1,900	1,630	2,700	3,550
North America	14,803	15,100	15,800	14,400	15,200
Asia	12,247	11,020	10,550	11,800	13,800
Latin America	2,096	1,760	1,830	2,280	3,120
Others	708	730	680	820	950
Total	46,402	45,540	45,010	47,070	52,130

Note: North American total includes light trucks

North America

Total plastic consumption in North American cars in 1998 was 1,610,000 tonnes. This is forecast to increase by 6.5% to 1,715,000 tonnes in 2007. This growth is well in excess of the growth forecast for car production which is not expected to be in excess of 1.0%.

The maximum increases in plastics usage will be in exterior and structural areas including glazing followed by fuel/engine compartment and electrical/ electronics.

Growth in interiors will be less, due to the maturity of this area.

The highest growth plastics will be, polycarbonate in glazing, and blends in exterior body parts (average 30%).

Polyamides in all the four areas under review (average 22%).

Polypropylene and polypropylene EPDM blends in exterior parts and interiors (average 10%).

Polyethylene in fuel systems and engine compartment (average 10%).

Thermoplastic polyesters in thermoplastic blends and in car electronics (average 10%).

Unsaturated polyesters in SMC and BMC exterior applications (minimum 10%).

Polyurethanes in interiors (minimal 1%).

PVC and ABS in interiors will decline by (−1%).

Western Europe

Total plastics consumption in cars produced in Western Europe in 1998 was 2,000,000 tonnes. This is forecast to increase by 10% to 2,200,000 tonnes by 2007. This growth is well in excess of the growth forecast for car production which is not expected to be in excess of 3%.

The maximum increases in plastics usage will be in exterior and structural areas including glazing followed by fuel/engine compartment and electrical/ electronics.

Growth in interiors will be less due to the maturity of this area.

The highest growth plastics will be polycarbonate in headlamp lenses and glazing, in blends in exterior body parts, and in some interior parts with high heat requirements (average 30%).

Polyamides in all the four areas under review (average 20%).

Polypropylene and polypropylene/EPDM blends will grow in interior and exterior/structural areas of the car (average 12.5%).

Unsaturated polyesters will grow in SMC and BMC applications in exterior structural components (average 11%).

Thermoplastic polyesters PBT and PET are likely to grow in exteriors where blends of PBT and PC are used and in electric/electronics (average 12%).

Polyurethanes' growth will be helped by the "soft nose" concept for pedestrian friendly vehicles (average 12%).

PVC will decrease eventually in interior components and also in car wiring (average −6%).

Asia

Asian car production is forecast to expand by 25% between 1998 and 2007 from 11.02 million to 13.8 million units. However, this overall figure masks some widely varying performances by country.

Like its counterparts in North America and Western Europe, the Japanese car industry is moving towards saturation and hence will be increasingly cyclical in character. However, the 1998 base year used for this study represents a low point in the cycle and therefore Japanese car output is forecast to exhibit modest growth of 6.3% during the period to 2007. In volume terms this implies that Japanese car output will rise from 8 million in 1998 to 8.5 million in 2007.

Plastics consumption in Japan will increase in excess of car production; we estimate that this will be approximately 10% to 2007.

Polycarbonate, Polypropylene and Polypropylene/EPDM blends will increase by an average of 25%. PPO, PBT/PET, PA and POM are likely to increase by approximately 15% and unsaturated polyesters and polyurethane foams by approximately 10%.

Polymers which are forecast to show a decrease are, ABS and other styrenics, approximately −5% and PVC, approximately −12%.

After experiencing strong growth during much of the 1990s the Korean motor industry has been seriously affected by Asia's recent economic setback. Quite strong growth of 17.6% is anticipated during the period 1998-2007 but this will be from a relatively depressed base. By 2007 it is forecast that the Korean motor industry will be producing 2 million cars, considerably below the industry's previous targets.

Elsewhere in Asia, strong growth is expected in both China and India as both countries see a build-up of demand and expansion in their domestic car manufacturing industries. In similar fashion, car output in other Asian countries including Malaysia, the Philippines and Thailand is set to grow strongly, and in this respect the recent economic difficulties have merely postponed rather than led to the abandonment of the motor industry.

Of the investment projects by international vehicle manufacturers, it is assumed that most of the planned projects, and others yet to be announced, will be operational by 2007.

However, it is important to keep the expansion in China, India and other Asian countries in perspective. By 2007 it is forecast that Japan will still be accounting for 61.6 % of the region's car output, and if Korea is included, the figure rises to 76.1%.

Plastic materials and process developments

New developments in the polypropylene sector will ensure the dominant position of this group of plastics in car applications in the future. High crystalline polypropylene (HCPP) with an improved stiffness is now used in car interiors and under the bonnet applications without the need to add 10 to 20% of talcum.

Car bumper shells can now be produced in a thickness of 2.4 to 2.6 mm, down from approximately 3.2 mm giving a substantial cost reduction. Also the new branched polymers permit cheaper processes for Energy Absorbing foams utilised in Energy Management Systems. A few producers are now involved in developing long fibre glass polypropylene (LFT-PP) for injection moulded car component applications where very high stiffness is needed.

Improved polycarbonate polymers are being developed, including a scratch resistant coating, by Exatec, a Bayer-GE Plastics joint venture, for the production of car quarterlights initially and later on larger car windows.

Sheet Moulding Compounds (SMC) with a lower density are now available for panels with a Class A surface, and new technology in the USA makes larger production volumes possible.

Natural fibre reinforced polypropylene and polyurethane, having a lower density than with glass fibre reinforcement, are now being developed with Mercedes, Ford and others for interior panels. Nano-composites are polymers mixed with a few percent of a special clay whose particles are much smaller than one micron. The reinforcing power in polypropylene or nylon is many times that of talcum or glass fibre. This type of composite will find use in under the bonnet applications, and in external parts.

Fluorinated plastics, such as PVDF, ETFE may find increasing use in co-extruded fuel line systems in Europe to cope with new legislation. A new plastic, polyaliphatic ketone, a copolymer of ethylene and carbon monoxide, with exceptionally low permeability to hydrocarbons, is actively promoted for fuel lines and for injection moulded items in the fuel circuit. Hydrolysis resistant polyacetals were developed for more aggressive fuel systems containing a common rail with so called biodiesel as a fuel component.

Thermoplastic elastomers have increasingly been used for under the bonnet applications such as the cooling circuit and the carburettor air inlet and calendered TPE-O foil for instrument panels and door skins. Now slush moulded instrument panel skins made of TPE-U powder are being used on higher class cars. The advantage over TPE-O foil is improved mar and scratch resistance and better dullness with good adherence to the polyurethane foam underneath.

TPE-V is a blend of polypropylene with EPDM rubber, thus a TPE-O, with a partly or completely crosslinked rubber phase. This product has better characteristics than the usual TPE-O's and can be extruded or injection moulded. It is used for the corners of windscreen encapsulation and under the bonnet where heat resistance is required. Reactor TPE-O or RTPE-O polymers are not physical blends but are copolymerised in the reactor and are cheaper. Although the properties are slightly lower than blended TPE-O's they are being used increasingly for bumper shells.

Another blend is that with a poly(ethylene-octene-1) elastomer made by the metallocene process and PP.

Most plastic car parts are still produced by established injection moulding techniques. Gas assisted moulding will be more frequently used to reduce weight.

In Mould Decoration (IMD) and Paintless Film Moulding (PFM) are new ways to improve aesthetics of instrument clusters or body panels.

Extrusion blow moulding is well entrenched as the technique to produce fuel tanks of high density polyethylene (HDPE) although it is expected that the six layer co-extrusion blow moulding used in the USA for the fuel tank production will come to Europe and Japan.

Long Fibre (glass or natural) Reinforced polyurethane (LFI-PUR) is used already for producing door panels of high stiffness and has good prospects for further penetration in car interiors.

Compression moulding technology has been developed in the USA for high volume production of panels with a Class A surface in low density sheet moulding compound (SMC) and similar technology is used for processing GMT. GMT is not used where Class A surfaces are required but where non cosmetic surfaces and a high degree of structural integrity during impact are required.

The lost core injection moulding process will still be used for air inlet manifolds in polyamide for difficult designs, whereas straight moulding and vibration welding will be used for relatively simple manifolds.

Competition from other materials

The principal competitors to plastics and composite in car applications are steels (particularly light weight grades), aluminium and magnesium.

Competition between materials is strongest in the exterior body panels sector. The development of lighter weight high-strength steels has resulted partly from the ULSAB programme. High-strength steels have application in the bodywork, chassis and suspension areas of the car.

Metal-plastic-metal (MPM) laminates, a sandwich construction using two layers of IF steel enclosing a layer of polypropylene, are used to combat NVH in areas like bulkheads and floor panels.

Aluminium, approximately 50% of the weight of steel, competes with both steel and plastics, and has proved itself in the space-frame construction of the Audi A8 and earlier cars. Its use in door, bonnet, roof and boot panels on more specialised vehicles such as Land Rovers and Electric Vehicles is also established.

Aluminium's greatest use is still in diecastings for engine components.

At present, the use of magnesium by car makers is greatest in North America. Uses include seat components, cross-car beams, steering wheel cores, and a number of other diecasting applications. It is in direct competition with plastics in these and other areas of the car.

Driving forces for market growth

Regulations and legislation have a continuing impact on the type and quantities of plastics used in a car.

Especially demanding for car designers and Tier 1 suppliers are those regulations covering the reduction to 20 mm/day of hydrocarbons evaporated from a car, the minimum of 85% and later, by 2015, 95% recyclability, as well as the occupant and pedestrian safety aspects.

The recyclability of a car in Europe is strictly regulated in directive EC 31/7/96, and although a weight percentage may be incinerated, this has an important effect on the choice and the number of different types of plastics.

Also in Europe the average fuel consumption of a car should be reduced by 25% in 2005 compared to 1997 which is stimulating car weight reduction and fuel injection systems. In the USA the Federal CAFE standards exist on average fuel consumption.

On passenger safety, crash test specifications have been introduced in Europe similar to those existing in the USA, but more and more test conditions are specified by consumer organisations - the NCAP tests - are gaining in importance. Passive and active safety restraint systems will also continue to be of importance.

The front part of cars in Europe is likely to change when legislation comes into effect on pedestrian safety systems, but will not be effective before 2005.

Recycling and disposal

Growing attention is being directed to the issue of end-of-life vehicles (ELVs) and the desirability of recycling as much as possible of their materials. This issue is becoming critical in view of the high numbers involved (currently and estimated 40-42 million a year worldwide, rising to a forecast 45-47 million by 2007) and the increasing pressure on landfill sites.

At present, typically around 75-80% by weight of a scrapped vehicle is recovered and recycled, with the remainder disposed of in a number of ways including landfill. The automotive industry has developed a number of voluntary codes (such as ACORD in the UK) aimed at raising this percentage progressively to the 95% level by 2015, and legislation is being formulated which will set targets.

In reaching this level, a far higher proportion of the plastics content of a vehicle will have to be recovered, which has a number of significant implications throughout the industry. A wide range of new initiatives are being introduced which will affect more and more the specification and use of plastics. Key priorities include reducing the number of plastic types in individual models, identifying them so that they may be sorted effectively at the dismantling stage and separating plastics from other materials so that contamination is minimised.

Table A.2

Plastics and selected car components they are used in:	Body Panels Exterior	Body Side Mouldings	Bumpers	Door Handles	Door Liners	Door Locks	Door Panels	Door Pillars	Drip Rails	Glazing	Mirrors Exterior	Number Plates	Roof Rails	Side-impact Beams	Spoilers	Under Body Seal / Cladding	Wheel Arch Linings	Wheel Trims
	Exterior, Structural, Doors, Glazing																	
Thermoplastics																		
Acrylonitrile butadiene styrene copolymer (ABS)					•		•	•			•		•					•
Acrylonitrile styrene acrylate (ASA)									•		•				•			
Aliphatic Polyketones (APK)																		
Polyacetal (POM)						•												
Polyamides (PA)	•			•		•					•		•					•
Polybutylene terephthalate (PBT)				•		•			•		•							
Polycarbonate (PC)										•								
Polyether imide (PEI)																		
Polyethylene (PE)																	•	
Polyethylene terephthalate (PET)																		
Polymethyl methacrylate or acrylic (PMMA)										•		•						
Polyphenylene sulphide (PPS)																		
Polyphthalamide (PPA)																		
Polypropylene (PP) *	•		•		•		•	•			•					•		•
Polytetrafluorethylene (PTFE)																		
Polyvinyl chloride (PVC)		•														•		
Styrene-maleic anhydride (SMA)																•		
Thermoplastic Blends																		
Polycarbonate/ABS					•		•	•			•		•		•			
Polycarbonate/PBT	•		•															
PPO/Polyamide			•															
Polyphenylene oxide (PPO HIPS)																		
Thermoplastic Elastomers																		
TPE-E (TPE)			•															
TPE-O (TPO)		•	•		•		•											
TPE-U (TPU)																		
Thermosets																		
Phenolic & epoxide resins																		
Polyurethane flexible foams (PUR)					•													
Polyurethane integral-skin foams							•	•										
Polyurethane RIM compounds ***	•		•											•	•			
Polyurethane semi-rigid foam																		
Unsaturated polyesters (UP) **	•		•															

* Includes GMT - Glass Mat Thermoplastic

** Includes SMC - Sheet Moulding Compound & BMC - Bulk Moulding Compound

*** Includes R-RIM, S-RIM, LFT-RIM

Interior Components, Seating																						Under Bonnet, Power Train, Fuel Systems																Electrics Lighting			
Airbag Covers	Arm Rests	Body Panels Interior	Consoles	Dash Board / Instr Panel	Floor Panels	Grilles	Head Liners	Instrument Panel Support	Interior Trim	Knee Bolsters	Mirrors Interior	Pillar Trim	Rear Parcel Shelf	Roof Linings	Seat Belt Components	Seat Cushioning	Seat Frames	Steering Wheels	Steering Wheel Shrouds	Sun Visors	Window Winders	HVAC Parts	Bearings	Brake pads	Cooling Systems	Fuel Connectors	Fuel Lines	Fuel Tanks	Gears	Heat Shields	Inlet Manifolds	Leaf Springs	Sound Absorption	Subframes	Under Bonnet Applications	Water Pumps	CVJ Boots	Elect/cal / Electronic Comps	Ignition Parts	Lamp Housings	Lenses
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Industry structure and relationships

During the past few years, changes in the structure of the supply chain to the car producers have been far reaching. Growing technical complexity of components and systems, resulting in higher R&D costs, have drastically reduced the number of Tier 1 systems suppliers who will increasingly operate on a global basis.

The development of world vehicle platforms means that, for example, a bumper system required in high volume will need to be manufactured in different locations, involving expenditure approaching US$100 million. This trend is expected to continue until a situation is reached where eight global car producers are supplied by a small number of widely based Tier 1 systems suppliers, who in turn are supplied by a reduced number of Tier 2 component suppliers.

The position of the raw material suppliers is also changing. Rapidly increasing development costs for new or improved polymers have resulted in joint ventures, and this trend will continue.

The most profitable route for these operations is a direct approach to both car producers and Tier 1 systems suppliers. Only by doing this will the case for plastics and composites be properly sold against the growing competition from metals, in particular magnesium for structural components.

1 Introduction

Timescale, geographical coverage and definition of cars

This report reviews the current usage of plastics and plastic composites in cars and assesses the changes which are forecast to occur during the period to 2007.

The coverage is worldwide, but clearly the technical development of the automotive industry, and hence decisions concerning the specification of materials for use in cars and light vehicles, is heavily concentrated in three key areas - North America, Western Europe and Japan. Recent developments in the structure of worldwide car manufacturing networks - and, in particular, the consolidation of the industry into fewer global producers, each with an increasingly worldwide reach - mean that this is set to become a permanent characteristic of the industry. In other words, the development of car manufacturing in all emerging markets, including the models produced along with their specification and materials usage, will be determined by one of the principal global car producers.

The one possible exception concerns Korea, which has attempted to emulate Japan by establishing a major league export-led vehicle manufacturing sector based on its own technology. However, the recent restructuring of the industry, leading to the pooling of the country's vehicle manufacturing networks into two companies (Daewoo and Hyundai) is widely regarded as the first step towards their eventual integration into wider global organisations.

This report examines plastics usage in cars and selected light vehicles including multi-purpose vehicles (MPVs) and sport utility vehicles (SUVs) but excluding light commercial vehicles. The position becomes somewhat confused due to trends in the North American market where a high proportion of "car" consumers buy a light truck, such as a pickup, in preference to a car. Taking light trucks in their broadest classification to include minivans, pickups and SUVs, they account currently for around 50% of North American "car" sales, a percentage which is rising. For the purposes of this study, therefore, these light trucks are included in the analysis and forecasts. Otherwise, the full list of car types considered are as follows:

Segment	Category
A	Minis
B	Superminis
C	Lower medium
D	Upper medium
E	Executive
F	Luxury
MPV	Multi-purpose vehicle (minivans/people carriers)
S	Specialist sports
SUV	Sport utility vehicle

Background to plastics and composites usage

The increasing use of plastics by vehicle manufacturers worldwide has been one of the most significant developments concerning the specification of materials used in cars during the past few decades. Accelerating technical progress during the 1990s has seen considerable progress in the performance and properties of plastics, leading to a widening of applications - for example, under the bonnet where the operating environment is clearly harsher than in the vehicle interior.

In many instances, the use of plastics has played an important role in meeting some of the automotive industry's most urgent needs, notably the reduction of vehicle weight - but also elsewhere, including the reduction of vehicle assembly costs. In other areas the material has assisted in terms of enabling car and light vehicle design to move forward by providing stylists and interior designers with a new range of possibilities.

However, there have been negatives too. In particular, the growing emphasis on environmental issues has exposed the difficulty of plastics recycling, especially where there is a wide variety of types which need to be sorted effectively at the time of disassembly. In addition, other materials have improved their technical specification and are providing greater competition to plastics in a number of applications.

Automotive Plastics & Composites provides an update to the report on automotive plastics and composites which was published by Elsevier Advanced Technology in August 1995. The sector's latest trends and developments are reviewed, new analysis is included and forecasts have been prepared to 2007.

Scope and contents

The report is divided into 13 chapters and contains:

- A description of the global automotive (car and light vehicle) and plastics industries, identifying the main players and the scope of their operations.
- A review of the changing trends in plastics usage, in terms of both material type and overall usage.
- An assessment of the competitive strengths of individual types of plastics, together with a review of other materials insofar as they are anticipated to affect the evolution of plastics demand.
- An analysis of the impact of external influences on the automotive industry's use of plastics, with particular reference to legislation on recycling.
- Forecasts of car production by major region (North America, Western Europe, Eastern Europe, Latin America, Asia) and by principal producing countries to 2007 and estimated demand for plastics by type and tonnage during the same timeframe.
- A directory of the world's principal car manufacturing and plastic parts and systems producers.

The contents by chapter are as follows:

Executive Summary

A round-up of the report's main findings and conclusions.

Chapter 1: Introduction

Explanation of the report's background and objectives, including definition of the terms used throughout. A description of the scope and contents.

Chapter 2: Industry Analysis

Analysis of the structure of both the car and related vehicles industry and the automotive plastics industry. The nature of the current and likely future relationship between the two is discussed. Future developments in this relationship are forecast and analysed.

Chapter 3: Plastics and Reinforcements used in Automobile Construction

A description of the thermoplastic and thermoset plastics and composites used in the automotive industry. An analysis of their main characteristics in relation to their use in car applications. Indications of new developments and future trends in plastics are presented.

Chapter 4: Plastics Processing Methods

Discussion of the most important processing methods to produce plastics and composites for the car and related vehicles industry. Their relative advantages and disadvantages within the car industry are assessed.

Chapter 5: Competition Between Plastics and Composites and Other Materials

An analysis of the position of plastics and composites and other materials used within the automotive industry. It includes a comparison of the advantages and disadvantages of the various materials. Their future in the car and related vehicles industry is also discussed.

Chapter 6: Environmental and Safety Requirements and Customer Demand

An analysis of the present and future legislation in respect of safety requirements, fuel consumption and fuel composition. Hydrocarbon emissions and suppliers' quality aspects, together with their effect on plastics usage, are described with examples of applications.

Chapter 7: Recycling and Disposal

An appraisal of the current and future trends in the recycling of automotive plastics and composites. An assessment of how these will affect the industry overall, with emphasis on the economics of recycling. Examples are given of legislation and how this is likely to affect future developments in the recycling industry.

Chapter 8: Examples of the Use of Plastics for Specific Components and Systems

This chapter provides an analysis of plastics usage in selected car components, including their use in new systems and applications. The increasing demands from car makers and legislators, and how these are being met by the use of new and improved materials and technologies, are discussed.

Chapter 9: Markets

Forecasts of car production and plastics demand, using 1998 as the base year and projecting to 2007. In addition to identifying the main regions and countries which are expected to experience the most rapid growth in car output, this chapter provides an indication of the changing composition of demand for plastics and composites in the car industry.

Chapter 10: Profiles of Major Car Producers

Detailed profiles of the world's 35 major marques, arranged in alphabetical order, starting with Alfa Romeo and ending with Volvo. Among the topics examined are scope of operations, recent performance, future model plans, production volumes and use of plastics.

Chapter 11: Profiles of the Major Suppliers of Plastic Components to the Car Industry

Profiles of selected suppliers of plastic components and systems to the global car industry. Information provided includes contact details, ownership, product range, subsidiaries and joint ventures, location of manufacturing operations and financial performance.

Chapter 12: Directory of Major Car Producers

A listing of the world's major car producers with contact details.

Chapter 13: Directory of Major Plastic Components Suppliers

A listing of major plastic component and system producers. The information is divided into three sections, corresponding to North America, Europe and Asia.

Plastics and composites definitions

Plastics are difficult to define, but in general, the term is used for all polymeric materials which do not exhibit the elastomeric characteristics of a rubber. A grey area is formed by the thermoplastic elastomers (TPEs) which have molecular chains built up from blocks of plastic and elastomeric material. The resulting product can be converted like a thermoplastic but also exhibits "rubbery" properties.

Plastics are divided into two categories - thermoplastics and thermosets.

Thermoplastics do soften or melt upon heating and can be converted by the usual means into articles, which can be ground into pellets and again softened or melted and converted.

Thermosets, however, are formed into articles by curing the molecules to a three-dimensional network which no longer softens or melts upon heat application. Thermoset articles therefore exhibit a much better resistance against heat and creep than those made from thermoplastics.

However, thermoplastics can be transformed into thermosets by the process of cross-linking the molecules to a three-dimensional network. For instance, the thermoplastic polyethylene is cross-linked under the influence of added peroxides to a thermoset-like structure used for potable water tubing or foamed products.

Composites consist of a polymeric material functioning as a matrix in which fibres in various forms and/or fillers are embedded. The result is a very hard and still product which finds increasing use in car applications.

Definitions specifically applying to plastics are:

Additives: these are in general low molecular weight chemicals added to plastics and rubbers to improve certain characteristics such as ultraviolet absorbers, antioxidants and heat stabilisers, lubricants, plasticisers, flame retardants, cross-linking and blowing agents, pigments and dyes. Impact modifiers are polymeric materials added to improve the impact resistance of e.g. PVC, PP, PBT, PA. A separate class of additives are the fillers such as talcum, wood flour, and reinforcing agents like glass and carbon fibres.

Alloys: strictly speaking, alloys refer to metals and do not exist in plastics. The term is used interchangeably with blends for mixtures of two or more polymers. Examples are alloys or blends of polycarbonate (PC) with ABS or with polybutylene terephthalate (PBT).

Amorphous: used for polymers lacking crystalline structures like acrylics (PMMA), polystyrene (PS), polycarbonate (PC) and polyvinylchloride (PVC). Amorphous plastics are usually hard, glassy and transparent in appearance and exhibit a wide melting or softening temperature range.

ASTM: American Standard Test Methods; is a scientific organisation defining standards on physical and mechanical testing of materials to obtain objective characteristics used for comparison purposes and for design of articles. The standards are partly used to formulate ISO (International Standards Organisation) ones.

Blend: an intimate mixture of two or more polymers to obtain the good properties of each, for example semi-crystalline polypropylene (PP) mixed with 10 to 30% rubbery EPDM results in a blend with good heat resistance and extraordinary impact resistance. Also the mix of polycarbonate (PC) with ABS terpolymer results in a blend with the good heat resistance of the PC part and the low temperature impact resistance of the ABS. Instead of the term blend, trade literature and producers also use alloy. Blends are made passing the components in powder or pellet form in a dry blender followed by a heated twin screw extruder to obtain an intimate blend.

Blow moulding: a process whereby an extruder produces a tube, which when placed in a mould, gets blown down by air to a container. Fuel tanks in High Density PE are made this way.

Calendering: a process in which a polymer preblend or premix passes through a short extruder onto a set of calender rolls to form a film or foil. PVC/ABS calendered foils for instrument panels and door and other trim are major applications. In addition, TPO foils can be calendered.

Compatibility: refers to the possibility of blending polymers on a molecular scale without separation. Incompatibility exists when two polymers cannot be blended into a stable mixture. Non-polar polymers such as polypropylene (PP) and polyethylene (PE) are blendable as well as polar ones like polycarbonate (PC) and polybutylene terephthalate (PBT).

Composite: is a solid product consisting of two distinct phases, a polymer matrix and a fibrous phase, such as glass fibre mat or long glass or carbon fibres. Often used to indicate a fibre containing a thermoplastic or thermoset.

Compound: a product ready to be converted consisting of a polymer blended with the necessary additives and colourants in an extruder or Banbury mixer and subsequently pelletised. Compounding is the process of blending or mixing raw polymers with additives, fillers and colourants in an extruder or Banbury mixer.

Copolymer: refers to a polymer obtained by reacting or polymerising two monomers together or directly after each other. In the last case, a block copolymer is obtained in the first one as a random copolymer. Three monomers polymerised together form a terpolymer. A polypropylene random copolymer is a product where propylene and ethylene units alternate in the molecular chain:- PP-E-P-EE-P. However, a block copolymer is one with blocks of ethylene units on the inside and propylene blocks on the outside: $(PPPP)_n$-$(EEE)_m$-$(PPPP)_o$. Polypropylene block copolymers are preferred in car applications because of the high impact resistance caused by the ethylene blocks.

Creep: plastics are viscoelastic, which means they exhibit both elastic and viscous behaviour, and therefore will deform under load with both an immediate response (elastic) and a slower response (viscous). A plastic part may deform slowly with time to relieve the load. The deformation is called creep or cold flow, the result of increasing strain under constant load. ASTM D674 defines a flexural creep method frequently used. Glass fibre reinforced plastics show a low creep behaviour, whereas plasticised PVC exhibits a high creep level.

Cross-linking: the process of bonding of the molecular chains together by chemical or physical means, obtaining a 3 dimensional network structure with enhanced heat resistance and simulating a thermoset. Curing a thermoset resin is also cross-linking. Cross-linked PP or PE foam in sheets can be obtained by a beta radiation step after extruding the foam or decomposing a peroxide by heating.

Crystalline: many plastics are semi-crystalline, which means that some 30 to 70% of crystallites are present in the structure surrounded by an amorphous polymer. These polymers are non transparent because they exist in two distinct phases. Examples are polypropylene (PP), polyacetal (POM), polyamides (PA), polybutylene terephtalate (PBT) and they exhibit a rather sharp softening or melting temperature.

Curing: this is the process of cross-linking the molecular chains to a 3 dimensional network by means of peroxides and heat, or other methods to arrive at a thermoset.

Cycle time: indicates the time between the start of a polymer conversion process cycle, such as in injection moulding or compression moulding and the beginning of the next cycle.

DIN: Deutsche Institut für Normung, the German Standards for characterisation and definition of materials, similar to ASTM and ISO.

Fatigue: a process of subjecting parts to cyclic loading, which may cause cracks or fracture. Fatigue strength is the number of cycles of stress or strain of a specific character that a given specimen sustains before failure.

Fillers: are usually finely ground powders of silica, talcum, pumice or wood flour added to the polymer (mostly PVC) to reduce cost and increase somewhat the stiffness. Talcum is often added in 10 to 20% to polypropylene (PP) for instrument panel supports.

Flame retardant: the measure in which a polymer supports flame propagation in case of a fire. Plastics can be mixed with chemicals, so-called flame retarders, to reduce the propensity to propagate the flame. For instance, PVC has a certain flame retardancy due to the chlorine atoms, whereas PP burns. For cable sheathing, flame retarded compounds need to be used. For car applications, the Federal Motor Vehicle Safety Standard (FMVSS) 302 applies. In this test a specimen of the plastic from the final article should not exhibit a flame propagation speed of more than 100 mm per minute. Obviously the speed depends very much upon the thickness.

Foam: the polymer has obtained a microcellular character by means of blowing agents. Well known examples in cars are polyurethanes for seats and headrests, and polypropylene foams in sunvisors, instrument panels, and parts of bumpers. Energy absorbing polypropylene foam (EA PP) parts are produced from blown up PP pellets which are sintered in a mould by live steam. These parts have a very low density of 25 to 150 kg/m^3.

Glass fibre: the most common reinforcement (10 to 50%) to enhance stiffness or a polymer through increased modulus. Glass fibres in plastics can cause anisotropy - a difference in properties in different directions in the moulded article - resulting in warpage. The Coefficient of Linear Thermal Expansion (CLTE) is considerably decreased by glass fibre reinforcements, while the creep resistance increases.

GMT or ***Glass Mat Reinforced Thermoplastic:*** A composite of glass mat compression moulded with a polymer, for example, polypropylene, to form a sheet or article.

Hardness: the hardness of a material can be measured by its resistance to scratching or indentation. Most hardness tests measure the resistance to indentation. It is usually expressed in degrees Rockwell hardness measured according to ISO 2039.

Heat resistance or ***HDTUL:*** heat distortion temperature under load; gives an indication of the heat resistance of plastic materials. ASTM D648 describes the DTUL or Deflexion Temperature Under Load, whereas ISO 75 describes the HDT/A and HDT/B with 1.8 MPa and 0.45 MPa load respectively.

Homopolymer: a homogeneous polymer produced from a single monomer as a repeating unit, for example polystyrene (PS), polymethylmethacrylate (PMMA) or polypropylene homopolymer.

Hydrolysis: the process of decomposition of polymers under influence of hot water or steam. This occurs with humidity sensitive or hygroscopic materials like polycarbonate, polyesters and polyamides during compounding in an extruder or during injection moulding. These products therefore need to be dried prior to conversion until a humidity level below 0.1% is reached.

Hygroscopic: the propensity of a polymer to absorb moisture with time, polar polymers with amide and ester groups in particular are hygroscopic. The moisture absorbtion of polyamide 6 and 66 presents a significant decrease in the modulus.

Impact resistance: the ability of a material to withstand shock loading. This property is measured according to IZOD method or Charpy, whereby the test specimen can have a notch as a crack initiator or not. The IZOD notched impact strength is measured according to ISO 180 and the value can be expressed in kJ/m^2 and the Charpy impact according to ISO 179. The impact resistance decreases rapidly below 0°C for most polymers. Impact resistant polymers are necessary for many car applications.

Injection moulding: A process in which plastic is softened by heating in a barrel, after which a screw pushes the soft polymer into an iron mould to produce the part desired. The plastic is cooled and ejected after opening of the mould. Most automotive parts are made this way.

ISO: refers to the International Standards Organisation. This body has defined worldwide standards for testing materials often combining ASTM and DIN standards.

Isotropic: the properties are the same in all directions in a plastic compound. The opposite is anisotropic.

LFT or ***Long Fibre Thermoplastic:*** a compound of long granules, with glass fibres of 5 to 25 mm length made by special compounding techniques. Properties resemble those of GMT. Short glass fibre thermoplastics, the usual commercial product, has fibres shorter than 1 mm to be converted by injection moulding.

Matrix: in a two phase system the matrix is the polymer surrounding the second phase. For instance, in composites, the polymer matrix surrounds the glass fibre and/or filler. In ABS polymers, the SAN is the matrix in which ABS graft copolymer particles are dispersed.

Modulus: the flexural modulus is the ratio of applied stress to the deflection in a bending test, and is a measure of the stiffness of a material. The tensile modulus is also an indicator of the stiffness measured by dividing the tensile stress over the strain at this stress. The last one is usually more accurate. Expressed in Mpa (megapascal) units.

Monomer: the single unit molecule which forms, after reaction with itself or a co-monomer, the repeating unit in the polymeric chain.

Polymer: indicates long chain molecules built up from replicating units of one or more monomers, chemically linked to each other often in a defined pattern. Polymer is a generic name and encompasses plastics, rubbers and natural products such as silk and wool.

Premix: a blend of one or more polymers either in powder or pellet form with additives and colourants ready to be converted, for example, by extrusion or injection moulding. In the case of thermosets, premix represents the mixture of the liquid resin with all the ingredients ready to be cured.

Pre-polymer: a low molecular weight polymeric product, usually liquid, which after addition of additive is cured to a thermoset. For instance, SMC compounds contain a liquid, syrupy unsaturated polyester or vinylester resin.

Recyclate: this indicates a polymer which has been recycled. Recyclates can have somewhat inferior properties compared to first class material. It is therefore often blended with virgin material.

Recycling: refers to the reuse of the materials or components of scrapped cars. Legislation is arriving in Europe, the end of life vehicle regulations requiring a minimum of 85% recyclability. A careful selection of polymeric materials is necessary since the plastic parts need to be ground and mixed with virgin plastic.

Reinforcement: polymeric materials can be reinforced by addition of fibrous or particulate materials enhancing the modulus, creep and thermal resistance. Fibres used are glass, carbon, aramid, natural and rock wool fibres. The disadvantage is the creation of a notch effect on the surface of a moulded item by the fibre which acts as a crack initiator. An interesting new development is the addition of so-called nano-fillers, which have particle sizes in the nano meter range (1 nano meter = 0.001 micro meter). The small particles fill up the intermolecular spaces giving a surprising reinforcement without the disadvantage of fibres.

Resin: this is a generic name for a polymer and interchangeably used with polymer. Often used for pre-polymers which are cured to a thermoset.

Rigidity: indicates the resistance to bending. The modulus of elasticity is an inherent property of a material which together with the thickness determines the rigidity of a plastic.

Saturated: most plastics are saturated in that they do not contain double bonds in the molecular chains. Rubbers are often unsaturated because the double bonds are needed for curing the rubber. Unsaturated polyester resins contain double bonds which react with cross-linkers to a 3 dimensional structure or thermoset. ABS resins contain polybutadiene rubber particles having double bonds, vulnerable for attack by UV radiation or heat.

Stabilisers: chemicals added to a polymer to improve the resistance to heat and light. Mostly used in conjunction with an antioxidant to form a synergistic mixture. The term is also used in UV stabilisers which absorb the UV light before this damages the polymer molecule.

Thermoplastic elastomers (TPEs): a group of, usually, copolymers, which behave like plastics but also have elastomeric properties. The molecular chain contains blocks of thermoplastic as well as elastomeric parts. Examples of TPEs are TPE-O blends of polypropylene with EPDM, copolyesters (TPE-E) or copolyamides (TPE-A). They have a fast growing role in automotive applications.

UV resistance: all polymeric materials degrade in different measures when subjected to sunlight or ultra-violet light radiation. For external car applications it is recommended to add carbon black and UV absorbers to a plastic or paint the part. ABS polymers cannot be used unpainted and need to be replaced by ASA.

Viscosity: is an inherent property of a polymer and determines the flowability during conversion processes such as injection moulding. The higher the molecular weight (i.e. the larger the molecular chain of a polymer), the higher the viscosity and conversion is more difficult.

Water absorption or ***moisture absorption:*** the determination of the measure of absorption, important with hygroscopic polymers, is carried out according to ISO 62 or ASTM D570 by immersion in water of a test specimen for a certain time and at a specified temperature. The weight increase is measured. This property is important since various plastics need to be predried to a moisture level below 0.1% before conversion.

Weatherability: is the resistance of a material against the exposure to outdoor conditions, for example, temperature, oxygen, pollution, humidity and UV radiation. Combined, they can result in a complete polymer degradation with a total loss of properties and colour. Selection of the polymer, additives and colourants is essential. For improved weatherability, carbon black is an excellent means to absorb UV rays and is added to the polymer.

Plastics and composites abbreviations

The following indicates the abbreviations used throughout this report for automotive plastics and composites, including some thermoplastic elastomers.

Table 1.1 Abbreviations

Symbol	Plastic or composite
ABS	Acrylonitrile butadiene styrene copolymer
APK	Aliphatic polyketone
ASA	Acrylonitrile styrene acrylate copolymer
BMC	Bulk moulding compound
BMI	Bismaleimide
DMC	Dough moulding compound
EP	Epoxide (epoxy)
EPP	Expanded polypropylene
EPS	Expanded polystyrene
ETFE	Tetrafluoroethylene copolymer
EVOH	Ethylene vinyl alcohol
GFR	Glass fibre reinforced
GMT	Glass mat thermoplastic
HCPP	Highly crystalline polypropylene
HDPE	High density polyethylene
HIPS	High impact polystyrene
LCP	Liquid crystal polyester or liquid crystal polymer
MF	Melamine formaldehyde resin
MPF	Melamine phenol formaldehyde moulding compound
PA	Polyamide (nylon)
PA-GF	Glass fibre reinforced polyamide
PAEK	Polyarylether ketone
PAI	Polyamide-imide
PAA	Polyarylamide
PAS	Polyarylsulphone
PAT	Polyarylterephthalate (polyarylate)
PBT	Polybutylene terephthalate
PC	Polycarbonate
PCTFE	Polychlorotrifluorethylene
PDAP	Poly (diallyl phthalate)
PE	Polyethylene
PEK	Polyetherketone
PEEK	Polyetheretherketone
PEI	Polyetherimide
PEN	Polyethylene naphthalate
PEOX	Poly (ethylene oxide)
PES	Polyether sulphone
PET	Polyethylene terephthalate
PF	Phenol formaldehyde (phenolic)
PI	Polyimide
PMMA	Poly (methyl methacrylate) (acrylic)
PMMI	Poly (methyl methacrylate imide)
PMP	Poly (methylpentene)
POM	Polyoxymethylene (acetal)
PP	Polypropylene

Table 1.1 continued

PPA	Polyphthalamide
PP-E	Expanded polypropylene
PPF	Polyphenylene ether
PPO	Polyphenylene oxide (=PPE)
PPS	Polyphenylene sulphide
PS	Polystyrene
PSU	Polysulphone
PTFE	Polyethrafluoroethylene
PU	Polyurethane
PUR	Polyurethane
PVB	Polyvinyl butyrate
PVC	Polyvinyl chloride
PVDC	Polyvinylidene chloride
PVDF	Polyvinylidene fluoride
PVF	Polyvinyl fluoride
R-RIM PUR	Reinforced reaction injected moulded polyurethane
SAN	Styrene acrylonitrile copolymer
SMA	Styrene maleic anhydride
SMC	Sheet moulding compound
S-RIM PUR	Structural reaction injection moulded polyurethane
TPE-A	Thermoplastic polyamide elastomer
TPE-E	Thermoplastic polyester elastomer
TPE-O	Thermoplastic polyolefin elastomer
TPE-U	Thermoplastic polyurethane
UF	Urea formaldehyde
UP	Unsaturated polyester resin
VP	Vinyl ester resin

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2 Industry Analysis

Chapter 2 examines the scope and structure of the global automotive and the plastic automotive components industry. It is divided into three sections as follows:

2.1 Structure of the automotive industry.

2.2 The changing structure of the automotive components industry.

2.3 The effects of developments in the structure of the automotive industry's supply chain on the plastic and composites sector.

2.1 Structure of the automotive industry

The structure of the world automotive industry has experienced considerable change over the past two decades as vehicle manufacturers have moved from being primarily national and regional players to operating on an increasingly global basis.

There are several reasons why this process of globalisation has become such a dominant characteristic of the sector but, crucially, the key one concerns the requirement to derive ever growing economies of scale in order to secure and maintain international competitiveness. More and more, vehicle manufacturers are adopting strategies and implementing investment programmes aimed at raising their level of output as a necessary condition for survival. Because of this, relationships with suppliers are experiencing important developments which, in turn, are resulting in far reaching change in the components sector as well.

Before examining these effects on the components industry in general and the plastic components industry in particular, it is worth examining the principal factors behind the automotive industry's move towards globalisation and how this has affected the recent development of the sector's structure, along with likely future developments.

One of the most significant drivers has been the growth of world trade in vehicles and the resultant internationalisation of the marketplace. As a consequence, competition is intensifying, and market shares are being determined increasingly on the basis of price - although, of course, there are other important factors including a range of attributes which, taken together, determine the position of the brand. An analysis of car sales in almost all major markets (including those of the US, France, Germany, Italy, the UK and Japan) indicates that imported content has risen during the 1990s, thereby placing producers under increasing pressure in their domestic markets and adding urgency to the search for export markets.

This greater emphasis on "foreign" markets is related to the increasing international scope of the industry's manufacturing operations which is one of the means that companies have used to supply international markets.

The two principal US producers, Ford and General Motors (GM), have had production operations throughout the world for many years, but typically these have tended to operate as individual stand-alone operations. More recently, though, many of these manufacturing operations have become organised on a regional basis - as seen, for example, in the formation of Ford of Europe. These regional facilities are now being integrated into global manufacturing operations. Again, Ford provides an interesting example with its Ford 2000 programme, whereby the company's North American and European operations are being merged into a single network as a first step towards establishing a completely integrated global network. Among other things, Ford 2000 and other globalisation moves have significant implications for model development programmes, component and systems procurement, and vehicle manufacturing locations.

For the past 20 years at least, Japanese vehicle producers have been to the fore in the development of global manufacturing networks through the establishment of so-called transplant operations in their major markets - initially in North America and subsequently in Western Europe. Typically, these produce models which are also assembled at facilities in Japan, albeit customised to accommodate local preferences. It is significant that Japanese vehicle producers have established design studios and R&D facilities in their major markets, thereby adding an important element of internationalisation to their operations.

In contrast, European producers have been noticeably more insular. However, this has changed recently due to two factors. First, the establishment of transplant operations in the US by BMW and Mercedes-Benz, with the likelihood that other marques will follow. Secondly, and more importantly, the increasing integration of European companies with the Big Three (Chrysler, Ford and GM). Clearly, the most significant recent development on this front has been the merger between Chrysler and Daimler-Benz in 1998 to form DaimlerChrysler, but there are other examples. GM has a 50% equity stake in Saab with an option to assume full ownership and has management control, while recent years have seen Ford acquire several European car marques including Aston Martin, Jaguar and Volvo.

American, European and Japanese vehicle manufacturers have invested in assembly facilities in emerging markets, either regionally (such as South America and South East Asia) or in individual countries which are regarded as having strong demand potential (such as South Africa and Turkey). The level of investment has tended to fluctuate according to prevailing economic conditions in these developing regions, but has remained at a high level recently notwithstanding the financial crisis which started in South East Asia during the second half of 1997 and subsequently spread to affect prospects in other developing regions.

In Brazil, for example, the vehicle manufacturing sector has seen substantial investment recently as car producers implement plans to establish production facilities in anticipation of an eventual rapid expansion of car demand in Brazil and neighbouring countries. Elsewhere American, European and Japanese car producers are establishing links and relationships with local companies and agencies in developing countries (such as China, India and South Africa) which offer the most promising prospects of long-term market growth.

At present, the one exception to this general rule whereby the worldwide automotive industry is being developed by one of the principal companies from the US, Europe or Japan arises over the position of the Korean motor industry. The Korean automotive industry has seen rapid expansion during the 1990s but has appeared increasingly vulnerable in the context of the latest economic downturn. A degree of restructuring has taken place which has resulted in the emergence of just two companies - Daewoo and Hyundai - both Korean owned and controlled. However, it is probable that the two will be drawn progressively into the wider manufacturing networks of the world's principal vehicle manufacturers.

Because of the need for scale, car manufacturing is experiencing a high degree of consolidation which is resulting in the establishment of a limited number of companies with worldwide operations. The extent to which this process of consolidation continues remains to be seen, but some analysts believe that worldwide car and light vehicle manufacturing will be controlled by between six and ten companies within the next two to three years.

Recent developments suggest that only five car manufacturing companies can be certain of long-term independence, these being DaimlerChrysler, Ford, General Motors (GM), Toyota and Volkswagen. This means that two will be American-based, two will be German-based and one will be Japanese-based. Already these companies embrace a wide and growing variety of marques - for example, recently Ford added the Volvo brand to its portfolio while Volkswagen has added Bentley and Lamborghini.

Of the remaining companies it is possible that Renault's recent alliance with Nissan forms the basis of another grouping, while other independent "survivors" may include Fiat and PSA Peugeot Citroën. With regard to Japanese companies, Honda appears well placed in manufacturing, technical and financial terms to maintain its global position. All other world car producers, though, will probably need to benefit from the economies of scale of a larger producer in order to achieve the manufacturing cost base and to secure the technological inputs which will be required to compete effectively in the international marketplace.

The positions of the individual marques are covered in greater detail in Chapter 10 "Profiles of Major Car Producers".

2.2 The changing structure of the automotive components industry

The automotive components industry has experienced considerable change during the 1990s. There are a variety of reasons for this, some of which relate to the process of vehicle industry globalisation referred to above.

In similar fashion to vehicle manufacturing, the production of components and systems is becoming increasingly consolidated into a limited number of companies with worldwide reach. These are typically referred to as Tier 1 companies which supply vehicle manufacturers directly with components and systems, and in turn are supplied by a wide variety of subcontractors or Tier 2 and Tier 3 companies.

At the same time, component and system producers are specialising in a limited number of products and divesting their more marginal activities. There are many examples of this trend, some of which are highlighted in Chapter 11 "Profiles of Major Suppliers of Plastic Components to the Car Industry".

An important factor behind rationalisation in the components industry arises over the growing technical complexity of components and systems, and the corresponding need to allocate a high level of financial resources towards research and development. It follows that the most successful component producers are those who have the necessary financial, technical and managerial muscle in the first place to assume a position of leadership in a product group, and then the necessary markets to ensure that these costs are spread over the highest possible volume of output.

Prevailing conditions have forced vehicle manufacturers to examine the strategic options for their own component manufacturing operations and implement some radical changes. This has had two main consequences: the divestment of marginal component manufacturing operations to independent producers; and the "ring-fencing" of major in-house facilities so that they enjoy a measure of independence, often as a prelude to full independence as in the case of GM's former components operation, Delphi.

A key characteristic in relationships between vehicle manufacturers and component suppliers during the 1990s has been a growing reliance of the former on the latter. Component suppliers have become much more involved in vehicle manufacturers' new model programmes which means that their role has evolved from being providers of parts which were produced to the vehicle manufacturers' drawings to becoming partners whose advice and guidance is critical in the design and development of new models. This development has been accompanied by the supply of bigger and bigger assemblies or modules, and the establishment of a supply base which is organised in Tiers, as noted above.

These changes have modified a number of the commercial relationships between component producers and their customers. For example, there has been a strong trend towards single sourcing, whereby the vehicle manufacturer's chosen development partners are rewarded with exclusive supply contracts for the life of the model.

Vehicle manufacturers' rising dependence on component and systems producers implies that making the right choice at an early stage in the product development programme is critical. Moreover, it has increased the chances of a reliable supplier continuing to retain the vehicle manufacturer's business for future models and thus has made it more difficult for other component companies to win new customers. Certainly, a potential new supplier needs to offer a convincing commercial and/or technological advantage, either through enhanced product features or manufacturing efficiencies.

There is now a greater emphasis on quality, including product quality and all aspects of the commercial relationship between vehicle manufacturers and component suppliers. Quality has become a critical factor for two main reasons: first, intense international competition in vehicle markets, not least from Japanese producers, has raised the expectations of consumers; and secondly, new technologies (such as new fuel injection techniques and the application of electronics) require high manufacturing standards and close tolerances. Parallel to this has been the ability to produce products to a consistently high standard due to advances in process technology, for example with regard to automation and measurement.

All of these developments have had a profound impact on companies which produce automotive components in plastics and composites and for system suppliers which use plastic and composite parts in their assemblies. In particular, the vehicle interiors sector has seen a high level of rationalisation as major Tier 1 groups such as Johnson Controls, Lear Corporation and Magna International have pursued a two-pronged strategy of acquiring independent and in-house seating operations and extending their expertise to other interior items such as floor coverings, door panels and headlining.

The time is fast approaching when a limited number of independent suppliers such as Lear and Magna are likely to win contracts to supply complete interiors for a model, with marked implications for the supply of plastic components. In this regard, an increasing number of plastic component producers which had direct relationships with vehicle manufacturers will have Tier 1 companies as their main customers.

It is interesting that the three groups referred to above are all based in North America but have developed extensive businesses in Europe and elsewhere. In Europe, the nearest competitor is Faurecia - the result of ECIA's friendly takeover of Bertrand Faure. However, the bias towards American control and ownership in Europe is a pronounced trend and has led to many takeovers of European plastic companies. Large European moulders, for example Peguform, have become subsidiaries of American parents (Venture Group).

As the worldwide automotive components sector continues to evolve, it is inevitable that a growing number of producers will lose their Tier 1 status while some will also lose their independence due to acquisitions. TRW's takeover of LucasVarity and United Technologies' divestment of its automotive interests to Lear Corporation provides an indication of the type of major moves which are likely to occur over the next two to three years, leading perhaps to no more than 50 or so global component groups controlling the supply of systems to vehicle manufacturers. In many cases, the production of plastics components will not be critical to the businesses of these companies, since the added value will come from the design, development, manufacture and supply of a complete system as opposed to the production of plastic parts.

For vehicle manufacturers, globalisation of the supply chain remains a key target and is another factor promoting the establishment of large component groups with international reach. The reduction in platform types within a vehicle manufacturer's range implies the ability to achieve substantial and growing economies of scale on a variety of fronts, including the supply of components.

Under these circumstances, it is anticipated that the main consideration will be the design and specification of the system rather than the materials used. As an example, Lear Corporation is claiming that it has developed a front seat set "Revolution", to fit a global platform in the 2001 model year. The system will use a large amount of polymeric materials to provide the necessary differentiation in models and markets, but the structural performance with respect to crash testing and other factors would be controlled through a set of common components and fixings to the platform. Such an approach logically leads to the incorporation of safety restraint systems within seats and points to the next integration step in the components sector.

2.3 The effects of developments in the structure of the automotive industry's supply chain on the plastics and composites sector

2.3.1 Economic units

In Europe and North America, the effect of the changes identified above are already being felt in vehicle manufacturers' supply chains. For a start, the importance of scale as a means of spreading R&D costs, raising manufacturing efficiencies and supporting customers in their international operations is paramount.

However, it would be premature to predict the end of the smaller injection moulding companies who currently supply car producers directly, although, more and more, it is likely that supply contracts will become less with the vehicle manufacturer and more with the Tier 1 and, possibly, Tier 2 suppliers. As changes in moulding technology enable the larger groups to manufacture limited volumes of small parts on small machines in the same production environment as manufacturing a large series of bumpers and other major parts, there is clearly a danger that the smaller moulding companies will be squeezed, especially in European and American markets. It is not certain, though, whether this trend will be quite so apparent in the Japanese and other Asian markets.

The plastics sector is not immune to the need for scale and focus mentioned earlier in this section. United Technologies' divestment of its automotive interests has already been covered, but there have been other significant moves too. A good example in the plastics industry is seen in Plastic Omnium, committed, according to its corporate strategy, to leadership across its entire business base, but agreeing to sell its automotive interiors division to Ford's components group, Visteon. This was seen as a necessary condition of securing the long-term future of its automotive fuel systems and non-automotive businesses.

Order sizes for plastic components are likely to rise noticeably in the context of the development of world vehicle platforms. As an example, a bumper system applied to a worldwide platform will be required in high volume at a number of widespread assembly sites, which implies the need to manufacture the system in more than a single location. This will require a considerable commitment on the part of the systems supplier, not least in allocating sufficient funds to support the manufacturing network. Investment in plant, quality and commercial systems to support the contract, will of course vary, but typically is likely to be around the $100m level for each product. It is difficult to see how the smaller independent businesses will be able to raise the necessary funds. An increasing number of them are set to be taken over by stronger and larger competitors as system development costs are pushed down from car producers to the supply chain in return for the guarantee of a long-term, single sourced contract.

The composites sector, though, has remained remarkably free from this trend towards globalisation. The various SMC and GMT moulders (Menzolit Fibron, Mitras, Polynorm) each have their respective partners within the US industrial base (Cambridge Industries, Budd and Continental Structural Plastics respectively) but none has an Asian counterpart, perhaps because composites are not as fully developed in the Asian vehicle sector as in North America and Europe.

2.3.2 Raw materials supply chain

The raw materials supply chain is undergoing rationalisation, leading to a reduced number of plastics suppliers who produce products focused on the automotive industry. BASF, Bayer, GEP, DSM, Montell, DuPont, Mitsubishi and Dow are the leaders in the supply of injection moulding materials.

The costs of developing new polymers suitable for automotive applications are extremely high, while the lack of profitability of existing materials is resulting in an increasing number of joint ventures - for example, the Bayer/GEP Exatec product range for automotive glazing applications.

Global sourcing of identical products from regional supply bases will become a major issue, since tooling will be manufactured using the highest level of CAD/CAM technologies and there will be a need for global quality standards of properties and moulding parameters.

In some cases the same model is being produced in various world locations. For example, the Mercedes-Benz A-class is manufactured in both Germany and Brazil and, although many of the components are moulded in Brazil, they are being produced from European-sourced raw materials to enable product quality to be of the highest reproducible standard.

The composites sector provides some interesting challenges, particularly in respect of SMC, GMT and RTM materials. Many of these newer materials are not being included in car manufacturers' databases of raw materials because design, raw materials selection and technology are now being delegated progressively to the car industry's suppliers.

This means that raw materials suppliers have to focus their efforts on the Tier 1 component supply industry. It should not be assumed that these companies are necessarily enthusiastic about using plastics, particularly in structural components. There has been growing interest recently in magnesium and, although the main competitor for the plastics industry has been steel, this is changing. Aluminium and magnesium are now major competitors and substitution of materials is possible.

2.3.3 Location

The establishment of new car plants in the developed markets of North America and Europe is not common, but also not unknown. Japanese investment has been a principal factor in adding vehicle manufacturing capacity in both regions and continues to do so. For example, Toyota's car manufacturing facility in France is scheduled to come on stream in 2000, and it is possible that Korean car producers will set up in Europe once their domestic operations regain stability after the effects of the economic downturn in South East Asia.

In Japan, there is a high level of overcapacity in car manufacturing at present due to weak domestic demand and less promising conditions in some export markets. As a result, some plant rationalisation is expected in the short to medium term. Nissan, in particular, is likely to feel the effect of rationalisation moves following the purchase by Renault of a substantial equity stake and subsequent review of its operations. This has indicated that plant closures and substantial job losses in Japan will be necessary in order to restore financial equilibrium.

Elsewhere, the potential for establishing new car assembly facilities is strong due to the high level of latent demand, although the pattern of expansion is likely to be bumpy. The setback in the world economy during the past two years has acted as a brake on the expansion plans of major producers, especially in South America and South East Asia.

In all cases where new car manufacturing investment is being made, there is a corresponding expansion of the components industry involving Tier 1 suppliers and their subcontractors, although many of the latter may well be locally based.

With regard to components produced from plastics and composites, new manufacturing locations are becoming a feature of the growth of supplier parks linked to, or in partnership with, Tier 1 suppliers. Just-in-time and sequential delivery, together with electronic data interchange (EDI), are important in these types of operations. Standardisation of EDI is advancing rapidly and the lower tier suppliers are able to implement this just as easily as the larger companies, enabling them to be located separately from their Tier 1 customers.

3 Plastics and Reinforcements used in Automobile Construction

This chapter describes the properties and uses of the polymers that are used in different areas of the vehicle. It does not attempt to provide full details of their chemical composition or methods of manufacture.

3.1 Thermoplastics

3.1.1 Polyolefins

Polyethylene (PE)

Polyethylene is a polymer produced from ethylene monomer in three basic forms:

1) Low Density PE or LDPE

2) Linear Low Density PE or LLDPE

3) High Density PE or HDPE

The polyethylenes can be modified by a wide range of additives, like fillers, glass fibres, crosslinking agents, certain rubbers and can be copolymerised with propylene, butene, hexene or octene to obtain certain characteristics.

The polymers can be injection moulded, extruded in film or sheet, blow moulded, rotational moulded and foamed after extrusion.

In automotive applications HDPE is used nearly exclusively because it is cheap, and has good chemical and impact resistance with a fair stiffness.

The dominant application is for blow-moulded fuel tanks, made from high molecular weight HDPE, as well as the fuel inlet piping. To reduce the penetration of fuel constituents through the PE wall the inner surface is fluorinated by fluorine gas. Barrier layers are increasingly used, to meet higher fuel emission specifications.

A further application is wheel-arch linings, but no specific requirements are needed. Recyclate could be used to mould or extrude sheet for this application. Some extruded and crosslinked PE foam is used in doors as watershields and in car boots as liners.

Metallocene polyethylenes (indicated as mPE) are a new technology based mainly upon Zirconium catalysts, replacing the usual Ziegler catalysts and having a much higher efficiency. They give highly stereospecific polymers and very regular copolymers, with narrow molecular weight distribution. An interesting spin-off is the group of so-called "plastomers", a regular copolymer of ethylene with octene-1, proposed for impact modification of PP, for example, for bumpers.

The important PE producers are: Borealis, BP Amoco, Chevron, Dow Chemical, DSM, Equistar, Elenac, Exxon, Mobil, Polimeri Europa, Fina, Sabic, Repsol Quimica, Japan Polychem, Sumitomo and Targor.

Polypropylene (PP)

Polypropylene has propylene monomer as the basic building block, produced with Ziegler-Natta catalysts, and is therefore more heat-resistant than polyethylene. This and the low cost, good modulus and the possibility to make a range of variations, makes PP a useful polymer in automotive applications.

PP is made in many forms: homopolymer, copolymer with ethylene, or homo- or copolymer blended with EPDM, to improve substantially low temperature impact resistance (also called TPE-O or TPO, when at higher levels of EPDM elastomeric properties appear). A new development is R-TPO or Reactor produced TPO, produced during polymerisation and reducing cost of manufacturing cost.

The fast growth of PP polymers in car applications was initially due to the development of suitable blends of PP+EPDM for bumpers, spoilers and exterior trim. Moulded parts need a flame treatment on the surface to facilitate paint adhesion by oxidising the surface, but new grades are claimed to make this superfluous. This is a key factor in the battle for market share with PC/PBT alloys also used for bumpers (for example, Ford) and which are directly paintable. Grades are available containing a small percentage of a mineral to improve dimensional stability of the bumpers. For instance, the VW Passat B5 and the Golf 4 have bumpers in PP+EPDM+10% filler.

Technology for moulding PP in thin sections for bumpers restores the price advantage.

Soft TPOs are calendered to a foil which is used as a skin for dashboards and other interior trim. Often painting may be necessary to improve scratch resistance (for example, Porsche Boxster). It is very important that such TPO skins exhibit very low "fogging values", the propensity to emit organic volatiles which condense on, for example, the windscreen, compared to PVC, PVC/ABS blends and polyurethanes. Companies calendering TPO foils include Gislaved (Sweden), Benecke-Kaliko and Alkor (Germany) and TMG (Portugal). Lamination with extruded OPP foam is also performed.

Some car producers favour an "all PP" approach, which means, dashboard rigid parts in talcum filled PP, covered by PP foam and a TPO skin on top, and the same for door panels. This would facilitate recycling to meet forthcoming legislation. As an example, for the new Honda Accord, PVC skin was replaced by TPO, and ABS mouldings by PP ones, which contributes to a claimed 90% recyclability, an improvement of 5% on the previous model.

Recent developments: "High Melt Strength" (HMS) PP, having a highly branched PP chain, which improves foaming, extrusion and blow moulding, has been developed by Montell.

Grafts of styrene or methylmethacrylate monomers onto polypropylene have been developed by the same company, marketed under the name of Hivalloy, rigid, high impact thermoplastics proposed for exterior applications and competing with engineering plastics.

Metallocene PP (mPP) will not have as rapid a development as metallocene PE, but new products are syndiotactic PP, EPR and EPDM rubbers and highly isotactic PP, with a high melting point.

A recent development is Highly Crystalline PP (HCPP) which, due to a high level of crystallisation, exhibits improved stiffness, heat resistance and scratch resistance, and can substitute 10-15% mineral filled PP compounds with the advantage of lower density and better surface aesthetics. VW Golf 4 and the new Passat B5 have A, B, C pillars moulded in HCPP. Both cars also have the rear door with a 1200 gram HCPP cover.

Energy Absorbing PP foam (EA EPP) has grown in automotive use by 20-25% per year during the past few years. It consists of Expanded PP beads or pellets which are subsequently sintered in a mould with live steam to the required part. Particularly, bumper beam cores (inside the PP+EPDM bumper shell) was and is rapidly introduced. This is also used as EA foam blocks in the doors in order to absorb part of the collision energy in case of a side impact. Other applications are sunvisors, kneebolsters, instrument panels, head rests and children's seats.

Important particle foam producers are: Fagerdala/Gefinex in Sweden, Germany and Belgium, Kaneka in Belgium, JSP in France, BASF and Montell in Germany.

Extruded PP and PE foam sheets are used in doors as watershields substituting simple PP film, and as a bootliner. Producers include Sekisui in the Netherlands, Troplast in Germany, Toray in Japan, Zotefoams in the UK.

Major PP producers include BP Amoco, Montell, Targor, Borealis, DSM, Elf/Total Fina, Exxon, Huntsman, Solvay, Mitsui and Japan Polychem.

3.1.2 Polyvinyl chloride (PVC)

Polyvinyl chloride (PVC) is made from vinyl chloride monomer and has become the second largest of the commodity plastics materials after polyethylene. However, PVC is rather unstable against heat and starts to degrade at temperatures above 150°C. PVC is a hard rigid polymer and must be compounded to give flexibility by the addition of 10-50% plasticiser. Stabilisers must also be added as well as lubricants to facilitate processing.

The advantages of PVC are excellent price/property ratio, considerable versatility and inherent flame retardancy due to the presence of 55% chlorine in the molecule.

There are a number of comparatively old established applications of flexible PVC in cars, notwithstanding environmental and health protests against PVC, particularly in North America and Western Europe.

PVC will continue to be used until such time as more satisfactory alternative cost effective material solutions can be found.

A major use for PVC in car interiors is for the instrument panel cover. Traditionally in the form of a calendered sheet when blended with ABS, this skin is usually backed with a polyurethane foam and gives the required feel, appearance and energy absorbing properties. More recently, the PVC slush moulding process has been adopted to give a softer and more luxurious feel to instrument panel covers in more expensive cars with higher trim levels.

Plasticised PVC compounds are established for sheathing of electrical wiring, mainly because of their flame retardancy. There are a number of different temperature level requirements according to the location of the wiring in the vehicle. These are covered by ISO 6722 with an overall temperature range of −40 to 200°C. PVC can only be used in the lower temperature classes of −40 to 125°C.

At present the German DIN 72551 standard for thin walled vehicle wiring of PVC (sheathing) cannot be met by polyolefin based compounds (PE or PP) containing high loadings of aluminium or magnesium hydroxide as flame retardant additives.

Extruded PVC sealing strips are established in use for some types of window seals and for sunroof seals. Extruded or moulded strips are used for body side protection.

PVC compounds are applied to the underside of cars and related vehicles in the form of a spray and are sintered by heating in the paint ovens. Their function is to underseal the car in order to prevent rust by the action, particularly, of road salt and by damage from other road debris.

The attitude towards the use of PVC among car makers is divided. Some like Opel and DaimlerChrysler put out a policy of maximum recycling and have made some headway in replacing PVC in, for example, instrument panel skins where calendered ASA sheet is used in the Mercedes S-class and TPO foil is used in the Opel Vectra. Others, including Audi and the latest Volkswagen models, have instrument panel skins made from slush moulded plasticised PVC.

As already noted, there are of course environmental and health protests against PVC, particularly in North America and Western Europe. The European End of Life (ELV) vehicle directive EC 31/7/96 includes a demand for dispensing entirely with PVC in the vehicle. This was intended to apply to all vehicles produced in 2002 onwards. At the time of writing, however, it is understood that PVC is unlikely to be affected.

Major Western PVC suppliers include Aiscondel, BASF (joint venture with Solvay), Cires, Elf Atochem, EVC, Geon, Goodrich, Goodyear, LVM, Norsk Hydro, Occidental, Oxychem, Rovin/Shell (Shin-Etsu), Solvay, Trikem, Vestolit and Vinnolit.

Japanese PVC suppliers include Dai-Ichi, Hanwha, Kanegafuchi, LG, Shin-Etsu and Zeon.

Other PVC suppliers in the Asian region include Hanwha in Taiwan and Lucky Goldstar in South Korea.

3.1.3 Styrene-based thermoplastics

Polystyrene (PS)

Polystyrene is produced in two basic forms: amorphous crystal (clear) PS (used mainly in packaging) and the impact-modified version, amorphous High Impact PS (HIPS) used for consumer electronics and packaging. Expandable PS (EPS) is used mainly in building and construction as well as packaging, but some EPS is used in car roofliners. Very little PS is used in cars mainly due to a lack of chemical resistance: there is a high propensity to "chemical stress cracking".

Major PS producers are: Asahi Chemical, BASF, BP Amoco, Chi Mei, Dow Chemical, Elf Atochem, Enichem, Fina, Nova/Huntsman.

Acrylonitrile-butadiene-styrene graft copolymers (ABS)

ABS is a group of copolymers in which styrene and acrylonitrile monomers are grafted onto polybutadiene rubber particles. For high temperature car applications, a methyl styrene-acrylonitrile copolymer is introduced. The rubber component imparts high impact strength, while the acrylonitrile gives resistance to chemical stress-cracking. Due to the polybutadiene component, the UV resistance is not very good. ABS has traditionally been used in a number of car interior applications such as the rigid parts of instrument panels and doors, consoles, glove boxes, HVAC parts and loudspeaker housings. It is also used in chrome-plated parts. For exterior applications such as radiator grilles, wheel covers, mirrors and rear light housings, painting is necessary unless the colour is dark grey, black or the part is chrome-plated. PP, ABS/PC and PPO/HIPS blends have made inroads however in these applications. ABS at about 30% rubber is still being used as a component of PVC/ABS calendered sheet for doorpanels and IP skins.

ABS/PC blends offer high impact with high heat distortion temperatures and have been used in car applications for around two decades. Applications include consoles, IP parts, HVAC parts, pillar trim. The IP of the Audi A4 is in ABS/PC/GF. The Jeep Cherokee has an IP in straight ABS/PC. The BMW 3 series and the M Coupé have several parts in chrome-plated ABS/PC, including outside door grips. They are also being considered for structural parts such as a plastic cross-car beam.

Suppliers of ABS/PC blends include BASF, Bayer, General Electric Plastics, Dow Chemical, DSM, Enichem and compounders.

ABS/PA: Audi S4 has a 3 kg bumper in Stapron N, a PA/ABS blend from DSM.

Coextruded PMMA/ABS sheet is used for body panels of some small volume electric cars like Ligier and Hotzenblitz. Thicknesses are 2.5 and 3 mm and represent a 40-50% weight reduction over 0.7 mm steel sheet. Painting is not necessary: the PMMA top part is coloured and UV resistant. The sheet is produced by Senoplast, Austria.

Producers of ABS polymers: Asahi, BASF, Bayer, Chi Mei, Dow Chemical, DSM, Enichem, GE Plastics, Japan Technopolymer, LG Chemical, Mitsubishi Rayon, Toray. BASF is acquiring DSM's ABS operations.

Acrylonitrile-styrene-acrylate graft copolymers (ASA)

These represent a variation of ABS in that the polybutadiene part is substituted by more UV resistant polybutylacrylate rubber. The UV resistance is markedly improved so that these polymers are used in exterior applications like radiator grilles and there is growing interest for internal applications. ASA calendered sheet is used by Mercedes-Benz as IP skin material. It is also used instead of ABS in calendered PVC/ASA sheet for similar applications, but the use is limited since the butylacrylate rubber does not have the low temperature impact strength of polybutadiene.

The Opel Astra features either a lacquered outside mirror in ABS or a plain one in ASA. In addition, this model's radiator grille is in ASA. The Ford Puma has a grille in ASA.

Blends of ASA include ASA/PBT (for example, Ultradur S from BASF) which is recommended for boxes for electronics and connectors. Several companies offer also ASA/PC blends, which are more UV resistant than ABS/PC.

Suppliers include GE Plastics, BASF and Bayer.

Styrene-acrylonitrile copolymer (SAN)

This is an amorphous transparent polymer with good chemical stress cracking resistance but low impact strength and is a precursor of ABS and ASA via blending. The automotive applications are limited to instrument covers and knobs because the material is too brittle. Most ABS producers also sell SAN.

Styrene-maleic anhydride copolymers (SMA)

The maleic anhydride monomer imparts better heat resistance than normal polystyrenes and, to improve this further, 10-30% glass fibre is added. The resultant product is still too brittle for most car applications and is therefore rubber modified. In the USA, SMA is used extensively in instrument panels, but to a lesser extent in Europe. Opel Omega, Sintra and Vectra have SMA IPs covered with PUR foam and skin. BMW's 3 and 5 series models have similar IPs, as does the Fiat Coupé. The VW Passat Variant has an IP in SMA covered by a slush-moulded PVC skin.

The producers are Bayer (Cadon) and Nova Chemicals (Dylark).

3.1.4 Polyamides (PA)

The main types available and used in cars are PA6 and PA66, with a relative newcomer PA46. PA11 and PA12 are used for fuel lines and pneumatic tubing of trucks. PA6, PA66 and PA46 are hygroscopic and therefore absorb moisture and need to be carefully dried before processing to avoid degradation. They have relatively low heat distortion temperatures under load, but this improves markedly by adding 10-50% glass fibre or a mixture of glass fibres with mineral fillers. Polyamides are semi-crystalline, and glass-reinforced mouldings tend to suffer from anisotropy and warpage. BASF claims to have modified the molecule, reducing the hygroscopy as well, and markets low warpage Ultramid grades.

PA46 is somewhat more expensive but has higher heat distortion temperatures (the GFR versions) than 6 and 66 and is used under the bonnet, where heat is a problem. DSM is the only producer (Stanyl 46). High stiffness is maintained at temperatures of 150-160°C which is important for applications close to the engine. Examples are the electronics components including sensors, connectors and switches which are all used under the bonnet.

A rapid increase in quantities of PAs used has occurred during the last three years, due to the development of engine covers and air inlet manifolds in reinforced PAs, saving up to 50% weight, and there are cost savings too. Used in 40-45% of new models on average, this could rise to 70% by 2000.

The R&D co-operation between GE Plastics and BASF resulted in PPE/PA blends with higher heat resistance than up to now possible. These products are used for applications such as fenders and can be painted "in line" resisting around 170°C oven temperatures. (See under PPE.)

PA11 is much less hygroscopic and, with PA12, more expensive than the other PAs, but with better low temperature impact strength and good chemical resistance. The polymer is used in its unfilled form, but often lightly plasticised for fuel lines and filters, and pneumatic tubing of trucks.

PA12 is a similar product to PA11, but produced from laurylactam, with slightly lower modulus and tensile strength.

PA12 is also used for fuel lines, filters and pneumatic tubing, often because of the high price and monopolistic situation of PA11. PA11 and 12 have good resistance to zinc chloride, formed from the action between the zinc coated steel plate and roadsalt under winter driving conditions.

Producers of PA12 are Elf Atochem (which produces PA11 too), Ems-Chemie, Hüls and Ube.

Producers of PA6 and 66 are: Allied Signal, BASF, Bayer, DSM, DuPont, Ems Chemie, Radici, Rhodia (Nyltech), Ube.

Aromatic Polyamides, like Kevlar from DuPont and Twaron sold by Akzo Nobel are not used on their own in car applications because they are too expensive and are mainly used in fibre form. However, high performance tyres may contain these fibres.

3.1.5 Polyurethanes (PUR)

Polyurethanes (used mainly in foam form) are generally classified as thermosets. A thermoplastic version is TPE-U, or TPU: thermoplastic polyurethane. (See under Thermoplastic elastomers.)

3.1.6 Thermoplastic polyesters

Polybutylene terephthalate (PBT)

PBT is a product of polyester fibres production, and came on the market at the end of the 1970s. It is a semi-crystalline product with, like PA, a high melting point but low heat distortion temperature under load (HDT). This, as well as the modulus, is improved by adding glass fibres and therefore most PBT is used with reinforcement. Because of the good electrical properties, PBT GF is used for electrical connectors, not only in consumer electronics, but increasingly also in cars. An example is the relay boxes of the VW Sharan, Ford Galaxy, and Seat Alhambra made in PBT GF10, from DSM. It has substituted nylons in some applications such as door handles and sunroof trim.

With glass fibre contents of above 20%, surface defects on the mouldings can appear which have inhibited the use for visible applications. BASF claims to have made improved Ultradur grades (B 4040 G2-G10) for exterior applications like mirror housings, windscreen wipers and door handles. The rather low impact resistance can be improved by adding a TPE-E or MBS type impact modifier.

Blends with PC offer higher impact resistance and are finding substantial markets in bumpers in competition with PP/EPDM (+10% filler); the advantage being the good paintability and shorter moulding cycles offsetting the higher polymer price. They also show some potential for body panels. The body panels of the MCC Smart car are made in self-coloured PC/PBT and laminated to a thin layer of UV resistant PMMA.

PBT producers are: BASF, Bayer, DSM, DuPont, GE Plastics, Hüls, P-Group, Ticona; BASF and GEP also have a joint 60,000 tonne plant in Germany. BASF markets a PBT/ASA blend under the name of Ultradur S. Japanese producers include Dainippon, Mitsubishi, Teijin, Toray, Toyobo.

A spin-off of PBT production are the polyester elastomers or TPE-Es which are produced in the polyester-ester form or polyether-ester form (see under Thermoplastic elastomers).

Polyethyleneterephthalate (PET)

Sizeable quantities of PET are used in cars in the form of polyester textiles as seat covers or laminated to rigid plastic parts. These applications will not be discussed. Besides the second large application, bottles for soft drinks, smaller amounts of PET are used for injection moulding parts for cars. Like PBT and polyamides the heat distortion under load improves substantially when reinforced with glass fibre and/or mineral filler. GFR PETs are hard, rigid products with good electrical properties and are therefore used in electronic and electrical systems like coil caps, relay bases, light housings. To facilitate crystallisation, and therefore reduce injection moulding cycle times, nucleating agents need to be added. An interesting development is Chrysler's Composite Concept Vehicle (CCV) with bodypanels in Impet, impact modified PET from Ticona.

Stapron E is a PET/PC alloy of DSM with high toughness and is promoted for car interior parts.

PETG is an amorphous PET copolymer produced by Eastman for transparent sheet extrusion. Car usage is not known.

Polytrimethyleneterephthalate (PTT)

This is an "improved" polyester, marketed by Shell Chemicals in trial quantities, also including automotive applications.

Polyethylenenaphthalate (PEN)

This is also an "improved" polyester, premarketed by Shell Chemicals, characterised by a high T_g temperature of 124°C against 80°C for PET, and very low permeability to gases like oxygen. Availability has been limited due to shortage of napthalene dicarboxylic acid (made by BP Amoco). When the product becomes cheaper with time and greater quantities are sold the high heat resistance could be interesting for under bonnet parts.

Liquid crystal polymers (LCP)

This is a group of aromatic polyesters in which the molecular chain has become more rigid and therefore LCPs (especially glass reinforced grades) exhibit high heat resistance. They can resist continuous temperatures of up to 240°C. LCPs exhibit low melt viscosities and can therefore easily be moulded into thin-wall components at melt temperatures above 300°C and with very short cycle times.

The high price inhibits more use in cars. Some expensive cars with high energy discharge lamps have LCP lampholders. A further application is in connectors and other electronics components.

Producers include: BP Amoco (Xydar), DuPont (Zenite), Eastman (Thermx LCP), Sumitomo and Sumikasuper, Ticona (Vectra). Nearly all plants are in the USA. Ticona also has LCP/PC blends in the product range.

3.1.7 Polyacetal (POM)

Polyacetal is supplied in two basic forms: homo- and copolymers. The copolymers are thermally more stable, POM has excellent tribological properties and is therefore used for gears. It has a spring quality which makes it useful for clips. Resistance to strong acids and alkalis is rather poor but resistance is good to car fuels, finding uses in injection moulded parts in the fuel system such as pump housings and sensor parts.

The Fiat Coupé and Palio, as well as Lancia Delta HF, have a 3.5 litre fuel expansion container in POM, moulded in two parts and hotplate welded together. The Mercedes C-class has a reservoir in POM copolymer components as well as the fuel pump. Audi has a POM fuel level indicator.

A new application in the USA is ORVR (On-board Refuelling Vapor Recovery) valves, which trap petrol vapours during refuelling. ORVR valves will be required on 80% of 1999 models and on all cars in 2000. After 2000, light trucks are also required to have these. POM has been chosen for most of the parts, although aliphatic polyketones are also used. Grades of POM with improved UV resistance and/or impact modified grades are suitable for exterior applications, such as door handles. The Fiat Punto has a tank cap in special UV-stabilised POM.

Major producers of Acetals (POM) include Asahi, BASF, DuPont and Ticona.

3.1.8 Polyphenylene ether (PPE)

This polymer is often described as Polyphenylene Oxide (PPO), but it is an ether compound and, according to the ISO standard, should be abbreviated PPE.

The base polymer has a high temperature resistance and is very difficult to mould in the semi molten state. GE Plastics developed a special compounding technique to blend PPE with high impact polystyrene (HIPS), in order to get a mouldable compound, usually abbreviated PPE/HIPS or PPE/PS. Much of the available production capacity is used for car applications, mainly instrument panel carriers in 10% or 13% glass fibre reinforced versions.

The VW Golf 4 has the IP rigid part in PPE/PS, covered with a PVC slush moulded skin. The latest Toyota Previa model, an MPV, has a large dashboard in PPE/PS as well as interior trim parts (chosen because of its heat distortion temperature of 118°C, necessary because of the flat windscreen). It is claimed that using PPE/PS for the dashboard of the Nissan "Pintara" a higher productivity could be obtained than with GF PP.

PPE/PS cannot be used for external applications unless painted because of its limited resistance to UV rays.

GE Plastics and Shell developed a very low density, closed cell, energy absorbing foam called CARIL, based on PPE/PS. It is supplied as beads and is moulded by steam chest moulding, similar to EA PP. Applications in continuing development include instrument panels, kneebolsters, energy absorbing door pads. The product is claimed to offer higher heat resistance and rigidity than expanded polypropylene (EA PP).

A new development in the last few years, with good potential, is a blend of PPE with Polyamide (PA) indicated as PPE/PA blends. These have still higher heat resistance and external body parts can be painted "on line" resisting paint drying oven temperatures of 170°C. GE Plastics markets these products under the name of Noryl GTX. Main applications at present are for fenders. The latest GM Saturn has fenders in GTX as well as the Nissan Figaro and some versions of The Renault Clio. The Clio fender, 2 mm thick, weighs only 850 grams against 2000 grams for a steel one. The Renault Mégane Scenic has front fenders in Noryl GTX 974, an inherently conductive polymer developed for electrostatic coating. A weight reduction of 3.2 kg per car is claimed, with resistance to minor impacts as well as greater design freedom.

The latest example is the fenders of Volkswagen's new Beetle, produced in Mexico, made in Noryl GTX 964 by Plastic Omnium and integrated with the TPO bumper. An exciting front design was possible using PPE/PS. The new Mercedes A-class has both fenders and tailgate in PPE/PS.

Development efforts are geared towards blends with even higher heat resistance (up to 190°C), than present GTX 964 and 974.

Producers of PPE blends are GE Plastics in the USA and Netherlands, and also Mitsubishi and Asahi in Japan. Technical compounders such as Lati SpA, LNP Engineering Plastics, Schulman and Victor International also supply these compounds for the automotive industry.

3.1.9 Thermoplastic elastomers (TPEs)

TPEs are a relatively new group of polymers which can be processed like thermoplastics but have rubbery properties. Depending on their precise formulation, TPEs can behave like plastics or like rubbers. For the purposes of this report only TPEs whose behaviour approximates to that of plastics are examined.

TPE polymers can be injection moulded, extruded into profiles, extrusion blow moulded or calendered into foil. The average quantity of TPE used per car is currently around 8-10kg.

In principle, there are two different types: blends of plastic and rubber like PP+EPDM and NBR/PVC; and block copolymers.

A development during the past five to six years has been the production of TPE foam profiles by means of nitrogen gas or water vapour as blowing agents. Interesting car applications are now being realised.

The main types of TPE polymers are presented in Table 3.1 while some of their properties are listed in Table 3.2.

Table 3.1 Types of thermoplastic elastomers

TPE group	Polymer	Abbreviation to ISO 472
Blends of a rigid plastic with a rubber	1. EPDM rubber with PP	TPE-O (or TPO)
	2. Reactor modified PP	R-TPE-O (or R-TPO)
	3. With vulcanised EPDM or butyl rubber in PP	TPE-V
	4. NBR rubber with PVC	
Block copolymers	1. Styrene-butadiene-styrene	TPE-S (or SBS)
	2. Styrene-ethylene-butylene-styrene	TPES SEBS
	3. Copolyesters	TPE-E (or COPE)
	4. Copolyamides	TPE-A (or COPA)
	5. Thermoplastic polyurethanes	TPE-U

Table 3.2 Some properties of TPE polymers

TPE group	Density (g/cm^3)	Hardness, Shore	Temperature (°C)	Price range ($/kg)
TPE-O	0.89–1.0	50A–75D	−60 to 120	1.5–3.5
TPE-V	0.9–1.0	40A–50D	−60 to 135	3.0–6.0
TPE-S	0.9–1.2	10A–75D	−70 to 100	1.5–5.5
TPE-E	1.1–1.4	35D–80D	−65 to 150	5.0–7.0
TPE-A	1.0–1.2	35D–70D	−40 to 170	6.0–10.0
TPE-U	1.1–1.25	70A–90D	−50 to 135	5.0–7.0

Notes: The temperature column presents a working range suitable for the polymers indicated. The price range is indicative and depends on polymer structure, quantities and other factors.

Thermoplastic polyolefin elastomer (TPE-O)

This is a blend of PP, homo- or copolymer with EPDM rubber. Latest developments are the reactor copolymerised polymers whereby the rubber part is chemically linked to the PP molecules during the polymerisation phase. The products are also called R-TPOs. This gives a substantial cost reduction over the compounded blends.

The products have very good impact strength and can be injection moulded into car bumpers, exterior trim or calendered into foil for instrument panel skins and door covers. TPE-O foil is often laminated to an extruded PP foam layer for car interior applications. Simple heating of both layers can provide a bond. For adhesion with PUR foams, the surface of the foil needs treatment by corona discharge or flame treatment. Polypropylene producers are trying to produce "paintable" TPE-O polymers by incorporating polar groups into the structure, which means that the moulded products do not need a surface treatment for obtaining a good adhesion. The pretreatment is rather costly.

New blends with polyethylene-octene-1 coploymers have been developed and are being produced by DuPont Dow Elastomers. These copolymers are made by the Insite metallocene catalyst and process technology. The higher the octene-1 level, the more elastomeric the product. Interest has been found in the automotive wire and cable industry.

Thermoplastic polyolefin vulcanisates (TPE-V)

In thermoplastic polyolefin vulcanisates the rubbery EPDM part is partly or fully cured or vulcanised during the compounding step. This gives an improvement in chemical heat and light resistance and in creep behaviour. TPE-V is used for corners in window encapsulation. Expanded TPE-V, with densities as low as 0.2 kg/m^3, is produced by proprietary processes involving, for instance, injecting steam in the polymer melt or by decomposition of water releasing compounds during extrusion on a single screw machine. Technology is available from AES/Berstorf and DSM. An oil resistant TPE-V for under-the-bonnet applications is a blend of crosslinked butylacrylate rubber with PP offered by some compounders.

Suppliers of TPE-V are AES, DSM, Uniroyal and Mitsui, while suppliers of TPE-O include nearly all PP and EPDM producers such as AES, Borealis, Chisso Corp, DSM, Elenac, Enichem, Exxon, Mitsui Chemicals, Montell, Nippon Petrochemicals, Solvay Engineered Polymers, Targor, Union Carbide and a number of qualified compounding companies.

Thermoplastic polyester elastomers (TPE-E)

These are based on PBT molecules with blocks of either polyester or polyethers attached. The product can be made in PBT or PET autoclaves or reactors, and the producers are therefore the PBT manufacturers. The polyester TPE-E is less stable towards hydrolysis, but has a good adhesion to polar plastics such as ABS, PMMA and PC, an important feature when overmoulding a soft TPE-E over a plastic.

Shore hardness range from 35–72.

This class of polymers is growing quickly in terms of the quantity used and is finding increasing applications in cars. TPE-E is being used in airbag doors and door grips where, in the latter, a combination of TPE-E and PBT gives rigidity and soft touch. This also applies to the use of TPE-E in integrated injection and blow moulding for ducting and other parts of car heating, ventilating and air conditioning systems.

Another major application for TPE-E is in CVJ boots where it substitutes for polychloroprene elastomer.

Producers include DSM, DuPont Dow Elastomers, Eastman, Goodyear, P-Group, Ticona, Toyobo and compounding companies.

Styrene block copolymers (TPE-S)

These consist of polystyrene blocks connected by polybutadiene, polyisoprene or ethylene-butylene rubber, and referred to as SBS, SIS and SEBS respectively. Most automotive applications substitute for rubbers, but TPE-S has also been used for bumper strips, sun visors and airbag doors.

Producers include BASF, Chi Mci, Dexco (Dow/Exxon), Enichem, Fina, LVM, Kuraray, Nippon Zeon, Shell Chemicals and compounders.

Thermoplastic copolyamide elastomer (TPE-A)

This group of products is based on a polyamide 6 or 12 structure with extension of the PA molecules with polyether blocks. The PA 12 based products are also called polyether block amides.

The polymers have good resistance to oils and hydrocarbons and to ageing at elevated temperatures. In the automotive sector, they are promoted for applications such as airbag covers and under-the-bonnet components.

The producers are Elf Atochem, Ems Chemie, Creanova, DuPont Dow Elastomers and UBE industries.

Thermoplastic polyurethanes (TPE-U)

This is a group of non-crosslinked polyurethanes, mostly based on a light stable isocyanate like hexamethylene diisocyanate (HMDT). This means the polymers can be used for exterior applications. There are two different types: those with a polyester basis and those with polyether blocks in the molecule.

In general, the polyester based products have better physical properties but are prone to hydrolysis, whereas the polyether types are less water resistant. Both are tough and very wear and tear resistant. They are used for bumpers, grilles, body panels, fascias and rocker panels.

An important development in the automotive sector is the use of TPE-U for slush moulded skins for instrument panels. These are produced by Textron Automotive Co and Benecke-Kaliko (Germany) for 1999 models of Chrysler and Ford/Jaguar respectively. It is claimed that TPE-U skins have exceptionally low temperature toughness, making them suitable for airbag doors as well.

The fogging problem appears to have been solved. Although TPE-U is around three times the price per kg of PVC skins, a large cost saving is obtained by not having to make a separate airbag door.

Producers include Elastogran (BASF), Bayer, Dow Chemical, BF Goodrich, Merquinsa and Morton Int.

3.1.10 Fluoropolymers

Polytetrafluorethylene (PTFE)

PTFE, commonly called "Teflon", is the polymer of tetrafluorethylene and consists of only carbon-fluor bonds. This gives the polymer its unique properties: a very low surface friction coefficient, very good heat and chemical resistance, and an excellent electrical insulator with low dielectric loss factor. PTFE can withstand continuous service temperatures of up to 260°C and exhibits exceptional flex properties.

Fillers are added to extend and upgrade the performance of PTFE for particular applications and can dramatically improve compressive strength, wear resistance, thermal conductivity and cold flow. Typical filler/reinforcements are glass fibres or spheres, carbon fibres, graphite and bronze.

New types of PTFE have been developed with TVM PTFE (by Dyneon) having improved properties such as better weldability.

Unfortunately the polymer is not melt processable and has to be formed into articles by heat sintering under pressure. Articles are usually formed by machining blocks or rods into the required shape. Automatic machines enable high volume production.

PTFE powder or microspheres are often added to polycarbonate, acetals, polyamides and other engineering plastics to improve surface lubricity and flame retardancy.

Car applications include bearings, packings, seals, reinforced tubings, glass-fibre and bronze filled PTFE is used for heat conductive bearings, piston rings and packings. PTFE steel braided hose has been used in Europe for fuel lines.

PTFE is produced by DuPont and Dyneon.

Polyvinylidene fluoride (PVDF)

This is a partly crystalline fluorinated polymer with a melting point of 170°C. Other properties include a very high chemical inertness and a high resistance to ageing. The material can be used for applications in the temperature range of −40 to 150°C.

In contrast to PTFE, this polymer can be transformed by injection moulding and extrusion processes.

Its use in automotive applications, especially in Europe, is in coextruded fuel lines with PA11 or PA12 on the outside and PVDF on the inside. The PVDF functions as a barrier to the hydrocarbons due to its very low permeability to fuel components.

Producers include Ausimont, Creanova, Elf Atochem, Kureha Chemicals and Solvay.

ETFE

This is a thermoplastic copolymer of ethylene and tetrafluorethylene and is transformable by injection moulding, extrusion and other processes. ETFE has high tensile strength and toughness with low flammability and is well suited for wire and cable insulation even at 155°C for 20,000 hours (see standard IEC 85). The polymer is sometimes used for car cable sheathing for the high temperature classes (upwards from 125°C) but is generally too expensive.

The most important car application is found in the USA where it is used in multi-layer coextruded fuel lines. ETFE is used as the inside layer of the tubing in an electrically conductive form. The outside layer is in PA12, with a middle one in normal ETFE. This is the construction of the "P-CAP" fuel lines.

Producers include Daikin America, DuPont (Tefzel), Dyneon and Asahi Glass.

Polyethylenechlorotrifluorethylene (ECFTE)

This polymer is an alternating copolymer of ethylene and chlorotrifluoroethylene, usually indicated by the acronym ECFTE.

This is a melt processable thermoplastic and can be converted by the same techniques as polyethylene such as extrusion, injection moulding and blow moulding or applied by electrostatic coating. The mouldings have a very smooth surface when compared to the other fluor polymers.

Inherently flame resistant with low smoke generation, passes UL 94 V-O in thicknesses as low as 7 mm and passes FMVSS 302 for cars. It has excellent barrier properties.

The polymer is suitable for high temperature sheathing applications in automotive cables and wiring.

The producer is Ausimont USA.

THV

THV is a unique terpolymer of tetrafluoroethylene, hexafluoropropylene and vinylidene fluoride. The material can be converted by the usual technologies such as injection moulding, extrusion, coextrusion, blow moulding, coating, impregnation and film lamination.

Important characteristics include the relatively low temperatures of conversion, the exceptional flex life and high clarity. The very low permeability and the low conversion temperatures make the polymer suitable for coextruded fuel lines.

The producer is Dyneon.

3.1.11 Other thermoplastics

Aliphatic polyketones

Aliphatic polyketones are still considered as "new" polymers since, although their development has taken over ten years, it is only in the past three years that they have undergone market development and have reached successful commercial applications.

In the production of aliphatic polyketones, ethylene and propylene are polymerised with carbon monoxide using specific catalyst systems. The resulting polymer range has linear, perfectly alternating molecular structures.

These semi-crystalline engineering thermoplastics can be compounded - for example, with glass fibres - to produce products with a wide range of properties including high temperature and enhanced fuel resistance as well as excellent impact strength, resilience and wear characteristics.

Automotive applications are probably the end-use area of greatest potential and fuel systems may well prove to be a major outlet.

There are two producers of aliphatic polyketones, these being BP Amoco (Ketonez) and Shell Chemicals (Carilon).

3.2 Thermoset resins

Common examples of thermosets are phenol-formaldehyde, melamine-formaldehyde and urea-formaldehyde, most of the polyurethanes, unsaturated polyesters (for example, used to formulate sheet moulding and bulk moulding compound, SMC and BMC respectively) and epoxy resins. The last two can be crosslinked by means of a catalyst without heat application.

There are also thermoplastics which become crosslinked molecules, for example, polyethylene foam or tubing, by means of a catalyst, a peroxide, and become thermosets.

In general, thermosets are characterised by good resistance to heat and creep, with a good resistance to solvents and a hard rigid surface.

3.2.1 Unsaturated polyesters (UP resins)

The pre-polymers are characterised by ester groups in the molecules and carbon-carbon double bonds which can react with each other and with added styrene by means of a peroxide as a catalyst and with application of heat.

Pre-polymers are made by the high temperature (150-200°C) melt polymerisation of maleic acid or maleic anyhdride with a glycol, like propylene glycol, and a modifying acid, for example, phthalic acid or anhydride. Other glycols used are diethylene or neopentylene glycols or bisphenol A. Maleic acid can be replaced by fumaric acid and phthalic by isophthalic acid, adipic or sebacic acid.

A crosslinking monomer, styrene, is added at about 35% of the still viscous resin or pre-polymer, forming by means of a peroxide catalyst and heat of about 100°C a hard and tough product. Styrene monomer (sometimes substituted by methyl methacrylate for improved transparency and weather resistance) dilutes the viscous polyester pre-polymer to a mouldable mass and acts as a crosslinker.

Unsaturated polyesters are liquid resins mixed with pigments, fillers and other additives, and a catalyst. For moulding, they are reinforced, usually with glass fibre. Mixing with the reinforcement can be done by the moulder, or ready-made compounds are available.

Sheet moulding compound (SMC) is a paste made of UP resin, styrene, a peroxide catalyst system, wetting and dispersion agents, colourants/pigments/fillers and dispersed within a loose matrix of glass fibre reinforcement laid down at random on a continuous belt of polyethylene or nylon film, over which another similar film is overlaid to form a flexible envelope. This continuous sandwich is rolled up after passing a series of rollers. SMC can only be compression moulded.

Modifiers like calcium carbonate act to reduce shrinkage to nearly zero and improve the surface aspects of the moulded parts. These compositions are known as "Low Profile" compositions because of the smooth surface obtained.

Moulded SMC articles exhibit very good structural properties with flexural and tensile strengths much higher than BMC and at the level of glass mat reinforced UP resins. The disadvantage is the high specific gravity of up to 1.85 g/cm^3. This is now overcome by so-called "Low Density" formulations substituting filler for hollow glass spheres.

Various techniques are available to obtain a Class "A" surface for automobile body panels like "In Mould Coating" (IMC). During the compression cycle the pressure is decreased to allow injection of the coat on the Class "A" side, after which the pressure is increased and curing continues. The quality can also be improved by "vacuum-assist moulding" systems. A vacuum is applied during the mould closing cycle to minimise air in the mould. This reduces air blisters and porosity in the moulded parts.

BMC is a type of fibre reinforced composite material which primarily consists of a UP resin as for SMC, glass fibre reinforcements and filler. Additional ingredients such as low profile additives, cure initiators, thickeners, mould release agents are added to enhance performance of the processing of the polymer mix. BMC is less loaded with glass fibres than SMC, but has a higher filler content and has therefore lower strength properties, which guarantees a higher temperature resistance and better surface. It is therefore used for car head lamp reflectors. BMC is, as the term indicates, supplied in bulk in containers and can be injection moulded in modified machines with pressures of 110-150 bar and mould temperatures of some 160°C. Trimming is necessary as for SMC because of flash formation.

Several other processes are used to combine resin and reinforcement, for various products and rates of output. Resin injection (in which a preform of reinforcement is placed in the mould and resin is injected) is the focus of much interest, as also is resin transfer moulding (RTM). These are described in Chapter 4.

UP resins are also used for "pultrusion" using preimpregnated and cured continuous glass roving. Up to 60% of rovings are added giving strength properties double those of SMC. Highly filled polyester resin compositions are used widely as automobile body repair putty.

Producers include Ashland, BASF, BIP, Cray Valley, Dainippon Ink, DSM, Menzolit-Fibron, Reichhold, Scott Bader.

3.2.2 Phenolic resins-phenol-formaldehyde polymer (PF)

Phenol-formaldehyde resins are the most important of the phenolic resins and were the earliest synthetic polymer to be manufactured as a commercial product (Bakelite). They are used as a thermoset plastic, an adhesive and also as a coating material.

The polymers usually contain a filler such as wood flour, cotton fibre or a fabric laminate but also glass fibre is added as a reinforcement. The polymers are hard, very resistant to chemical attack and exhibit good electrical properties. Due to the yellow-brownish base colour which darkens in sunlight, the resins are difficult to colour.

For PF moulding compounds, the standards include: ASTM D 700, 3881, DIN 7708 part 2, ISO 800.

Automotive applications include pulleys, pump housings, brake pistons and commutators. Special compounds are made for high performance applications like rocket parts, brake and clutch linings serviceable up to 500°C, carburettor heads, and cylinder head covers in cars. Glass fibre filled granulated compounds are used for high impact, heat resistant parts.

Producers of PF resins include Allied Signal Inc, Asahi, Bakelite AG, Borden Inc, Crios Resinas Sinteticas SA, Georgia-Pacific Resins Inc, Global Chem International, Cray Valley, Perstorp Chemitec AB, Raschig AG, Sumitomo Bakelite and Vyncolit NV (Perstorp).

3.2.3 Epoxy resins

Epoxies are resins which cure to a high toughness and exhibit low shrinkage during curing, high adhesion to many substrates and good chemical resistance, although the properties depend very much on the curing system used.

For nomenclature and compositions the following standards are of interest:

ISO 3673-1: Epoxy Resins; Part I: Designation

ISO 4597-1: Hardeners and accelerators of Epoxide Resins

ASTM D1763: Specification for epoxy resins

Compounds are delivered as dry compounds in granules or flakes. They have limited shelf-life, depending on the curing system. The products can be processed by compression, transfer and screw injection moulding at low pressures. Another form is glass cloth prepregs with EP resin and a glass content of 35-60%, in approximately 1 metre wide rolls. High performance composites have aramid or carbon fibres. Such products are converted by compression moulding and used in structural parts for the aircraft and aerospace industries.

Epoxy resins are claimed to be superior to UP and vinyl systems in fatigue resistance in humid conditions, better dimensional stability due to negligible water absorption and virtually no shrink, also zero volatiles during processing as no styrene is present.

Epoxies have a cost and performance higher than is normally required in the automotive industry. Resin transfer moulding of epoxies is regarded as a cost effective process up to 20,000 parts. The Mercedes-Benz Unimog UX 100 small commercial vehicle has a cabin with 11 epoxy/carbon fibre parts weighing 30 kg out of total weight of 70 kg for the whole cabin.

A revolutionary car design, the "aXcess Australia" has a primary body structure in a carbon fibre/epoxy composite rather than cast magnesium. Gypsum was used for the moulds. The framework was produced by a lay-up process. Various other parts like body panels, interior fittings and roofing are in composites as well. Glass fibre prepregs have been used for vehicle leaf springs.

Producers include Bakelite AG, BASF Corp, Bayer AG, Borden UK, Ciba, Dow Chemical USA, Ems Chemie AG, Reichhold Chemie AG, Shell Chemicals and Union Carbide.

3.2.4 (Thermoset) Polyurethanes (PUR)

This is a class of mostly thermoset polymers with a very large number of car applications, not least due to the variations of combinations possible.

The chemical basis for PUR is the isocyanate group (-N-C=O), able to react with a host of compounds having active hydrogen atoms, such as polyols, amines, carboxylic acids. Basic isocyanates are: toluene diisocyanate (TDI) and methylene diphenyl diisocyanate (MDI); for weather resistant PUR the more expensive hexane-1, 6-diisocyanate, also called hexamethylene diisocyanate (HMDI), is used. Isocyanurate triisocyanate is used to produce heat resistant polyisocyanurate foams. These compounds react with di-or polyols such as Polyether polyol with chains formed by ethylene and propylene oxides, Polyester polyols, for example, from adipic acid and glycols or glycerol, are used for certain flexible foams. The last ones are more expensive but exhibit better oil but lower hydrolysis resistance. Other polyols such as polycaprolactones, polybutadiene diol and sucrose are used. Di and polyamines used as reactants with the isocyanates lead to the group of polyureas. These are also produced by the addition of water to the reactants.

Polyether polyols are almost exclusively used for products processed by reaction injection moulding (RIM) for automobile fascias, bumpers and panels. They provide good low temperature impact strength and high temperature stiffness (heat sag). Flexible PUR foams are formed by a process of simultaneous polymerisation and expansion. The gas for expansion is primarily carbon dioxide formed by the reaction of isocyanate with water. For rigid foams chlorofluorocarbons (CFCs) can no longer be used as blowing agents and the industry is carrying out a lot of R&D work to produce a new formula.

Hollow glass microspheres, added to polyurethane reaction injection moulded (RIM) parts, achieve weight savings. A good combination of weight saving, satisfactory surface finish for painting and improved mould-filling is achieved with 2% loading by weight of microspheres. The inclusion of microspheres increases material cost, but weight savings resulting from the 10% lower density of the final part are considered to justify their use. Besides weight savings from incorporating a less dense material, the method allows use of a resin density reduced from the normal 700-550 kg/m^3.

Microsphere technology can be retrofitted into existing production setups without system modification or additional tooling costs. A negative point is an increase in porosity defects which rise by some 3%, but these are a small part of all moulding defects. On the other hand, both blister and flash defects are decreased due to elimination of over-packing, and the combined benefit of weight reduction and increased yields has resulted in a 9.3% decrease in raw material usage, with consequent savings.

Energy absorbing (EA) PUR foam is a semi-closed cell type used in blocks in doors to absorb part of the energy in case of side impacts. Audi has EA PUR whereas others like VW use EA PP foam. EA PUR foams are used also in bumpers, now mostly replaced by EA PP, in instrument panels, knee bolsters, sunvisors, A-, B- and C pillars for compliance with FMVSS201.

In RIM processes a mixture of two or more reactants with surfactants and catalyst added, is injected into a mould where the mix reacts to form a cross-linked foam with a solid skin, for example, as seen in steering wheel covers.

R-RIM uses added short chopped strands in the mix to reinforce the final article.

S-RIM is similar but first glass fibre mat is put into the mould prior to injecting the reactants for the production of structural parts such as the instrument panel carrier of the BMW 5 Series. A new development uses LFI-PUR, long glass fibre (approximately 50 mm average length) and also natural fibres. These are sprayed randomly into the mould simultaneously with the reactants. The German machine companies Krauss-Maffei and Hennecke GmbH, part of Bayer, as well as the company Cannon SpA have developed machines for this process. Mercedes-Benz door panels are made by the Krauss-Maffei process, although the Bayer-Hennecke process "NafpurTec" is used as well with sisal/flax fibres.

R-RIMs can also compete on weight with SMC as the 1999 models of Chevrolet Silverado and GMC Sierra pick-up trucks show where PUR has replaced SMC. This is covered under reinforcements in this chapter.

The Belgium company Recticel produces PUR solid skins for instrument panels for BMW 3 and 5 Series by their patented Colofast process.

Thermoplastic elastomers (TPE-U) find increasing use in car applications, for example as instrument panel skins and under-the-bonnet applications.

Important producers of polyurethane components and products are: BASF-Elastogran, Bayer, Dow Chemical, Enichem, BF Goodrich, Huntsman ICI Holdings, Lyondel, Shell Chemicals, Witco Corp.

3.2.5 Other thermosets

Vinyl ester resins are used as a more expensive substitute for high temperature applications, up to 150°C and when improved chemical resistance is required especially against acids. Oil sumps are sometimes made in vinyl ester compounds instead of UP resin compounds because of the high acidity of motor oil after sometime.

Urea-Formaldehyde (UF) and Melamine-Formaldehyde (MF) resins are of the same class as PF, but are collectively known as "aminoplastics" since they contain amino groups in the molecular structure.

MF resins are produced by addition and condensation reactions involving 1,3,5-triamino triazine (melamine) and formaldehyde. Their main use is as impregnating resin for decorative papers and as a core layer in high pressure laminates, also as a crosslinker in, for example, automotive finishes, as a binder for wood materials, in conjunction with PF for brake and clutch linings, and as a binder for glass fibre mats and weaves. Melamine resin foam moulding compound is produced with a low boiling blowing agent and cured. The foam is of the open cell type and is heat resistant up to 220°C. BASF sells the foam under the Basotect name which is used in applications close to the engine.

UF resins are produced by condensation of urea with formaldehyde. The moulding compounds, supplied as fine powders or granules, are colourless and light resistant and can be coloured with suitable pigments. Inert fillers are added such as cellulose fibre, wood flour and stone flour. Moulding is by hot pressing or injection moulding. A UF open cell foam is produced as well commercially, for example for sound and heat insulation.

Producers of MF and UF resins or compounds include BIP Ltd, Carmel Chemicals Ltd, Elchi Srl, Perstorp AB and Sud-West Chemie GmbH.

3.3 Reinforcements

Selections from the above products are mixed or blended into polymers at a level of 5 to 60% in order to change the properties of the base polymer. Mixing takes place in a Banbury heated internal mixer or in a dry mixer with subsequent extrusion of the blend or alternatively by extrusion compounding with the addition of the ingredients directly into a single or twin screw extruder.

Usually a distinction is made between fillers, property enhancers and reinforcing agents although there is no clear cut separation.

Fillers, irregular shaped small particles (< 3 microns) and aspect ratio (length/width ratio) > 1 are added to make the final compound cheaper, although they often increase the modulus of the resulting compound. The following products are classified as fillers: Barytes or barium sulphate, precipitated calcium carbonate (particle size < 1 microns) or ground chalk (particle size < 3 microns). Dolomite, Feldspar, Kaolin, Siliceous earth, Metal powder, Quarz flour, Talcum, (Hollow) Glass beads, Wood flour. Often they are used in plasticised PVC, thermosets and, in car applications, for example, PP (or PP +EPDM) with 10-20% of talcum. The filler particles can be coated with a chemical "coupling agent" to improve the adhesion with the polymer molecules or have a cheaper coat with an organic material similar in dipole moment as the resin.

Talcum and glass beads for instance increase the tensile strength when suitably coated to provide a chemical link between the filler surface and the polymer molecule. This may be considered to be reinforcement.

Reinforcing products increase not only the modulus but also the tensile strength of the polymer or sometimes as with nylons, polyesters and acetal resins the impact strength and heat distortion temperatures as well.

Reinforcing products are considered short and long glass fibres, glass mat, glass microbeads, cellulose, wood, aramid, carbon, graphite and metal fibres.

Most important in the car sector are short and long glass fibres as well as wood fibres.

3.3.1 Glass fibres and glass mat

Glass fibres are produced by feeding molten glass bushings (blocks pierced with hundreds of tiny holes) of platinum alloy. The molten glass flowing from the holes is drawn away at high speeds giving rise to between 50 to several thousands of filaments. The filaments have a diameter of 5-25 microns. Together they form a strand. The filaments are coated with a "size" a watery dispersion of a silane chemical "coupling agent". They provide for a strong bond between the glass and the polymer increasing the reinforcing effect. Various types of glass are produced. The majority of the fibres are of E-glass and there is also R-glass for high mechanical performance, D-glass when high dielectric strength is needed and AR-glass which is alkali and corrosion resistant.

The basic strand is transformed into chopped strands, continuous filament mat, roving and cake (See Figure 1).

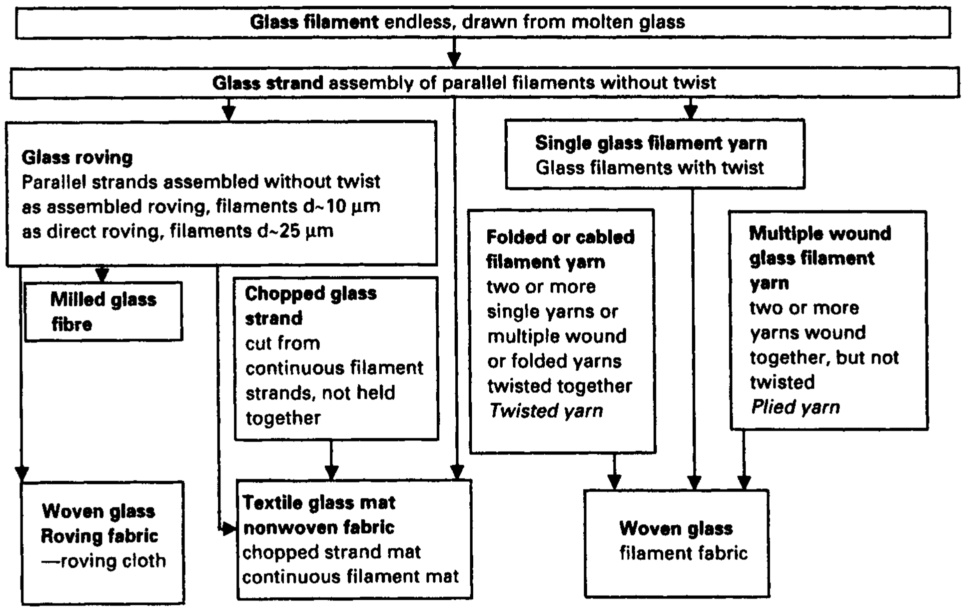

Fig. 1. Filament textile glass products according to ISO 472.

Around glass fibre and reinforced products a number of ISO standards have standardised nomenclature and testing. Basic concepts are presented in ISO 472, fabrics in ISO 2113, rovings and chopped strands in ISO 2078, mats in ISO 2559, SMC in ISO 8605, BMC in ISO 8606.

With glass fibre thermoplastics it is possible to distinguish short fibres of < 1 mm length and long fibres 1-5 mm (LFT) for injection moulding applications and for compression moulding long fibres, 5-25 mm and glass mat, 10 mm to infinite. Thermosets are reinforced with chopped strands and (hollow) glass beads or glass mat. For car applications, however, mostly sheet moulding compound (SMC) or bulk moulding compound (BMC) are used. All these products are known as composites.

Glass reinforced thermoplastics

It is estimated that on a worldwide basis some 43% of all reinforced thermoplastics are used in automotive applications. The major part of glass reinforced themoplastics overall are polyamides with approximately 45%, followed by PET/PBT with 25% and PP with 12%. For every polymer a specific type of glass fibre has been developed with a coating promoting an optimum bond between the fibre surface and the polymer molecules. This chemical coupling is essential to optimise the tensile strength, creep resistance and stiffness of the composite.

Polyamides (PA), polyesters (PET/PBT) and polyacetals (POM) have rather low heat distortion temperatures under a load of 1.82 MPa (HDTUL to ASTM

D648). Adding glass fibre (usually short < 1 mm) from 10% upwards, presents a remarkable improvement in HDTUL and creep resistance, besides the usual increase in stiffness and tensile strength.

With high impact amorphous polymers like ABS and Polycarbonate (PC) the addition of glass fibres presents a dramatic decrease of impact strength due to the notch effects of the fibre on the surface of a moulding or testbar.

With PA and PET/PBT, however, strong increases can be measured since the starting level is already low. These are the reasons that PA, PET/PBT and POM are used for the majority of the applications in the glass reinforced form. Often an impact improving polymer is added like reactive PP or EPT copolymers or TPE-A or TPE-E to improve further the impact strength.

Table 3.3 The effect of short GF on PBT and PA6 compound properties*

	PBT	PBT+30% GF	PA6	PA6+30% GF
Specific gravity g/cm^3	1.31	1.52	1.14	1.35
Tensile strength @ break, MPa	34	140	85	190
Flexural modulus, MPa	2700	9000	2800	9500
Notched Izod Impact @ 23°C, J/M	30	95	50	120
Hardness, Rockwell	M80	M98	R120	R122
HDTUL @ 1.82 MPa, °C	62	210	80	205

* Data taken from commercial brochures; data for PA6 are for unconditioned testbars; for conditioned bars the values are significantly lower except for the Izod values.

Table 3.3 shows clearly the reinforcing effect of short glass fibres. The disadvantages though are the increase in specific gravity, since glass fibre has already a density of 2.6-2.7, the significant decrease in elongation at break, a rougher surface and the anisotropic behaviour of the polymer. This anisotropy is caused by the orientation of the glass fibres in the direction of the polymer flow. This gives a different shrinkage upon cooling between the two directions with flow and perpendicular to it. Careful mould design and injection moulding conditions are necessary to avoid warpage of the moulded part.

Many applications of glass reinforced plastics are non visible or do not have an aesthetic purpose or are covered. Very fast growing applications are the air intake manifold of engines and cylinder head covers in 30% glass fibre polyamides. Sometimes a mixture of filler and glass fibre is used to reduce the anisotropic behaviour. Pedal assemblies in GF-PA are expected to grow fast as well. Established applications in GF-PA are fans, fan shrouds, connectors and fuse boxes.

Other glass reinforced polymers used in car applications are PC/ABS, PPE/PS and SMA with 10-20% GF particularly for instrument panel or door panel carriers. As mentioned above, addition of glass fibre to these polymers shows a significant decrease in impact strength. In the case of SMA-GF additional impact modifier is added. However this product is still rather brittle. All producers of the above polymers market glass fibre reinforced grades.

The above products contain short glass fibres incorporated into the polymer by the usual compounding techniques. Relatively new and with fast growth in the car sector are the Long Fibre Thermoplastics (LFT). The fibres have a length of up to 5-6 mm incorporated in pellets of up to 10 mm length. Special compounding techniques are necessary using rovings to avoid too much breakdown of the fibres.

LNP Engineering Plastics has an interesting patented process for its Verton LFT-PP and LFT-PA, whereby glass rovings are fed into a twin screw extruder. Other companies like Ticona (Celstran), Appryl (Pryltex), DSM in joint venture with Owens Corning, Borealis (Nepol) and others are entering this field, especially with polypropylene as the matrix.

The long fibres give a much stronger reinforcement than the short ones, especially in fatigue resistance and with tensile strength of 60% LFT-PA at the same level as zinc and magnesium alloys. The impact strength is significantly superior to that of the short GF compounds as the impact increases with fibre length. Also, the anisotropy is also much lower. The LFT-PA can substitute diecast parts for applications requiring a temperature resistance below 175°C. Car oil sumps is an application that several companies are developing. Some precautions need to be taken in injection moulding the LFT in order not to break too many of the fibres. The feed throat needs to be wide enough to handle 10 mm long pellets, the screw must have a lower compression ratio, moderate injection speed and reduced back pressure need to be applied.

Glass mat reinforced thermoplastics (GMT) can be made in different processes and different fibre set-up. There is a long fibre version with lengths of 5-25 mm which can be supplied as pellets or as a mixture. There is also the glass mat which can be directionalised or not. The above products are usually supplied as sheets in laminate form. Various polymer matrices are possible such as PP, PC, PBT, PA66. Glass contents vary from 20 to 60% by weight.

These types of composites are competing with thermoset composites like SMC. All these variations are transformed via hot stamping, compression moulding or, in the case of long chopped strands, thermoforming.

Azdel BV, the Netherlands and Azdel Inc USA, part of GE Plastics, offer AZDEL PP reinforced with long chopped fibre, random glass mat or directionalised glass mat in percentages of 22-42% by weight and AZMET based on a PBT matrix and AZLOY with PC and PC/PBT as base polymers.

Ticona, a subsidiary of Hoechst AG, offers a whole range of composites. CELSTRAN contains approximately 10 mm fibres, COMPEL on average 25 mm and FIBEROD with endless fibre. Basic polymer matrices are PP, PA66, HDPE and special types are available with PC/ABS, PPS, PBT, POM as the resin part. The product range also contains carbon and aramid fibre reinforced grades.

Applications include bumper beams, seat pans, load floor instrument panels, battery trays, and bonnet lids.

The main products used in automotive applications are sheet moulding compound (SMC) and bulk moulding compound (BMC), with reinforced reaction moulding (R-RIM) and structural reaction moulding (S-RIM) of PUR are becoming important as well. Chemically PU resins are thermosets since crosslinking takes place during conversion.

The technology in the USA is more advanced than in Europe in the sense that in the USA techniques have been developed for an economical high volume production of up to 300,000 parts per year by a reduction in cycle times, scrap and defective parts. This compares to injection moulded GF thermoplastic parts. Both products have suffered from the image of "low volume products" and the applications in SMC and BMC have been limited to low volume cars.

SMC for car body panels has various advantages over thermoplastics:

1) a very low coefficient of thermal expansion, similar to that of steel

2) panels can be painted in-line passing ovens at 190°C with a good paint adhesion

3) the surface quality of the moulded parts has been improved considerably in the 1990s

4) the development of "low density compounds" adding hollow glass spheres: usually SMC/BMC have a density of 1.8, but this can be reduced to 1.3. For instance, the Isuzu Forward has a front panel in light weight SMC with a density of 1.35.

5) electrically conductive SMC is in development for electrostatic painting.

SMC is used for "2 dimensional" mouldings as it is supplied in sheet form and converted by compression moulding. Vacuum assisted moulding is a newer process whereby a vacuum is applied before closing the mould. A better surface quality is obtained this way. BMC is injection moulded and therefore suited for "3 dimensional" pieces. The surface smoothness is better than that of SMC parts, but the mechanical properties are inferior due to breakage of the glass fibres.

SMC and BMC are based on unsaturated polyesters (for under the bonnet applications vinylesters are used), styrene monomer, glass fibres, chopped strands of 12-50 mm, fillers and various additives like polymerisation initiator, thickener, mould release agent and other substances. A typical SMC formula for a "Class A" surface or so called "low profile" could be:

Material component	% by weight	% by volume
Unsaturated Polyester Resin (UP)	20-27	33-42
Glass fibre	25-30	18-30
Filler	40-50	29-39
Other additives (initiators, thickeners mould release agents, wetting and dispersing agents)	3-5	6-8

For high temperature applications in an oily environment, vinyl ester replaces unsaturated polyester. Low density formulations contain a high percentage of hollow glass spheres. For a "Class A" surface it is essential to keep the glass fibre content below 30% by weight and low in viscosity which fills up the mould and releases any trapped air bubbles. SMC is supplied as sheets up to 1.5 metre wide and 4 mm thick, packed between two films. When the SMC is ready for moulding, the material is spread onto a cutting table and cut into pieces of predetermined shape. Weighing may take place to verify the charge weight. The charge is placed on the heated mould surface.

This mould consists of a set of forged steel dies that are plated or surface treated to reduce wear. The mould is oil or steam heated to 130-170°C. After closing the mould, a pressure of 50-100 bar is applied for a low profile surface. The cure time may be 30-150 seconds. The porosity can be reduced by the application of a mould coating.

BMC is similar to SMC but supplied in a bulk mix of the components, and is injection moulded with pressures from 100-150 bar.

An example of a standard BMC formula for automotive applications is:

Resin	20%
Glass fibres	15%
Low profile agent	9%
Others (peroxides, mould release agents)	2%
Calcium Carbonate	54%

The additives play an important role in the formulation and since not only curing agents and mould release chemicals need to be present but also thickeners, wetting (of fibre and filler) and dispersion additives. A low profile agent improves the smoothness of the surface, which can show profiles after curing and shrinking.

The injection moulding of BMC is well developed whereby the product is injected into a hot mould (160°C). The BMC heats up and flows easily into the cavity. The curing time can be a bit faster than with SMC. One of the advantages over SMC is the greater freedom of design. As mentioned before, the surface roughness is less than with compression moulding. Trimming is necessary after moulding.

DSM, The Netherlands, has recently launched a high modulus sheet moulding compound called HMC and with the commercial name Shimoco, which has around 40% better mechanical properties than standard SMC. It is based on a blend of polyester and vinylester thermosetting resins and very long glass fibres.

The Alfa Romeo 156 model's bonnet is made from SMC with the inner part in injection compression moulded BMC. This has given freedom of styling and lower investment cost against traditional steel sheet. BMW bumper beams are in SMC with benefits of styling freedom, lower investment cost, low deflection during impact and corrosion resistance. The sunroof frame is in low density SMC as well with added recyclate. A weight reduction of 25% is realised.

R-RIM and S-RIM

Interesting developments which will have a future in car applications are with R-RIM and S-RIM Polyurethanes, where the R stands for glass fibre reinforced and S for glass mat equivalent. In Germany, in particular, there is a tendency, however, to substitute glass for natural fibres like flax and sisal as a contribution to the environment e.g. for Mercedes door inner trim, 1.7-1.8 mm thick panels in 60% of a 50/50 blend of flax and sisal with 40% PUR are mass produced by Becker Europe GmbH in Wuppertal.

Whereas in the conventional processes very short fibres (0.1-0.3 mm) were mixed with one of the PUR components or glass mats put into a mould prior to foaming, new developments using long fibres (LFI) opens up a host of possible applications for LFI-R RIM. Now machines have been developed delivering long glass fibres of up to 100 mm but typically 50 mm average length, are delivered into the mould at the same time as the foam components. Substantial cost savings over conventional S-RIM are possible. Exterior panels can be produced of which it is claimed that they are competitive to SMC and PPE/PA blends.

General Motors makes a switch from SMC to R-RIM for its latest pick-up truck beds and both the Chevrolet Silverado and GMC Sierra will have R-RIM side fenders as well. R-RIM fenders were already used for small volume cars like the Pontiac Firebird and the Corvette.

The German machine producer Krauss Maffei has developed equipment for LFI-PUR systems launched at the K'95 fair. Various machines have been sold to Becker Europe who produced door panels for Mercedes models. In this process, long glass fibres (12-100 mm) are wetted with the PUR system in the process head before being discharged into the mould cavity. The fibres are cut from roving directly in the head by a special chopper.

The machine producer Hennecke had on display at the K'98 fair its Nafpur-Tec process whereby some 55-65% natural fibres (sisal, flax, hemp) are combined with 35-45% polyurethane, to produce 1.5-2.0 mm thick door panels.

Also the Italian company Cannon SpA has developed similar machines.

The main advantages of R-RIM and S-RIM are the high level of design freedom, high rigidity, resistance against heat and humidity.

3.3.2 Other fibres

Natural fibres

As mentioned above, a number of car producers - for example, Ford and Mercedes-Benz - have a growing preference for flax, sisal or hemp as a substitute for glass fibre. Wood fibre has been in use for some time (Fibrit and Lignotock, Germany). Weight savings are possible since the density is considerably lower than glass. Further, the element of environment and ecological image play an important role and in certain applications noise absorption as well.

Ford's Cologne lab has done extensive experiments with flax-PP and found this nearly equivalent to GF-PP. The injection moulding temperatures need to be kept low enough to avoid discolouration. Ford uses flax-PP for the Mondeo produced in Belgium. The hatch door cover of the Audi Avant A4 and the luggage compartment liner of the Cadillac Catera are in flax-PP as well. The product is not brittle at low temperatures, has improved noise reduction and is some 30% lower in weight than the glass fibre PP equivalent.

Mentioned above already, the Becker Group Europe GmbH, Wuppertal, Germany, now part of Johnston Controls supplies Mercedes-Benz with door trim panels made from their "Fibropur" natural fibre mat polyurethane composite. The fibres are a blend of 50% sisal and 50% flax. SAI Automotive AG, Europe's leading system supplier of cockpits and doors, has developed "Lignoprop", a blend of wood fibre and PP, for their own production. Similar products were developed by Fibrit, Grefrath, now part of Becker, as a further development of their wet process.

Aramid fibres

These fibres are spun from aromatic polyamides with a high proportion of 1.4 chemical bonds directly between the aromatic rings, giving more linear molecules.

Producers are DuPont with Kevlar and Akzo Nobel with Twaron. These highly priced fibres have a very high strength and heat resistance and are utilised in bullet proof vests, heavy duty rope, but also in performance tyres, for example for trucks and recently as a reinforcement in car drive and timing belts.

Specialised companies have a product range of aramid reinforced polymers like RTP Comay, USA-France, Ticona, LNP Engineering Plastics, USA-Netherlands. Ticona, for instance, has 30% aramid fibre in a matrix of PA, POM and PPS. LNP has developed PA46, PPS and PAEK reinforced with aramid. The company claims the figures exercise a lubricating effect.

Aramid fibre reinforced thermosets are increasingly used in aeroplane construction. At present no substantial use is envisaged in car applications because of price reasons.

Carbon fibres

These fibres are produced by two different processes: carbonisation under exclusion of air or polyacrylonitrile (PAN) continuous filament and from pitch. Carbon fibre like aramid, are high strength fibres and are essentially used as a plastic reinforcement in sport applications (racquets, golf clubs) and in aerospace industry. Increasingly, aeroplanes have wing flaps and tail parts in C-fibre epoxy resins and of course racing cars, Formula 1, have body parts in CF - thermosets made by special hand lay-up techniques.

Producers include Akzo Nobel in USA, Mitsubishi and Toho Rayon in Japan, Carbon in Germany.

Various plastic companies have CF - thermoplastics such as Ticona, but at present no major volume car applications have been established.

Metal fibres

Metal fibres are very seldom used but find applications in electroconductive plastics for EMI shielding, for instance. LNP has taken over the "Faraday" products from DSM, complimenting its own range.

Particulate reinforcements

In the plastics industry, "reinforcement" usually means the use of a fibrous material in a compound, to improve tensile and impact strength, stiffness, and occasionally thermal stability. Particulate materials, such as talc, also exhibit a marked reinforcing effect, and new grades of calcium carbonate have come on to the market with surface treatments to improve the bond strength with a polymer matrix, improving the mechanical properties. This is part of a general industry trend to improve the value added to plastic compounds by additives, introducing multi-functional additives and, specifically, taking fillers where possible out of the commodity group and into a higher-performance group of technical materials which can therefore command a higher price.

Nanocomposites

Over the past ten years, work with nano-sized (less than 0.001 mm) particles of minerals, such as clays and silicates, has suggested that these can improve mechanical characteristics, gas barrier properties and flame retardancy, at relatively low rates of addition. For cars, this could mean tougher but lighter components. The reinforcing fillers currently examined are smectite clays, such as montmorillonite and vermiculite. The first commercial results are beginning to emerge in packaging, films and automotive components.

Table 3.4

Plastics and selected car components they are used in:	Exterior, Structural, Doors, Glazing																	
	Body Panels Exterior	Body Side Mouldings	Bumpers	Door Handles	Door Liners	Door Locks	Door Panels	Door Pillars	Drip Rails	Glazing	Mirrors Exterior	Number Plates	Roof Rails	Side-impact Beams	Spoilers	Under Body Seal / Cladding	Wheel Arch Linings	Wheel Trims
Thermoplastics																		
Acrylonitrile butadiene styrene copolymer (ABS)					•		•	•			•		•					•
Acrylonitrile styrene acrylate (ASA)									•		•				•			
Aliphatic Polyketones (APK)																		
Polyacetal (POM)						•												
Polyamides (PA)	•			•		•					•		•					•
Polybutylene terephthalate (PBT)				•		•			•		•							
Polycarbonate (PC)										•								
Polyether imide (PEI)																		
Polyethylene (PE)																	•	
Polyethylene terephthalate (PET)																		
Polymethyl methacrylate or acrylic (PMMA)										•		•						
Polyphenylene sulphide (PPS)																		
Polyphthalamide (PPA)																		
Polypropylene (PP) *	•		•		•		•	•			•					•		•
Polytetrafluorethylene (PTFE)																		
Polyvinyl chloride (PVC)		•														•		
Styrene-maleic anhydride (SMA)																•		
Thermoplastic Blends																		
Polycarbonate/ABS					•		•	•			•		•		•			
Polycarbonate/PBT	•		•															
PPO/Polyamide			•															
Polyphenylene oxide (PPO HIPS)																		
Thermoplastic Elastomers																		
TPE-E (TPE)			•															
TPE-O (TPO)		•	•		•		•											
TPE-U (TPU)																		
Thermosets																		
Phenolic & epoxide resins																		
Polyurethane flexible foams (PUR)					•													
Polyurethane integral-skin foams							•	•										
Polyurethane RIM compounds ***	•		•											•	•			
Polyurethane semi-rigid foam																		
Unsaturated polyesters (UP) **	•		•															

* Includes GMT - Glass Mat Thermoplastic

** Includes SMC - Sheet Moulding Compound & BMC - Bulk Moulding Compound

*** Includes R-RIM, S-RIM, LFT-RIM

Interior Components, Seating																						**Under Bonnet, Power Train, Fuel Systems**																**Electrics Lighting**			
Airbag Covers	Arm Rests	Body Panels Interior	Consoles	Dash Board / Instr Panel	Floor Panels	Grilles	Head Liners	Instrument Panel Support	Interior Trim	Knee Bolsters	Mirrors Interior	Pillar Trim	Rear Parcel Shelf	Roof Linings	Seat Belt Components	Seat Cushioning	Seat Frames	Steering Wheels	Steering Wheel Shrouds	Sun Visors	Window Winders	HVAC Parts	Bearings	Brake pads	Cooling Systems	Fuel Connectors	Fuel Lines	Fuel Tanks	Gears	Heat Shields	Inlet Manifolds	Leaf Springs	Sound Absorption	Subframes	Under Bonnet Applications	Water Pumps	CVJ Boots	Elect/cal / Electronic Comps	Ignition Parts	Lamp Housings	Lenses
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The original work was done by Toyota Central Research and Development Laboratories (Aichi, Japan) and some subsequent applications stem from these patents. Most of the original work was done with nylon 6, but more recently there has been positive development with PP matrices, which could have more wide ranging effects.

In PP, General Motors Research and Development, working with the PP producer Montell and the leading US producer of smectite clay, Southern Clay Products, has developed a reactor-made thermoplastic olefin (TPO) containing a rubber phase and a new compatibiliser which, at 5% addition of smectite clay, offers stiffness characteristics equivalent to those of a compound filled with 25-35% talc. This reduces the density and improves the surface finish for better painting. Shrinkage is also claimed to be 50% that of standard TPOs. In mid-1999, GM was reported to be considering this material as a replacement for PC/PBT body panels on the Saturn model - but the next stage will be to test it as a small, less critical part in current production.

Other potential applications include bumper cladding, instrument panels and components in the engine compartment.

Other groups working on nanotechnology for automotive plastics include: Ube Industries (PA), Dow (working with Magna International) Ford/Visteon (PP), Allied Signal (PA) and Solutia (PA).

4 Plastics Processing Methods

This chapter examines the processing methods used in automotive parts manufacture. The various processes used to produce thermoplastic and thermoset parts are reviewed briefly in turn. Examples given are illustrative only and are not intended to provide an exhaustive list of applications.

The main factors to influence processing technology in the automotive components field in recent times include: the globalisation and consolidation of converter companies; substitution of materials and parts to achieve weight savings and facilitate subsequent recycling; a trend towards more integrated sub-assemblies; more computer control of machinery; added safety features and greater understanding of material properties.

Door trim panels, instrument panels, front end modules and seating are examples of greater integration of functions brought about by advances in plastics design and manufacturing methods.

4.1 Thermoplastic processes

4.1.1 Injection moulding

This process is analogous to pressure die-casting of metals, and has been used for decades for parts where precision is important. It is likely to remain the main way of processing thermoplastics. A modified form can be used for thermosets.

Thermoplastic granules are melted and injected into matched dies (usually steel, sometimes other materials, such as aluminium). As the resin injected is in a very viscous state, high moulding pressures have to be used. Presses of up to 3,000 tonnes are used and larger presses have been tested. This is partly because components have tended to become larger, but also because it is often cheaper to make several components in one pressing.

The advantages of injection moulding include short cycle times, the ability to make complex components with good dimensional tolerances and high finish and design flexibility permitting the elimination of finishing and assembly operations. The process allows full automation and is now largely computer-controlled, together with peripherals such as robots. The main disadvantages compared with other plastics processing methods are: high investment costs, long lead times for production of moulds, and the need to use complex machinery. Computer-aided engineering is reducing lead times considerably.

In injection moulding, crystalline resins tend to shrink more in one direction than the other, and become anisotropic (i.e. their physical properties in the direction of stress differ from those perpendicular to the direction of stress). This can be overcome to some extent by using warm moulds and fast injection times, but also by reinforcement with mineral fillers or glass fibres.

Until recently, injection moulding plant could not accommodate long fibres or prepregs, limiting the stiffness obtainable with thermoplastics. However, fully impregnated long fibre materials are now available, which enable the benefits of increased fibre length to be obtained. The process uses 10-25 mm long pellets made by a patented pultrusion process. Moulding requires slow screw speeds. Products made by this process have increased stiffness, high impact strength, dimensional stability, good surface finish and enhanced chemical resistance.

Applications include all types of high volume complex parts: bumpers, grilles, interior panels, interior trim items, electronic components and under-the-bonnet parts.

The dual injection moulding process has been adapted for the injection of two materials in sequence, using laminar flow technology. This is of interest in the use of mixed recycled materials: these can be used to give a central non-structural core to a component, while higher grade virgin material is injected round it to give acceptable engineering behaviour.

In gas-assisted injection moulding an inert gas (such as nitrogen) is injected to expand the inner core or to produce a central void, so creating an apparently thick moulding without having to cool a large mass of molten plastic.

The technique used is the full-shot method in which the gas is injected after the polymer has completely filled the mould cavity. The process has several advantages: greater structural strength and rigidity can be achieved by incorporating hollow closed cross-sections; thick wall sections can be introduced with much reduced pressures; the hollow sections relieve the degree of shrinkage in ribs and thicker sections; finally, bumpers can be produced with reduced overall wall thickness, saving weight and material.

This process is used for the 4 kg, PP/EPDM Class A finish front bumper of the Ford Cougar - an example of a part with variable cross-section. The gas channel adds to rigidity and improves cosmetics through elimination of sink marks on presentation faces.

On a smaller scale, Hashimoto, in the north east of England is making the license plate holder for the Nissan Primera also using the gas injection moulding system. The part measures some 907 mm long by 231 mm wide and 70 mm deep with a general wall thickness of 3 mm. The plate holder includes both large hollow structural sections and smaller channels to distribute even packing pressures across the whole moulding.

Gas-assisted injection moulding is gaining in popularity. More and more vehicle parts are being made this way in a variety of materials. These parts are being produced by technology licensed by Cinpres Limited of Tamworth in the UK. The company has 290 licensees around the world and reckons the automotive sector accounts for some third of its gas-injection market.

The main benefits of this type of processing compared with structural foam moulding are better surface finish and thinner walled components, resulting in significant cost savings. Other advantages include better dimensional stability and closer tolerances.

Low pressure moulding is a term for various processes which ultimately result in a low pressure in the cool cavity compared with conventional injection moulding. It has several advantages: lower pressure allows the use of in-mould lamination processes for the application of skins in a single step (the usual reason for using the method); reduced and more uniformly distributed stress in the part; cheaper tooling and smaller presses.

Variations of the process include vertical clamp injection-compression, horizontal clamp injection-compression and vertical clamp melt application-compression. These processes are most commonly used in the manufacture of door panels and other exterior and interior parts.

A form of injection moulding is used to mould PU foam and solid parts. Multi-hardness foam cushioning is now in widespread use in car seating. In recent years densities of foam have been reduced from around 60 kg per cubic metre towards 32 kg, allowing cost savings with no reduction in comfort and durability.

BMW's new 3 Series provides an example of the recent move to thinner seat assemblies. ICI and others have reduced the thickness of the front seat cushion by about 40% (from 85 to 48 mm) in a move away from a deadpan seat to a seat with metal springs. This line of development is continuing.

A variant is foam-in-fabric cushions, involving inserting a preformed fabric cover in the mould before injecting the polyurethane mix. The fabric cover can be either of a barrier or non-barrier type. In the former, the seating fabric is backed with an impermeable film - generally TPU (thermoplastic polyurethane) - to allow vacuum forming of the textile. Advanced production equipment is needed for this unit seating technology to provide accurate, computer control of rates, isocyanate/polyol ratio, etc.

Another area of PU injection moulding concerns integral-skin components such as steering wheel covers. The challenge recently has been the elimination of the CFC 11 blowing agent, because of its ozone depletion potential. This has largely been achieved and now systems are being introduced giving, in some cases, better properties.

Injection moulding accounted for about 30% of all thermoplastic materials processed in 1994; this is expected to rise to about 34% by the year 2000.

4.1.2 Extrusion

This process, consisting of forcing plastic material through a die, is used to produce sheet, film, hoses, cable covers, sheaths and many profiles for trim and sealing.

Having the economic benefits of a continuous process, rather than the intermittent output of most moulding processes, extrusion is a growing technology. There will be more computerised control in this area, as elsewhere, to deal with the many parameters such as drying temperatures, delivery rates, pressures and temperature profiles as well as any ancillary processes such as drilling, punching or embossing.

A robotic extrusion process for making complex and hollow thermoplastic elastomer profiles around rigid inserts has been developed as an alternative to injection moulding profiles around rigid parts. The main benefit of this extrusion process is reduced tooling cost, coupled with flexibility to accept a variety of differently shaped parts. The first commercial application was a sound-deadening pan for under the engine of certain Mercedes-Benz models.

4.1.3 Blow moulding

This consists of blowing a thermoplastic in the form of a tube into a shaped mould. The process is mainly used to produce hollow articles, for example, tanks and containers. It offers great flexibility in the shape that can be formed. The mould cost is low, but the finish can be poor, though development work is in progress to remedy this. The process can be used to produce multi-layer items, and this approach has been widely used in fuel tanks.

Blow moulded items can be designed to be cut to render components which are no longer hollow, such as bumpers.

4.1.4 Thermoforming

This process involves heating material in sheet form, transferring it to a mould and forming it by a vacuum applied inside the mould (and sometimes augmented by high air pressure applied to the outer surface of the sheet). Advantages include low tooling costs (typically 10% of comparable injection moulding tools); speedier set-up and economy in short runs. The system is also convenient for forming laminates of different materials. Disadvantages include long cycle times and poor dimensional accuracy, although recent advances in process control now give greater dimensional accuracy and consistency in appearance and finish. Thermoforming is economic for runs of 200 to 10,000 units. Machine costs are about half of comparable injection moulding machines.

4.1.5 GMT-sheet moulding

Glass mat thermoplastics are made by melting extruded thermoplastic films against a continuous glass filament mat, which is then compressed under heat to form a polymer-based sandwich. The materials are produced by Azdel, Symalit and Idemitsu Petroleum. Similar products are also made by Ahlstrom, PP films are generally used for the matrix at present, but other types of matrix (PA, PET, PBT and PU) are under development for the automotive industry.

Like sheet steel, GMT is easily stamped or formed on conventional presses. It is light (30% lighter than SMC), has short process cycle times and gives wide scope for automation. Glass fibre content of up to 43% can be achieved. There is no limitation imposed by a short pot life. By using cool dies, the integral moulding of, for example, carpets and foils is possible. As the resin is a thermoplastic, recycling is easy. However, because of glass fibre intrusion on the moulded surface, most GMT components to date have been non-visible or painted. Also, the process is inherently wasteful of energy, as the components have to be reheated and pressed at least twice.

GMT is increasingly replacing steel in structural applications in cars as it offers an outstanding stiffness to toughness ratio.

Hybrid GMTs based on Vetrotex's Twintex have already found applications in European cars. This is a promising development, exploiting aligned fibre thermoplastic composites based on comingled E-glass and PP fibre in the form of a hybrid yarn. The comingled concept offers several advantages, as follows:

- intimate combination of fibre and matrix reduces flow lengths and moulding pressures
- conventional textile techniques can be used to produce flat fabrics or circular braids
- flexible fabrics permit pre-forming at ambient temperature before heating and consolidation

- fabrics can be laminated with GMT, polymer films or other materials to produce a sandwich. Lamination with a GMT core enables complex shapes and thickness changes to be accommodated in a way which would be difficult in a monolithic fabric laminate.

This approach is largely at the development stage, but examples of its use include the 10 kg battery tray for the prototype Ford Ecostar electric vehicle and transmission undershields.

GMT's uses include battery trays, spare wheel wells, seat backs, inner door panels and integrated front ends.

4.1.6 Rotational moulding

With rotational moulding a precise charge of thermoplastic polymer (usually PE, PVC or PA - in powder form) is placed in a cold, closed mould made of either cast aluminium or fabricated steel sheet. This is placed in an oven and heated while being rotated biaxially to distribute the resin evenly over the complete surface of the mould. The temperature and rate of rotation depends on the type of material used and the characteristics of the moulding. The mould is then cooled, rotation continuing throughout.

This has to date been a small-run process, but it is beginning to be used for making automotive components on a commercial scale, especially in Germany and the UK. It has been used for several components for Rover, including the heater box housing assembly for the MG RV8 sports car. The process has also been used for fuel tanks by Ford in Australia, Audi in South Africa and by a number of European car manufacturers for low volume models.

4.1.7 Lost core moulding

Lost core moulding is used to produce hollow plastic or composite parts of arbitrary internal shape at automotive production volumes and rates. A fusible alloy core is inserted in the mould and polymer injected around it. After moulding, the fusible core sublimates.

The first major application was the production of plastic air intake manifolds with smooth internal surfaces allowing uniform and predictable delivery of precise fuel-air ratios to all engine cylinders, thereby improving fuel economy by several percentage points over identical metal manifolds. Water pump housings, thermostat housings and other cast parts through which fluids flow are other candidates for the process.

4.1.8 Casting

This process is confined largely to optical components, including some types of rear view mirrors. The material used is usually PC, although PMMA can also be used. Ceramic moulds are used and these can be electrically or oil heated. Temperature control of these must be precise to prevent premature solidification, leading to frozen-in stresses. If these occur, annealing is necessary, making the process more expensive.

4.1.9 Calendering

Calendering is an old established process where a compound coming from a sheet extruder is fed into a stack of temperature controlled rolls and worked to make a sheet or film product with close thickness tolerances. Polishing or texturing rolls are used to provide the desired surface finish. For automotive interiors the products fabricated are based on ABS/PVC, ASA or TPO sheet. The calendering process is still used for instrument panel skins and door trim and, to a lesser extent, for headliners. Other uses include the flexible rear windows of cabriolet-type vehicles, car covers and tool bags. The process can be integrated with a lamination step - for example, with an expanded thermoplastic directly behind the calender and/or with vacuum forming.

4.1.10 Powder slush moulding

This is a process for moulding objects originally from a free-flowing plasticised or semi-rigid PVC powder blend, but other plastics are now suitable also. The powder blend is poured into a heated hollow metal mould and rotated to distribute the powder uniformly over the interior surface. The powder sticks to the mould surface and fuses, with excess surface powder being poured from the mould before fusion is complete. The thickness of the fused material is governed by the mould temperature and by how long the powder remains in the mould.

This process is used mainly to produce textured instrument panel skins which are thinner and more uniform than components made by rotational or injection moulding and lack mould parting lines caused by rotational or injection moulding. Low plasticiser formulations give stiffer skins and less fogging, but these do not flow well and are difficult to process. Better grain retention and surface dullness is obtained than with calendering-vacuum forming of PVC, TPO or ASA. Examples include the VW Golf and Audi models which have a slush moulded instrument panel skin in PVC.

4.1.11 Foam moulding

Steam chest moulding is used to make bumper cores, sun visors, door energy absorbing foam and head-rest cores from expanded polypropylene pellets. In essence, PP pellets are blown into a mould, after which steam is injected, thereby sintering the blown pellets together to form a rigid structure. After cooling, the mould is opened. The moulds, usually of aluminium, are relatively cheap and the method presents great design freedom. It has been adopted from the packaging area.

4.1.12 Other thermoplastic processes

4.1.12.1 Long fibre thermoplastic (LFT)

This process is based on a PP matrix and is not unlike GMT, but involves the use of long fibre (10mm+) glass rovings instead of a continuous glass mat.

LFT is manufactured on-line, eliminating the need for a semi-finished product which has to be reheated before loading the mould, thus saving energy. The process is claimed to guarantee outstanding mechanical and physical properties, high rigidity, very good dimensional stability and excellent impregnation of the reinforcing fibre and, unlike GMT, it gives a Class A surface. An on-line recycling process permits waste material and parts to be re-used immediately. Appryl Composites' Pryltex range features grades with various fibre lengths (12, 18 and 25 mm) and can be processed using traditional injection moulding for bulky parts, compression injection moulding for large surface area parts, and compression transfer extrusion for structural parts.

LFT is used on the front end of the Volkswagen Passat. Other parts include the front end for the Skoda Fabia which was launched during mid-1999 and engine capsulation parts for a German car producer.

A variant of LFT now under development is the long fibre granular (LFG) process, whereby fibre reinforced thermoplastic compounds with granulated and recycled GMT materials are processed in a single screw extruder into mouldable plasticised materials. The process is thought suitable for parts such as spare wheel covers, instrument panels and battery trays. The Mercedes-Benz A-class spare wheel cover is being made by both LFT and LFG processes to compare results. Mitras (Germany) is also testing the LFG process.

4.1.12.2 Hybrid metal-plastic processes

Bayer and other companies have recently examined the production of hybrid components made up of pressed metal and plastic. An advantage is that load bearing metal structures can be designed thinner, since a perforated, moulded-in plastic rib structure reduces significantly the tendency of thin metal parts to buckle and bend under load. Much of Bayer's experience in this area has been based on nylon materials.

The process combines a metal deep drawing process with injection moulding. A perforated sheet steel part is placed in an injection mould, which is then filled with plastic melt in the normal way. During the injection cycle, the melt flows into and around the perforations in the metal part and forms a series of "rivet heads" between the mould wall and the metal so that a high strength, composite structure is created between the mould wall and the metal. The plastic and metal are locked together by both force and shape, with no adhesive required.

The first formal application of Bayer's plastic-metal hybrid technology was a front end cross member on the Audi A6, moulded of 30% GFR rubber-modified PA6 over high strength steel. The one-piece "outsert" moulded part replaces compression moulded GMT parts that required numerous inserts. Another benefit of the hybrid part is that it does not need to be post-mould trimmed. A similar process is used for the front end of the new Ford Focus with the result that the part, made from GFR PA and profiled steel plate, is both stronger and 40% lighter than the equivalent front end made solely of steel.

Another application of this technology is seen in the "cross-car beam" developed in the US by GM, Delphi and Bayer. The need for excellent mechanical properties, together with the numerous functions demanded by an instrument panel, made this an ideal application for hybrid plastic-metal technology. Component and capital costs were reduced by 10% and weight by 40%. Ford has also produced a hybrid instrument panel for the new Mercury Cougar, and in this case the resin used is a GFR PC/ABS blend.

4.2 Thermosetting processes

4.2.1 Contact moulding

Contact moulding is an open process: composite material is either laid by hand (hand lay-up) or sprayed (spray-up) into an open mould.

Hand lay-up

Here a mould release agent is first applied to the wall, then a gel coating is applied and allowed to cure. Alternating layers of laminating resin and chopped strand mat (CSM) are then applied. Woven rovings can also be used, alternating with layers of CSM. After maturing for several hours, the piece is removed from the mould. No pressure is used and the moulding has only one smooth surface. While this method is slow and labour intensive, large complex shapes can be produced with little limitation on moulding size. Typically, it is used to mould short-run car bodies, especially monocoque designs.

Spray-up

This is a contact moulding process offering higher production rates than hand lay-up. Catalysed and accelerated resin and chopped glass rovings are simultaneously sprayed, together with a predetermined proportion of peroxide catalyst, onto the gel-coated mould surface until a layer of the required thickness has been built up.

Both processes, particularly hand lay-up, are slow which is a disadvantage in long runs. Also, being open mould processes, it is difficult to avoid emission of styrene fumes. However, use of suitable ventilation and of LSE (low smoke emission) resins is likely to prevent contact moulding from being wholly abandoned, and they are still likely to be used where closed mould methods cannot be used economically. Contact moulding is occasionally encountered in small run models (for example, some racing cars) and in prototype work.

In 1998 hand lay-up and spray-up accounted for approximately 33% of unsaturated polyester usage in Europe. They are not expected to increase.

4.2.2 Compression moulding with SMC

Compression moulding generally involves high pressure moulding of sheet moulding compound (SMC). SMC is supplied as a rolled sheet of material where each layer (one layer of chopped glass fibres between two layers of resin) is separated from its neighbours by an upper and lower release film, usually PE or PA. Filler content can be as much as 60% The material is loaded into a high pressure mould between two matched steel die surfaces. The hot mould is closed and pressure is applied to make the SMC flow into the remainder of the mould and cure so that it has sufficient strength to be handled when the mould is opened. Much technical development has been needed to achieve enough accuracy in die matching to ensure uniformity.

SMC mouldings are smooth on both faces and show almost no glass structure. They can be relied on to produce a Class A finish.

A typical formulation of 25% resin, 25% fibre and 50% filler with additives keeps material costs low, but the high cost of steel tools means minimum economic production is usually regarded as being about 30,000 units a year. SMC is a long-run process for high volume cars. A US source suggests economical production levels of up to 200,000 a year.

SMC has a number of variants. The most important are flexible moulding compound (FMC) and high modulus compound (HMC).

4.2.3 Injection moulding with BMC

BMCs are materials consisting of a mixture of glass fibres, polyester or epoxide resin together with a catalyst and a filler (such as calcium carbonate). E-glass is usually used at levels between 12 and 18%. BMC has only 60% of the strength of SMC, but gives a high quality surface. It tolerates introduction of relatively large particles of filler, so giving a route for the disposal of SMC or other thermoset scrap. Before pressing, BMC looks rather like a mass of dough (its former name was dough moulding compound): it is weighed and inserted into an open mould, which is then closed and pressure applied at between 4 and 7 MPa. When polyester is used, moulding temperature is between 120 and 150°C.

BMC is injection moulded using equipment similar to that described earlier in this chapter (see section 4.1.1 Injection moulding).

BMC is used for hatchbacks, boot lids, exterior door handles, rear spoilers and front-end trim.

A low viscosity moulding compound (ZMC) has been specially developed for injection moulding exterior parts such as hatchback doors for the automotive industry. It allows more freedom of style and design.

ZMC, a process developed by Vetrotex and Billion, was designed to reduce the break-up of fibres occurring when BMC is prepared in a mixer and finally extruded. Fibres up to 25 mm long are retained in the moulded part and a balance between high strength and good finish is achieved. ZMC uses a combination of injection and compression moulding, giving tolerances of less than 0.1% in component weight and dimensions.

Another development of BMC uses kneaded moulding compound (KMC), which incorporates some aspects of SMC technology. Here, fibres and resins are mixed by passing between two rollers that are continuously fed with resin. However, KMC fibres are about 25 mm long, and processing is on a plunger injection press to reduce the risk of degradation.

4.2.4 Compression moulding with prepregs

Prepreg moulding is used particularly for compression moulding complicated shapes. It is similar to SMC moulding, but involves the use of pre-impregnated woven or knitted fibres or moulded chopped fibre preforms. A preform is placed in a mould and catalysed resin poured over it. The mould is then closed and excess resin pressed out. The preforms used are stronger than the chopped fibre reinforcements or rovings used for SMC and allow precise fibre placement and strict control of the reinforcement: fibre ratio, which is vital for quality control in advanced component production. Prepregs can be used with thermoplastics as well as thermosets.

4.2.5 Injection compression moulding

A combination of injection and compression moulding was developed to improve surface finish in compression moulding, and adapted to mould large area parts and textile-covered panels in thermoplastics. In the former, compression moulding proceeds normally until the mould is closed and full pressure has been applied. A low-viscosity, reactive polymer (usually polyester) is then injected onto the appearance side without opening the die, at a pressure higher than moulding pressure, so that the injected resin moves between the base resin and the die. For thermoplastics, melt is injected into a partially opened mould, which is then closed, compressing the melt.

4.2.6 Reaction injection moulding (RIM)

Although thermosetting epoxies, unsaturated polyesters and thermoplastic nylons have been used in RIM, the matrix is now usually either polyurethane or polyurea. The latter is increasingly used as its high temperature performance exceeds that of polyurethane. Some observers think nylon might make a come-back in this process.

In the basic PU RIM process, isocyanate and polyol are prepared separately and mixed before injection into a heated mould. Injection pressures are very low, so the RIM clamp and mould are usually much lighter and cheaper than in injection or compression moulding. The polymer is cured partly in the mould, and often removed from it to finish curing on a separate fixture while the next cycle continues.

Another variant uses several mould bottoms on a carousel, filled in sequence from the mixing equipment and a single clamp top. The parts cure completely in the mould: the extra bottom moulds eliminate the need for separate post-cure fixtures. Production rates are comparable with hot-press SMC moulding.

Hollow glass microspheres added to polyurethane reaction injection moulded (RIM) parts, achieves weight savings. A good combination of weight-saving, satisfactory surface finish for painting and improved mould-filling is achieved with 2% loading by weight of microspheres. Inclusion of microspheres increases material cost, but weight savings resulting from the 10% reduction in density in the final part are said to justify their use. Besides weight savings from incorporating a less dense material, the method allows use of a resin density reduced from the normal 700-550 kg/m^3.

Microsphere technology can be retrofitted into existing production setups without system modification or additional tooling costs. A negative point is the presence of porosity defects which increase by some 3%. But these are a small part of all moulding defects. On the other hand, both blister and flash defects are decreased (through elimination of over-packing) and the combined benefit of weight reduction and increased yields showed a 9.3% decrease in raw material usage, with consequent savings.

4.2.7 Reinforced reaction injection moulding (R-RIM)

This is similar to RIM, but differs in that solid filler particles (chopped or hammer-milled glass fibre or mineral filler) are added at one side of the RIM monomer supply before injection to increase strength and stiffness, reduce elongation and improve high temperature performance. The particles must be small enough to pass through the mixing and injection equipment without fouling it. PU-based R-RIM is one of the most important processes used to make plastic body panels.

R-RIM has previously been thought of as essentially a long-run process. Use of metallised epoxy moulds, which are 10–20% of the cost of steel moulds and have an expected life of 20,000 demouldings, is being investigated. If this proves successful, it would meet the automotive industry's requirement for a process capable of producing individualised components for specific customer demands.

4.2.8 Structural reaction injection moulding (S-RIM)

This process has points in common with both RIM and RTM, and is intermediate between them. It involves the use of dry fibre preformed reinforcements (for example, glass mat) and inserts (such as foam and metal parts) placed in a heated mould before a polymer mix is injected. As the fibre is pre-placed, orientation of the fibres and their density in the finished part can be closely controlled. The fibre content is high, as it takes about 30% by volume of glass to fill the mould tightly enough to prevent inflowing polymer from washing it out of place. The method can be highly automated, which speeds output and reduces labour costs, but limits usage to medium and large volume series.

Krauss-Maffei has developed machines for long fibre S-RIM which is now called LFI-Long Fibre Injection. Fibre length can be 12–100 mm. A typical density of LFI is 0.6g/cm^3. The Becker Group (now part of Johnson Controls International) is using these machines to produce door trim panels for Mercedes-Benz.

Hennecke is working on S-RIM PU door panels for a major North American car manufacturer that involves introducing the long fibre reinforcement into the mould along with the wet PU mix. The main aim of the FipurTec process is to reduce the labour content of the process. A wall thickness of just 2.5 mm is wanted.

An example of recycling process scrap is found in work carried out by ICI in which LD-S-RIM interior door panels are pulverised and the resulting powder added (at up to 15% on overall system) to fresh polyol as filler. The addition of recyclate filler to the polyol does not have a significant effect on the material reactivities or flow, nor on the part's physical properties.

4.2.9 Resin transfer moulding (RTM)

This process is growing in importance for moulding glass reinforced resin. Dry fibre reinforcements (like glass mat) and inserts (foam, metal parts) are placed inside a pair of matched moulds before a thermoset resin (usually UP) is injected into the heated mould from a transfer pot. As the fibre is pre-placed, fibre orientation and density in the finished part can be controlled closely. The fibre ratio must be high, as it takes about 30% by volume of glass to fill the mould tightly enough to stop inflowing polymer resin from washing the reinforcement out of position. Pumping pressures range between 20 and 200 psi, so mould costs are low and perimeter clamping is enough for the low pressure methods. High strength-to-weight ratio parts result and the freedom to integrate numerous inserts are the main advantages of the process.

Preforms can be produced in two ways. The spray-up method involves the projection of chopped fibres in a liquid binder onto a screen in the mould, or a continuous strand mat produced by thermo-forming can be laid automatically or by hand in the mould. The former allows production of more complex shapes, but less control over fibre orientation while the latter can allow unacceptable variation in the density of the preform. Processes introduced and marketed by Owens Corning (based on robot direction) and Cambridge Consultants Ltd (involving the production of woven preforms) are now claimed to overcome these problems.

RIM, R-RIM, S-RIM and RTM are increasingly used for fascias, wings, bonnets, door panels, boot lids, tailgates and many other components, for medium-run production rates. The equipment is cheaper than that used in injection or compression moulding because of the lower pressures. Tooling costs, too, are lower as cheap, easily shaped materials such as zinc or nickel can be used, making these processes attractive for short production runs. These processes give a high standard of finish, but labour costs are higher. Their use is likely to grow because of the combination of low cost and high quality which they offer. In 1998 the RTM process accounted for approximately 3% of all FRPs processed in Europe.

4.2.10 Filament winding

Filament winding is an automated manufacturing process involving winding resin-impregnated fibre, rovings or tape around a mandrel to produce the desired shape. Filament winding machines take continuous reinforcement fibres from one or more sources and direct them through a batch of resin to a feeding head which winds them around a mandrel of suitable design. Where pre-impregnated roving is used, special lathes lay down the reinforcement in a predetermined pattern to give maximum strength in the desired directions. Curing takes place by the mandrel being heated, in an oven or by infrared radiation.

Thermoplastic resins can be used as a matrix instead of thermosets, with the advantage that tubes or components can be processed further, especially when curves are required. However, the field is dominated by thermosets.

A variant of FW is mandrel wrapping. This uses prepreg sheet or tape cut to the desired shape with the reinforcing fibre oriented in the prepreg at the required angle. It is used to make tubular components when fast production speeds and low costs cannot be achieved by conventional FW. Typical of the components made by mandrel wrapping are parallel sided and tapered tubes with wall thickness of 1-2 mm. In 1998 filament winding accounted for approximately 8% of all FRPs processed in Europe.

4.2.11 Pultrusion

Pultrusion is used for continuous production of profiles of constant cross-section; it involves pulling resin-impregnated reinforcement through a heated die. Usually, the reinforcement is drawn through an impregnating bath containing catalysed resin and then pulled through the heated die. In another variant, the reinforcement, accurately positioned and under tension, is drawn through the die, where impregnation of the fibres and cure of the resin system takes place.

Pultruded profiles have considerable advantages in engineering uses over aluminium extrusions and rolled steel in terms of weight, cost, corrosion resistance and electrical insulation. However, pultrusion can make only straight products of constant cross-section (although, to a limited extent, curves or other modifications can be made by forming while the section is still partly cured. Also, the process is slow −1 m/min is typical. This can be increased by appropriate temperature control. Some of these problems can be solved by using thermoplastic resins, which permit subsequent shaping to be carried out. These can be processed at about 10 times the speed of thermosets.

Pultrusion is slow and expensive, and has to date been used little in car manufacture. Pultruded space frame elements have been tested by several manufacturers, but have not yet reached commercial use. Pultrusions are used to reinforce S-RIM or RTM parts. The pultrusion process is also of interest for the production of pellets containing long fibres for injection moulding (see section 4.1.1 Injection moulding).

4.2.12 Other thermoset processes—Long Fibre Injection – LFI-PUR

ICI Huntsman Holdings and Krauss-Maffei have developed a long-fibre injection process which is now being used for PU door panels for the Mercedes-Benz CLK convertible.

Other similar processes are: Hennecke's FipurTec chopped fibre process which blends the PU and glass strands outside the mixing head, thus reducing air bubbles and allowing better control over the mix; and Cannon's InterWet process, which uses more glass. The mixing heads can use chopped scrap foam, mineral fillers of pulverised plastic, thus facilitating the PU mixture to be more recyclable.

The LFI-PUR technology offers a number of advantages over other glass reinforced PUR-based processes such as RIM, R-RIM and S-RIM. Fibres up to

100 mm long are automatically blended with PU and then poured by robotically controlled nozzles on to a mould in a criss-cross pattern. This process is reported to be approximately 40% more economical than S-RIM. Savings occur through shorter cycle times and reduced labour costs, and flash is eradicated.

4.3 Plastic painting processes

Painting was typically a process in the automotive industry which contributed heavily to pollution. However, suppliers of paints and coatings for vehicles have made concerted efforts in recent years to develop products which are less harmful to the environment. In large measure, this has been prompted by increasingly stringent environmental requirements as determined by legislation. Until recently, paints and coatings contained a high level of volatile organic compounds (VOCs) which resulted in a high level of atmospheric pollution when applied to bodywork and components. An example of the type of legislation to curtail this type of environmental damage is provided by the European Commission's Directive 97/C99/02 which limits the allowable emissions of VOCs in certain industrial sectors, including the paints and coatings industry.

Two solutions are available for meeting the new standards when painting car bodies and components. These are: carrying out the painting process in a sealed chamber which is equipped with very efficient special filters; or alternatively, the use of water as a solvent for the paint resin, rather than toluene or xylene. The latter process, however, has a major drawback due to the high energy required to evaporate the water. This amounts to 590 kcal/kg of energy, compared to approximately 94 kcal/kg for toluene, and therefore the process requires larger and more powerful ovens. On the other hand, the use of water as a solvent has a number of important advantages including reduced smell and toxicity, lower fire risk and less environmental harm.

Large companies such as Akzo Nobel, DuPont, Herberts Automotive Systems and BASF Coatings have developed hydrophilic resins, water-based paints and coatings with high solids. A further improvement has been obtained through the elimination of heavy metals from the composition of the coatings.

Exterior body parts in either plastics or thermosets are preferably painted with the same paint and in the same process as the rest of the (metal) body. A so-called Class A surface is a prime requirement, and the base resin should not be susceptible to chemical stress cracking caused by the coating.

Achieving a Class A surface is a function of the polymer system used and the conversion method. Usually a thermoplastic which is injection moulded at high back pressures in a highly polished mould is converted into an article with a very smooth and glossy surface.

SMC body parts were characterised for a long time by the lack of a smooth surface, but the past few years have seen the development of new formulations ("Low Profile" SMC) which, with somewhat modified conversion techniques, enables a Class A surface to be realised. The advantage of SMC - along with BMC, polyurea and LFT - over unfilled thermoplastics is that the parts can be painted in line, they have a low expansion coefficient and they do not sag at high oven drying temperatures. The material is therefore highly suited for horizontal parts such as the bonnet (hood).

The fenders of the Renault Clio and Mégane Scenic are injection moulded in an unfilled PPO/PA blend, are painted in line and can be subjected to 175°C in the cataphoresis chain. New formulations may be developed to pass through ovens at 190°C without the fenders sagging. Cataphoresis is generally carried out at a temperature of 190°C. Electrically conductive grades are available for electrophoretic coating.

For a good paint or coating adhesion to the plastic substrate a hydrophilic surface is preferred. In practice this means a resin with a large amount of polar groups in the molecule. Therefore parts in PP, like bumper shells, need a pre-treatment of the surface to increase the surface tension. This can be achieved by a number of means: by flame treatment, usually used for 3D surfaces; corona discharge with preferably flat surfaces; and the new method of plasma treatment. However, parts in PPO/PA blends, PC/PBT, SMC, RIM-PUR and GF PET do not need such pre-treatment. Polypropylene manufacturers are all investing heavily to develop PP resins with built-in polar groups.

Car interior parts, such as instrument panels and door panels, are being produced increasingly with a skin in calendered or extruded TPO foil. Since the surface is rather scratch and mar sensitive, a flexible, dull and scratch resistant paint is applied to the surface. However, this requires the corona treatment, as indicated above, for a good adhesion. This treatment can be applied directly after the calendering operation, taking care that "blocking" of the wound up foil does not occur.

Future developments in the use of plastics will tend to avoid the expensive paint operation. For example, the MCC Smart car has 11 body panels made in an injection moulded PC/PBT blend with two thick layers of a transparent and UV resistant coating, based on a reactive polyisocyanate loaded with UV absorbers. The base resin is already pigmented in the right colour, also with selected UV resistant pigments. GE Plastics and BASF have a joint development programme in this area.

Paintless Film Moulding (PFM) - a joint development between BASF, Engel (the Austrian-based machine producer), Röhm (the German-based PMMA producer) and Senoplast (an Austrian-based extrusion company) - provides co-extruded panels of a pre-coloured base sheet covered with a UV rays-resistant film of PMMA for external body panel applications.

5 Competition Between Plastics and Composites and Other Materials

The growing use of plastics and composites in car applications implies that other materials - such as steel, aluminium and copper - are being substituted on an increasing scale. In addition, of course, there is growing competion between these other materials, with aluminium and magnesium, for example, being specified increasingly due to their light weight and other characteristics. Meanwhile, producers of these other materials are engaging on research and development programmes in the attempt to maintain their competitive positions. In particular, worldwide steel producers have developed a number of initiatives (notably the Ultra Light Steel Automotive Body) in order to ensure that steel remains the preferred material for car bodies.

This chapter examines the ways in which metals are being used currently in cars and identifies the new formulations which have been developed to bolster competitive positions. In many cases, it is clear that these are a considerable improvement over previous grades and represent a serious alternative to plastics.

Only those applications where plastics and plastic composites are a viable alternative to metals are discussed. Engineering steels, cast iron and non-ferrous metals, along with metal matrix composites and ceramics, are rarely specified where the use of plastics is feasible, and therefore they are not covered here. The principal competitors to plastics for automotive applications are steel and aluminium, but magnesium, titanium, copper and zinc are also considered.

5.1 Criteria of choice

The choice of materials used by vehicle manufacturers and their components and systems suppliers depends on a combination of factors, the main ones being cost, mechanical and physical properties and weight. Other attributes, such as surface finish and paintability, may also be important for particular components. When assessing the cost factor it is important to take into account both the cost of the material and the cost of processing it into the finished product.

Indeed, the economic advantages and disadvantages of competing materials depend heavily on material and processing costs. In the case of sheet, aluminium is one of the most expensive materials and steel the cheapest. Plastic sheet materials vary widely in price, depending on the level of performance required.

An assessment of material cost cannot, of course, be carried out on a weight-for-weight basis. Plastics are less dense than steel and have less tensile strength and stiffness. A plastic sheet like, for example, sheet moulding compound (SMC) will thus need to be thicker than a steel sheet for the same application.

To illustrate this point, the characteristics of different sheet materials used in car bodywork with the same bending strength have been calculated in Table 5.1.

Table 5.1 Comparison of material properties

Property	Units	Steel	Aluminium	SMC	Low Density SMC	Magnesium
Modulus	GPa	210	7	–8	–8	47
Density	g/cm^3	7.9	2.7	1.9	1.3	1.8
Density specific modulus	(GPa cm^3)/g	26.6	25.9	5	6.2	25.9
Relative cost	\$/kg steel reference	1	3.7	3.1	3.7	6
Relative cost specific modulus	GPa/\$ steel ref.	210	18.9	3.5	2.6	7.5

Source: Sears (6).

Table 5.1 provides a number of important pointers with regard to material choice for automotive applications. For example, aluminium is three times as expensive as steel in terms of material cost, and also offers less than one tenth as much stiffness per dollar spent. There is an even greater difference when SMC and magnesium are considered. An analysis carried out in terms of tensile strength would reach much the same conclusions.

It follows that, where stiffness and tensile strength are the most important criteria, steel will have an advantage, though this can be compensated to some extent by design. However, where these factors are unimportant, others come into play. Tensile strength and modulus are, for example, of little significance in the interior fittings of cars. Here comfort and appearance are the determining factors.

Competition between materials occurs mainly in bodywork panels, where there is increasing interest in the potential of high strength steels and aluminium, as well as plastics. Other product areas where there is competition include bumpers, front ends, dashboards, interior trim, seats and some engine and suspension components.

5.2 Steel

Steel sheet is a very good bodywork material for cars. Vehicle companies have used the material for as long as cars have been in production, with the result that the processing operation holds no mysteries.

Among its attributes, steel sheet is tough, strong and stiff. Of crucial significance, it is also cheap and there is an excess of plant for making and pressing steel sheet. It resists heat and corrosion, although a major negative is its propensity to oxidise and hence turn to rust.

The crash behaviour of steel sheet in bodywork makes it highly suitable for automotive uses. Steel can be recycled without loss of quality and there is a well established network of scrap merchants and processors.

However, conventional mild steel sheet has disadvantages. It is heavy, which is a big impediment as vehicle manufacturers attempt to reduce the weight of cars in order to improve fuel efficiency. The shapes which can be produced by pressing are limited (for example, it is not possible to produce re-entrant cross-sections) which means that complex parts often have to be made in many pieces and fastened together. These constraints give an incentive for designers to consider lighter materials or those which offer greater design freedom.

The future for steel in bodywork depends on new grades being developed which keep its desirable qualities of strength, toughness, stiffness and processability while cutting down weight. There have been major developments in recent years in high strength steels and metal-plastic-metal (MPM) laminates.

5.2.1 High strength steels

High strength steels are defined as those with a minimum yield strength of 210 MPa, while ultra high strength steels are those with a minimum yield strength of 550 MPa. Several kinds of high strength steel are now being developed or used for car body panels, as follows:

- Interstitial free (IF) steels, with very low carbon and nitrogen content and alloyed with small quantities of manganese, phosphorus, silicon and/or boron.
- Bake hardenable steels, whose composition allows stresses to be relieved and hardening to take place in stoving. Both interstitial free and conventional mild steels may be bake hardenable.
- TRIP (transformation induced plasticity) steels, alloyed with carbon/silicon/manganese, are also being developed. TRIP steels are attractive to car makers because of their excellent formability, and very high yield and tensile strength, but no commercial applications have yet been recorded. It is probable that their commercial use is about ten years away.

Ultra high strength steels have so far been used only in structural members.

The proportion of high strength sheet steels used in car manufacture was about 10% worldwide in 1991, but by the end of the 1990s it has risen to over 30%. It is anticipated that the proportion will rise to over 65% by 2002. High strength steels are important in the engine, chassis and suspension areas. They have been used for intake manifolds, springs, suspension arms and wheel discs.

The potential for achieving weight reduction by using high strength steels has been explored in the Ultra Light Weight Steel Auto Body (ULSAB) programme which involves a consortium of 35 steel makers. Phase 1 (a concept design study) showed that the weight of a medium sized car body can be reduced by an average of 24%, while at the same time increasing static torsional rigidity by 69% and reducing cost by 14%. In this study the body-in-white is treated as an integrated whole, rather than as a collection of independent components or modules, so that performance improvements in one area lead to mass savings in another. This is important, as material choice aimed at weight reduction is often concentrated on reducing the weight of a single component.

The ULSAB design requires widespread use of high strength steels (forming over 90% of the ULSAB structure) and advanced manufacturing technology including laser welding, tailored blanks and hydroforming. Parts designed in ultra high strength steel include the front dash cross member, the front floor support and the kick-up cross member. Steel sandwich materials are used in parts such as the spare wheel well and the dash panel insert. The design was modified to take into account the reduced formability of the material and to facilitate assembly by mechanical fixing and adhesive bonding. High strength steels are important in the bodywork, chassis and suspension areas.

Table 5.2 summarises the structural performance of the ULSAB vehicle compared with reference and target values.

Table 5.2 Performance summary of ULSAB Stage 1

	Reference	ULSAB	Target	Difference
Mass, kg	271	205	200	–66
Torsional rigidity, Nm.deg–1	11,531	19,506	13 000	+7525
Bonding rigidity, Nm.–1	11,902	12,529	12,200	+627
First B/W mode, Hz	38	51	40	+13
Cost, US$	1,116	962	–	–154

Source: Hewitt (8).

In the second stage of the ULSAB study, Porsche built several light-weight steel bodies to validate the findings of the design stage. These had been assembled, weighed and tested by early 1998. The conclusion was that the ULSAB design surpassed all safety and performance targets while weighing 25% less than the average of the comparator vehicles - in other words, an ULSAB car could carry an extra passenger at no extra cost. Physical tests showed an 80% increase in torsional stiffness and a 52% increase in bending stiffness. The body met all mandated crash requirements.

The ULSAB design gives a steel body structure which is light-weight, safe, structurally sound and affordable - and one, moreover, which can be built with proven techniques. It offers lower fuel consumption and CO emissions while keeping the proven recyclability of steel.

The ultra light-weight steel auto closures (ULSAC) project was a spin-off from the ULSAB project with the objective of demonstrating the potential for using steel-based car closure panels (doors, bonnets, boot lids and tailgates). These were seen to offer major weight savings compared with conventional steels hitherto used, without penalties in terms of structural performance or cost. The methodology was similar to that used in the original ULSAB project.

High strength steels were used for all of the outer panels. Sheet hydroformed bake hardenable steel with a minimum yield strength of 220 MPa proved to have excellent formability as delivered, and gained additional strength and dent resistance after press forming and paint stoving. Higher strength steels were selected for other components, such as hinge areas of the inner door panels, and a 1200 MPa yield stress ultra high strength steel was used for side intrusion bars to give side impact resistance at low weight. High strength hydroformed tube also reduced the weight of the frame-integrated and frameless floor and tailgate designs. As in the ULSAB project, the use of tailored blanks was crucial.

Steel sandwich panels were also used to reduce weight. The ULSAC design study showed that using them for bonnet and boot lid inners increased weight savings by 3%, though at some penalty in cost.

Other techniques used to reduce mass and/or improve structural stiffness included part consolidation, functional integration, incorporating feature lines in outer panels and designing inners to support outer panels. Finite element analysis calculations were carried out on each part to confirm that the design would give acceptable structural performance. For the doors, frame rigidy, door sag, torsional rigidity, check load and side intrusion were evaluated. For the bonnet, boot lid and tailgate designs, torsional rigidity and bending stiffness were the critical elements, while data on side beam stiffnesses were obtained for the bonnet and boot lid. All designs met the set targets.

Weight reduction targets were set at 10% lower than the best-in-class of the normalised weights of the benchmark closures. Structural performance targets for each closure were set at the midpoint of the range observed in the benchmark survey. The weight savings achieved are shown in the following table.

Table 5.3 Weight savings achieved by ULSAC

Part	Benchmark	Target	ULSAC design	% weight saving
Roof integrated door	19.7	15.5	15.1	23
Frame integrated door	19.7	15.5	14.3	21
Frameless door	19.7	15.5	14.3	27
Bonnet	11.6	8.0	7.9–8.5	26–32
Boot lid	11.2	8.0	8.0–8.6	23–29
Tailgate	13.9	11.3	9.5–10.9	22–32

Source: Kimberley & Rogers (AA).

To predict side impact performance, the concept doors were subjected to side intrusion load. First, the side impact beams in the model were placed as specified by the FMVSS 214 standard. Then the door was constrained at the hinges and latch and loaded from the outside. The first 150 mm of intrusion were simulated with the analysis performance exceeding the FMVSS 214 standards.

Table 5.4: FEA door calculations (measurements in mm)

Load case	Target	Roof integrated	Frame integrated	Frameless
Frame rigidity front	43	45	64	N/a
Frame rigidity rear	43	38	52	N/a
Door sa	287	318	299	346
Torsional rigidity – upper	94	146	155	170
Torsional rigidity – lower	94	278	107	117

Source: Kimberley & Rogers (AA).

For the bonnet and boot lid, two alternative panels were designed to save weight: a 0.8 mm polymer core between 0.2 mm sheet steel, and a 0.6 mm thick sheet steel. For the tailgate, two designs were tested. In one an increase in stiffness at a lower weight was achieved by specifying a tubular hydroformed frame for the glass, resulting in a reduction in part count. In the other, a sheet hydroformed outer was hemmed to a stamped tailored blank inner panel, and this exceeded mass and performance targets at a lower cost than for the tube hydroformed design.

A preliminary cost analysis was also carried out. This showed no discernable difference between "baseline" and "concept" costs for two of the three door designs: the "concept" frame integrated door cost about 7% more. For bonnets, there was no additional cost for the sheet steel solution, but an increase of about 10% for the steel sandwich design. A similar conclusion emerged for boot lids. Costs for the "concept" tailgates were estimated to be 12-24% above "baseline" costs.

The ultra light weight steel auto body – advanced vehicle concepts (ULSAB-AVC) project

The global consortium of steelmakers behind the ULSAB project has now launched the ULSAB-AVC project on advanced vehicle concepts, an automotive design and engineering programme planned to take two years.

The project will investigate the use of the latest high performance steels and technologies with the objective of helping the automotive industry to address the increasing legislative pressures to improve fuel efficiency by reducing weight and to increase vehicle safety. The programme will take a holistic approach to the development of a new advanced steel automotive vehicle architecture. For the first time the programme comprises the main body structure, closures, suspension, engine cradle and all structural components and components relevant to vehicle safety.

5.2.2 Metal–plastic–metal (MPM) laminates

Steel sandwich materials consist of two layers of IF steel enclosing a layer of polypropylene.

The main examples of the use of MPM laminates come from North America, where they have been used for engine parts, oil pans, valve train timing covers and front-end covers. Their commercial use so far in Europe has been limited to items such as bus interiors, train doors and truck bumpers. The ULSAB programme, described above, has explored their use.

Panels made of MPM laminates can act as effective barriers where NVH (noise vibration harshness) is a critical issue and, because of the higher standards now demanded by consumers, sandwich sheet is being more widely used in bulkhead and floor panels of new passenger models.

Compared to solid steel sheet, MPM sheet is limited in the extent to which it can be press formed, while spot welding also requires some changes in technique. There is also the disadvantage that the middle PP layer cannot be economically recycled.

However, the material's engineering advantages are sufficient to justify its use, especially in upmarket models. The first model to make significant use of steel sandwich panels was the original Lexus LS400.

5.3 Aluminium

The lightness of aluminium compared to steel is one of its main attractions for car makers. By helping to reduce a vehicle's overall weight the material makes an important contribution to improved fuel efficiency.

Moreover, aluminium's high strength-to-weight ratio means that it can deliver an equivalent performance to steel and save 60% in weight over bake-hard-enabled steel.

There are other attributes too which make the material particularly appropriate for vehicle applications. It absorbs energy well, to the extent that aluminium is claimed to absorb 50% more energy than steel in a crash. Unlike steel, it resists atmospheric corrosion and requires no anti-corrosion treatment. It can be formed and finished using essentially the same processing equipment as steel, although aluminium's greater spring-back calls for great care in die design. Many parts can be made with shorter cycle times than their plastic or steel equivalents.

However, there are a number of negative factors to consider. Aluminium's main mechanical disadvantage is its relative lack of stiffness (modulus of elasticity equals 70 MPa). This means that wall thicknesses have to be increased in areas where rigidity is important. Even so, it still offers a considerable weight saving.

Aluminium cannot be welded using conventional welding techniques, as an oxide film forms immediately when a welding flame is applied. Rather than use inert gas welding techniques, car makers usually use adhesives at points where steel would be welded.

Perhaps aluminium's most serious limitation concerns its high price and, equally worrying, the volatile way in which the price moves. This makes it difficult to calculate with confidence the cost of an aluminium component during a model's life cycle. Within the automotive industry it is widely recognised that an aluminium structure will weigh half as much as a steel structure, yet cost twice as much. Even so, it is anticipated that the price gap between steel and aluminium will drop as technology develops and high quality aluminium scrap becomes available. Also, an improvement in fuel consumption of about 8% which is implied through the specification of an aluminium-bodied car will compensate for the extra retail price of the car over a 100,000 mile life expectancy, even at current fuel prices.

Virgin aluminium requires a very high energy input, but the material can be recycled easily and aluminium scrap uses only 5% of the energy needed to produce the virgin material, giving big environmental and cost advantages. Recycling also helps to dampen the material's aforementioned price fluctuations, which means that an increase in aluminium recovery through recycling should help to reduce and stabilise the price. At present it is estimated that only about a third of aluminium scrap from all sources is now recovered in Germany, compared to about 90% in Japan. However, the position is not entirely clearcut since automotive applications invariably require high grades, while the use of alloys means that recycled aluminium is not always suitable for re-use in vehicles.

Aluminium is already used quite extensively in current models, with manufacturers citing an average of 60-70 kg per car. This represents about 5% of a typical car's kerb weight. Of this, about 30% by weight is used in the chassis and engine, 50% in the gearbox and 15% in the bodywork.

Methods used to manufacture aluminium components include sheet and strip, castings and forgings, sandwich sheets and superplastic forming.

5.3.1 Sheet and strip

Rolled coil, strip and sheet accounted for about 25% of the weight of aluminium used in cars in 1990, according to Hydro Aluminium. Alloys usually chosen are either non heat-treatable 5000 series magnesium alloys for formability and corrosion resistance, or 6000 series heat-treatable magnesium/silicon/copper alloys for dent resistance.

Aluminium sheet gives an equivalent performance to steel and saves 60% in weight compared to bake-hardenable steel. It is claimed that in a crash it can absorb 50% more energy than steel. It needs no anti-corrosion treatment and can be formed using much the same equipment as steel, although its greater spring-back calls for great care in die design, as noted earlier.

On the other hand, its relative lack of stiffness (modulus of elasticity equals 70 MPa) means that wall thicknesses must be increased where stiffness is important. Even so, it still offers a weight saving. It cannot be welded conventionally and, instead of inert gas welding techniques, car manufacturers usually use adhesives in places where steel would be welded.

Apart from body panels (which are examined below) many small grilles, profiles and other similar items are pressed from rolled aluminium strip. However, the most important development in recent years has been the use of aluminium sheet in space frame construction.

The aluminium space frame concept

The aluminium space frame concept involves aluminium panels being fixed to an aluminium tubular frame, thereby giving major savings through lower processing costs. The tubes provide strength and stiffness and absorb energy in a crash. As many as 300 or more pressed steel components welded into place can be replaced by under 100 aluminium extrusions and robot welded pressure cast joints. This technology is unsuited to volume production, where steel remains cheaper, but suits low volumes where die costs are more important than material costs: it is only economic where production is less than 50,000 cars a year.

The Audi A8 model, introduced in 1994, is the most important example so far of aluminium space frame construction. Customer interest and experience is claimed to be favourable. Other models using similar technology which have been announced subsequently include the Vauxhall/Opel MAXX and the Renault Sport Spider, and it seems probable that this method of construction will be used more and more for limited volume models.

Aluminium body panels

Land Rovers have featured aluminium body panels since 1948. Ferrari and Aston Martin use aluminium alloy for all external panels, while Toyota, Ford US and Porsche use it for some door, bonnet, roof and boot panels.

Monocoque construction

Aluminium monocoque construction was used by Ford US in its AIV programme and by General Motors in its EV1 electric car. Vehicle producers in America are well ahead of their European counterparts in applying this technology, and so far there has been no commercial use of aluminium monocoque construction in Europe. Monocoque construction is unsuitable for low volume cars because of high capital equipment costs, which need long production runs to be amortised. Expansion into the high volume market seems unlikely in Europe during the next 10-15 years.

Other sheet and strip products include intake manifolds, heat shields and heat exchangers. Heat shields represent an application of increased importance due to the widespread specification of catalytic converters with their very high operating temperatures. Toyota use aluminium for heat shields.

5.3.2 Castings and forgings

Castings account for the bulk of aluminium usage in cars. Hydro Aluminium estimated that, of an average 64 kg aluminium content per car in 1990, 85.7% was in the form of castings, but this percentage has clearly declined during the 1990s as more sheet and strip has been used. A high proportion of aluminium castings and forgings is accounted for by cylinder blocks and cylinder heads, applications where the commercial use of plastic is unlikely in anything other than the long term, if then.

Other uses of aluminium castings include manifolds, pumps, housings, transmission cases, gearbox housings, cylinder liners, suspension components, hydraulic cylinders and subframes. Plastics enter into competition with cast aluminium for many of these applications, but there is no clear pattern of development, and in some cases there has actually been a reversion to aluminium from plastic.

The original aluminium wheels, which were adopted to enhance the appearance of sports models rather than to save weight, were forged. Lightweight cast aluminium wheels have been under development, and new fabricated wheel designs combine cast centres with rims from rolled, fabricated sheet.

Wheels provide a good example of a component where cast and forged aluminium compete with plastics, but no clear trend is emerging either in the supply of original equipment or in the increasingly important aftermarket where stylish wheels are often retro-fitted.

5.3.3 Sandwich sheets

Sandwich sheets (for example, Hoogovens' Hylite) consist of a polypropylene core between two aluminium sheets which contain 4.5% magnesium. They have good drawing quality, paintability and recyclability, together with useful sound-deadening qualities. The NedCar Access model at the 1996 Geneva motor show featured a Hylite bonnet and roof panel. Hylite is aimed at the next generation of cars for horizontal uses such as the bonnet, roof and boot lid.

5.3.4 Extrusions

Aluminium extrusions are used for bumper beams, side impact bars, seat and window frames, dashboard support beams, heat exchangers, fuel rails, aerodynamic spoilers, oil, pneumatic and hydraulic pipes and intake manifolds. Extrusions are commonly used for window and sunroof frames and housings. Other applications include seat runners, roof rack rails, radiator grilles and bright trim parts, engine mounts and fuel tank necks.

5.3.5 Foams

Attention is now being paid to the potential of aluminium foam - one of the many materials that were developed originally for defence purposes. Unlike other cored metallic materials - such as aluminium honeycomb - foam can be used to produce stamped and formed complex sheet metal structural parts, which are claimed to be up to 50% lighter and ten times stiffer than conventional steel parts. Aluminium foam may be made in one of three ways:

(i) Powdered aluminium is mixed with a metal hydride, which gives off hydrogen gas when heated. The gas forms bubbles in the semi-molten metal to create a foam-like structure.

(ii) Air jets blow bubbles through a stirred bath of molten aluminium to create a foamy "head" which is continuously drawn off onto a conveyor belt and coiled into sheets. Alumina or silicon carbide particles are added to keep the molten metal thick enough to preserve the bubbly structure as it cools.

(iii) A container is packed with powdered aluminium and pressurised with an inert gas such as argon, which fills all the tiny gaps between particles. The container is then heated to fuse the particles, trapping the gas in the spaces. The metal is then rolled out and heated in a furnace, where the trapped gas expands to form a foam.

The first method is best suited to form three-dimensional shaped parts, the latter two for slab and sheet. Foamed sheet may be used to form a sandwich by roll cladding it between two layers of aluminium sheet.

European car makers plan to use aluminium foam as part of the "fire wall" separating the engine from the passenger compartment. Besides being effectively fireproof the foam forms a very good sound dampener. Another application being actively pursued is in luggage compartment walls. In the longer run it may be used in body panels.

Aluminium foam also has excellent energy absorption properties, making it a prime candidate for energy absorbers for frontal and side impact. Several car companies are showing interest in making side impact beams and knee bolsters out of aluminium foam. By tailoring the density of the foam, designers will be able to fine-tune mechanical properties such as rigidity to suit each part.

Wilhelm Karmann GmbH recently exhibited a concept car featuring foamed aluminium panels consisting of a sandwich of sheet aluminium and a core of aluminium foam. In the long run, aluminium foam sheet may be used commercially for body panels, but this is some way off yet.

5.3.6 Superplastic forming

Superplastic aluminium alloys stretch many times their original length at high temperatures. Complex shapes can be made from flat sheet by applying air pressure, stretching the sheet into a female die or over a male tool. Shapes with features such as ribs, bosses and recesses can be designed into a single component.

The latest Morgan +8, +4 and 4/4 sports models incorporate super-plastically formed aluminium one piece wings produced by Superform Metals, a British Alcan subsidiary. Superform has also launched a set shell made from superplastic aluminium weighing less than 5 kg. The process has also been used for body and door panels for models in the US and Europe, for Volvo utility conversions and for smaller, complex components such as rear wing inner stiffeners for Bugatti. Alcan are working with Aston Martin and Ferrari to make hard-to-form parts in SPF aluminium. This is not a high volume process, but the specialist automotive market is seen as promising.

5.3.7 Powder metallurgy

Mass produced PM aluminium components are currently only made in Japan, but interest is being shown in Europe. Components produced by PM technology include: rotors for car air conditioning compressors, pistons, con rods, cylinder liners (developed in Japan, but not yet in production), inlet valves (under development), compressor impellers for turbo-supercharger and valve retainers.

Mr. W. Jandeska, of the GM Powertrain Group, is quoted (LL) as foreseeing potential applications for P/M aluminium alloys in transmission oil pumps, balance shaft gear sets and con rods. He said that one of the attractions of P/M aluminium in transmission oil pumps was in matching the thermal expansion of the light alloy housing and for balance shaft gears was in reducing the total weight of the balance shaft. Problems in overcoming resistance to the application of aluminium P/M technology for con rods lay in matching competing materials' wear resistance, thermal fatigue in operation at 150°C, elastic modulus, dimensional tolerance and cost.

5.3.8 Semi-solid metal processing (SSM)

Shaping of metals by SSM relies on the peculiar flow behaviour of slurries containing non-dendritic solids. If the alloy is uniformly disturbed during freezing, discrete round particles are formed instead of the normal dendrites and the slurry is very fluid. The slurries are thixotropic: the more they are stirred, the more fluid they become, but on standing without stirring they begin to solidify; stirring again restores low viscosity.

Novel forming processes are used to make parts, for example, rheocasting. Here the stirred slurry is introduced into the short sleeve of a cold chamber pressure die casting machine and then injected into the die in the normal way. An alternative is thixocasting, where rheocast slugs are produced by rapid cooling of the slurry, and when required reheated to the semi-solid condition and injected into a die.

SSM forming has the following advantages. It eliminates liquid metal handling. As alloys are formed in the semi-solid state, processing temperatures are typically 100°C lower than in normal casting, leading to longer die life and reduced production cycles. For a given component, the energy required for SSM processing is about a quarter less than for casting. The product has less porosity and a finer microstructure than its cast counterpart. Higher integrity allows use of thinner sections. As the process is nearer net shape, machining is considerably reduced.

America has the lead in exploiting SSM technology. Applications there include air conditioning compressors for Ford, master cylinder caps for Bendix and electronic connection devices. Chrysler uses SSM processed aluminium for the rocker shaft pedestal, and timing belt tensioner pivot brackets.

European applications include master brake cylinders for Volvo, BMW and Audi, and fuel rails for Ford and Fiat. The ultra advanced multi arm rear suspension for the Alfa Romeo Spider marks the start of SSM production of structural load bearing components. Japanese companies have been investigating SSM, but there is as yet no evidence of commercial production.

A further development of SSM is thixomoulding, where SSM is processed by injection moulding by the thixomolding process. The first applications of thixomoulding have been in the processing of magnesium SSM (see below), but work is currently being carried out on developing thixomoulding methods for aluminium SSM.

5.3.9 Combinations of processes

Sub-components can be made by separate processes and then joined. A joint development by Ford and Showa Aluminium produced an intake manifold for a 1.9 litre 4-cylinder engine that gave a 50% weight saving over cast aluminium, and improved the engine's power output by 5%. It used cast flanges at intake port and throttle body joints, with a thin-walled 6063 alloy forging, hydraulically bulge-formed for the plenum chamber. The intake pipes were formed from 6063 extruded tube, bent to shape, then brazed to the plenum and mounting flanges.

Despite the increasing use of aluminium in cars, its high cost has limited its use in major applications, especially in bodywork. Should the electric car concept develop, the weight saving potential of aluminium will reduce this disadvantage and possibly even reverse it.

5.3.10 Prospects for aluminium

The main limitation on use of aluminium is its price. An aluminium part may weigh half as much as its steel counterpart but cost twice as much. How far aluminium will be used in future depends on how far the price of aluminium falls as high quality aluminium scrap becomes available. Recycling requires greater segregation of alloys than is the case with steel: in particular, silicon and non-silicon grades need to be separated. Recycling damps price fluctuations in raw material prices, which have in the past been high.

The critical area for aluminium lies in its use in body panels, particularly in the whole-body use of aluminium. Increased use of aluminium for these purposes depends on:

- how the cost of aluminium evolves, which will depend in turn on success in the recovery of scrap aluminium;
- how aluminium panels and bodies perform in practice. Experience with the Audi A8, so far reported to be favourable, will plainly be of importance here;
- how practical it is to repair aluminium bodies. Some concern has been expressed about this though Audi says that 95% of accident repairs will be carried out by its dealer network.

Use of aluminium foam panels may be expected in the not too distant future. Their greater stiffness may make the use of aluminium panels more attractive than is the case with conventional aluminium sheet panels.

5.4 Cost comparisons between steel, aluminium and plastic composite structures

Studies of the relative costs of steel, aluminium and plastic composite structures have produced two - of particular note - the MOSAIC project and the study by Matthews et al.

5.4.1 MOSAIC project

Renault has cooperated with European material suppliers, including Ciba-Geigy, DSM, Enichem and Montedison, in the MOSAIC (Material Optimisation for a Structural Automotive Innovation Concept) research project, aimed at reducing the weight of vehicle structures.

As part of this project, MOSAIC researchers took Renault's Clio small car as their subject in work aimed at finding methods of reducing the structure's weight by about 30%, at an acceptable cost level without sacrificing quality or safety. After a feasibility study it was decided to concentrate on two alternatives: making better use of steel, and using a hybrid structure consisting of an extruded aluminium framework with a composite sub-frame and front end.

The steel structure which was developed used high-yield strength steels and bonded anti-vibration sandwich steels. It can reduce the vehicle weight by about 10% without any effect on production cost.

The hybrid structure comprised an upper structure wholly made from extruded aluminium stripe formed into a cage to replace stamped steel. The roof and quarter panels were in aluminium sheet and the dashboard and floorpan were made of glass reinforced plastic. The composite chosen was high modulus compound (HMC), a high strength and stiffness variant of sheet moulding compound (SMC) based on polyester and vinyl ester.

Two solutions were tested for the front end: one was of aluminium and the other of nine composite parts. Both gave a weight saving of about 30% compared with a production Clio, without any reduction in vehicle performance.

There were other advantages. Composite materials offer the possibility of moulding complex shapes in one piece, thus greatly reducing the number of separate parts and assembly operations. Furthermore, composite parts do not corrode, eliminating the need for painting or surface treatment of parts not directly visible - an advantage shared by aluminium parts.

However, the aluminium and composite front ends were much more expensive than the current production model steel front end which acted as comparator. For a production rate of 1800 vehicles per day the cost of the composite front end is 20-30% higher than the comparator, and the aluminium front end is 40-60% more expensive.

Looking at the costings in more detail, it was found that material costs for aluminium was 4-5 times greater than for steel (being also subject to large price fluctuations), and for composites 3-4 times greater. Against this, the capital cost of plant and tooling was much less for both aluminium and composities than for steel. The study concluded that small runs of 300-500 vehicles per day are best suited to the hybrid method of production.

It is expected that a commercial model incorporating at least some elements of the hybrid structure will be launched within 3-5 years.

5.4.2 Matthews et al. study

The second study examined the life-cycle cost of an automobile component made of steel and an alternative material, side by side, including specifically:

- Material costs
- Fabricating costs (including tooling costs)
- Operating costs of the automobile over the life of the component
- Disposal costs at the end of the component's life.

The study concluded that, assuming a consumer discount rate of 24% pa, cost equivalence can only be achieved if:

- The aluminium alloy component weighs about 43% of the weight of the steel component it replaces.
- The SMC component weighs about 74% of the weight of the steel component it replaces.
- The injection moulded thermoplastic component weighs about 55% of the steel component it replaces.

If the actual alternative material weighs more than the percentage values indicated above, steel is favoured on a life cycle cost basis. If the alternative materials weigh less than the percentages noted above, then the alternative is more favourable on a life cycle cost basis. The prices used were those current in 1991/2.

The two studies obviously consider two different aspects of the cost aspects of material substitution - the MOSAIC study deals with manufacturing costs only, and the study by Matthews et al. deals with whole-life costs. However, a number of conclusions are suggested:

- Both aluminium and plastic composites are likely to be suitable only for comparatively short run production models.
- It is not possible to generalise on the subject of substitution of one material by another.
- Weight savings resulting from substituting steel by aluminium or plastics need to be substantial: marginal savings are unlikely to be justified by savings either in manufacturing costs or in whole-life costs.

Recent new applications of aluminium include the following:

- The 1996/7 all-new Corvette became the first North American car to have both front and rear aluminium cross members.
- For the 1998 model year, aluminium was expected to be used for the hoods and rear cross members of the new Chrysler LH platform.
- BMW has introduced all-aluminium suspension to the 5-Series saloons and estate cars.
- Apart from the rear cross member, all links and subframes of the rear suspension of the Porsche Boxter are of aluminium.
- Ford Lincoln LS6 and LS8 models coming onto the market in 1999 will make extensive use of aluminium. They will be the first North American production cars for very many years to carry light alloy fenders. In addition, the Lincolns will have light alloy bonnets and boot lids and aluminium wheels. The V6 and V8 engines will be produced largely from aluminium. It is estimated that there could be as much as 230 kg of aluminium in each car.

5.5 Magnesium

Magnesium is the 8th most common element. Its attraction to car-makers is its lightness (1.81 g/cm^3 against 2.7 g/cm^3 for aluminium), but magnesium alloy parts are also claimed to have higher dimensional stability than aluminium ones, with consistent shrinkage and minimum distortion. They machine faster than other metals and damp NVH better than aluminium or steel. Magnesium is stable in alkaline environments but is subject to attack by some acids and by chlorine.

Magnesium has been used as a structural material in cars for many years. The Volkswagen Beetle was a major user between the 1950s and the 1970s, and in 1971 used 42,000 tonnes (about a quarter of world production). However, use dropped when the price of magnesium rose and Volkswagen stopped making the Beetle in Germany.

Magnesium use by car-makers varies. Ford used 14,500 tonnes of magnesium parts in 1996, followed by Chrysler (6,100 tonnes), GM (5,600 tonnes) and Toyota (3,000 tonnes). Mercedes-Benz (2,000 tonnes) is the biggest European user, followed by the VW/Audi group (900 tonnes).

Typical mechanical properties of the main types of magnesium alloys are shown in the following table:

Table 5.5: Typical mechanical properties of some magnesium alloys

Alloy	Condition	Density (g/cm^3)	Young's Modulus (GPa)	Proof stress (MPa)	Ultimate tensile stress (MPa)	Elongation % in 50 mm
Mg-6Al-3Zn-0.3Mn (AZ63)	Sand cast	~1.8	~45	75	180	4
	Peak aged	~1.8	~45	110	230	3
Mg-9.5Al-0.5Zn-0.3Mn (AZ91)	Cast and peak aged	~1.83	~45	127	239	2
Mg-6.5Al-1.0Zn-0.3Mn (AZ61)	Extruded	~1.8	~45	180	260	7

Source: Martin, J.W. "Materials for Engineering". The Institute of Materials, London 1996.

World production of magnesium diecastings is as follows:-

Table 5.6 World demand for magnesium diecastings 1991–1997 (000 tonnes)

Region	1991	1992	1993	1994	1995	1996	1997
N. America	10	12	14	18	23	31	39
Europe	8	7	6	9	10	9	16
Pacific Rim	1	1	2	2	2	3	3
Other	5	5	7	8	7	8	9
Total	24	25	29	37	42	51	67

Source: Magers (15).

Production of magnesium diecastings nearly tripled between 1991 and 1997. About two-thirds of world production of magnesium diecastings is in North America. Demand is expected to rise by about 50% between 1997 and 2002. About 80% of this growth is expected in automoibile components.

Recycling is no problem. If components are not separated from steel, magnesium does not impede recycling of the steel. This does not apply to aluminium, which can cause embrittlement.

Use of magnesium by car makers varies considerably. The greatest use of magnesium in cars is made by North American and European car-makers. The Japanese use magnesium little - mainly for smaller components like air bag retainers, pedal brackets, speedometer hoods, cylinder head covers, steering wheels and steering column components. So far the Japanese have not used magnesium for exterior applications. The Koreans make even less use of magnesium, though it is used for some seat frames.

North American and European manufacturers are using magnesium for instrument panels, cross car beams, knee bolsters, seat frames, radio frames, airbag retainers, pedal brackets and carburettor parts. In drivetrain applications magnesium is used for cylinder head covers, and in steering column components for steering wheels, keylock housings, miscellaneous steering column parts and in various electric motor housings. In exterior applications magnesium is used for sunroof components, cabriolet roof frames and headlight retainers. There is rather greater use of magnesium by European manufacturers, the main difference in practice being in the drivetrain, where European manufacturers are using magnesium in CHC oil baffle plates, manual transmission housings, inlet manifolds, engine air cooler housings, timing gear covers, fan clutches, oil pump housings.

The main component groups where magnesium diecastings are used or under development are: instrument panel substrates and cross-car beams, seat frames, steering column components, engine cylinder head covers, transmission housings and intake manifolds.

(a) Instrument panel substrates and cross car beams

Audi first used magnesium here in the late 1980s, developing a light-weight structure for the cross car beam, with provision for mounting the speedometer, radio and glove box. A high ductility AlMg alloy was used which would bend but not break, performing well in crash testing. There was a big weight reduction (down to 3 kg) compared with the steel used previously, and a significant reduction in the number of components.

Audi's initiative was followed by a similar application by Fiat, who found that compared with steel the magnesium solution yielded better static performance (rigidity and resistance to bending, traction and stress) and dynamic performance (vibration and crash properties), with a 41% weight reduction and no extra cost. There was also a considerable reduction in the number of separate parts which had to be assembled.

GM used magnesium for cross-car instrument panel support beams on the 1997 Buick Park Avenue. Fiat currently uses magnesium for the instrument panel cross-beam on Fiat Bravo and Fiat Marea cars and for the instrument panel cross-beam, steering wheel frame, seat frame and steering column support for the Alfa Romeo 156.

(b) Seat frames

Mercedes-Benz first used magnesium for the seat cushion frame, back frame and belt retainer of the SEL roadster, using diecast ductile AlMg alloys. This design weighed 8-9 kg: designs in use or being developed today consist of a one piece pan frame and one piece back frame weighing together 2-2.5 kg. Seats represent an areas of high developmental activity to take advantage of magnesium's ductility and crash performance, especially in sports vehicles, minivans and estate cars. Magnesium is forecast to grow considerably in this application. Lear Seating and Findlay Industries are currently putting a good deal of development work into magnesium seat frames.

Johnson Controls and Findlay Industries are studying the use of magnesium stamping for seat bottom rails, frame supports, back components and other parts: the latest designs weigh 40% less than current steel seat components.

(c) Steering column components

The extra weight incurred by putting airbags in steering columns changed handling and steering characteristics. Lighter materials than zinc, steel or a combination of aluminium and steel had to be found urgently. Toyota and associated company Tokai Rika pioneered the use of magnesium die castings for steering wheel cores, key lock housings, tilt mechanisms and other steering column parts, using high dutility AlMg alloys for steering wheel cores and AZ 91D alloy for the smaller components.

In North America, GM fitted the 1997 Oldsmobile Cutlass and Chevrolet Malibu with one-piece magnesium steering column support brackets, as did Chrysler's 1997 Jeep Cherokee and Dodge Dakota.

(d) Intake manifold

GM use of magnesium for the Northstar engine intake manifolds in the early 1990s was abandoned but has now been taken up by Piersburg in Germany, who have developed several magnesium intake manifold systems and invested heavily in magnesium diecasting operations. The company sees a bright future for magnesium in the multi-piece intake manifold they are already supplying to Mercedes-Benz, and they plan to continue to expand into fuel management systems with magnesium components which are lighter than the aluminium parts they replace and need less machining because of magnesium's better casting characteristics.

Other reported uses include: brake pedal brackets, steering column support brackets, engine accessory drive brackets and valve covers.

Prospects

There is increased interest in use of magnesium in cars because of its physical characteristics, because it does not degrade when recycled and because of technical advances in processing.

5.6 Titanium

Titanium is the ninth commonest element in the earth's crust, but presents great difficulty in extraction, which makes it expensive. Its attraction is that it combines strength and lightness: it can provide the strength of steel at about half the weight. It also resists corrosion very well.

Titanium is expensive because it is hard to extract from its ores. However, it is being used increasingly in the automotive industry in limited applications. The main applications for titanium in cars where it competes with plastics are: suspension springs and chassis parts. Form memory alloys are also of interest for the future.

Suspension springs

Titanium suspension springs have been used for some years. Cost is the main problem, but cheaper ferro-molybdenum alloys have been developed which largely replicate the previously used beta alloys: these permit a weight saving of more than 70% compared with steel.

Chassis parts

Titanium has been used for suspension sub frames by designers and operators of racing and other high performance cars, using high strength beta alloys originally developed for aerospace applications.

Titanium alloys have also been used in wheels and corrosion resistant, damage tolerant underpanels and wing mirror fixtures. Other components identified by the Japanese Titanium Society as being candidates for substitution include front and rear bumpers, door panels and door sill covers.

Form-memory alloys

In form-memory titanium nickel alloys a part may be changed in shape mechanically but renew its original shape when heated. In Japan the automotive sector represents half the market for form-memory alloys. Japanese companies have developed two applications aimed at the automotive market: Daido Steel has developed an alloy containing cobalt as well as a Ni-Ti mix, which raises shock resistance and prevents rust; Kanto Special Steel has developed a carburettor using a Ni/Ti alloy. The valve changes shape in response to changes in temperature.

Prospects

Demand for titanium in the automotive market is increasing. A virtuous spiral will develop: as demand increases, the price will drop, and as the price drops, demand will increase.

5.7 Copper

The main use for copper in competition with plastics is brake tubing. It is used in the tubing carrying hydraulic pressure to the slave cylinders on the wheels in hydraulic brake systems. This tubing is subject both to pecking by stones thrown up from the road and to corrosion by salt, for example, coming from the road and from the brake fluid itself. Copper-nickel tubing (9 parts copper to 1 part nickel with small additions of iron and manganese) was used for some years in the aftermarket and is now fitted as standard equipment to Volvo, Lotus, Aston Martin, Audi and some models of other manufacturers.

5.8 Zinc

Zinc is used in cars in two ways: as coatings (where improved zinc coatings have made PVC underbody coatings largely obsolescent) and in the form of diecastings.

Diecastings

Zinc diecastings have been used for many years for small components like door handles, window winders and the like. Over the past ten years these have tended to be taken over by plastics: for example exterior door handles are now generally made of polyamide and window winders of acetal.

In recent years improvements in diecasting methods have enabled castings to be made by the pressure die process which can be made to very close tolerances (and so make more economical use of material), have excellent surface finish, have a range of useful mechanical properties (especially ductility) and can receive a wide range of applied finishes. These process improvements, together with the development of new alloys, have helped zinc castings to hold their own, particularly where strength and applied finishes are required. A result of the process improvements has been that castings can be made much thinner, thus using much less metal. This has led to weight savings, a valuable point in automotive applications. Even so, it is likely that the main role of zinc will continue to be as a protective coating of steel.

5.9 Conclusions

The title of this chapter is really a misnomer. In many cases weight reduction is being approached in different ways by different companies (and often in different ways by the same company). Cylinder head covers and intake manifolds are cases in point.

It would be nice if at any given time there were one optimal solution for each component, but life isn't like that. For any car-maker costs are critical: what is economic for a low-volume sports car may well be out of the question for a high production popular model, and vice versa. Each model has individual requirements for physical and mechanical properties: the solution for one may be quite wrong for another. Recyclability is important, and a manufacturer unused to a particular material may well hesitate before introducing it.

There is every indication that designers are increasingly adopting a "horses for courses" approach. Different materials are not regarded as being in competition but as being complementary. An artist does not regard red as being in competition with blue, after all: as with artists throughout the ages, so with designers now.

6 Environmental and Safety Requirements and Customer Demand

This chapter will deal with the effects of environmental and legislative pressures on car design features where plastics are involved. Five main aspects will be reviewed.

1. crash worthiness and passenger safety; crash testing and specifications
2. reduction in fuel consumption and car weight, changes in fuel quality and exhaust gases
3. end of life vehicle; recyclability of cars and car components and the effect on the materials choice
4. noise, vibration and harshness (NVH) and the choice of materials
5. quality aspects.

6.1 Crash tests, active and passive safety systems

Motor vehicle crashes cause about half a million road fatalities annually throughout the world. Furthermore, around 15 million people are injured in traffic accidents.

Passenger safety has been and still is a major feature in the 1990s with the introduction of legislation and relative passive safety features such as airbags to complement safety belts, anti-blocking brake systems (ABS), use of energy absorbing foams, exterior as well as interior and special reinforcing metal beams and crumple zones.

Seat belts have become increasingly complex and are seen working together with airbags. New generations of belts can feature pretensioners using sensors and gas generants to retract the webbing upon impact.

In Europe, the use of belts is obligatory and not wearing them can be punished by fines and, in case of accidents, the insurance companies may not compensate the damages. In the USA, the use of the seat belt is not obligatory in most States, only the passive safety systems in the car interior as well as exterior protect the passengers. The airbag was therefore first introduced in the USA and only came in the early 1990s to Europe where from early 1999 every new car has as standard at least a driver airbag and most also have a passenger one. The non-visible adjustments include side impact beams and front and rear crumple zones which absorb as much collision energy as possible. Further, most cars are equipped with energy absorbing foams (EA-EPP and EA-PUR) in bumper cores, in doors as crash pads and in interior parts. Metal honeycomb structures some 7-8 cm thick and 30-40 cm long in doors are also used, for example by Volvo, to absorb the impact energy of side collisions.

6.1.1 Car interior parts tests

Interior parts need to comply with USA and European legislation, which are very similar. In the USA this is currently the Federal Motor Vehicle Safety Standard FMVSS 201, issued by the National Highway Traffic Safety Administration, NHTSA. In Europe, similar test methods are in force: the ECE 21 and the European Union 74/60/EEC. Basically, all upper vehicle interior parts need to be tested by impacting a featureless Hybrid 111 headform of 10lb weight travelling at a speed of 6.7m/s (15 mph or 24 km/h) over a distance minimum of not less than 25 mm.

The revised FMVSS 201 standard specifies criteria for the upper interior parts. An equation establishes a dummy equivalent head injury criterion (HIC) that is used to measure compliance of specific interior upper components. On July 1998, the 201 was expanded by the NHTSA to include dynamically deploying interior head protection systems. The new revised FMVSS 201 U regulation, which is also used by European car manufacturers, is currently to be phased in:

1999: 10%

2000: 25%

2001: 40%

2002: 70%

2003: 100% of all cars produced

An HIC value of < 1000 is required by the legislation, which corresponds to serious head injuries for 1 out of 6 people. The interior parts concerned by the FMVSS 201 are: instrument panels, pillars, sun visors, head liners, steering wheels, knee bolsters. For these parts energy absorbing EPP or PUR foams are being promoted.

In the USA, since wearing seat belts is not obligatory in most states, in addition, two front airbags are obligatory as well as adequate knee protection by a knee bolster.

A further important safety aspect requiring plastics are child restraint systems. Since April 1993, it is mandatory in Europe to use approved child seats. According to ECE R44 03 five groups are distinguished, covering the age range between babies and 12 year olds. For every group a different seat needs to be used.

6.1.2 Car exterior impacts

There exists legislation in the USA and Europe covering and limiting the consequences of frontal and side impacts by means of laboratory tests as indicated in Table 6.1. Both test methods are in principle quite similar, the conditions differ somewhat, however. The European front impact test calls for a deformable barrier colliding with the front of a car at a speed of 56 km/h (35 mph) with an overlap of only 40%, whereas the FMVSS 208 calls for a full frontal impact with an undeformable barrier at a speed of 30 mph (48.3 km/h).

The side impact tests do show larger differences, in that the EEC test prescribes a deformable barrier of 950 kgs (2,090 lbs), 300 mm (12 inches) above the ground level, bump into a car at a 90° angle and a speed of 50 km/h (31.1 mph). The FMVSS 214 method demands an angle of impact of 27° to the car axis and a speed of 33.5 mph (53.8 km/h) of a moving deformable barrier mounted on a sledge. A US side impact dummy (US-SID) is placed in the front and rear seat, whereby during the test the average value of maximum acceleration of the ribs and of the breast bone must not exceed 85 g. The maximum load on the pelvis must not exceed an acceleration of 130 g.

Table 6.1 Different impact tests valid in Europe and USA

Organisation	Component testing	Front impact test	Side impact test
ECE (whole Europe)*	ECE 21	ECE 94	ECE 95
EU (European Union)*	74/60/EEC	96/79/EEC+	96/27/EEC+
FVMSS (USA)	201+201U	208**	214

* The ECE (Economic Commission for Europe) is a body of the United Nations located in Geneva, issuing recommendations which every country has the freedom to implement. The European Union issues drafts, which are quite similar, and when approved by the Council of Ministers, become law in all the 15 member states. For the front and side impact test this happened in October 1998.
There is also active involvement from the European Enhanced Vehicle Safety Committee (EEVC) and ACEA, the European association of car constructors based in Brussels.

+ Both tests have become obligatory for new car models only since October 1998, whereas in 2003 all cars in the total car parc need to comply.

** Recently (1998) the NHTSA released a Notice of Proposed Rule making for an update of FMVSS 208, which requires "Out of Position" (OOP) testing with several small dummies. In the OOP test, a dummy is positioned very close to the instrument panel, so that the distance between dummy and airbag is very small. Then the airbag is activated and several injury parameters have to remain below certain levels.

The dummies that have to be used in these tests are the Hybrid 111 3 year old, the Hybrid 111 6 year old, the CRABI 12 month old child dummy and the 5th percentile adult Hybrid 111.

Consumer organisations have started, first in the USA, then in the UK and other countries to carry out alternative crash tests to the ones made by the car manufacturers. These have quite an influence on the public since they are publicised. Table 6.2 presents an overview for Europe.

Table 6.2 Crash tests by some consumer organisations in Europe

Organisation/test	Speed in km/h	Load	Inspection of:
ADAC*-Frontal, 40% overlap	80 (48 mph)	2 passengers plus load	Passengers, car structure damage, interior area, fuel system damage, ability to carry away car
AMS-Frontal	55 (33 mph)	2 passengers	Same as above
ADAC, AMS, UK-NACP, side impact, 950 kg barrier	50 (30 mph)	2 passengers or 1 passenger-load	Same as above
UK-NCAP frontal and 40% overlap	64 (40 mph)	2 passengers + load	Same as above
Euro NCAP** front impact, deformable barrier, 40% overlap	64 (40 mph) EEVSC test + 8 kph	Driver + passenger	Head, shoulders, breast, upper and lower legs, feet and ankles
Euro NCAP, side impact by trolley with deformable front	50 (30 mph) impact into the drivers side	Driver	Damage to head, shoulders, breast and abdomen
Euro NCAP, pedestrian/ cyclist impact; child and adult	40 (25 mph)	Test according EEVSC guide-lines	Assessment of legs, child head, adult head; bumper and bonnet assessment

* ADAC is the German Automobile Association (Allgemeine Deutsche Automobil Club).
** UK-NCAP: NCAP stands for New Car Assessment Programme and the UK was the first country in Europe to carry out similar tests as the NCAP ones in the USA and Australia. The tests are more demanding than the official regulations
** Euro NCAP is a combined European effort to provide a fair and objective assessment of the impact behaviour of cars. The TNO Crash-Safety Research Centre, Delft, Netherlands, carries out series of tests on equivalent cars, for example, recently (1998) on 7 luxury cars; Audi A6, BMW 5, Mercedes E-Class, Opel Omega, Saab 9-5, Toyota Camry, Volvo S70 (see table) with positive results.

Contributing to Euro NCAP are: UK Ministry of Transport, Swedish National Road Administration, Dutch Ministry of Transport, European Commission, Federation Internationale de l'Automobile (FIA), ADAC, International Testing (IT) on behalf of European Consumer organisations. Other European countries are likely to join.

Increasingly, vehicle design specifications include greater demands for improved behaviour in side impact accidents. The problems are as follows:-

- deformation paths are too short
- the front structures of the penetrating vehicles are too rigid
- side structures are too soft
- direct contact of the impacting body with the occupant is possible.

A number of steps have been made to improve this situation:

- vehicle transverse reinforcement members with floor structure
- the use of higher strength steels
- interlocking the door with the sill
- door reinforcement members; already mentioned above are the EA PP or EA-PUR foam crash pads, steel reinforcements and honeycomb structures in the doors
- various cars are now being equipped with side airbags, coming out of the side of the seats or door panels to protect the head. Also of interest are the sausage airbags covering the area from A to C pillar of the BMW, the new bigger head airbag of the Volvo 580 as well as the Inflatable Tubular Structure (ITS) of Delphi Automotive to protect the head in case of a side collision and to meet revised FMVSS 201.

6.1.3 Pedestrians/cyclists/"soft nose"

The NCAP collision tests consider also, both in the USA and Europe, impacts with pedestrians. So far the consumer organisations claim nothing has been done by the car manufacturers to protect pedestrians legs and avoiding the hard bounce of the head against the engine hood in case of collision. The "soft nose" concept was born. The Euro NCAP crash tests at TNO, Delft, Netherlands gave the same poor results in respect of collisions with pedestrians/cyclists.

The European Experimental Vehicle Committee (EECV) - working group WG10, has formulated requirements for car front parts to give adequate pedestrian protection. It is expected that in the medium term the European Commission may issue regulations on the basis of these guidelines. The ACEA, Brussels, a joint automobile producers lobby group has calculated that there will be additional production costs of US$350 to US$550/car with a 55-85 lb weight increase. The difficulty is apparently to arrive at a customer acceptable design of the front part. Legislation will start by the year 2002 in Europe. (Reportedly, in the US companies do seem to occupy themselves with "soft nose" designs).

Table 6.3 presents an overview of the main test methods related to the flammability of the plastic and rubber materials used in car applications.

Table 6.3 Flammability, children restraint systems and head rests

Legislative body	Flammability	Children restraint	Head rests
FMVSS (USA)	302*	213	202
ECE (United Nations, Geneva)	ECE 34	ECE 44	ECE 25
EU (European Union)	In preparation**	In preparation	78/932

Notes:
* The FMVSS 302 on the flammability of materials used stipulates that the part shall not burn or propagate a flame at a rate higher than 4 inches (100 mm) per min. This is of course very dependant on the thickness of the part, but the limit presents in general no problem for plastics and composites. For foams also the density is an important factor. In Germany, FKT (Fachausschuss Kraftfahrzeug-Technik) DIN 75 200 prescribes a test specimen of 350 mm x 100 mm x thickness. A 2 mm thick ABS specimen has a flame propagation rate of around 50 to 60 mm/min, so, well within the limit of 100 mm/min.
** European car manufacturers take into account FMVSS 302.

6.1.4 Other specifications/test methods

1. For vehicle lighting there is a USA standard: SAE J 576c
   This standard includes 3 years of weathering trials in Florida and Arizona. A list of acceptable plastics for optical lenses and reflectors on automobiles are published by AMECA, Automotive Manufacturers Equipment Compliance Agency Inc, PO Box 76960 Washington DC 20013-6960 USA.

2. As in the USA, in Europe the ECE R42 standard calls for energy absorbing bumpers able to withstand a 4 km/h speed of collision without damage. Some new cars like the latest VW Passat model are claimed to pass a 15 km/h collision test. The additional advantage is a lower insurance premium. This has led to the design of a bumper shell with a core of Energy Absorbing PP or PUR foam blocks.

3. Increasingly, car producers are preoccupied with the so-called "whiplash", the damage to the neck and head in case of a collision in the rear. For instance, Faurecia has developed their "Spinal CARE System" for improved passenger protection in case of a rear collision. Volvo has developed the WHIPS chair, the whiplash protection system.

4. Pole side impact testing of complete vehicles. This is an important testing procedure during the product development process to determine the severity of injuries resulting from this type of accident and an important factor in door development.

5. Some more European directives

Component	European Union	ECE-R
Car interior	EC/74/60	ECE21
Steering wheel		
Impact protection	EC/74/297	ECE12
Seats, head rests	EC/74/408	ECE17
Exterior car parts	EC/74/483	ECE25
Safety belts	EC/77/541	ECE16
Fuel tanks	EC/70/221	

6. Some US FMVSS Standards

Component	FMVSS Standard
Seat strength, static testing	207
Seat belt systems	209
Rollover, dynamic or static	In preparation
Offset frontal barrier with 30, 40, 50% overlap	In preparation, possibly Amendment to 208
Dynamic roof crush	In preparation

6.2 Fuel consumption and weight reduction, fuel quality and exhaust gases

Fuel economy is becoming increasingly important since a reduction of the overall global increase in carbon dioxide emissions is needed because of the suspected danger of global warming. Road transport contributes to some 10% of the global CO_2 emissions, whereas powerstations emit 25% of the total and domestic emissions are at 23%. Politicians and especially the "green groups" want to increase the already high fuel prices in Europe (around 4 to 5 times those in the USA) even further to reduce the overall use of cars and stimulate public transport.

Likewise, a reduction of the emissions of NO_x, CO, SO_2, lead, benzene and other hydrocarbons in the exhaust gases is wanted to reduce/avoid high levels of smog and ozone in the environment. The obligatory use of catalytic converters on exhaust systems of cars has a tremendous effect in the reduction of the emission of these pollutants. Changes in the composition of petrol and diesel fuels as well as the increased use of direct fuel injection and the common rail have an effect on the selection of plastic and rubber materials especially in the fuel circulation.

6.2.1 Fuel economy

On fuel economy, the automobile producers in the USA must meet the Federal CAFE (Corporate Average Fuel Economy) standards or face penalties of US$50 per vehicle per mile/gallon (approximately DM40 per km/litre). The present standard calls for an average 27.5 mpg or 11.7 km/litre consumption of the car fleet and 20.7 mpg or 8.8 km/litre for light trucks, including minivans and SUVs. To avoid heavy penalties, Chrysler and Ford have started to construct ethanol fuelled vehicles like Dodge Caravan, Plymouth Voyager and some Ford Taurus saloons. The engines can use mixtures of petrol and ethanol.

The complex rules give a much higher mpg rating to vehicles which run on fuel with less than 15% petrol, in spite of the fact that ethanol tank stations are hardly available in the USA.

In Europe, the European Commission has made an agreement with the car industry to reduce the average fuel consumption by 25% in 2005 compared to 1997. Fiscal measures by the member states to stimulate the sales of low fuel consumption cars are allowed.

The European Parliament has voted in favour of a 5 litre/100 km (47 mpg) car by 2005 and a 3 litre/100 km (78 mpg) car by 2010. Although this does not have legislative power it is an indication of the political pressures on the car manufacturers. Volkswagen claims that its recently (end 1998) launched Lupo TDI is the first production model meeting the 3 litre/100 km requirement. This is obtained by a diesel engine with fuel injection. Reduction of fuel consumption can be achieved in various ways:

1. weight reduction of cars by, for example, material substitution

2. better engines, cylinder designs, number of valves, lower friction, diesel engines

3. the use of fuel injection by, for example, common rail techniques

4. hybrid technologies, fuel cells

5. reduction of the rolling resistance of tyres

6. reduction in air resistance by design.

Weight reduction of cars started in the 1970s to reach a minimum in the USA around 1982. Since then an increase is evident mainly due to new added safety and comfort components. The substitution of steel parts by aluminium, magnesium and plastics has continued, however. Back in the 1970s, plastics averaged just 6% of the total weight of a mid-range car, by 1996 this has increased to approximately 13%. In addition, there is around 13% by weight of elastomeric components. It is worth mentioning here the Mercedes A-class having some 200 kg of plastics, partly in the wings and tailgate and the MCC Smart car with PC/PBT body panels. Also, DaimlerChrysler promotes its "Plymouth Pronto Spyder" roadster with car body parts made in PET, thermoplastic polyester. This model is based on DaimlerChrysler's Composite Concept Vehicle. Alternative materials which may increase in use in cars, such as flax and sisal reinforced plastics, instead of glass fibre, and the recently launched nano-fillers, 5% of which in PP presents the same properties as 30% talcum, are anticipated to have a good future.

The last 4-5 years saw a tremendous increase in polyamide consumption for engine covers and air intake manifolds as well as the use of PPE/PA blends in car wings. Steel manufacturers are attacking with their new "Ultra Light Steel Auto Body" (ULSAB) concept using high strength steels. An auto body has been developed weighing 200 kg instead of the usual 270 kg. A 3% lower fuel consumption is claimed. Latest car models contain these high strength steel alloys already, including some 50% of the BMW 3 Series, 30% of the Smart car and some 34% of the Porsche 911 Carrera.

"Hylite", from the Dutch steel and aluminium producer, Hoogovens, which is a light-weight laminate of two sheets of aluminium enclosing a thin layer of polypropylene also enables weight savings to be achieved.

6.2.2 Hydrocarbon (HC) emissions

Hydrocarbons are emitted into the environment in three ways:

1. during filling up of the tank quite a bit of dissolved butane and other low volatiles are emitted

2. the hydrocarbons are also liberated by permeation through the tank skin and the fuel system as well as through leakages

3. when driving, the exhaust gases contain a small percentage of hydrocarbons.

The first item has been addressed in the USA, for many years already, by limiting the amount of butane which petrol producers can add to the fuel according to the season (temperature). Further, the use of ORVR (On Board Refuelling Vapour Recovery) systems was begun in the USA in 1998 for 40% of passenger cars. By 2000 all cars and by 2003 light trucks will need to have these controls. ORVR valves trap gasoline vapours during refuelling and are welded to the tank and made from acetal resins or aliphatic polyketones. These systems may come to Europe as well in the medium term, although a different system is being discussed in which the vapours are sucked away from the car tank and recovered into the main fuel tank.

The permeation of HCs via the car's fuel system is of great concern to the regulators. In the USA, the "Shed Test" (Sealed Housing Emission Determination) has been in force for several years and is used to measure the total hydrocarbon emission from a vehicle, by evaporation or fuel leakage, over a 24 h period. The limit is 2 g/day of hydrocarbons for new cars and valid for 10 years of service or 160,000 km.

In Europe, the Europe 2000 (or EURO 3) requires also 2 g/24 h maximum emission of hydrocarbons. This Euro 2000 will become effective January 1, 2000; also Norway and Eastern Europe may adopt the spec. Japanese car companies stick to this requirement as well. The present ECE 34, in Europe, calls for a maximum of 5 g/24h of fuel permeating. The state of California has decided already to reduce this limit to 0.7 g/24 h by 2004. It is not clear yet whether this will be followed by the rest of the USA, Europe and/or Asia.

The California Air Resource Bureau (CARB) and the US Environmental Protection Agency (EPA) require 0.1 g/24 h for a plastic fuel tank. This favours the 6 layer co-extruded tank construction with ethylene-vinyl alcohol (EVOH) as a barrier layer, and already diffused in the USA. The technology is from Kautex Textron, Germany. The usual fluorinated HDPE tanks, used very much in Europe and meeting ECE 34, do not fulfil this requirement, since the fluorinated layer is washed away with time. The tanks are subjected to the so-called "Slosh Test" with 1 million cycles. Plastic fuel tanks based on a HDPE blend with 6 to 8% Selar RB from DuPont seem to have problems as well, since the test fuels prescribed contain aggressive methanol in Germany and ethanol in the USA.

With direct fuel injection systems, the recirculating system and other parts contribute to a large increase of surface area exposed to liquid and gaseous fuel. The fuel lines and connectors need to be made of more impermeable plastic or rubber than so far used. The use of the common rail system in diesel engines requires special stabilised acetal resins or PPS to be used in the fuel circuit. This is because fuel temperatures could reach 110°C and test fuels currently contain rape seed oil at levels of up to 100%.

The problem of hydrocarbons in exhaust gases is being attacked as well, mainly by use of catalytic converters. The hydrocarbons are, however, benzene, aldehydes, polycyclic aromatic hydrocarbons and others. The catalytic converter functions when hot, but not when cold or during warming up. Preheating of the converter is a possible way to pass the stringent Californian ULEV requirements (ULEV = Ultra Low Emission Vehicle). Tight Californian regulations required hydrocarbon emissions to be reduced by 55% between 1998 and 2000 and that 2% of the vehicles sold reach zero emissions by 1998 and 10% by 2003.

These last percentages cause problems with car producers since they are only possible with battery driven cars.

In Europe, for petrol engines, the limit for hydrocarbon emission in exhaust gases of 0.2 g/km (in EURO 3) by the year 2000 will reduce to 0.1 g/km by 2005 (in EURO 4). Above this, cars will need to be equipped with an "On Board Diagnosis", the function of this component is to monitor continuously the exhaust gas purification system.

Honda has developed an engine having emission values 90% lower than the toughest limit for the Californian ULEV. Three catalysts are present of which one is an HC absorber. Several industrial groups are developing the fuel cell as an energy supplier. In an advanced stage is the joint development of DaimlerChrysler with Shell and Canadian Ballard. The fuel cell will now be tested (1999) in Icelandic buses and DaimlerChrysler, Shell and Norsk Hydro have invested US$1 billion in the project. The cell produces hydrogen gas from normal petrol or diesel fuel which is used to produce electricity for an electric engine. DaimlerChrysler claims to have the fuel cell engine for the A-class ready for mass production by 2004. A tremendous reduction in petrol consumption is possible.

6.2.3 Fuel quality

The above environmental requirements have a large influence on the composition of both petrol and diesel fuels which are in a rapid phase of change and this affects the choice of the correct plastic (or rubber) for the fuel system.

The sulphur content in petrol is to be reduced from the present 500 ppm to 150 ppm by 2000 and only 50 ppm by 2005, in view of the development of new "Denox" catalysts. Also diesel fuels need to have lower sulphur values than the present 400 ppm as supplied for instance in Germany. The octane number needs to increase, by law, from 49 to 51. To reduce the benzene emissions the contents in fuel will be lowered from the maximum allowable level of 5% (in practice approximately 2.5%) to a maximum of 1% or lower. This is not yet mandatory, but legislation is expected to be introduced in the medium term.

The disappearance of tetraethyllead as anti-knock component led to the introduction of MBTE (methyl tertiary butyl ether), EBTE, methanol and ethanol.

Test fuels used in Germany for testing fuel lines and systems are:

FAM-DIN 51604-A
FAM-DIN 51604-B
M 15 (petrol + 15% methanol)
Pure methanol

Testing of fuel lines at −40°C

DIN 73378 for impact and
DIN 53758 for burst resistance

US fuels contain 10% ethanol or 10 to 15% MBTE or EBTE.

Some standard US fuels:

ASTM-C
Haltermann

Testing fuel lines at −40°C SAE 12043

Ford test	Sour gas resistance for 1000 h in PN 180
GM test for fuel lines	Sour gas test according to GM 213M
	GM 9061-P fuel hose permeation test

Rape seed oil methyl ester (RME) or Biodiesel is becoming more widely used as "renewable" fuel in substitution of the usual diesel fuel. Some European car manufacturers like VW/Audi, Mercedes-Benz and Ford specify some diesel engine models for 100% RME fuel. In France, PSA specify a 5% replacement of diesel. In Germany, 100% where tax exemptions make RME the same price as diesel.

RME's main constituents are oleic and linoleic methyl ester, which are unsaturated compounds and therefore prone to oxidation, especially at higher temperatures and in the presence of metal ions. De-esterification by absorbed water liberates the corresponding acids and methanol, both are rather corrosive and attack normal acetal components.

The fuel system needs to be able to resist these conditions, aggravated by the diffusion of the common-rail by which the fuel heats up to peaks of 100–120°C. Fiat test at 120°C with a 5% RME diesel fuel.

Polymer producers have been quick to develop special stabilised acetal resins for fuel contact applications. The fuel lines and tanks will, especially in Europe, undergo rapid changes due to the new legislative pressures.

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7 Recycling and Disposal

7.1 Background

The increasing emphasis during the 1990s on recycling - as opposed to waste disposal - has had significant implications for the automotive industry. Vehicle manufacturers and their component suppliers have directed growing attention towards what happens to their products when they reach the end-of-life stage and accordingly have implemented a number of initiatives and procedures aimed at ensuring that vehicle disposal is achieved in an economical and effective manner. In this regard it has been necessary to conform to an increasing number of legislative requirements which have tended to vary from country-to-country and region-to-region.

Two key factors have been the move to design and make vehicles so that they are easy to disassemble and to specify materials which lend themselves to efficient and effective recycling practices.

Before examining the four stages which have an impact on recycling practices it is worth noting that, for the automotive industry, plastics are generally considered to be a "problem" material. This is because they constitute a high proportion of current automotive shredder residue (ASR), much of which still goes to landfill, and a range of new recovery techniques will need to be developed and introduced if voluntary and mandatory targets, to which the automotive industry is committed, are to be met.

In addition, plastics recovery has not by tradition assumed a high priority because most recycling targets have been set by weight and therefore the natural action has been to ensure that the metals are recovered. Moreover, metals recovery is relatively straightforward - one of the selling advantages used by aluminium suppliers is the material's ease of recycling. Even so, plastics are high visibility components and, in specific kg/car terms, relatively easy to isolate.

At present it is estimated that approximately 75-80% of a scrapped car by weight is recovered for recycling, a high proportion of which is accounted for by ferrous and non-ferrous metals. In contrast, the proportion of plastics recovered is much lower. The position is all the more critical in view of the lower weight of plastics - which means, of course, that the mass is proportionately greater for any given tonnage - and the growing use of plastics in contemporary and future vehicles, which implies that the issue will become more and more acute as recent and current car output reaches its end-of-life stage.

In the UK, the ACORD (Automotive Consortium on Recycling and Disposal) project has established some demanding targets. ACORD is a voluntary agreement but it seems unlikely that the members of the consortium would be able to back off from the commitments they have made. These envisage that 85% of car material content must be recycled by 2002, rising to 95% by 2015.

On the wider European stage, there is an EU Directive EC 31/7/96 on end-of-life vehicles (ELVs) which contains a requirement for car producers to assume responsibility for disposal costs. This could influence the timing of a recycling directive together with the choice of materials usage, especially if plastics recycling techniques are not developed in time.

With regard to recycling targets, the EC's proposed Directive is less demanding than ACORD insofar as an 85% recovery rate is required by 2005 - three years later than ACORD's equivalent rate, although this rises to 95% in 2015 - the same as the ACORD target. However, a crucial difference is that the EC plans to impose constraints on thermal recycling and is laying an emphasis on materials recovery. In 2005 (when, as noted above, 85% of a scrapped car must be recycled) a maximum of 5% is allowed to be recycled by thermal means, and in 2015 (when the 95% requirement becomes effective) the thermal element must be a maximum of 10%. This makes the establishment of effective and efficient plastics recycling procedures all the more necessary and urgent, and again may prove to have an influence on materials choice.

It is worth noting that a number of SMC producers and raw material suppliers in Europe founded ERCOM Composite Recycling GmbH in 1991 to prove that thermosetting composite materials were capable of being recycled and reused for essentially the same applications. In France, Valcor Composite Recycling was founded. ERCOM has a fully operational plant in Germany. A 25% recyclate in virgin compound is required by car manufacturers. With suitable additives, Class "A" surfaces can be obtained with the 25% ground SMC. ERCOM RC 1000 is such a regrind product and Menzolit-Fibron claims to add 30% of regrind.

Elsewhere recycling targets, where they exist, are not dissimilar from European rules. In Japan, two targets have been identified, one set by the Japan Automobile Manufacturers' Association (JAMA) and the other by the Ministry of International Trade and Industry (MITI). JAMA's targets were announced in January 1998 under the banner of "Voluntary Action Plan for End-of-Life Vehicles Recycling Initiative" and envisage that by 2002 at least 90% of the vehicle should be recycled. MITI's proposals were announced in May 1997 and are known as "End-of-Life Vehicles Recycling Initiative". They are rather less demanding in the short term in that the 2002 target recycling figure is at least 85%, but there is also the aim that the amount of ASR destined for disposal by landfill should be 40% lower than the 1996 level. MITI's target for 2015 rises to at least 95%, by when ASR disposal in landfill should be 80% lower than the 1996 level. The targets established for Japanese vehicle manufacturers conform closely to European ones.

In the US vehicle recycling is a based on a voluntary code involving vehicle manufacturers, component and system suppliers, dismantlers, shredders and processors of materials. As such it tends to be driven by market forces, although the establishment of targets elsewhere - and particularly Europe - means that Ford and General Motors with significant vehicle assembly facilities in Europe are implementing the same policies and procedures aimed at boosting recycling performance.

7.1.1 The scale of the problem

In Western Europe it is estimated that around 10-12 million cars and light vehicles are scrapped annually and, as market saturation approaches, the point between manufacture of new vehicles and scrappage of old ones is narrowing.

This is also the position in North America and, to a lesser extent, Japan. In the US it is estimated that around 12-13 million vehicles reach their end-of-life stage each year and, of these, probably 94% (and maybe more) are subject to some form of recycling. As in Europe, a minimum of 75% of the vehicle by weight is recycled.

In emerging country markets, including many in South East Asia and Latin America, scrappage is not the issue that it is in the West for two main reasons: first, the car parc is much smaller; and secondly, there is a propensity to extend vehicle life way beyond western standards through constant repairs. Recycling will become more of an issue in these markets at some future point but probably not in the timescale of this report.

In total, therefore, it is estimated that worldwide car and light vehicle scrappage amounts to 40-42 million and that this could rise to 45-47 million by the end of the forecast period.

7.1.2 The establishment of a dismantling industry

The growing volume of end-of-life vehicles (ELVs) coupled with the need to organise their disposal on a more professional basis implies that a dismantling industry will become established which, in terms of the number of vehicles handled, will not be noticeably smaller than the vehicle manufacturing sector itself, especially in North America and Western Europe. An imperative will be for ELVs to be disposed of by a network of authorised facilities, some of which will be general and others (perhaps manufacturer-owned) will be dedicated to one or more marques.

It could be that these operations will need to be subsidised, hence the furore at present in Europe concerning who should bear the cost of disposal. From the plastics standpoint this is an important point because new, probably expensive, techniques will need to be developed and recycling equipment installed, the cost of which will not be compensated by the value of the recovered material.

7.1.3 Four factors to promote plastics recycling

Discussions with vehicle manufacturers and component suppliers indicate that four actions will assist in expanding the scope of plastics recycling. These points are evident time and again in the recycling initiatives pursued by vehicle manufacturers and highlighted later in this chapter:

- There is an objective to reduce the number of plastics used in vehicles which typically has amounted to 20 different types.
- Plastic parts have to be clearly identified in order to assist sorting at the dismantling stage. Even when highly advanced sorting techniques are used it is still desirable to provide guidance to assist manual sorting.
- It is desirable to be able to separate plastics parts from other materials - for example, fasteners (including adhesives) - which contaminate.
- Vehicle manufacturers are looking for agreements with plastic suppliers to take back old parts for raw material. However, this is dependent on the specification of the material.

7.2 Four stages in recycling policy

There are four principal stages in a vehicle's life when recycling policy has to be considered. These correspond to:

- design/development;
- manufacturing;
- vehicle in use;
- scrappage.

Each stage needs to be taken into account when specifying materials usage, and it is probable that recycling considerations will become increasingly crucial as vehicle manufacturers' experience and understanding of recycling issues expands. This is likely to be especially the case with plastics and composites where there is the definite prospect of new variations of existing plastics and composites reaching the market during the timeframe of this report.

7.2.1 Design/development

At the design and development stage, vehicle and system manufacturers need to accommodate four considerations. First, it is desirable to choose materials which lend themselves to easy recycling. This has tended to work against plastics in the past but is becoming less of a consideration in the context of more sophisticated recovery techniques. Moreover, the inherent advantages of plastics over other materials in specific applications tends to outweigh any disadvantages at the recycling stage.

Secondly, there is a natural tendency among vehicle manufacturers to reduce the number of materials in their products. Again this has tended to work against plastics since, in the early days of their use in automotive applications, the specification of a plastic material invariably added to the number of materials used. Now the emphasis is towards materials rationalisation so that complexity at the time of recycling is minimised.

Thirdly, design and materials usage needs to take into account the ease and speed with which vehicles can be dismantled. This is especially so with plastics since a growing number of dismantling procedures have to be adopted to retrieve the parts. This is in contrast with metals where crude crushing and subsequent melting operations are able to recover much of the material.

Fourthly, there has to be easy recognition of materials so that different plastic types may be sorted and recycled appropriately. Much attention has been paid to the development of an international standard for plastics recognition. This obviously reflects the extensive international trade in vehicles but also the fact that plastic types are not necessarily easy to sort in the absence of a code.

7.2.2 Manufacturing

At the manufacturing level, the issue of plastics recycling is concerned with two areas, one associated with component and system production, while the other involves recycling packaging materials which been used in the shipment of components from component/system manufacturer to the vehicle assembler and is therefore outside the scope of this study.

With regard to component and system production, the objective is to recycle process waste as quickly and efficiently as possible. Process waste normally joins new material at the point of component production, but this is not always possible and is dependent on the specification of the virgin material.

7.2.3 Vehicle in use

Recycling at the vehicle in use stage is typically limited to components which are subject to regular replacement (such as batteries) and parts which are replaced as a result of crash damage (bumpers are an obvious example).

The processes involved in material recovery do not vary from those at the end-of-life stage and, if anything, the sorting is more straightforward since the parts are gathered by special outlets such as garage service departments, fast-fit centres and bodyshops.

The critical factor at this phase is the organisation of an economical collection service which, in similar manner to local authority recycling initiatives, is not always clearcut. In particular, it is important that the environmental costs of collection do not exceed the environmental benefits of recycling the scrapped parts.

7.2.4 Scrappage

Finally, and most obviously, there is the scrappage stage. At this point the effectiveness with which the first stage (design/development) was conducted shows through. The key functions are dismantling (disassembly) and separation of materials, and the key objective is minimal waste to landfill.

7.3 Issues in plastics recycling

Plastics present particular problems in recycling, including contamination, limited recyclability of thermosets, degradation of thermoplastics and the many varieties of plastics.

7.3.1 Contamination

Plastic waste may be contaminated by rubbers, paint, textiles, oils, heavy metals and chemicals such as polychlorinated biphenyls. This makes disposal of ASR both difficult and hazardous. Metal waste is also contaminated by the same agents, but does not present the same problems, as metals can be heated to a very high temperature while retaining their properties. Most plastics degrade and lose their properties at about 300°C. Most recovery schemes concentrate on recovering "clean" components with minimum contamination, for example, bumpers. To increase the recovery rate, chemical methods are being developed by several companies which can remove contamination and allow components concerned to be ground down and reused.

7.3.2 Limited recyclability of thermosets

Unlike thermoplastics which, when heated, melt and return to virtually their original composition on cooling, thermosets degrade when heated and cannot be reconstituted, thus losing their useful properties.

Up to now the only feasible way to recycle automotive thermosets like SMC and BMC has been to grind them down and use them as fillers for new SMC panels. Ground down even finer, they can also be used for BMC components. Using processes developed by Dow Europe, the new part can incorporate up to 30% recycled material, and also effect a saving in other reinforcement materials (for example, glass mat) required. Similar approaches are proving successful in the USA.

The limited recyclability of thermosets deters designers concerned with environmental issues. Some European car makers are turning to other materials for exterior panels; GMT may be used for panels which are not visible. Of the major car makers, Volkswagen, Mazda and Volvo have expressed the strongest intentions of eliminating use of thermosets, or at least minimising their use. Japanese car makers take much the same line - in any case they have traditionally made comparatively little use of thermosets, particularly of SMC. However, in the US, car makers have traditionally used thermosets much more, and new applications are constantly being reported there.

7.3.3 Degradation of thermoplastics

Reprocessing leads to some degradation of the properties of thermoplastics through changes in the polymer chain's structure. This is usually accommodated by a sequence of "cascade" recycling in which the material is moved down the quality scale to a use where properties are less vital. Research continues into ways to reduce the effects of property degradation.

Recycling works best if the scrap materials are all from the same plastic family, allowing them to be reprocessed with minimum degradation, and avoiding a step down in the cascade. With more complex polymer compounds, grinding and remelting is less successful because of greater degradation. More virgin material must be added if the material is not to drop to a lower level of the cascade. Experience suggests that unblended plastics such as polyolefins and polyurethanes will be favoured in future, though Dow and Fiat have had success in recycling ABS.

7.3.4 Variety of plastics

The plethora of plastics, and variations in their recyclability, imposes big problems. The US Society of Automotive Engineers identified close to 100 plastic "families", few compatible with each other. The market for low-grade plastic mixtures is limited, being confined to floor tiles, picture frames, shoe heels, etc. New processes and materials are continuing to extend the range of plastics used in cars. It is desirable that the number of different plastics used should be limited, and that those used should be chosen for recyclability, or at least compatibility. Automotive manufacturers are working with materials suppliers to make this standard practice.

7.4 Initiatives by manufacturer

Although legislative bodies are laying down an increasing number of rules concerning future recycling targets, vehicle manufacturers are implementing their own procedures, often in advance of legislative requirements. In some instances vehicle manufacturers are co-operating with their component, raw material and system suppliers and there are examples of co-operation with other vehicle manufacturers. In addition, as noted earlier, there are examples of industry-wide initiatives (such as the UK's ACORD) which may pre-date and pre-empt governmental demands.

7.4.1. BMW (including Rover)

Recycled plastics are considered to be of major importance in BMW's environmental strategy. Both BMW and its UK subsidiary, Rover Group, place an emphasis on designing vehicles which are both easy to dismantle and facilitate ease of recycling of polymers at the end-of-life stage. Model development procedures adopted by both companies during the first half of the 1990s are expected to result in the recovery of recyclable polymers during the first decade of the next century as the models involved are scrapped in increasing volume.

The parts involved are primarily easy to recycle plastic parts which can be either identified by material type or separated during the dismantling of vehicles. In view of BMW's comparatively recent takeover of Rover, the two marques' policies are not yet integrated, although they have followed a similar line.

An indication of the growing use of plastics, the need to establish comprehensive recycling procedures and the possibilities for re-using recovered plastics in further automotive applications is seen with reference to the current BMW 5 Series. This model contains almost a tenfold increase in plastics which have been recycled, from 2.5-24 kg.

For example, all reflectors in the tail lights of the 5 Series consist of recycled materials. All electrical components are now integrated into a separate and easily dismantled compartment. Product design geared to recycling has made the model more suitable for disassembly. Similarly, the model is equipped with a rear parcel shelf which is manufactured from materials recovered during the manufacturing of the instrument panel. In turn, the instrument panel is one of the first implementations of a unitary materials strategy. It uses R-RIM PU as an armature, PU foam as a soft feel and energy absorbing phase, and is finished with an in-mould coated PU skin.

In the case of polyurethanes, BMW has instigated with its suppliers a scheme for depolymerisation and utilisation of PUR parts.

More than 50 components in the 3 Series are made from recycled plastics, amounting to a total weight of 15 kg which is equivalent to about 10% of the total weight of plastics used on the model. Polyurethanes are used almost exclusively for the instrument panel of the 3 and 5 Series, and a recycling scheme has been established with the supplier using a depolymerisation technique. The luggage compartment bottom sheet won a recycling award in Germany due to its sandwich construction which uses 90% production PUR scrap from other parts.

Rover has followed a similar line with regard to plastics recycling and is a participating member of ACORD. One innovative process developed at Rover is that of dual injection of low grade polymer materials, over-moulded with high quality materials.

7.4.2 Fiat

Fiat has been examining the environmental impact of its products for many years with regard to a variety of aspects. On the recycling front the company established a project called FARE (Fiat Auto REcycling) with the ambitious aim of achieving a total recovery of materials used in a car, and various agreements have been concluded with raw material suppliers.

As might be expected, a major part of the FARE initiative has involved an examination of plastics recycling opportunities, with the result that a number of important conclusions have been reached which have been implemented throughout the organisation. For example, internal studies indicated that the use of a single material, polypropylene, for door panels facilitates recycling. This involves the specification of PP fabric, PP foam, TPO skin and a PP carrier.

Fiat has made a number of agreements with other vehicle manufacturers concerning car collection schemes for recycling.

7.4.3 Ford

Like many aspects of Ford's operations and approach to issues of public interest, Ford's policy with reference to plastics recycling is developing on a global basis. As a US-based company, Ford has been keen to demonstrate its environmental credentials and is active in developing policies which enable plastics to be easily recovered and recycled from its scrapped vehicles.

In addition, there is a growing trend towards utilising recycled plastics in the specification of original equipment parts, thereby creating demand for post-consumer waste. Moreover, these applications for new parts are being developed from recycled plastics which are being sourced from non-automotive as well as automotive scrap. As an example, plastic bottles and carpets are being used as raw material for the production of parts which are being fitted to new vehicles and the objective is to manufacture parts made from 100% recycled material. In the US, nylon carpet waste is plentiful and is being used in the manufacture of air intake manifolds and air cleaner linings. Battery trays are being recycled and are 100% recycled polypropylene, since Exide and other battery manufacturers all use PP.

One of the practical problems in plastics recycling concerns the different colours used - for example, in light clusters. In Europe, light clusters are being recycled and are being separated with regard to both material types and colours. This provides Ford with a considerable advantage from the point of view of recycling and using recyclate.

Major modifications towards a simplification of plastics usage is occurring whenever economics permit. This is not always at a facelift or new model stage but can involve changes to an existing model at any time.

As a major international producer with extensive manufacturing facilities in both North America and Western Europe as well as elsewhere in the world, Ford is often affected by differing priorities according to region. A good example is seen with reference to PVC. Political pressure in Europe is militating against the use of this material but this is far less of an issue in the US. Even so, Ford (and its compatriot, General Motors) is moving towards a "single material solution" and has stated that it will be possible to produce instrument panels entirely from polyolefins. This will obviously make the recycling process easier, since separation of the parts will no longer be necessary. However, Ford believes that some development on TPO will be required to make the material match the durable and soft luxurious feel of PVC slush moulded skin.

More recently, Ford has moved towards directing its component suppliers to make greater use of recycled material in their products. Ford is proposing to set levels which indicate a specific percentage of recycled materials for any given vehicle weight. Materials specially targeted under this new initiative include glass, rubber and plastics. It appears that targets in the plastics sector will be especially demanding and there will be an emphasis on using post-consumer waste.

7.4.4 Mercedes-Benz

A number of vehicle manufacturers (including BMW, GM-Opel and Mercedes-Benz) are avoiding the use of PVC which, because of its low thermal stability, acts as a contaminant in recycled plastics. For the E-class, ASA skin is used in preference to PVC on the instrument panel cover.

Another example of the phasing out of PVC is seen in the S-class which no longer has a PVC anti-rust underbody coating. Instead there are large plastic panels produced from polypropylene. The total weight of these is 4 kg whereas the PVC coating weighed 10 kg, so the change of material has led to a useful weight saving as well as a recycling benefit. The S-class contains a total of 19 kg of recycled plastic which equals 14% of the model's total plastics usage of 136 kg.

7.4.5 Mitsubishi

Mitsubishi has started an intensive programme for car recycling and has used its environmentally friendly policies as a promotional factor in marketing. The company claims that all new models are 85% recyclable and Mitsubishi aims to increase this to 90% by 2000.

Bumpers are recycled into wheel covers and battery trays and other applications for the recyclate are being sought.

7.4.6 Nissan

Nissan has been one of the leading Japanese companies in developing and implementing recycling initiatives. The declared aim is to reach a position whereby a minimum 90% of a car's weight is capable of being recycled for all models launched from 2000 onwards. This is a voluntary commitment and is in excess of the JAMA and MITI targets referred to earlier

Nissan considers ease of identification as a top priority and has implemented material marking on plastic parts in accordance with the North American standard (SAEJ 1344) and European standard (VDA 260). Large parts such as bumpers are marked in several locations in case they are cut during the dismantling process.

Another important development at Nissan arose over the use of a single material for parts and systems. For example, instrument panels will be produced from olefins only, in contrast to the traditional use of PVC (surface), urethane (foaming agent) and PPC (core material). Under the new method the materials used are TPO (surface), PP foam (foaming agent) and PP (core material) - all olefins.

In similar fashion, carpets will be produced using just PET for surface, backing and sound absorption, as against the usual combination of PET, PA, PP (surface), EVA, PE (backing) and felt, urethane (sound absorption).

There are four main plastics groups which Nissan intends to integrate in this way, these being polypropylene, nylon, styrene and polyester fibre. These families of plastics are used quite extensively in automotive applications. The objective of integration into a single family is to prevent the degradation of their physical properties after the recycling process.

Nissan is using recycled bumpers as raw material for other parts such as engine tray, battery cover and boot trim. This means that the material recovered from bumpers is used for less demanding applications, but in June 1999 Nissan announced that it had perfected a technique whereby plastic parts can be recycled into new parts which serve the same purpose. This represents an important step forward since many of the problems associated with recycled material arise over the deterioration in the material's properties and therefore its suitability only for less critical applications. This is particularly the case with aluminium and hence any development which allows plastic materials to be recycled for the same automotive application represents a significant competitive advantage.

It is logical to suppose that Nissan will be co-operating more and more with Renault in the future with regard to recycling matters, now that the French company holds a sizeable equity stake in the company. The likelihood is that Renault will handle the recycling of Nissan cars in Europe, while Nissan does the same for Renault in Japan.

7.4.7 PSA Peugeot Citroën

In September 1997, PSA Peugeot Citroën announced a commitment to recycling from the design of new models to the ecological elimination of scrapped vehicles. This commitment is based on the principles of the French outline agreement which was made official in March 1993.

The signatories of the outline agreement have committed themselves to ensure that, by 2002 the final waste generated by scrapped vehicles amounts to no more than 15% of the weight of the scrapped vehicle, with a ceiling of 200 kg. The long term objective is to ensure that final waste amounts to no more than 5% of the weight of the scrapped vehicle.

The PSA Group's design offices start with the standardised principles which optimise the car's usefulness at the end of its life. These include making batteries, fluid holders and other parts more accessible, thereby providing easy access and removal of parts.

Another important initiative involves reducing the number of polymer groups used and favouring easily recyclable materials. There is an emphasis on designing components to use just a single material and limiting the combination of non-compatible materials. As an example, the use of polypropylene on the 406 accounts for 50% of total plastics usage compared with 33% on the 405.

One of PSA Peugeot Citroën's first recycling initiatives with regard to plastics dates from 1990 when a partnership was formed with Fiat, Enimont and ICI to secure funding under the EU Eureka programme. The initiative was named Recap (Recycling of Automobile Plastics) and was divided into four specific projects:

1. Identification of industrial residues and establishment of a data bank for detailed real time management.

2. Definition of separating techniques and treatment for recycling polymers by family.

3. Design of parts to be easily removable and recyclable with low energy consumption.

4. Finding non-energy consuming uses for crusher residue.

Early work included the designing of the Citroën ZX to use materials that could be recovered and easily recycled without generating pollution. Plastics represented approximately 12% of the weight of the Citroën ZX in only seven families of plastics. In addition, new assembly techniques were developed to facilitate disassembly.

PSA and Renault joined forces to establish a factory at Athio-Mons in order to recycle plastic car parts.

PSA also set up a joint venture with Compagnie Francaise des Ferrailles and cement manufacturer VICAT. This was a "zero waste" pilot plant, near Lyon, using cars collected through its dealers under a FF5,000 trade-in discount scheme. This was to encourage new car sales. The investment in the facility totalled FF30m and involved processing two cars an hour with a four man team. The total weight disassembled was 165 kg (285 kg including the engine). The top priority recovery items were bumpers, exterior trim, wheel covers and fuel tanks.

7.4.8 Porsche

Porsche provides a good example of the recycling policies adopted by a specialist car producer whose reputation is founded on quality and performance. In specifying materials top attention is paid to their effect on the overall ambiance of the vehicle and there is an above average willingness to specify advanced materials due to the premium prices that Porsche is able to obtain for its products. Even so, the Porsche design and development function follows the same broad principles as volume car producers, insofar as materials are chosen where possible according to their ease of recyclability. Also, vehicle design is directed towards achieving quick and straightforward disassembly, even though Porsche is a marque whose vehicles enjoy a longer than average operational life and many are preserved as classic cars.

An example of Porsche's recycling policy in practice, with regard to plastics, is seen over its choice in the polyolefin family when TPO skin and EPP foam were chosen with the objective of achieving good recyclability.

7.4.9 Volvo

Around 10% of the plastic parts on Volvo's S80 range are produced from recycled material. Like other vehicle manufacturers, Volvo is tending to avoid the use of PVC.

Volvo's cars have a higher than average recovery of materials and it is estimated that recyclability amounts to around 85%. Every plastic part of more than 50 g is labelled with an internationally recognised symbol.

7.5 Conclusions

Procedures and techniques associated with the recycling of plastics have to move centre stage if the voluntary and mandatory targets concerning recovery of materials from ELVs are to be met. With this in mind the automotive industry is implementing initiatives which will lead to a much greater recovery of plastics but there are formidable obstacles to overcome. The main points may be summarised as follows:

- Vehicle, component and system manufacturers' design, development and manufacturing functions are taking into account more and more the implications of end-of-life vehicles (ELVs).
- Plastics choice is favouring types which can be easily dismantled, sorted and recycled. This has an important impact on the economics of recycling since it is clearly essential that vehicles should be capable of being dismantled in an economic time, the more so as ASR reduces and more parts are recovered.
- Plastics types are being rationalised where feasible by model, in order not to complicate separation at the recycling stage.
- Vehicle manufacturers are speaking increasingly with one voice concerning recycling issues and are setting up joint programmes independent of legislative requirements. Clearly this is to enable legislative targets to be met, but in some instances voluntary agreements are exceeding legislative targets.
- On a practical level, vehicle manufacturers are co-operating over the establishment of procedures and facilities to recycle plastics. In particular, there is considerable scope for achieving economies of scale with regard to the collection of plastic scrap, not least with regard to replacement parts and accident damage
- There is strong concern throughout the industry over the economics of recycling in general and plastics recycling in particular. On a general level the likelihood that many of the materials recycled will not repay their recovery price due to a glut is a serious concern. This is made all the worse by the fluctuating and unpredictable nature of recycled material prices which makes a mockery of establishing budgetary targets. The position with plastics is all the more acute due to the need to move towards near 100% plastics recycling if the European and Japanese target of 95% recovery is to be met by 2015. Moreover, a depressed price structure is likely to be self-generating since the greater recovery of recycled materials will naturally lead to their greater availability.
- All model development programmes include a recycling audit in which a part-by-part recycling programme is developed. From the recycling standpoint, components fall into three principal groups: those which are able to be recycled by means of current recovery practices; those which will be able to be recycled when scrappage occurs in the future; and those for which new technology will have to be developed before recycling becomes feasible. Plastics fall into all three categories but, over time, a shift is occurring from the last to the first. This will enable the recycling targets to be met.

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8 Examples of the Use of Plastics for Specific Components and Systems

Chapter 8 provides examples to illustrate the ways in which the applications of plastics, including selected thermoplastic elastomers, have developed with the increasing sophistication of Tier One and Tier Two component and system suppliers. In addition, future trends in materials choice are given where possible.

A total of 15 component and system groups are examined, as follows:

8.1 Air intake manifolds

During the past five years air intake (or air inlet) manifolds (AIMs) have experienced a rapid substitution of metal for plastic as the material of choice. The position at the end of the 1990s is that approximately 50% of cars and SUVs are equipped with air intake manifolds made from Polyamide with glass fibre and mineral filler. It is estimated that by 2008 an average of approximately 75% of car and SUV engines will be equipped with plastic AIMs.

The use of plastics for AIMs offers a number of major advantages including no rusting, a substantial weight saving and more design freedom with the incorporation of other functional parts. There are also the added benefits of superior lack of vibration and noise dampening properties compared to metal ones.

PA6 and PA66 with a 30-35% glass fibre are mostly used since they fulfil the requirements of resistance to 130°C with peaks of 200°C and the quick burst strength test. Also, PA46 is offered because of better mechanical properties than PA6 at the 130-150°C temperature of the motor oil. The grades have special heat stabiliser systems added to the polymer.

The initial process for the manufacture of AIMs was injection moulding by the lost-core moulding process. In this, a preform is made in a low melting point metal alloy and then inserted into the mould around which the polyamide is pressed. Subsequently the part is put into a hot oil bath to melt the metal, which is then reused to make a preform. The MBW diesel engine has a complex part consisting of the manifold, the cylinder head cover, an air filter housing, exhaust gas recirculation valve and an oil separation system, produced in PA6 GF and PA66 GF.

The 1998 car of the year, the Alfa Romeo 156, has a manifold in PA6 GF 30 with a weight reduction from 7.5 kg for the metal one in the previous model to 3.5 kg for the PA6 manifold, including added integrated functions.

However, although the lost-core process is still used, a much cheaper process, vibration welding, is replacing it. In this process the two halves are injection moulded and are vibration welded to each other to form the manifold.

This two-step moulding and welding process is firmly established in Europe and is now being introduced in North America. Ford applies this technique to its 1999 F-Series 150 and 250 trucks and the luxury SUV 5 Lincoln Navigator and Expedition. The polymer used is a special welding-enhanced Zytel PA66 grade with 35% GF. An approximate 40% cost saving is claimed. A significantly higher static burst pressure of the weld is claimed, compared to standard PA66 grades. The capital investment is around half of the lost-core method. It is therefore expected that the welding method will eventually gain a 65-70% share. However, the lost-core process is still necessary for complex designs.

The Audi A6 2.4 and 2.8 litre engines have a complex design in that two different air stream paths are present, one for low engine speeds and the other for high speeds, laid on top of each other. The lost-core technique was the only one suitable. The piece weighs 4.5 kg, half the weight of a comparable aluminium one, and is made in PA66 GF35. Also the latest VW Golf and Passat models have lost-core moulded manifolds made in PA66 GF35. The Korean car manufacturer Daewoo has chosen Allied Signal Plastics as partner for the substitution of present aluminium manifolds by vibrationally welded PA assemblies of e.g. the new Matiz mini car. The manifold for the three cylinder engine is manufactured in three pieces with two welding operations. The product used is a Capron PA66 type with 33% GF.

Future models may have PA6 since this polymer is claimed to have higher burst strengths and lower warpage than PA66. The Mercedes-Benz A-class four cylinder petrol engine has an AIM in PA6 GF30, made by moulding three parts and welding them together, and which acts also as a support for the air intake assembly and helps in the need to absorb energy in case of a crash.

The polymer producers, such as BASF, Bayer, DuPont and UBE, have optimised their PA grades for vibrational welding in that these polymers have a low viscosity at the high shear rates of injection moulding, but high viscosities under the vibrational welding conditions. This gives strong weld lines and high burst strengths.

The company UBE has developed the so-called "injection welding" in which two halves are injection moulded in the same mould against each other. This certainly reduces overall production cost.

It is expected that plastic will continue to substitute aluminium in air inlet manifolds, where vibration welding will be the favoured technology. It is possible that new technologies such as UBEs injection welding and blow moulding of isotactic PP may be introduced in the medium term. For the time being optimised polyamide grades are the materials used.

8.2 Body panels

8.2.1 Exterior body panels

Exterior body panels can be classified into four broad groups, as follows:

- horizontal panels such as the bonnet, boot lids as well as the roof panel, where a high modulus material combined with a low part weight is necessary to prevent sagging.
- hang-on vertical panels which do not require a high stiffness level since they do not participate in the overall structural rigidity.
- doors and tailgates, for which dimensional stability in use is essential.
- fenders and side wings.

By definition, exterior panels are highly visible and therefore need plastic panels to fulfil the following requirements:

1. Must have a "Class A" surface finish.

2. Paintable with good paint adhesion.

3. Preferably in-line paintable which means a high heat resistance is required. Hang-on panels can be painted off-line.

4. Good impact resistance at low temperatures.

The choice of material is dependent on the temperatures reached during the painting process. With temperatures approaching 200°C the choice is limited to thermoset materials like SMC. At lower temperatures, 170°C, PPO/PA blends are used. At still lower temperatures PC/ABS blends are suitable.

With regard to the actual production of plastic exterior body parts, various plastics processing technologies compete with each other and with the long-established metal forming techniques. Compression moulding of SMC prepregs (pre-impregnated semi-finished product), injection moulding of thermoplastics and BMC, technologies for R-RIM and S-RIM, as well as thermoforming of thermoplastics, are important. Since these technologies are markedly different from established production methods, they lead to hesitation on the part of car manufacturers who are reluctant to make major changes, especially when heavy investment in existing plant and equipment becomes obsolete as a result.

Hang-on panels can be found on special low volume cars. The electric cars Ligier and Hotzenblitz have panels of 2.5 mm and 3 mm thick co-extruded and vacuum formed ABS/PMMA sheet made by Senoplast, Austria. The ABS is coloured and has a high impact resistance, whereas the external PMMA layer serves for the UV resistance. This application has triggered off a more sophisticated development between BASF, Senoplast, Austrian Moulding and PMF System. This development avoids costly painting (cost of up to 70% of total part cost) and makes use of the "in mass" colouring of the plastic.

Large, complex panels with high impact resistance can be produced in high volume. The system passes the usual OEM tests like steam jet, wash/brush and stone impact.

The system consists of a three-layer co-extruded film of PMMA/pigmented PMMA on a base of ASA/PC. This film is placed into a mould for back moulding of a layer of ASA/PC or PBT/PC. Alternatively, a film of PMMA on coloured ASA/PC can be used. A roof module is in development whereby a RIM-PUR layer is foamed between the above system and the cloth ceiling liner.

Chrysler unveiled the CCV, the Composite Concept Vehicle in 1998, with injection moulded glass-filled PET panels for weight and cost savings. Two off-shoots are the two seater Plymouth Pronto Spyder with four body panels and the Dodge Intrepid ESX2 with six panels. The ESX2 panels substitute 80 steel parts and presents a 50% weight saving. Also 35% GF "Hivalloy", a PS onto PP graft copolymer from Montell is under evaluation. Chrysler leased a special 8800 tonne clamp pressure injection moulding machine from Husky for these applications.

The US company, Allied Signal Plastics, presents High Performance "PETRA" for such applications, a PET from recycled PET bottles. Reportedly, the material can withstand temperatures of 200°C in paint ovens, which is better than Noryl GTX, a PPO/PA blend, much used in Europe for fenders. The company reckons to sell several thousand tonnes by the year 2000.

The panels of the Smart car, produced by MCC, a Daimler Benz/SHC joint venture, in Hambach, France, are the fruit of intensive collaboration between BASF and GE plastics in which GEP brought in the Xenoy, PC/PBT, technology and BASF the UV and weathering resistant pigmentation and coating. The 11 panels made by Dynamit Nobel, Germany, consist of injection moulded properly pigmented Xenoy, a PC/PBT blend, subsequently twice coated with a UV and weathering resistant polyisocyanate. The panels can be exchanged in a few hours at a material cost of US$700.

Examples of the use of GMT-PP are the bonnet of the Landrover Freelander and the inside part of the hatchback door of the Mercedes-Benz A-class. This inner door weighs 7 kg and is bonded to an outer layer painted skin of Noryl GTX.

Noryl GTX is used in two versions: an electrically conductive grade, GTX 97774, for electrostatic paint deposition, and a normal grade. They are extensively used by Renault for the fenders of the Clio and the Mégane Scenic, although GM already used GTX for the Buick Le Sabre 1988 and more recently the Saturn. The last one has vertical panels in GTX as well. Also the Nissan Figaro wings are in GTX, as well as the recently launched Volkswagen New Beetle, produced in Mexico.

The wings of the Renault Clio are 2 mm thick and weigh only 850 g against 2 kg for a steel construction. The fenders are in-line paintable if the temperature of the ovens does not exceed 170°C. Higher heat resistant grades for panels are in development. A problem however, is the high expansion coefficient of the plastic part. To avoid problems in the ovens, a special design is necessary.

Whereas fenders do not need high stiffness roofs, like other horizontal parts, they are part of the structure and the plastics used need a high modulus. In the USA, SMC for horizontal panel applications is more advanced than in Europe. The Jeep Wrangler has a roof in mass pigmented SMC eliminating the need for painting the interior. The Pontiac Firebird and Chevrolet Camaro are equipped with RIM-PUR wings and SMC doors, roofs and spoilers. The EU sponsored development programme MOSAIC produced some years ago a concept Renault Clio with a complete front end in SMC and a floor pan in S-RIM. The SMC consisted of unsaturated polyester/vinylester blend with 45% glass fibre. At that time the process was economically viable for run sizes of 300-500 per day, but lost out against steel for production sizes of some 1800 per day, and the project did not materialise in actual production. New technology from the USA seems to make a substantial cost reduction feasible also for high volume production runs.

Low density SMC has hollow glass spheres incorporated as a filler instead of calcium carbonate, but cannot yet be used for exterior panels because no Class A surface has been obtained. Lite SMC which has a different calcium carbonate as filler is used for the hood of the Dodge Viper. A weight reduction of 15% over conventional SMC is obtained. The Ford Lincoln Continental is a further example of the successful use of SMC for the hood, deck lid and fenders. Cost savings in tooling were substantial. The same is the case with the 1999 Ford Mustang.

In general, it is expected that SMC automotive components will show a strong increase in the USA in the next five years, specifically because of its relative low thermal expansion coefficient (see Table 8.1 for comparison) and new production technology.

Another story concerns the vertical parts of the GM Silverado and Sierra Pickup made in RIM-PUR, substituting SMC, which withstand 177°C oven temperatures without problems and present a weight reduction of 38% over SMC.

A special development is the Hylite panel from Hoogovens, the Netherlands. This laminate is composed of two 0.2 mm (0.008 inch) thick aluminium outer skins and a 0.8 mm (0.03 inch) inner layer of PP. Total thickness is 1.2 mm. Weight savings of some 65% over steel and 30% over aluminium are claimed for horizontal body panels. The same presses as for steel can be used for forming. The laminate has sound deadening qualities.

NedCar, Netherlands, presented a concept car at the 1996 Geneva Motor show with the bonnet and roof panel in Hylite. The Volkswagen Lupino, a 3 litre/100 km car has a Hylite hood but a general breakthrough for cars is still awaited.

Table 8.1 Expansion coefficient for some panel materials

Material	Coefficient of thermal expansion @ 23 °C, $\times 10^{-6}$
Steel	11
Aluminium	23
Magnesium	25
SMC	16–24
GMT (20–40% GF)	25–35
PPO/PA blends	approx 90
PC/PBT blends	93–95
PC/ASA blends	60–75

Note the difference between metals and thermoplastics in expansion coefficient is large, with thermosets and glass reinforced plastics in between. Use of plastics requires careful design.

In Europe, regulations limiting fuel consumption and a level of petrol prices which is around four times higher than in the USA - together with the prospect of further increases - will provoke a rapid increase in the amount of plastics and other light materials used for exterior body parts on cars.

8.2.2 Interior body panels

As interior panels can be regarded as door and roof interior panels, package trays and luggage compartment linings, the property requirements for these groups are different. In the cockpit area the panels must have esthetical qualities besides impact resistance at low temperatures, non-splintering upon collision and low in fogging and odour.

Originally the panels were made from fibreboard with an appropriate decorative covering of foamed PVC or a textile fabric. These systems are still in use. The development of large thin wall mouldings in ABS or PP backed by textiles gave the possibility for contoured panels with recesses, something not possible by vacuum forming or pressing.

Wood stock is still very much used for interior panels as well. The material consists of wood flour mixed with polypropylene and can be made into vacuum formable sheets. Wood flour is described as particularly suitable as a filler for PUR composites as its reactive hydroxyl groups form strong wood/PUR bonds with the isocyanate. Large quantities of wood-filled thermoplastics are also used in the USA. One source, North Wood Plastics, Wisconsin, has indicated that over 13,000 tonnes of wood-filled PP is used in the US auto industry.

The original Fibrit process in Grefrath, Germany, now owned by Johnson Controls, consisted of a wet process in which wood fibres are mixed with a binder and settled over a sieve and subsequently pressed. Also Lignotock, Germany, now part of SAI Automotive, has a similar system.

The Johnson Controls plant now produces panels of natural fibres (60%) reinforced PUR, called Fibropur. The panels are only 1.7-1.8 mm thick, weigh 1.3-1.6 kg/m^2 and are made for door inner trim panels of Mercedes-Benz cars, for example, S-class. The fibres (50% flax/50% sisal) are first formed into a mat and then spray-impregnated with Baypreg F PUR from

Bayer. The mats are subsequently placed in a compression mould and pressed into shape at 130°C for less than 60s. A substantial cost reduction is claimed since the natural fibres are cheaper than glass fibres.

The Research Centre of DaimlerChrysler in Ulm, Germany, has thoroughly tested flax and sisal fibres as a reinforcement for PP for injection moulding of interior panels. Flax and sisal represent a substantial weight saving over glass fibre and also have a "green image". Mercedes-Benz introduced in Brazil, jute fibre-reinforced PP not only for interior claddings but also for head and arm supports of their utility vehicles. Schuster GmbH & Co. KG, Dachau, Germany produces in a cheap one step process, flax-PP linings for the Audi A4 Avant and the Cadillac Catera luggage compartment cladding. Flax-PP is claimed to present up to 30% weight savings, improved recyclability and better sound-deadening properties.

Also Ford Cologne, Germany has experimented with flax reinforced PP for injection moulding of panels. A special flax has been chosen. Nevertheless, careful temperature control is necessary to avoid decomposition and therefore discoloration of the fibres. Linpac Automotive, Overpelt, Belgium, supplies the Ford Mondeo with door inserts consisting of three layers with an outer layer of PP and a core of bamboo fibres, formed by low-pressure compression moulding to a thickness of 2 mm. Chopped strand mat of hemp fibre is used for the parcel shelf of the Ford Transit in the UK. It is expected that other applications will follow.

The BMW 3 Series has a door panel in PP/natural fibres covered with a TPO foil. TPO calendered or extruded foil, laminated with PP foam or not, is often applied as a skin to obtain the so-called soft touch. Conventional door panels are still in use made, for instance, of an ABS/PC carrier in Volkswagen's New Beetle, or an ABS sheet covered with PVC/ABS foam foil for the Audi A6 and other Volkswagen models.

Another system can be found in the small Ford Ka having upper door parts in PP+EPDM+25% mineral filler and the lower parts in PUR foam covered with textile. Also the MCC Smart car has door and hatch door panels in a PP compound. The Citroën Berlingo, however, has door covers in extruded PP foam.

It is expected that in coming years PP products will be favoured by those OEMs who, for recyling reasons, have chosen for the "one material concept" for interior and exterior. The Fiat group has concluded that PP rigid parts covered with PP textile is a solution to be favoured. Also the PSA group (covering the Peugeot and Citroën marques) want to concentrate on PP, likewise Ford and GM in the USA.

One source says that by 2000 around 55% of the cars sold in Europe will have PP interiors. Also the textiles employed for the car interior - seats and the roof and side panelling will be made increasingly from PP. Volkswagen Golf IV and Passat have, however, injection moulded ABS carriers covered with a PVC foam foil for door panels. This is probably done to match the PVC slush moulded instrument panel skin. However, the latest smaller cars of VW have PP in the interior.

Often with interior panels the technology of back moulding is used. A preformed textile or other skin is put into a mould and ABS, PC/ABS or talcum filled PP is moulded at the back of the cover. This one-step moulding/lamination operation gives strong bonding and avoids the use of adhesives and has economic advantages.

Delphi Interior and Lighting Systems have developed together with GE Plastics "Super Plug", an innovative, fully integrated door module comprising handles, lock, window winding and loudspeaker. It is based on PC/PBT resin and gas assisted injection moulding. It clearly shows the possibilities in economy using plastics in the right way: the door module reduces sixty-one separate parts to a single moulding. In Germany, Bayer, together with system supplier Kiekert and plastic converter Gerhardi, developed a similar system based on a ABS/PC blend as a rigid part.

Another innovation is the relatively new LFI (long fibre injection) with polyurethanes for the production of large area trim parts. A decorative part (e.g. a fabric) is put into a mould and sprayed simultaneously with pre-impregnated long glass fibres of 30-100 mm (1.2-4 inches) and PUR. After closing of the mould the PUR is allowed to react, after which the finished part can be taken out. This technique can be used for the production of not only door panels but also parcel trays, interior roofing and luggage compartment linings.

A new development of "Soft Touch" sheet consists of a co-extrudate of a special PUR/ABS blend and ABS as a carrier, giving a mat surface, and having a high impact strength and vacuum formability. The surface can be given a leather-like look.

The usual way for producing parcel trays is back moulding of a fabric with a thermoplastic such as ABS, PP with talcum, ABS/PC. But also S-RIM PUR is applied with textiles as a cover.

A special parcel tray was developed for the Landrover Freelander 4x4 by Tompson Plastics with GEP using glass reinforced PP and thermoforming in shape. Other parts like the engine undersheet are in the same material.

A relatively new material is being used for the hatchback door of the VW Passat B5 and the Golf IV, namely HCPP, High Crystalline PP. In the case of the Passat the PP panel is covered with velour. As mentioned previously, HCPP by means of its high modulus, substitutes talcum filled PP presenting a substantial weight saving.

8.3 Bumpers

The requirements for bumpers performance would appear to be splitting into three separate technical performance areas:-

- North American - MVSS 215/Part 581
- European - EC42 no damage low speed plus pedestrian safety, legislative and insurance company tests
- Asian - legislative for home market plus export requirements

Against the background of the technical criteria, the integrated bumper front end is becoming increasingly a design and styling issue. Front end, in this context, does not refer to topics covered in item 8.5, these being non-cosmetic structural parts. Examples demonstrating the integrated styling line on current models could be considered to be the Ford Focus or the Alfa Romeo 155.

Technically, the US remains philosophically committed to the spirit of the 5 mph (8 kph) no-damage requirements. Because of the large volumes involved in many of the US models, a metal beam with energy absorbing PP or PU foams remain the materials of choice. Whether the US will make substantial use of the weight saving potential of composites in the long term remains in doubt. Both SMC and PP based GMT are used, by and large for lower volume (less than 200,000 cars a year) as bumper beams.

Up to the end of 1999 in Europe, diversity of approaches will be able to exist since the legislative requirements are minimal. From this point onwards, however, pedestrian safety legislation will be having a dramatic effect on the whole front end of vehicles, including the bumper. In general, bumper systems protrude less from European cars in comparison with their American or Asian counterparts. The dynamics of the various pedestrian impact tests proposed under the European directives suggest that the depth of the bumper for a currently non-conforming European bumper system will have to increase to the level of that of a conforming system (that is to say 60-80 mm increase in section) and, additionally, that approximate amount of material depth will have to be added, or incorporated, into the bonnet and front wing areas. This will have a considerable effect on the styling of vehicles from 2002 onwards. With respect to the materials, performance can be expected from PU, and Bayer have announced that their semi-rigid Bayfill EA foam can achieve the requirements for bumpers, when combined with a thin-walled R-RIM cover made from Bayflex 180.

The position for other EA materials is less clear since EPP has a considerable and fast hysterisis response, quite the reverse of that required. Another engineering consideration is that many bumper beams have a dual function, combining armature with front cross-member. These will have to be lowered or moved back to allow for intrusion during impact.

High market value vehicles in Europe tend to have aluminium front armatures and SMC or GMT rear bumper armatures. Typical examples are BMW

5 Series and Mercedes-Benz C-class. The potential for GMT and hybrid systems in the next generation of bumper beams looks promising, since it is possible to tune the properties of the armature to suit the specific impact characteristics needed for each of the pedestrian protection requirements whilst retaining the characteristic of a no-damage bumper system at low speeds.

With respect to cover materials, the use of PU RIM has been in decline because of the growth of companies such as BMW and DaimlerChrysler and their need to switch to high volume low cost processes. Within the range of PP materials used for bumper covers, there is a gradual switch to high modulus PP co-polymers, which have the additional benefit of good paintability. The use of blow moulded one-piece bumper systems has not attracted any lasting success.

There is, however, considerable interest in the newer injection mouldable alloys, such as PC/PBT, PPO/PA, because these have potential to be painted on line, with the trend towards being able to go through the E-coat process.

8.4 Electrical and electronic control systems

To keep up with the automotive industry's requirement for more and more intelligence into the car, far reaching changes are now taking place.

This section focuses on some of the major electrical and electronic components in current models except for certain elements, such as front and rear lights and batteries.

Various examples of components in the following groupings are given as follows:

- solid state ignition systems
- low voltage cabling and wiring
- switches
- sensors
- fibre optics.

8.4.1. Solid state ignition systems

Distributor heads have now been replaced almost entirely by a solid state electronic assembly. The coil is encapsulated in epoxy resin in an injection moulded tray which is usually PBT. An over-moulded PET housing is used to encapsulate the whole assembly.

General Motors was the first to adopt a microprocessor system for the purpose of ignition.

Housings use a number of different polymers including some BMC mouldings particularly in North America.

However, mainly glass fibre reinforced thermoplastic polyesters and polyamides, also some polyacetal resins, are used. The major properties required are high temperature resistance and good dimensional stability.

PVC is likely to continue to be used as sheathing on high tension cables.

There have been changes in the use of plastics for coil insulation of the solenoid. Glass reinforced polyamides and other injection moulded reinforced thermoplastics are now established because of advantages in production and reliability compared with previously used thermosets.

8.4.2. Low voltage cabling and wiring

Traditionally, PVC sheathing has been used for the covering of low voltage car wiring. Up to now a lesser quantity of cross-linked polyethylene has also been used.

There are a number of underbonnet applications where very high temperature resistance is required as well as good resistance to petrol, oils and greases.

Here it is necessary to specify high temperature and oil resistant materials such as silicone or fluorelastomers.

With the rapidly increasing number of electronic systems that are present in cars and SUVs, there have been parallel developments in low voltage cabling and wiring. The main ones are:

1. The use of connectors which has increased rapidly over the past five years. These are usually multipin in the form of complex mouldings. PBT is now the principal polymer used and has tended to replace general purpose polyamides 6 and 66. Very little PET is used.

   For very high temperature areas, however, Stanyl PA46 and other aromatic polyamides (HTN) are necessary. They fill the price performance gap between PA6, PA66, PBT and PET on the one hand and much higher priced higher performance thermoplastics such as Polyimides, Polyethersulphone, Polyphenylene Sulphide and Liquid Crystal Polymers.

2. There is the continuing trend towards increasing pre-assembly of harnesses. More integration of wiring takes place for example in prefabricated units in dashboards, but also in different areas of the car particularly in floors, roofs and pillars.

   Moulded clips usually in PA6 or 66 are increasingly used to attach wiring to the car body. POM is also suitable for spring and snap clips for cables and pipes.

3. The use of printed circuitry is steadily increasing. Whilst the majority of printed circuit boards are rigid using epoxy resins for the substrate, there is an increasing trend towards the use of flexible circuit boards with polyphenylene sulphide or polyetherimide as the substrate material. Otherwise known as moulded interconnect technology (MIT) there are however still cost and other factors to be dealt with before the space saving and other advantages of this technology are used in volume car production.

4. Multiplexing has been talked about and experimented with for some years. These systems have also been used on steering columns and lighting circuits but their biggest potential yet to be realised is in the seat, window and door areas.

The effect of multiplexing will certainly be to reduce the further increase in wiring systems which, particularly on top range higher priced models threaten to become unmanageable to install in the vehicle. It is considered that it will not be until the year 2004 at the earliest that there will be an established usage of multiplexing in different areas of the vehicle. From then on there will be a marginal reduction in the number of connectors used in the models produced.

8.4.3 Switches

There is now a considerable variety of switches installed in current models. These will increase still more in the future with the growing use of more sophisticated electronics in cars and SUVs.

Interior input control switches e.g. multi-function turn/signal switches and master light control units are examples of the use of reinforced polyamides and thermoplastic polyesters. Requirements include good stiffness, impact and chemical resistance and low warpage. These materials are also used to meet high temperature requirements.

For electro-mechanical switches where operation is required over long periods in relatively extreme conditions, an example is a plunger switch for door, brake and boot light locations, POM (acetal) resins have been chosen on account of their excellent wear resistance and low friction properties.

In the development of a shift mechanism for an automatic gear box, the company GHSP in the USA has used a modified version of polyamide 66 with self lubricating properties (Lubricomp RFL). This component is a pivot handle and the moulding has saved two stampings, two gauges, one welding and one riveting operation required by the original metal version.

Polyamide 46 30% glass filled has been successfully used for switches in hostile environments such as continual contact with brake fluid and hot gearbox oil.

8.4.4 Sensors

There are several types of sensor used for cars and SUVs. The most basic is the fully mechanical unit, a "potentiometric" sensor. This is low cost, is highly reliable but is subject to wear. Most car makers are moving away from potentiometic sensors in favour of Hall effect sensors and magneto resistive sensors. These two types of sensor now have over 65% of the European market in cars and SUVs. They operate in areas such as ignition and fuel injection timing, throttle valve position, gearbox revolution, anti-lock braking, wheel and axle speed, differential, and steering wheel position/direction. These functions take place in different environments including extremes of temperatures and corrosive conditions. Typical temperature requirements are −40°C to 150°C. The trend towards placing sensors inside gearboxes and engines has pushed tolerances up to 170°C.

The use of PA66 is established for a number of sensor applications which are now increasingly an injection moulded plastic unit rather than the original construction of metal packaging, with plastic inserts surrounding the wiring.

Uses of PBT includes anti-lock brake sensors and wheel sensors.

Other polymers that are being used include acetal (POM) where snap assembly is facilitated, for example, in an outside air temperature sensor.

Where a hostile environment demands a particularly high level of properties, polymers used include polyphthalamide (PPA) and polyphenylene sulphide (PPS).

8.4.5 Fibre optics

In spite of growth predictions for increasing use of polyoptical fibres in, for example, LAN systems in passenger cars, there is little evidence of the use of PMMA or PC in these types of applications in European or North American cars. What use there is, is centred on higher priced Japanese cars.

The use of these thermoplastic fibres is at present very costly and when replacement of copper wire is considered on a one for one basis this proves to be uneconomic.

Other approaches to this situation include the use of multiplexing where less optical fibre is required.

Whilst PC is less brittle than PMMA, its transmission properties still need to be improved to make it competitive, taking total physical properties into account. High viscosity PBT has found application as a sheathing material for polyoptical fibres. Research continues by the material manufacturers to improve further both the limited bending properties and the thermal resistance of the fibres themselves.

8.4.6 Future developments in electronics

It is now generally accepted that electronic systems in cars and SUVs will continue to expand in number and complexity over the next ten years and beyond. This continued expansion in use will necessitate further miniaturisation of componentry in order to accommodate these increases. Overall weight reduction is a priority.

The average number of sensors in small/medium sized cars will rise from approximately 15 per car in year 2000 to over 20 by 2007. Large cars will have on average over 25 sensors by 2007.

An important development will be the introduction of drive-by-wire electrical steering. This is likely to be introduced in higher priced cars in the next three to four years.

A development which is further ahead is brake-by-wire or electronic braking systems.

With this will come high voltage (for example, 36 volts) systems to serve the demands of the high powered electronic motors and back-up solutions that will be required. It is estimated that brake by wire is likely to have developed sufficiently to be adopted on higher priced cars by 2007.

8.5 Front ends

The front end or assembly carrier is not yet a common design feature across all cars. The key to its usage is dominated by the design of the vehicle to enable walk-in entry for the engine during the assembly of the vehicle, this is by no means common. With the growth of worldwide platforms there is a divergence of approach between the Europeans and the USA and Japan.

The classical European design was seen in the early 1990s in respect of the use of GMT in the Volkswagen Group's product range. This typical 4 kg moulding of 40% glass content GMT has been refined and probably is now closer to 3 kg than 4 kg. It will integrate bonnet latching mechanisms, HVAC components and lighting systems. Cross-car stiffness is supplied via a simple metal pressing which can also act as a bumper beam on many small vehicles.

SMC is still used, particularly in France, although the competitive pressures for cost and weight saving of this segment would not point to its continued usage.

In the US, the approach is much more towards extending the grill opening panel to provide more function whilst retaining an integrated metal cross-member. This has been partially caused by US attitudes towards bumper requirements.

The materials used in Europe are currently undergoing a high degree of competitive pressure. Several forms of LFT (Long Fibre Thermoplastic) have entered the market and three companies, Volvo Olofström Sweden, Menzolit Germany and ECIA in France, have commercialised processes that replace GMT in front ends, Volvo S70 and V70, Volkswagen Passat and Peugeot 206 models. Although the entry product differs, the final process is that of compression moulding, enabling direct substitution of GMT. The glass content, however, appears static at a maximum of 30%.

The prime mover behind looking at replacement of GMT by LFT products is to eliminate the semi-finished product form (Symalit or Azdel). The perception is that GMT is an expensive semi-finished product, its technology having a high cost of entry and requiring a secondary heating process, representing secondary cost and a potentially damaging step in processing. In simple terms, the idea is to plasticise the polymer and dose in glass fibre at the end of the barrel causing as little damage as possible to the fibres. Another type of LFT process has been developed by Plastic Omnium whereby a long fibre injection moulding type of pellet is plasticised to produce a dough followed by compression moulding.

A significant newcomer in respect of the process has been the thermoplastic injection moulding hybrid technology developed by Bayer. The principle is that of insert moulding, encapsulating a series of steel pressings into a polyurethane Durethan BKV 30% glass content PA6 moulding. Initial development carried out in Europe by ECIA and Bayer together, for an Audi part, has led to the specification for the worldwide Ford platform for the Ford Focus.

The development, carried out in the US, has led to a part without the full function of a front end, 3.2 kg total weight with 2 kg of polymer. This is manufactured by Visteon in the US and Dynamit Nobel in Europe.

For the future development of front ends based on GMT compression moulding technology, the key would appear to be further integration to include either hybridisation as in the use of metal components to provide additional stiffness, or to use hybrid GMT systems which have begun to be commercially available. The first of these based on Symalit GMT and Twintex co-mingled polypropylene glass yarn is becoming available and has already found use in bumper systems. An additional area of significance is changes in European legislation with respect to pedestrian safety. It will be possible to design front ends, including energy absorbing areas, to meet the legislative needs which begin in 2002.

8.6 Fuel lines

In the past five years there has been a great deal of development in the area of fuel lines driven by existing and imminent legislation about emissions of hydrocarbons and exhaust gases. In the USA, the 1991 Clean Air Act and its successive amendments call for a total maximum hydrocarbon emission by the car of maximum 2 g per 24 h measured by the so-called SHED test. The limit of 2 g is valid for new cars and for ten years or the first 160,000 km of service. For trucks this is eleven years and 192,000 km.

In Europe there are the draft regulations called EURO 2000 and 2005 restricting the hydrocarbon emissions in a similar manner.

As indicated under the example of fuel tanks, the composition of the fuel is changing. Tetraethyl lead has disappeared from gasoline and more aggressive alcohol and MTBE is added in the USA and methanol in Europe. Diesel fuel is changing as well in composition in that more and more Rape Oil Methyl Ester (RME) or Biodiesel is added. It is used at 100% level by VW as a test fuel.

Due to evidence of ground water contamination in the state of California by leakage of MTBE from storage tanks, its government has ruled that MTBE should be phased out as a fuel additive by 2002. However, there is strong opposition from the US Oxygenated Fuels Association (OFA) and the future use of MTBE is therefore uncertain.

In Germany, standard petrol compositions have been defined to test fuel systems, both containing methanol, these are covered by:-

FAM-DIN 51604-A
FAM-DIN 51604-B

The benzene levels in petrol need to be reduced from their present 2.5% to possibly 1% in Europe and even further in future, necessitating additions of MTBE, TAME, and/or ethanol. The sulphur level of diesel fuel will be reduced in Europe to 350 ppm by the year 2000 and 50 ppm by 2005.

A third reason for changes is the legislation relative to fuel reduction in order to minimise emission of unwanted exhaust gases.

Diesel engines with common rail injection increase the fuel temperature to 100-120°C, by which the "acidity" of the fuel increases and so the aggressiveness towards fuel lines. This is described in more detail in Chapter 6.2. Other requirements are the wide temperature range (−40 to + 100°C) the fuel lines are subjected to and the necessity to resist salt and brine and zinc chloride. Zinc chloride is formed by reaction of salt and brine with the zinc metal coating of the under bodywork. Polyamide 12 shows a good resistance in this respect. In the long term a lot may change with the introduction of the fuel cell electric engine which may be fed with methanol or methane as fuel.

Two types of fuel lines can be distinguished: the chassis lines running along the bottom of the car and the jumper hoses connecting the tank with the chassis lines also called fuel tank jumper hose and from the chassis lines to the engine so-called engine jumper lines. Connectors keep the various lines in place. The chassis lines are fixed to the chassis so flexibility is not of importance, but impact and corrosion resistance are.

Plastics have a varying degree of hydrocarbon permeability and the right choice of material or combination of materials is of optimum importance.

Acetal resin widely used for injection moulded parts in the fuel system has good permeability values but at present cannot be extruded into tubes. Permeation tests are done according to ASTM E96-66 and GM 9061-P, a General Motors test.

Chassis lines are either in coated steel or aluminium tubing or in PA 12 single or multilayer extruded tubing. Fuel tank jumperhose is often made from a multilayer rubber tubing with an inner layer of a fluorelastomer for a decrease in permeability. However, also PA 12 tubing is often used with a co-extruded PVDF or an ETFE innerlining.

The USA market is dominated by the P-CAP multilayer systems supplied by Pilot Industries. The following constructions are promoted:

P-CAP 2 - consists of a non-conductive ETFE inner layer and a PA 12 outer layer.
P-CAP 3 - is for direct fuel contact and made of a conductive ETFE inner layer, followed by a normal ETFE and outer PA 12 layers.
E-P-CAP 3 - has an inner layer of conductive ETFE, followed by an ETFE one and an FKM fluorelastomer outer layer.

The ETFE (Ethylene-tetrafluorethylene polymer) serves like PVDF as an excellent fuel barrier.

PA 12 producers like Elf Atochem, Creanova and EMS offer systems around PA 12. Three and four layer systems have been developed by Creanova. A three layer consists of impact resistant PA 12, a modified PA 12 inner layer followed by a PVDE barrier layer. This simple system reduces the permeability of methanol containing fuel by 15 times compared to PA 12 tubing. A middle layer of 0.2 mm PBT between two layers of 0.4 mm PA 12 is also used.

Elf Atochem offer their MLT (multilayer tubing) structures with a barrier of PVDF and an outer layer in Rilsan PA 12. Further development has provided the use of an inter-layer bonding to avoid delamination. Five-layer structures for both vapour and wet lines have been developed. The company Ticona promotes polyphenylenesulphide (PPS) for fuel lines because of an excellent chemical resistance market and low permeabilities for a host of fuels. Ford use PPS for their 6 cylinder engines for those reasons. The low impact strength and high price of polyphenylenesulphide limits its market potential however.

A relatively new material being developed for fuel lines and moulded parts is aliphatic polyketone (APK). The product has an excellent low fuel permeability and good impact resistance. Various fuel line producers like Veritas, Germany have extruded and tested APK. Compared to PA 12 this polymer has a very high stiffness, possibly too high, where flexibility is required.

8.7 Fuel tanks

The fuel tank is an application where plastic has made fast inroads in the last six to seven years, especially in Western Europe. The first on-board plastic fuel tank was for the Porsche 911 in 1967, creating the interest of VW so that by 1980 around 100% of all Volkswagen tanks were plastic. In the USA, Ford has blow moulded single layer plastic tanks at its Milan, Michigan, plant for the Escort and Ranger models since 1984.

Now nearly 80% of cars sold in Western Europe have a fuel tank made of blow moulded HDPE. Plastic gives more design freedom than metal, so that complex shapes, like "saddle" shaped tanks, can be made at relatively low investment cost, since the mould used for blow moulding can be made cheaply compared to injection moulding. The other advantages are the low polymer price, the weight saving, the corrosion resistance (a severe problem with steel tanks and low-lead fuels) and incorporation of parts which, with steel, are to be made separately and need welding together. Several polyethylene producers (including BASF, Fina, Solvay) have developed special high molecular weight HDPE types for blow moulding of fuel tanks, fulfilling also the European Regulation EC34, Appendix 5 on fire safety and the US equivalent FMVSS 302. These producers have embarked on joint development programmes with car producers and fuel tank manufacturers.

The high molecular weight improves the toughness of the final tank against impacts and improves the mouldability.

Fina offers an experimental high molecular weight, high modulus, HDPE grade, Finathene WR 201B, for which it claims a possible weight reduction of the tank of at least 10%. An improved creep resistance as well as shorter moulding cycle times are mentioned.

Fuel tanks are tested by dropping them, filled with glycol at a temperature of −40°C, from a 6 m height on their seams onto a concrete floor. They should not rupture. The ECE 34 regulation means that the tank must resist an open fire placed directly underneath them for 2 min without leaking and without sagging by more than a set amount. Heavy duty vehicles often have a steel heat shield under the tank for protection.

HDPE exhibits a good chemical resistance towards different fuels. Unfortunately, the polymer is rather permeable for hydrocarbons, so that untreated HDPE tanks may lose measurable quantities of fuel by "evaporation". An average untreated HDPE fuel tank can lose up to 20 g/day of fuel, whereas a maximum of 2 g/day is allowed (the US "SHED" test) for the whole car. There are several established technologies to reduce the permeability:

1. By sulphonation of the HDPE polymer in the tank interior, a layer of sulphonated HDPE with reduced permeability is formed. This method is not used very much.

2. By fluorination of the internal HDPE polymer layer. By treatment of the tank interior with fluorine gas a few microns of fluorinated PE are formed having a reduced hydrocarbon permeability. In practice, one distinguishes two methods: in-line and off-line fluorination. A disadvantage is that with time, especially with methanol or alcohol-containing fuels, this thin layer wears off, leaving the tank with no barrier. This is proved by the so-called "slosh test" with one million cycles representing ten years of use. The answer could be the so-called "super fluorination" i.e. creating a thicker barrier layer. The company Solvay Fluor and Derivate GmbH are actively promoting this system.

3. The addition to the HDPE of 5-7% of Selar RB-901, a modified Nylon from DuPont and made compatible with HDPE. The barrier consists of many discontinuous and overlapping platelets of Selar within the HDPE. It is claimed that a level of 4-5% Selar could present tanks meeting a 5 g/24 h limit under the ECE 34 test conditions. Higher concentrations of 7-8% are claimed to give fuel tanks with permeabilities:

   0.1 to 0.2 g/24h under ECE 34 test conditions
   less than 0.1 g/25 h in the CARB "SHED" test (ASTM-C fuel, Haltermann and fuels containing MTBE and ETBE)

   The new fuels containing methanol and/or alcohol are problematic for Selar RB 901. Therefore, German car manufacturers do not use Selar since the test fuels contain 15% methanol.

   Fiat, Volvo, Kia, Saab, Toyota, Mitsubishi use tanks made with Selar (1998).

4. Multi layer co-extrusion blow moulding with a barrier layer of EVOH (ethylene-vinyl-alcohol) polymer. The latest variation of this technology consists in producing a 6-layer tank: HDPE/tie/EVOH/tie/recHDPE/HDPE. Tie layers take care of "gluing" together incompatible layers of HDPE and EVOH. RecHDPE is recycled production scrap. The overall EVOH content could be 2%. This system is insensitive towards the newest fuel qualities.

   The machines are supplied by Krupp Kautex Maschinenbau GmbH, Bonn, Germany. Reportedly, also Japan Steel Works has developed such machines.

5. An internal barrier layer of nylon in a blow moulded HDPE tank. This has been developed in the USA, but it looks likely to be superseded by technology 4).

6. Completely experimental is the introduction of APK polymers (Aliphatic polyketones), high barrier resins produced by Shell Chemicals and BP Amoco, for fuel systems and tanks in particular. APK polymers cannot be blow moulded and need to be converted by injection moulding. This means injection moulding parts of the tank and welding the pieces together. The tank construction can have many more features than blow moulded ones and less problems with interior tank equipment. Trials are in progess with a major tank producer.

7. an experimental technique, of which it seems a major commercial breakthrough by Plastic Omnium is imminent, consists in coating a monolayer HDPE tank with an approximate 45 micron layer of "Nanosilicates" on the inside. This improves the barrier properties very significantly.

In view of the requirements of the 1991 Clean Air Act and amendments of the USA, the maximum allowable quantity of diffused hydrocarbons (HC) coming off a vehicle is limited to 2 g/24h as measured in the "SHED" test, and the changes in fuel composition (in the US fuel contains alcohol), technology 4, the multilayer co-extrusion, is gaining ground. SHED stands for Sealed Housing Evaporative Determination. The State of California has decided to reduce this level to 0.5g/day of HC released, by the year 2004. It is not certain yet whether the rest of the world will follow, but this is judged to be possible in the long term.

The multilayer barrier technology was first introduced on a massive scale in the USA in collaboration with Ford. Ford has equipped its Milan, Michigan, USA, plant with Krupp six-layer machines. The custom moulders Solvay Automotive, Walbro Automotive and Kautex Textron also invested heavily in this technology.

Walbro in Europe is introducing this technology as well. The added advantage is that the regrind layer takes up 40% of the production scrap. Also, Ford is using further regrind mixed with virgin HDPE on the remaining single-layer blow moulding machines to produce HDPE bumpers. It is expected that this technology will prevail in the USA on a medium term basis and the substitution of metal tanks will continue at a rapid pace.

Because of the heavy investment in blow moulding machines by the major players, it is not expected that APK polymers, in spite of their excellent barrier properties, will make a major breakthrough medium term, although Plastic Omnium, one of the major fuel tank producers in Europe, is experimenting with injection moulding technology. It is, however, still unclear clear what the maximum allowable level of HC emission in Europe will be by 2005. If super fluorination and multilayer are not usable because of more stringent regulations, APK injection moulded tanks may have a chance. The advantage of injection moulding and subsequent welding is that more parts can be incorporated in the moulding and do not need to be welded on.

Super fluorination presents some problems with welding additional pieces onto the tank and it is therefore necessary to fluorinate off-line, as is done by Plastic Omnium, when the parts are already welded on. This technique allows the Euro 2000 regulation to be passed comfortably and will certainly increase its market penetration in Europe mid-term.

The US producers who do not like fluorination and prefer the multilayer co-extrusion technology instead, may have a very good alternative, if trials are successful, with the internal coating techniques of a monolayer HDPE tank with nanosilicates.

8.8 Glazing

Automotive glazing is subject to national and international legislation. The European norm ECE R43 formulates minimum requirements, although customer demands are usually more severe. A British standard BS AU 209 part 4, formulated in 1995 deals with the security of car passengers from external attacks and specifies the minimum requirements for the performance of security glazing.

In 1998, an average car had 40-45 kg of glass for front, side and rear windows. With most cars only the windscreen contains plastic since it is usually a laminate of two sheets of 2.1 mm glass on a 0.76 mm thick film of Polyvinylbutyral (PVB), a transparent and light resistant polymer. The other windows consist of 3.85 mm tempered glass. Top of the range models like the 1998 Mercedes-Benz S-class and the Audi A8 have laminates with PVB film also for side and backlights. This gives more security against window breaks and more security for the passengers. It is expected that in the medium term, this will be applied to lower priced cars as well. The quantities of PVB used worldwide for car glazing amount to around 75,000 tonnes and are expected to grow further in the medium term.

Producers of the PVB base polymer are:

Sekisui Chemical Japan
DuPont
Solutia
Wacker-Chemie (only for coatings sector)

PVB film is produced by:

Sekisui S-LFC in Japan, Mexico, Netherlands
Dupont in USA
Solutia in USA and Belgium
HT Troplast in Germany

The price indication for 0.76 mm PVB film is around US$5.40/m^2.

8.8.1 New developments with glass and plastic

Considerable effort is undertaken to improve present systems by both glass and polymer manufacturers.

The following criteria are to be taken into account:-

1. Decrease in overall weight, since this translates into a lower fuel consumption.

2. Protection against aggression from outside, for example, car-jacking.

3. Excellent mechanical properties like stone impact, high stiffness, high scratch resistance and edge strength.

4. A minimum of fragmentation density after breakage according to ECE R43.

Glass manufacturers like Sekurit Saint Gobain are proposing to reduce glass thicknesses to 1.6 and 1.1 mm for the laminate with PVB film for the windscreen, and propose this also for the side and backlights. A weight reduction of 20-25% is possible in this way with improved security. The minimum thickness of tempered glass sheets is regulated by ECE 43R demanding a certain fragmentation density after breakage.

Better security is obtained with a windscreen in a 1.6 mm and 1.1 mm glass sheet laminate with PVB film (0.76 mm), with the side lights in a laminate of two 1.1 mm glass sheets on a 2.0 mm polycarbonate sheet and backlights in the same structure as the windscreen. A weight reduction of some 25% is possible. High penetration resistance is provided by the PC core. Problems seem to exist with the acoustic damping which is not yet satisfactory. The system with the PC sheet core laminate is developed by Saint Gobain under the brand name Lamilight.

An interesting niche market arises from the special laminate made by, for example, HT Troplast, where a laminate is produced of 2 × 0.38 mm PVB film, with inside a 50 micron vacuum metallised film of Bioriented Polyester (BOPET). This is the standard laminate with glass sheets and reflects some 25% of the sunlight, reducing the load on the airconditioning systems and providing a higher security level. This type of construction is used for the 1998 Mercedes-Benz S-class, the Audi A8 and some Renault models.

Efforts to substitute the PVB film with one made of aliphatic polyurethane (TPU) have not yet met with commercial success, possibly because of the higher TPU film price.

8.8.2 Transparent plastic sheets

Efforts have been made to substitute glass with plastics like Polymethylmethacrylate (PMMA) and Polycarbonate (PC). Whereas PMMA has a good light resistance but lacks impact, PC shows good impact resistance, but discolours in light with time, even when UV stabilised with a laminated film. All plastics have low scratch and abrasion resistance as well as low stiffness if used untreated. It is therefore not the case that large weight savings can be made using plastics for glazing, as may be assumed at first glance from the difference in densities, since the thickness needs to be at least doubled to get an acceptable stiffness.

A very interesting development is the joint R&D effort of GE Plastics and Bayer to develop side and rear windows in a polycarbonate type of polymer. The resources are brought in the joint venture company called "EXATEC" with development centres in Bergisch Gladbach, Germany and Detroit, USA. Another GEP/Bayer joint venture in silicone polymers, has available and is developing coatings to render the PC windows scratch resistant. These coatings are already in use for the PC headlamp lenses of many car models.

Windscreens are excluded from the development programme due to the low modulus of polymers compared with glass. The high and varying air pressure would deform the windscreen continuously. Plastic windscreens are currently banned by legislation. Initially, cars will be equipped with PC sheet for the triangular fixed windows. New polycarbonate polymers will be developed with inherently improved sunlight and scratch resistance. Crash tests are to be carried out in Detroit. In Phase 4 of the programme movable side windows are planned. The main problem up until now is the low stiffness. It is expected that PC side windows will be in mass production by 2010.

8.9 Heating, ventilation and air conditioning systems

In both the USA and Japan the use of air conditioning and the evolution to a discrete HVAC system has occurred to a 95% uptake level, whereas in Europe the penetration of air conditioning systems is not as high.

New materials technologies are emerging, copper radiators replaced by aluminium and with prototype plastic (polyamide) radiators under test. The supplier chain is still relatively fragmented but with groupings beginning to emerge based around companies such as Denso, Valeo and Visteon. Metal suppliers have some position in the developments, since polymers do not have inherent heat exchange capacity. Packaging requirements are a major constraint in European vehicle development and increased usage of plastic materials can be expected. The segment offers opportunities for recycled materials.

The radiator itself is well established as a major user of hydrolytically stabilised glass-filled polyamide 66. The majority of automotive radiators in the world use injection moulded end tanks and the material is able to be adapted to cope with the increasing temperatures and pressures that the system requires. Both Bayer and EMS are offering high temperature versions of polyamides with a view to coping with the additional loadings required. Durethan HTS is based on nylon 6 technology whereas EMS concentrates on developing its nylon 12 materials. Polyamide and PPS are both used in water pump constructions.

The growth in automotive electronics means that the control system for the heating and air conditioning can be separated from the physical heat exchanger and this, combined with pressure on packaging space in the interior of the car, may lead to the heater element of the heat exchange system being relocated to the engine compartment. Although polymeric materials have a role to play, the emphasis is on improving the efficiency of heat exchangers and smart systems to enable the whole environment of the car to be altered in a more intelligent manner, with an energy saving.

Whilst the air inlet manifold has some tendency to be integrated with the air filter, the existence of integrated front end structures is only starting to influence the use of fan technologies, based around a shroud and a fan. Although the majority of fan shrouds continue to be made from normal injection moulding grades of glass-filled polypropylene, in well established parts recycled material is beginning to be used. Visteon Europe, for example, is moulding 13 tonnes per day of post-consumer waste, and similarly Valeo is highlighting the potential through the use of a light weight low cost hybrid metal and plastic structure housing the lighting and engine cooling units.

There are a few uses of long fibre injection moulding grades appearing. These are cross-over applications with the front end modules used in many European cars. The front end modules currently made from GMT or LFT technologies are only present in approximately 30% of the European vehicles and the shroud is incorporated into the moulding. Neither US nor Japanese practices incorporate, as yet, large usage of GMT in front ends. The US commonly uses an extension of the grille opening panel (typically a painted part) in combination with a cooling fan shroud module, which can be up to 3 kg in weight. Ford/Visteon in the US reports the use of an integrated air cleaner tray and battery tray manufactured from Ferro Corporation polypropylene, the component being called a "fully integrated air induction module". This 4 kg part is fitted to the Ford F350.

Similarly, the GM Corvette model for the 1999 model year replaced a two-part SMC assembly with an M A Hanna mixed mineral and glass fibre grade of nylon, injection moulded radiator support and a lower, more integrated air management system manufactured from PP. The hybrid steel/injection moulding technology developed in France and the US for front ends lends itself to be used in cooling system areas where high dimensional tolerances and resistance to vibration and fatigue are important. Japanese cars continue to use substantial amounts of steel in the front of the car and the fan shroud is a relatively small moulding,

The cooling fan itself principally remains manufactured from injection moulded polypropylene with various reinforcements. Larger, higher stress blades are, in the main, manufactured from glass-filled nylons, although there has been some substitution by long fibre thermoplastic injection moulded grades. The use of polymers in cars was highlighted at the 1999 SAE conference where the PSA Group's first engine fan for a 1955 Citroën DS 19 sedan, moulded from Dupont's Zytel®, was entered into the Hall of Fame.

8.10 Instrument panels and cockpit components

Changes in the worldwide sourcing of components whereby tier one or whole system suppliers are awarded contracts for global quantities of materials will lead to innovation in materials selection and processing. It is highly likely that processes will be chosen to reflect business strengths, for example, Magna has hydro-forming technology, Ford has recently invested in magnesium and Lear has considerable composites strengths. Against this background, global contracts for the instrument panels will reflect the skills and technology in-house.

Instrument panels and cockpit components will continue to contain large quantities of a diverse range of polymers, but the detailed design and construction will become dependent on the in-house manufacturing resource, for example, a Ford contract placed with Visteon will have a large injection moulding content and, similarly, one with Magna will reflect their skill and knowledge of PU. The strain imposed by a unitary materials recycling strategy, such as that recently decided by BMW (PU) cannot be expected to be duplicated by a contract placed by Volkswagen (which would probably be PP oriented). Whilst safety requirements are increasing, it is not possible on a worldwide instrument panel to have totally common features. For this reason, the structure of the instrument panel will be the common linking element and not the trim or energy absorbing component. Legislative trends suggest a more cocooning approach on a worldwide basis, despite the fact that Europe has mandatory seat belt use. This means that the cockpit "package" begins to consist of a seating set, door set and instrument panel and steering wheel.

Thus, it is possible to see three types of instrument panel coming to the market:

1. A global, low-cost injection moulded baseline product, probably PP covered with a soft feel skin, selectively with TPO/foam pads. Improvements in properties are likely, including improved scratch resistance and thinner wall moulding capabilities, much of this due to Metallocene catalyst systems.

2. A semi-structural component, around which an integrated instrument panel and/or cockpit module is manufactured. It will be capable of supporting airbag and base level of function, initially with the help of metals. The materials used will continue to be glass filled, despite limitations on ductility and impact performance, with typical examples being the Volkswagen Golf using Noryl glass filled and Opel models using SMA. Some, for example French companies, will continue to use unfilled PC/ABS, the limitation with this material being its lack of stiffness and structural strength. In Germany, Mercedes-Benz could be pointing the way forward in their use of PP composites for this type of dashboard, both Azdel and the LFT materials are being used. This application area in the US will remain dominated by Dylark SMA, although both there and in Asian vehicles, talc filled PP armatures, flame treated to aid adhesion of

PU foams will remain for some time. At present it would appear that these types of materials do not have sufficient properties to achieve the full capability of a cross-car beam. The trend to replace ABS for minor components with PP, building on the new Metallocene polymer technologies, will increase. PU foam will continue to dominate this segment but there will be additional material involved in the construction of cockpits and the use of PP foam will grow.

3. The highest level value-added instrument panel will be a base level structural component with integrated cross-car beam. If the predictions of the growth of electronics within the car are to be realised, a stable beam will be a necessity, and in the medium/large car sector a substantial growth in the use of cross-beams can be expected. Initial indications suggest that the instrument panel will be manufactured in two parts, the cross-car beam will be made from HSLA steel or magnesium diecasting, assembled to an upper component manufactured from thermoplastics. It will be possible to use PP or PC/ABS depending on the requirements. Eventually polymer based composites may be used to achieve the desired properties and to integrate the upper part of the instrument panel, including HVAC ducts and, as and when drive-by-wire technology is in place, to support the steering wheel and brake pedal equipment. A hybrid cross-car beam has already been prototyped for Delphi, manufactured from PA 66 GF on the Audi A6 and various developments from European suppliers are looking composites. Legislative changes are ongoing in both European and US markets with the change to a dynamic testing for side impact and a reduction in HIC levels for interior components. Both of these will affect the design of vehicles, probably more than the choice of materials.

8.11 Lenses – including lens housings

8.11.1 Headlamp lenses

In the USA and Japan, car manufacturers already used polycarbonate plastic for headlamp lenses in the 1980s, whereas in Europe only since January 1992 can glass be substituted. The first European car with PC lenses was the Fiat Coupé. It is expected that by 2000 some 90% of all cars produced in Europe have PC lenses. The highly curved shape of the Fiat Coupé lenses indicated the advantages of using PC in this application:

1. large freedom of design;
2. weight reduction;
3. impact resistant;
4. improved productivity;
5. allowed the development of a new headlamp concept.

For instance the Mercedes-Benz E-class has PC lenses with a weight saving of 1.5 kg.

Basically, there are two waterwhite transparent materials which can be used:

1. PMMA, this product is highly UV resistant, has a certain scratch and mar resistance, but lacks impact resistance. The polymer is cheaper than PC.
2. PC having high impact and temperature resistance, but insufficient in UV and scratch resistance.

The material of choice is PC, but a special coating on a silicone base is necessary to improve the scratch and weathering resistance.

The PC producers have developed special grades; Bayer developed Apec HT an aromatic polyestercarbonate with better heat and light resistance, they also offer Makrolon AL, whereas GE Plastics propose their Lexan LS2 resin. GEP supplies also the silicone hardcoating system. Bayer is offering here "ormoceres", short for ORganically MOdified CERamics. This coating is claimed to give the scratch resistance of glass. As an alternative, surface coating by plasma chemical vapour deposition (CVD) is increasingly competitive. The production of the PC polymer grades must happen in dust free areas as well as the injection moulding of the lenses to avoid contamination with dust.

A standard for vehicle lighting in the USA is SAE J 576 C, which includes 3 years of weathering trials in Florida. A list of acceptable materials for lenses and reflectors is to be found in the positive listing of AMERC (Automotive Maufacturers, Equipment Compliance Agency Inc. Washington DC, USA).

High Intensity Discharge (HID) lamps are considered to be a quantum leap in automotive lighting systems after the introduction of the halogen lamps in the 1970s. Prices are declining and it is expected that by 2000 all luxury cars will have the system and half of the mid-class cars. The use of this system requires high temperature-resistant materials especially for the reflectors.

A relatively new system, introduced by system supplier Valeo in 1989 is the Complex Surface Headlamp (CSH), in which the reflector is used to focus the light beam rather than the lens. The surface of the reflector is calculated by advanced computer technology. The latest technology is suitable for both high and low beams allowing more light to be liberated from a single bulb. First introduced in the luxury segment it can now be found, for example, in the Ford Ka and the Nissan Primera. It is claimed that, with the Primera, complex surfacing resulted in a 70% improvement in low beam performance.

8.11.2 Other lenses

Traditionally, the rear lamp lenses are made in PMMA in several strictly controlled colours. The injection moulding process is somewhat difficult with the injection of different colours. A development may get introduced in which clear PMMA or PC is injection moulded against a coloured or preprinted film of PMMA, a form of in-mould decoration (IMD). This would reduce the production cost substantially and when PC is used the impact resistance is improved. Low level lamps which are subject to stones are made in PC. The Volkswagen New Beetle has the taillight lenses in PC as in the headlamp lenses, the bezel in ABS, the reflector in electroplated ABS/PC. A similar construction is to be noted with the Mercedes-Benz A-class. This shows that substitution of PMMA by PC has started.

8.11.3 Lens housings

As far as housings are concerned it is necessary to distinguish between headlamps and rearlights. With modern headlamp systems much heat is generated so that a high heat-resistant material is needed. The Ford Puma made in Europe, for instance, has a lens in PC fitted in a housing made from PBT-GF20. The glass fibre serves to give temperature resistance and reduce the coefficient of thermal expansion.

The Ford Ka model has the lenses in PC as well, but the housing in PP-TD40 and the reflector in UP-MD60. The PP-TD40 with 40% filler has improved heat resistance. The reflector, getting very hot, is in thermoset with 60% filler, so that a very low level of thermal expansion is realised. Reflectors are also made in easy metallisable polyetherimide (PEI) or liquid crystal polymer (LCP) glass fibre reinforced.

Bezels for headlamps require high heat-resistant polymers as well as special high heat PC or the new product Noryl Xtra which can be metallised easily. Housings are usually produced by injection moulding halves and welding these together.

The housings for the rear lamps do not require a high heat-resistance, although this is a function of the number of light bulbs present. Often a so-called medium heat resistant ABS is used with a good impact resistance. Examples are the Volkswagen New Beetle, Ford Puma, Mercedes-Benz A-class. Also ASA polymer is applied when a UV resistance is needed. An example is the MCC Smart car.

Another material used is PP with low level of talcum (10-20%), because it is relatively cheap. More expensive is ABS/PC blend, used when a better heat resistance is required.

8.12 Rear view mirrors

8.12.1 Interior mirrors

The housing for the interior rear view mirror is moulded from a material which blends with the other finished materials in the cockpit. This would normally be polypropylene homopolymer or an ABS moulding. Only structural parts are reinforced.

On most cars conventional interior glass mirrors have been superseded by polycarbonate mirrors.

8.12.2 Exterior mirrors

Both flat and spherical front surfaced mirrors were originally made from glass with TiO_2 or AL/TiO_2 coatings. Because they are expensive to manufacture and are not recyclable, the glass has now largely been replaced by polycarbonate. This gives cost savings and also offers a weight saving compared with glass. Improved scratchproof and related protective coatings have been developed.

A new formula based on PBT glass fibre reinforced from BASF gives a smooth surface especially for exterior mirrors. The exterior mirrors of some Volvo models are moulded in Ultradur 4040 G10 PBT. The exterior mirror housing and foot of the Ford Focus is also moulded in Ultradur 4040 G10 PBT and the mirror base plate in Ultramid A3 WG6 PA66.

The Opel Astra has two types of mirror housing, lacquered and unlacquered. The first one is moulded in ABS and the second one in ASA which has higher weathering resistance.

The Ford Ka has mirror housings moulded in ABS. BMW 3 Series also has mirror housings moulded in ABS. An exception to this is the BMW M3 which has a mirror housing in PA6+15% GF + 25% mineral filler, painted.

The MCC Smart car has a mirror housing and support, also the mirror base, in 15% GF reinforced PA black (ultramid B35GB black). This is produced by Magneti Marelli. The Mercedes-Benz S-class has outside mirrors made by Resitter and Schefenacker. They can be electrically heated and are self-adjusting to the driver. ASA is usually specified for exterior mirror housings of Mercedes-Benz cars.

The Porsche Boxster thin walled exterior mirror housing is moulded by gas injection pressure after holding the pressure according to the Airpress 111 Technology. It obtained the 1997 SPE award patent (USP-S5090886).

The exterior housings of some Pontiac cars are moulded in PA6 (Ultramid B3GM3S).

Exterior mirror housings may be filled with EPP particle foam and extruded PP foam. A relatively new material proposed for exterior mirror housings is a PP/PMMA graft co-polymer Hivalloy W produced by Montell. This has excellent impact and weathering resistance.

The UK mirror producer Britax International has been licensed by Montfort Management, based at Lichfield in the UK, to produce a new type of exterior mirror based on a "Prism" technique. Several car makers have shown an interest. It will go commercial at the end of 1999 in one or two new car models. The mirror protrudes 60% less than the standard design of mirror. Aerodynamic resistance is practically eliminated. PA6GF or a mineral filled grade of PA6 is used but competition from PBTGF is present because of its lower moisture absorption.

8.13 Safety restraint systems

Since the first edition of this report, the industry has undergone change essentially encompassing vertical integration of components supplied and reduction in the number of tier one systems suppliers. The sector was growing at a very high rate during the latter half of the 1990s and the strains imposed produced pressure on pricing which, in turn, focussed the integration of electronics, safety belts, airbag and steering wheel businesses. The major systems suppliers include TRW, Autoliv, Delphi and Takata.

8.13.1 The airbag system

Whilst polyamide 66 remains the textile fibre of choice for the construction of the bag itself, there remains a divergence of viewpoint in respect of coated or uncoated bag construction. In Europe, uncoated bags made from lower, 350 dtex fibres have been the norm since the growth in the early 1990s, whilst in the US and Japan, coated fabrics, now mostly lightweight silicone (16–20 gsm) remain the preferred choice for drivers' side bags. In the US the passenger car market remains predominantly 470 dtex fabric, coated, in the case of drivers' side and uncoated for both passengers' side and the various side impact and tubular bags, deployed from headliner areas. There is limited use of polyester fabric although cost considerations suggest that usage can grow at the expense of nylon. The adoption of the Simula Inflatable Tubular Structure by Delphi for upper head requirements is likely to have a knock-on effect in that it has potential, through the use of weaving technology, to lower the cost of these types of bags.

The module housings, historically manufactured from diecast magnesium, have begun to be replaced by injection moulded housings principally from PA 66 GF. This is because of the increasing complexity of the components in respect of packaging into the seating or trim areas and the lowering, in temperature, of the gas emitted by the deployment of the airbag, eliminating the heat-sink necessity of metal.

Airbags have to be deployed rapidly and this has led to some innovative use of materials, in respect of tear characteristics in all the component fields.

8.13.2 The seat belt system

From the materials standpoint, there is relatively little movement in the use of plastics. Polyester fibre remains the fibre of choice for seat belt webbing, the lower elongation compared to nylon combined with dimensional stability under conditions of humidity continues to give it the edge. The mechanisms remain substantially an area for PA 6, 66 and POM for technical components due to their mechanical properties, impact resistance and excellent lubricity and wear characteristics. For trim components PP and ABS blends follow the classical interior line.

8.13.3 The steering wheel and pedal systems

Whilst the use of polymers in the steering wheel remains principally that of polyurethanes, there is increasing integration of this component group to include polymeric materials. Mercedes-Benz A-class is the first to use a pedal box from injection moulded PA 66 GF and, whilst the use of plastics was first seen in this application in the mid-1980s, there is a focus towards composites to confer improved crash worthiness into the structure of the fire wall.

8.14 Seating

The seating system is set to be a major user of engineering thermoplastics for structural use. However, it must not be forgotten that the key criteria of comfort will continue to be met by PU foams. Seating systems, together with instrument panels, are the significant component groups which will be specified on a worldwide platform basis for vehicle manufacturers. Flexibility, however, will be allowed to enable local market requirements i.e. minor legislative needs, combined with the aesthetic or comfort criteria variations from market to market. It can be demonstrated, using the BMW 3 Series, that change in design of the seat is reflecting the amount of PU used. The old E36 model had PU moulded foam 85 mm thick at 60 kg/m^3 and a dead pan construction. The new model has 48 mm of foam at a density of 55 kg/m^3 with a sprung system. Japanese car manufacturers still tend to use full foam dead pan seat constructions but the comfort requirements are able to be met with a 10-20% reduction in foam density, whilst maintaining the necessary resilience and durability requirements. Side airbag deployment, at least on the front seats, will continue to be met by the positioning of modules in the seating in order to minimise the out of position impact requirements. Standardisation of the major legal requirements is being achieved on a worldwide basis with the exception of freedom to use safety belts or not. With the trend towards lap diagonal systems, the potential exists to integrate further (Magna Europe's 50% interest in ACTS) a safety systems and module development joint development with TRW.

The seating system has been one of the areas where the supply chain has undergone substantial restructuring and represents one of the few truly global situations. Companies such as Delphi have ceased seating manufacture and the emerging pattern is that of Lear Systems and Johnson Controls International as the leaders, with the quite recent merger between Faure and ECIA to form Faurecia seeking to build on the combined strengths of the two companies. Magna is seeking a niche position, through acquisitions and reorganisations, to create a strong minority in the seat frame business.

From a structural materials standpoint, the increasing complexity of function and value of a seat suggests that the materials used in automotive seating will change considerably during the period. At the present time, it can be seen that structurally lightweight metal, such as magnesium die castings, has the edge for front seats at least. However, the recent announcement of a structural seat shell made from Durethan BKV 230, a glass fibre reinforced, elastomer modified PA6, for the Mercedes-Benz A-class front seat is a first for this type of material. This seat was developed in Europe by Keiper/JCI and moulded by Dynamit Nobel.

With global seating sets being proposed as the way forward, the underlying structural mechanisms will be designed and specified by the systems suppliers and not the OEMs. The advantage of having a single large order for 0.5 million vehicles, including derivatives, enables the cost advantage of the global best choice of material to be made. Plastics and composites, with their high level of integration, structural strength and rigidity, combined with high speed manufacturing should offer a competitive solution to that of magnesium and metal seat frame structures.

Seat manufacturing is essentially a JIT assembly procedure and, whilst trimming can be carried out at the local factory, the structural components may well be made elsewhere. Considering the structural components of front seats, injection moulding technology, short fibre and long fibre PA6 will be competing with the stamping processes such as GMT. In addition, it is possible to increase the rigidity of the car through use of cross-car beams integrated into the seating set. This, however, requires the design from the outset in order to save costs. For the finishing of the seats PP and ABS will continue to be the materials of choice on the basis of cost and performance.

Rear seating has been influenced by increasing amounts of composite materials. Initially, GMT was used in estate cars. Volvo for the V70, Mercedes-Benz for its T-class, and eventually spreading to Audi for its two-thirds/one-third split rear seats designs. Also, GMT has now become established as a solution which enables excellent design integration and impact performance to meet the recent European safety belt changes. The rear of the car is currently the subject of much competition to find solutions to increase the carrying capacity and flexibility of the rear space. This lends itself to the complexities achievable by the moulding of plastics. The combination of safety belt restraint loadings and the luggage intrusion test clearly indicates only high performance composites, such as GMT and possibly injection moulded hybrid materials, have any chance.

8.15 Wheels and wheel trim

Plastics have been little used in car wheels because of low thermal conductivity in enabling the heat of the brakes to dissipate away. A further problem may be the lower moduli of glass reinforced plastics than metals. Trials were carried out with 50 and 65% glass fibre SMC compounds but no sizeable production rates materialised. To arrive at a weight reduction, manufacturers have used aluminium and magnesium alloys.

For wheel covers no big changes are noticeable. ABS, ASA, ABS/PC and mineral-filled PA6 are used in an injection moulding process. The three styrenic polymers exhibit a good paintability and good dimensional stability. ABS, ASA and the blend ABS/PC are easily chrome-plated by a combination of electrochemical and electrical metal deposition processes. As paint or coating a low temperature curing polyurethane coat based on aliphatic isocyanates is recommended. A low temperature cure is necessary since the heat distortion temperatures are relatively low.

In choosing a PA6 grade, a special mineral filler is necessary to avoid excessive moisture absorption which can be up to 12% for unmodified PA6.

In choosing the right ABS or ASA, they should be types with an elevated acrylonitrile content because these have improved chemical resistance. In painting or coating these products, solvents like aromatic hydrocarbons, ketones and esters should be avoided, since they can create chemical stress cracking.

Mercedes-Benz and SEAT have models with 30% mineral filled PA6, whereas the Ford Mondeo and Fiesta have wheel covers in ABS as is the case with Nissan, Toyota and Renault models. The Mercedes-Benz Vito has covers made from ASA. This product has better UV stability and thus, if suitably pigmented, does not need to be painted or coated. Other products need to be coated, painted or chrome-plated for protection and maintaining long-term aesthetics.

9 Markets

This chapter examines the likely use of plastics and composites by car producers and their suppliers up to 2007. Forecasts of global car production are provided by major region, although the detailed forecasts of plastics use cover the three main producing regions of North America, Western Europe and Japan. There are less detailed forecasts of plastics use in Eastern Europe, Latin America, South Korea, Other Pacific Rim and Rest of World.

9.1 Car definitions and forecast methodology

As noted in "Chapter 1: Introduction" the car production forecasts prepared for this study include the nine main car categories, as follows:

A	mini
B	supermini
C	lower medium
D	upper medium
E	executive
F	luxury
MPV	multi-purpose vehicle (minivans/people carriers)
S	specialist sports
SUV	sport utility vehicle.

In addition, figures for North America include light trucks due to their dominant position in the marketplace where they account for around 50% of "car" demand.

The following provides a guide to the composition of the segments, although it is important to note that these definitions are not necessarily all-embracing and an element of overlapping is beginning to occur due to some blurring of model types. For example, some Segment A models have four or five doors and engines in excess of 1 litre, while a number of smaller MPVs are being introduced which do not meet the standard MPV definition.

Segment A comprises small, typically 2-door minicars or "city cars" with an engine size of up to 1 litre. They are popular in European and certain Asian markets but do not feature at all in North America. This sector is seeing an increasing number of new entrants, many of which are producing innovative models with a strong emphasis on space saving. Examples of long standing contenders include Rover Mini and Fiat's smallest model (Seicento in current guise), while newer contenders include Ford's Ka and the MCC Smart car.

Segment B, typically referred to as superminis, are small cars like the Ford Fiesta, Nissan Micra and Renault Clio. They have a larger body than Segment A cars while engine size ranges from 1-1.5 litres.

Segment C, also known as lower-medium, represent a major proportion of the automotive industry's output in Europe and Japan and cover models like the Ford Focus, GM Astra, Toyota Corolla and Volkswagen Golf. Engine sizes stretch up to 2 litres.

Segment D, also known as upper-medium, similarly accounts for a major part of world car output. Models include Ford Mondeo and GM Vectra, and engine sizes are as large as 3 litres but more usually are in the 1.5-2 litre range. An increasing proportion of North American production falls into this sector as domestic car producers have downsized their model ranges and Japanese transplant operations have expanded their output.

Segment E, which corresponds to executive models which generally have larger engines and bodies than Segment D models. However, there has been a noticeable tendency recently for manufacturers to develop downsized Segment E models, in line with the need to accommodate concerns over congestion and fuel economy. A strong differentiation compared with Segment D is that Segment E models tend to have more luxurious features, although again the gap in specification is tending to narrow. Examples include BMW 5 Series, Mercedes-Benz C-class and Volvo's V80/S80 range.

Segment F covers luxury cars which normally have large engines of over 3-litres and have the most luxurious interior fittings including leather and wood. Manufacture is limited to marques such as BMW, Jaguar and Mercedes-Benz and, of course, specialist ones such as Rolls-Royce/Bentley.

Segment MPV (multi-purpose vehicles) is more usually known as minivans in North America, while another term is people carriers. The genus was developed by Chrysler in the US where a ready and growing market was discovered. Chrysler's success encouraged Ford, General Motors and others (mainly Japanese manufacturers) to enter the sector, and more recently there has been intense product development activity among European manufacturers. MPVs are best described as two-box estate cars with a high roof and a defining characteristic is their ability to seat at least seven people. They have a much higher driving position than a "normal" car and may have two or four-wheel drive. In North America the segment is represented by models such as Chrysler's Voyager and Ford's Windstar whereas European models are smaller and include the Renault Espace and Ford Galaxy. Japanese versions include the Toyota Previa. It is important to note that small MPV-type models, such as Renault's Mégane Scenic, are not classified as MPVs but are included in earlier segments - Segment C in the case of the Scenic. These smaller MPVs are expected to become an increasingly common product offering by European and Japanese manufacturers.

Segment S comprises specialist sports cars. "Specialist" means that they are not derived from an existing range in another segment. There are various body styles including saloons, coupés (fixed head) and convertibles (also known as roadsters and cabriolets). The segment includes a wide range of body and engine sizes and covers mass produced models such as the Mazda MX-5 to more specialist models like the MGF and exclusive product offerings from Ferrari and Jaguar.

Segment SUV is characterised by four-wheel drive (4WD) models and their concomitant ability to travel off-road. In many cases their off-road capabilities are never used and this has resulted in the development of so-called lifestyle versions which appeal to consumers who desire the attributes of a rugged, slightly utilitarian vehicle. This market is being met by models such as Toyota's RAV-4 and Land Rover's Freelander, while more mainstream models include the Land Rover Discovery and Chrysler Jeep Cherokee. The segment is of growing significance in Asia where models like the Toyota Kijang and Mahindra Jeep are ideally suited for local operating conditions.

Finally, reference must be made to light commercial vehicles (LCVs) since these are included in the North American production figures and forecasts where they are referred to as light trucks. These models comprise vans, pickups and minibuses and, as noted earlier in this chapter, are included in the North American figures due to their importance in that region's "car" market where latest figures indicate that around 50% of buyers are opting for a light truck.

9.1.1 Segment shares

It is difficult to arrive at precise segment shares for a variety of reasons, not least the lack of comprehensive and reliable worldwide data which cover production by model. Even so, various industry sources have been used to construct Table 9.1 which provides broad estimates of world car production by type in 1998, and the same sources have been used to provide an estimate for 2003. These percentages should be regarded as tentative, although they are believed to represent a fair approximation of the current and likely future evolution of car production by type. They exclude light trucks.

Table 9.1 Estimated worldwide car production by segment in 1998 and forecast for 2003 (%)

	1998	2003
Segment A	6	7
Segment B	17	18
Segment C	28	29
Segment D	23	20
Segment E	7	7
Segment F	2	2
Segment MPV	5	4
Segment S	1	1
Segment SUV	11	12
Total	100	100

The figures for 2003 show little change compared with 1998, but there is the expectation that Segments A, B and C will strengthen their presence to the detriment of Segment D. This corresponds with forecasts throughout the industry which indicate that the motorisation of developing countries will occur through the use of small vehicles and also that a continuing trend towards smaller cars will be noticeable in certain developed markets.

Elsewhere few changes are expected, although Segment MPV has been reduced in favour of Segment SUV. There are two main reasons for this: first, MPVs are not expected to hold their position in European markets, least of all following the availability of more and more mini MPV models, and are unlikely to feature in the build-up of demand in developing markets; and secondly, a growing number of SUV models are being introduced by vehicle manufacturers in developed countries in response to growing demand, and also the relevance of SUVs in developing markets is strong.

9.1.2 Methodology

In deriving the forecasts contained in Tables 9.2–9.8 the approach has been to examine the broad economic outlook by region and then assess the implications of the regional economic outlook on individual producing countries. Car output has been based on an assessment of the likely evolution of demand in the individual countries along with the potential for international trade and the prospect of internal car demand being satisfied from external sources. In addition, the investment and production intentions of each country's major manufacturers have been noted, although these have been treated with a degree of caution since often they prove to be in excess of the actual outcome.

These forecasts, which have been derived by Dick Mann Associates (DMA), have been checked against other forecasts from independent agencies and the automotive industry, and broadly comply with the sector's own expectations. Differences occur over the anticipated ramp-up of output in developing countries where the DMA view is that recovery from the latest downturn and likely growth prospects are somewhat less rosy than the industry consensus.

With regard to the short term, forecasts of production continue to be influenced by the recent downturn in the world economy which itself was triggered by the start of the Asian financial and economic crisis during the second half of 1997. Economic forecasting groups are in general agreement that the worst is now over, but the position in many countries remains uncertain and recovery to pre-crisis levels is likely to take several years.

9.2 Global car production to 2007

It is estimated that global car production in 1998 amounted to 45.1 million units, almost unchanged compared with the previous year. During the period up to 2007 it is forecast that worldwide car output will increase by an annual average rate of 1.7% to reach 52.5 million units in 2007, an increase of 7.4 million units over the 1998 level.

After a strong performance in recent years, there was a general expectation at the beginning of 1999 that world car output would slacken during the year and this has occurred to a certain extent. Latest figures at the time of preparing this report indicate that European countries experiencing a decline include Belgium, Italy and the UK, while Germany and Spain are more or less unchanged. Of the major European producing countries only France shows a noticeable advance and both the Netherlands and Sweden have performed strongly. Elsewhere car production in both Japan and the US has remained unchanged, although there has been a strong advance in North American light truck production.

Table 9.2 provides forecasts of car production by region for 1999, 2003 and 2007. There are several points to note. First, car output in countries of the two major producing regions of North America and Western Europe have reached - or are close to reaching - saturation. This is clearly seen in the case of the US which has been in this condition for several decades. However, this does not imply that car production in these regions will remain on a plateau year-by-year. Cyclical swings, occasionally pronounced, are expected to be evident with the result that there is a chance of widely different levels of output in the countries of North America and Western Europe during the study's forecast period.

Moreover, the automotive industry will remain vulnerable to the effects, some positive but mostly negative, of external factors over which it has no control and which cannot be predicted with accuracy or, indeed, any degree of realism. For example, the impact of another energy crisis prompted by political circumstances in the Middle East would have significant ramifications in the same way as in 1973/74 and 1979. From the standpoint of 1999, the risk of a disruption for this reason is low but cannot be discounted completely.

On another issue, the world economy appears to be avoiding the worst predictions made at the time when the Asian financial and economic crisis was at its peak, and prospects for growth appear stronger than might have seemed possible at the start of 1999. Even so, the position remains fragile and there is the chance that further shocks will occur to upset the outlook, especially in the world's developing regions. Experience shows that economic misfortune in developing countries has a habit of building up slowly and then having a sudden impact, as seen recently in countries as diverse as Brazil, Korea, Mexico and Thailand.

The forecasts in Table 9.2 provide an indication of car production based on the natural evolution of marketplace demand. It takes into account likely trade flows in finished vehicles, although there are unlikely to be significant developments on an inter-regional basis. In particular, the chances of Korea fulfilling its hugely ambitious export targets to Europe and North America look very slim, and it is unlikely that exports of built-up vehicles from Japan have the potential to grow much further.

A further point to note is that the strongest growth is expected to occur in Eastern Europe, Latin America and certain parts of Asia, but in 2007 the three principal producing blocks of Western Europe, North America and Japan will still be accounting for the majority of output - 39.2 million cars out of 52.1 million or 75.2%. This compares with 38.1 million cars out of 45.5 million or 83.7% in 1998.

Table 9.2 Global car production by region 1997–98 and forecasts for 1999, 2003 and 2007 (000s)

	1997	1998	1999	2003	2007
Western Europe	14,508	15,030	14,520	15,070	15,510
Central and Eastern Europe	2,040	1,900	1,630	2,700	3,550
North America	14,803	15,100	15,800	14,400	15,200
Asia	12,247	11,020	10,550	11,800	13,800
Latin America	2,096	1,760	1,830	2,280	3,120
Others	708	730	680	820	950
Total	46,402	45,540	45,010	47,070	52,130

Note: North American total includes light trucks.

9.2.1 Western Europe

There are five principal car production countries in Western Europe. In descending order of output in 1998 they are Germany, France, Spain, the UK and Italy. In addition, cars are produced in more limited volume in Sweden, the Netherlands and Belgium, and there is a small amount of output in Austria, Finland and Portugal.

Considerable care is required in interpreting car production figures in Western Europe due to the potential for double counting. This arises when car manufacturers (principally in France and Germany) send KD (knocked down) kits for assembly in other countries (notably Belgium). Some statistics include this output in the country of origin, while others include it in the country of assembly. This study adopts the former, which explains why the French and German production figures are higher than some other sources, while the Belgian production figure is correspondingly lower.

As Table 9.3 demonstrates, few significant developments are anticipated during the period to 2007 in terms of West European car production by country. Perhaps the most significant feature is the potential for further output gains in the UK as Japanese manufacturers (notably Honda and Nissan) continue to expand and Ford's investment in Jaguar leads to new models and a considerable increase in annual output. On the other hand, the UK contains a number of marginal operations which may be threatened, especially if a marked cyclical downturn causes international car producers to reassess the structure of existing production arrangements.

The region continues to experience corporate consolidation and rationalisation, although so far there has been little impact in terms of plant closures and production rationalisation. It is not certain that this will remain the case. It is true that a number of marginal operations have been closed in recent years - typically not without political repercussions - and there is the possibility that more substantial assembly operations may become casualties during the early years of the next decade. This is all the more likely in the context of extensive overcapacity in the European car industry coupled with the existence of many low productivity assembly facilities.

The future structure of Western Europe's car assembly operations is heavily dependent on the effectiveness with which individual governments are able to persuade international vehicle manufacturers to upgrade inefficient plants. The recent manoeuvrings concerning the future of BMW's Rover operation at Longbridge in the UK provides a good example. This assembly facility, with one of the lowest productivity rates in Europe, is to be saved through the combination of government subsidy and BMW investment. There are several other assembly facilities in Europe which are failing to meet world class productivity standards and it would be prudent to anticipate some closures within the timeframe of the current forecast. However, it would be misleading to speculate on individual plants and anyway the overall forecast would be unaffected.

In addition, there are questionmarks over several companies and joint ventures. For example, the future of NedCar in the Netherlands - the joint venture between the former Volvo Car Corporation and Mitsubishi - remains uncertain following Ford's takeover of Volvo's car operations. It is also possible that further rationalisation moves will take place involving the two French companies, PSA Peugeot Citroën and Renault, Fiat and possibly BMW. Certainly Fiat has made no secret of its desire to seek a partner in the car sector in order to reduce unit costs and there is continuing speculation concerning the likelihood of BMW seeking an alliance or merger with another group.

Table 9.3 West European car production by major country 1997–98 and forecasts for 1999, 2003 and 2007 (000s)

	1997	1998	1999	2003	2007
Germany	4,678	4,800	4,650	4,700	4,500
France	3,351	3,550	3,450	3,500	3,600
Spain	2,010	2,200	2,100	2,200	2,400
UK	1,698	1,730	1,700	1,900	2,100
Italy	1,563	1,550	1,500	1,560	1,650
Belgium	356	340	310	340	350
Sweden	376	380	360	380	380
Netherlands	197	200	190	220	230
Others	279	280	260	270	300
Total	14,508	15,030	14,520	15,070	15,510

9.2.2 Eastern Europe

With the help of international car producers, notably European ones, the East European car sector can look forward to strong growth during the period to 2007. The forecasts in Table 9.4 suggest that car output between 1998 and 2007 will rise by 86.8% from 1.9 million to 3.55 million. The three principal producers in the region are Russia, Poland and the Czech Republic.

There are two main factors behind this growth: first, the opportunity to export built-up cars into West European markets and distribute them through the western partner's dealer networks. In some cases, Eastern Europe is the sole source of the model as with Fiat's Seicento. Secondly, and more important, there is huge pent-up demand for cars in the former Eastern Bloc countries and hence the major portion of production growth will be generated from local demand. It follows that the growth potential identified in Table 9.4 is heavily dependent on a relatively smooth and steady development of local economies which may not always be the case.

The biggest cause for worry at present is Russia which, due to its size, offers the region's greatest long term potential for car output. However, there are a large number of political, social and economic unknowns with the result that the country is expected to be producing cars at a rate no higher than 1.5 million units a year by the end of the forecast period.

An important point from the plastics standpoint is that East European car output will become indivisible in terms of quality and specification from western and Japanese cars. This is already clearly evident with regard to current models from Skoda, thanks to Volkswagen's influence. In other words, the previous reputation for poor quality cars constructed from inferior materials and components no longer applies.

Table 9.4 East European car production by major country 1997–98 and forecasts for 1999, 2003 and 2007 (000s)

	1997	1998	1999	2003	2007
Russia	982	850	500	1,200	1,500
Poland	520	550	600	700	1,000
Czech Republic	321	350	370	400	550
Others	217	150	160	400	500
Total	2,040	1,900	1,630	2,700	3,550

9.2.3 North America

Of all the car producing regions, North America has the greatest exposure to a cyclical downturn due largely to the saturated state of the US and Canadian markets. An analysis of North American car and light truck production during much of the second half of the twentieth century demonstrates the effect of the economic cycle on the automotive industry's fortunes. Notwithstanding several years of strong output performance, there is no reason to suppose that this pattern has been suspended and hence the first half of the next decade is expected to see a reversal in the current level of production. This is manifested in Table 9.5 with reference to the 2003 forecast, and even in 2007 the level of production is anticipated to be little changed from the 1998-99 level.

There are two points to note. First, activity in 1999 has been noticeably higher than was expected at the beginning of the year. Secondly, there is no evidence that American consumers are reversing their increasing propensity to purchase light trucks - including pickups and minivans - in preference to cars. Indeed, almost all of the production increase noted in 1999 stems from the light truck sector.

Table 9.5 North American car production by country 1997–98 and forecasts for 1999, 2003 and 2007 (000s)

	1997	1998	1999	2003	2007
USA	10,866	11,100	11,500	10,500	11,000
Canada	2,602	2,700	2,900	2,500	2,700
Mexico	1,335	1,300	1,400	1,400	1,500
Total	14,803	15,100	15,800	14,400	15,200

Note: North American total includes light truck production.

9.2.4 Asia

Table 9.6 highlights the damage done to the region's automotive industry as a result of the economic and financial crisis which started during the second half of 1997. The anticipated level of output during 1999 is almost 2 million below the 1997 outcome, with particularly sharp falls in the region's two leading producing countries, Japan and Korea.

From the standpoint of the closing months of 1999 it seems that the worst is over with the result that individual countries will be able to anticipate brighter economic conditions during the early years of the next decade. The Asian Development Bank has reported that economies in the region are recovering much faster than expected with industrial production and exports in most of the crisis-affected countries showing an increase.

However, this does not mean that previous activity levels will be regained in the short term and, moreover, recovery has been rather patchy with Korea, the Philippines, Taiwan and Thailand performing better than some other countries. It seems probable that the consistent high economic growth rates which characterised the region during the mid-1990s will not be replicated for some years.

Both China and India have failed to match previous expectations. Both countries have been recipients of substantial automotive industry investment which, so far, has failed to produce the desired returns. The region's prevailing economic conditions have not helped, of course, but it is possible also that predictions on which the investment has been based have been unduly optimistic. Certainly the ability of the Indian market to accommodate a rapidly rising level of output has been exaggerated and it seems likely that much will depend on the availability of a new generation of small, economical and attractively priced car models which will be within the price range of an expanding range of potential car owners.

Some of the most encouraging signs are evident in the Philippines while, at the other end of the spectrum, Indonesia is facing political and social turmoil which threatens the country's economic fabric.

Japan and, to a lesser extent, Korea deserve separate consideration due to the international stature of their car producers and their extensive export trade. Taking Korea first, the country's recent economic troubles coupled with the restructuring of the automotive industry have had the twin impact of providing a more realistic base from which to operate and simultaneously destroying the sector's ambition of replicating the Japanese automotive industry's growth and position of world influence. As a result, the recovery in car output during the opening years of the next decade and in the period to 2007 looks impressive but is forecast to leave the industry producing at a lower rate than in 1997.

In the case of Japan, there is little doubt that the country's car manufacturing sector is in the same position as that of the US - saturated and dependent on the vagaries of the world economic cycle. Two further points are relevant to a consideration of the Japanese automotive sector: first, the buoyancy of exports is determined to a larger extent by prevailing exchange rates; and secondly, the potential for built-up car exports from Japan has been curtailed by investment in overseas assembly capacity, notably in North America and Europe.

Table 9.6 Asian car production by major country 1997–98 and forecasts for 1999, 2003 and 2007 (000s)

	1997	1998	1999	2003	2007
Japan	8,492	8,000	7,800	8,200	8,500
Korea	2,308	1,700	1,500	1,800	2,000
India	486	450	450	600	950
China	481	450	400	650	1,100
Others	480	420	400	550	1,250
Total	12,247	11,020	10,550	11,800	13,800

9.2.5 Latin America

The car manufacturing sector of Latin American is dominated by Brazil which in 1998 accounted for 79.5% of the region's output. Vehicle manufacturers' investment programmes for the region confirm that this is likely to remain the position during the opening decade of the next century and hence Table 9.7 shows that Brazil is forecast to be producing 76.9% of Latin America's cars in 2007. Substantial growth is expected in Argentina, albeit from a low base, while the expansion and establishment of car assembly facilities in other countries is anticipated to see a sharp rise in percentage terms in countries such as Colombia and Venezuela, again from a low base.

There is no doubt that Latin America has been one of the automotive sector's big disappointments over the years. The promise of strong demand growth is ever present but invariably prospects have been dashed by recurrent economic setbacks. Developments during the closing years of the 1990s have conformed to this pattern with the result that car demand has been slack at the same time that international vehicle manufacturers have been investing in new plant and equipment in the expectation of strong demand growth.

As the world economy has slowed down, manufacturers have tended to scale back their investment intentions and the position has been aggravated by the failure of some government agencies to provide the promised incentives. For example, Ford held back from a major project in the south of Brazil for this reason, although others including DaimlerChrysler have proceeded.

Table 9.7 Latin American car production by major country 1997–98 and forecasts for 1999, 2003 and 2007 (000s)

	1997	1998	1999	2003	2007
Brazil	1,680	1,400	1,450	1,800	2,400
Argentina	366	320	340	400	500
Others	50	40	40	80	220
Total	2,096	1,760	1,830	2,280	3,120

9.2.6 Other countries

Tables 9.3-9.7 have provided details of car production forecasts in the world's main producing regions and countries. In addition, there are three countries - Australia, South Africa and Turkey - where car manufacturing takes place on a modest scale. In the case of South Africa and Turkey there is a strong probability that output will grow steadily during the period to 2007.

Table 9.8 Car production in other countries 1997–98 and forecasts for 1999, 2003 and 2007 (000s)

	1997	1998	1999	2003	2007
Australia	312	340	310	350	350
South Africa	171	180	170	220	250
Turkey	225	210	200	250	350
Total	708	730	680	820	950

9.3 Plastics usage

There is an absence of official statistics from government or industry sources on plastics usage in cars. Whilst figures for limited ranges of plastics are published in a number of journals (such as *Modern Plastics International, European Plastics News*) these generally relate to automotive production as a whole.

Calculation of 1998 plastics usage in cars therefore involved extensive industry consultation among car makers and other sources including tier I, tier II and tier III suppliers in the automotive supply chain.

Published reports and conference papers were consulted, also the latest available University of Michigan Delphi study and figures from the American Composites Association, the American Plastics Council, the APME, AVK, JAMA, JAPIA, the Korean Automotive Parts Association and others.

Coverage of the subject also included personal visits to a number of conferences and trade exhibitions including "Automotive Supplier", "ISATA", "VDI" and "K98" and Interplas 99.

Illustrative projections of future plastics usage in 2003-2007 were made. More reliance can be given to 2003 projections which lie within the period of plastics development up to the second model change. The year 2007 lies within the period of the third model change ahead, with design intentions being much less certain. What is important is not the individual figures but the overall trends which the figures indicate.

9.3.1 Plastic usage forecasts (metric tonnages)

In the first edition of this report (1995) we emphasised that the market for automotive plastics in the three major car producing regions of the world, North America, Western Europe and Japan would on average enjoy only slow growth during the period to 2003.

In these regions the use of plastics in cars is now reaching near saturation levels and during the period to 2007 can be expected to enjoy only moderate growth. This view will hold notwithstanding the use of plastic exterior panels in city cars.

If, after that time there is a major breakthrough in the use of plastic exterior panels and structural parts at the expense of their steel and aluminium equivalents then this further market penetration will cause an additional increase in the level of automotive plastics usage in these regions.

Using the above figures of actual 1998 and projected 2003 and 2007 car production as a base, we make the following analyses of 1999, and projected 2003 and 2007 plastic usage in the various areas.

North America

Table 9.9 North America estimated plastics consumption 1998 (000 tonnes)

	Interior	Ext. structure glazing	Fuel/engine compartment	Electrics & electronics	Total
PE	60		35	25	120
PP	190	80	2		272
PP/EPDM	47	60			107
PVC	70	15		45	130
SUBTOTAL commodity plastics	367	155	37	70	629
• ABS	100	25			125
Other styrenics	40	15			55
PMMA	10	14			24
• PA	30	38	35	17	120
• PC	6	50	3	4	63
• PET and PBT	5	30	5	15	55
POM	9	6	7	3	25
• PPO	30	20	6	4	60
Other mid-performance ETPs	2	2	3	1	8
SUBTOTAL mid-performance ETPs	232	200	59	44	535
SUBTOTAL high-performance ETPs			2	2	4
SUBTOTAL thermoplastic blends	599	355	98	116	1168
UP		60	20	25	105
Epoxy + phenolic	1	4	16	4	25
PU	225	59	25	1	310
Other thermosets		1	1	1	3
SUBTOTAL thermosets	226	124	62	31	443
TOTAL	825	479	160	147	1611

Footnotes to tables 9.9, 9.10, 9.11, 9.12, 9.13, 9.14, 9.15, 9.16, 9.17, 9.18 and 9.19

- ABS includes ABS content of ABS/PC blends
- PA includes PA content of PPO/PA blends
- PC includes PC content of PC/PBT and ABS/PC blends
- PET and PBT includes PBT content of PC/PBT blends
- PPO includes PPO content of PPO/PA blends

Table 9.10 North America projected plastics consumption 2003 (000 tonnes)

	Interior	Ext. structure glazing	Fuel/engine compartment	Electrics and electronics	Total
PE	60.1	0.0	35.1	25.0	120.2
PP	190.3	80.1	2.0	0.0	272.4
PP/EPDM	47.1	60.1	0.0	0.0	107.2
PVC	63.4	13.6	0.0	40.8	117.8
SUBTOTAL commodity plastics	360.9	153.8	37.1	65.8	617.6
• ABS	90.6	22.7	0.0	0.0	113.3
Other styrenics	38.2	14.3	0.0	0.0	52.5
PMMA	9.5	13.4	0.0	0.0	22.9
• PA	31.5	39.9	36.7	17.8	125.9
• PC	6.6	54.9	3.3	4.4	69.2
• PET and PBT	5.0	30.1	5.0	15.0	55.1
POM	9.0	6.0	7.0	3.0	25.0
• PPO	30.1	20.0	6.0	4.0	60.1
Other mid-performance ETPs	2.0	2.0	3.0	1.0	8.0
SUBTOTAL mid-performance ETPs	222.5	203.3	61.0	45.2	532.0
SUBTOTAL high-performance ETPs	0.0	0.0	2.0	2.0	4.0
SUBTOTAL thermoplastic blends	583.4	357.1	100.1	113.0	1,153.6
UP	0.0	60.1	20.0	25.0	105.1
Epoxy + phenolic	1.0	4.0	16.0	4.0	25.0
PU	214.7	56.3	23.9	1.0	295.9
Other thermosets	0.0	1.0	1.0	1.0	3.0
SUBTOTAL thermosets	215.7	121.4	60.9	31.0	429.0
TOTAL	799.1	478.5	161.0	144.0	1,582.6

Table 9.11 North America projected plastics consumption 2007 (000 tonnes)

	Interior	Ext. structure glazing	Fuel/engine compartment	Electrics & electronics	Total
PE	66.0	0.0	38.5	27.5	132.0
PP	209.0	88.0	2.2	0.0	299.2
PP/EPDM	51.7	66.0	0.0	0.0	117.7
PVC	64.3	13.8	0.0	41.3	119.4
SUBTOTAL commodity plastics	391.0	167.8	40.7	68.8	668.3
• ABS	91.9	23.0	0.0	0.0	114.9
Other styrenics	40.3	15.1	0.0	0.0	55.4
PMMA	10.1	14.1	0.0	0.0	24.2
• PA	36.6	46.3	42.7	20.7	146.3
• PC	7.8	64.9	3.9	5.2	81.8
• PET and PBT	5.5	33.0	5.5	16.5	60.5
POM	9.9	6.6	7.7	3.3	27.5
• PPO	33.0	22.0	6.6	4.4	66.0
Other mid-performance ETPs	2.2	2.2	3.3	1.1	8.8
SUBTOTAL mid-performance ETPs	237.3	227.2	69.7	51.2	585.4
SUBTOTAL high-performance ETPs	0.0	0.0	2.2	2.2	4.4
SUBTOTAL thermoplastic blends	628.3	395.0	112.6	122.2	1,258.1
UP	0.0	66.0	22.0	27.5	115.5
Epoxy & phenolic	1.0	4.1	16.2	4.1	25.4
PU	226.7	59.4	25.2	1.0	312.3
Other thermosets	0.0	1.1	1.1	1.1	3.3
SUBTOTAL thermosets	227.7	130.6	64.5	33.7	456.5
TOTAL	856.0	525.6	177.1	155.9	1,714.6

The 1998 usage of plastics in cars in North America and the projections for 2003 and 2007 are summarised as follows:

Table 9.12 Summary of 1998 North American plastics usage in cars with projections for 2003 and 2007 (000 tonnes)

	1998	2003	2007
PE	120	120.2	132.0
PP	272	272.5	299.2
PP/EPDM	107	107.2	117.7
PVC	130	117.8	119.4
SUBTOTAL commodity plastics	629	617.7	668.3
• ABS	125	113.3	114.8
Other styrenics	55	52.5	55.4
PMMA	24	22.9	24.2
• PA	120	125.9	146.3
• PC	63	69.1	81.7
• PET and PBT	55	55.1	60.5
POM	25	25.0	27.5
• PPO	60	60.1	66.0
Other mid-performance ETPs	8	8.0	8.8
SUBTOTAL mid-performance ETPs	535	531.9	585.2
SUBTOTAL high-performance ETPs	4	4.0	4.4
SUBTOTAL thermoplastic blends	1,168	1,153.6	1,257.9
UP	105	105.2	115.5
Epoxy + phenolic	25	25.0	25.4
PU	310	295.7	312.3
Other thermosets	3	3.0	3.3
SUBTOTAL thermosets	443	428.9	456.5
TOTAL	1,611	1,582.5	1,714.4

Comments:

From the above tables it will be seen that the estimated increase in total plastics usage between 1998 and 2007 is 6.5%.

It is now of value to consider the areas of the car and the principal individual plastics that are used.

Areas of the car

The two areas of the car where maximum increases in plastics usage will take place are in "exterior" and "structural" including glazing and in fuel systems and "engine compartment". The increase of usage of plastics in those areas is 10% to 2007.

The growth of plastics in car interiors although steady will be less, due to the maturity of these uses in the car. It is estimated that overall growth to 2007 will be slightly over 3.5%, less than half the average rate.

The increase in the use of plastics in electrical and electronic applications will be in step with the average growth rate, i.e. just over 6%. Increases in the number of electronic components per car will to some extent be offset by factors such as miniaturisation and multiplexing.

Individual plastics

The highest growth is likely to be shown by polycarbonate which is forecast to increase by a little under one third. This is due mainly to the introduction of polycarbonate glazing but also to marginal increases in the use of polycarbonate blends in exterior body parts.

Polyamides are expected to show steady growth in the four areas under review. The overall increase is approximately 22% as polyamides continue to replace metals. Air intake manifolds will continue to account for a significant proportion of the increase closely followed by other smaller components in the engine compartment. Electrical and electronic components will also continue to be important outlets.

Polypropylene and polypropylene EPDM blends will both show steady growth in excess of 10%. We expect the greatest increase to be in exterior parts like bumper covers and panels. Some further substitution by polypropylene and TPOs will also continue to take place in car interiors.

Polytheylene will also continue to enjoy steady growth which will be driven largely by blow moulded fuel tank usage as well as wheel arch liners and windscreen washer bottles. This will be of the order of 10%.

Thermoplastic polyesters PBT and PET will also exhibit a combined growth of the order of 10% with PBT increasing in car electronics and in thermoplastic blends.

Unsaturated polyesters (UP) will enjoy steady growth on account of SMC and BMC developments particularly in light trucks (SUVs). This will be a minimum of 10% to 2007.

PVC and ABS are both forecast to show a decline of at least 10% in the period to 2007.

Polyurethanes are likely to remain virtually the same with forecast growth of less than 1%. On the one hand there is the major drive to reduce the weight of polyurethane by changing the density of car seat foams and on the other there are developments in long fibre and glass mat reinforced polyurethane for structural and door components.

The "soft nose" concept for pedestrian friendly cars may involve the use of polyurethane EA foam and RIM polyurethane bumper skins. This concept could well have become mandatory in North America by 2007.

Western Europe

Estimates of total plastics usage in car production in Western Europe in 1998 with illustrative projections for 2003 and 2007 are shown in Table 9.16.

Comments:

It is likely that the increase in total plastics usage between 1998 and 2007 by the Western European car industry will be 10%.

We now consider the areas of the car and the principal individual plastics that are used.

Areas of the car

As in the case of North America the two areas of the car where maximum increase in plastics usage will take place are in "exterior and structural including glazing" 12.75% and "fuel/engine compartment", 11.40%.

Again as with North America there will be steady but relatively low growth in the use of plastics in car interiors. It is estimated that overall growth to 2007 will be 7% or over half the average growth rate for plastics overall.

The increase in the use of plastics in electrical and electronic applications to 2007 is estimated to be approximately 6.5%, again slightly under the average growth rate for plastics overall.

Individual plastics

Polycarbonate is forecast to exhibit the highest growth to 2007 with an increase of a little under one-third more than the 1998 tonnage. This estimate is based on the increasing use of polycarbonate in headlamp lenses, also the adoption of polycarbonate albeit to a limited extent in glass replacement in rear window/quarter lights of a number of models. In addition the use of PC/ABS blends in IP supports and instrument cluster housings where higher heat resistance is required.

Polyamides will show steady growth in all of the four areas under review at a level of twice that of the average increase of 10% by 2007. Air intake manifolds are the most important single component application, but in addition there are a number of other components in the engine compartment that are now being moulded in various polyamides including PA46 and these developments are likely to continue. Examples are rocker covers and engine covers. As in the case of North America their use in electrical and electronic components will continue to increase. Polypropylene and polypropylene EPDM blends will both grow at a rate of approximately 12.5% to 2007. Both exterior structural and interior areas of the car will account for the bulk of these increases.

Polyethylene will probably decrease by approximately 5% by 2007. Blow moulded fuel tanks are likely to be reduced in size due to a greater proportion of smalle vehicles with increased fuel efficiency.

Unsaturated polyester (UP) will show slightly above average growth. This will be contained however by the increasing competition to SMC and BMC from GMT and LFT. The main areas concerned are exterior structural components and systems, including bumper beams and front ends.

PVC is forecast to decrease by approximately 6% by 2007. Its use with ABS in instrument panel cover skins is likely to reduce as soon as satisfactory and economic TPO skins become accepted in a wider range of models than at present.

PVC sheathing for car wiring is likely to decrease mainly on account of the growth of moulded interconnect technology (MIT) and multiplexing. These developments will reduce the amount of low voltage wiring in future models.

Thermoplastic polyesters PBT and PET are forecast to grow at about 12% to 2007. As in North America the bulk of the applications are in "exteriors" where blends of PBT and PC are used in "electric/electronics". Connectors and sensors are two components that provide major outlets for PBT. There is strong competition from polyamides, particularly in connectors.

Polyurethanes will continue to show some growth which at approximately 12% to 2007 will be helped by the soft nose concept for pedestrian friendly vehicles. This is forecast to be in place in 2004 when 20% of new vehicles produced in Europe are expected to incorporate it. This should be more than 75% by 2007.

Table 9.13 Western Europe, estimated plastics consumption 1998 (000 tonnes)

	Interior	Ext. structure glazing	Fuel/engine compartment	Electrics and electronics	Total
PE	35	3	50	14	102
PP	327	101	25	5	458
PP/EPDM	90	68			158
PVC	71	16		43	130
SUBTOTAL commodity plastics	523	188	75	62	848
• ABS	105	12			117
Other styrenics	10	5			15
PMMA	14	20			34
• PA	25	30	85	20	160
• PC	5	45	2	3	55
• PET and PBT	3	25	10	20	58
POM	10	3	8	5	26
• PPO	22	24	4	2	52
Other mid-performance ETPs	2	1	2	1	6
SUBTOTAL mid-performance ETPs	196	165	111	51	523
SUBTOTAL high-performance ETPs			2	1	3
SUBTOTAL thermoplastic blends	719	353	188	114	1,374
UP		40	20	30	90
Epoxy + phenolic	1	3	8	3	15
PU	370	110	36	2	518
Other thermosets		1	1	1	3
SUBTOTAL thermosets	371	154	65	36	626
TOTAL	1,090	507	253	150	2,000

Table 9.14 Western Europe projected plastics consumption 2003 (000 tonnes)

	Interior	Ext. structure glazing	Fuel/engine compartment	Electrics and electronics	Total
PE	34.5	3.0	49.3	13.8	100.6
PP	356.6	110.2	27.3	5.5	499.6
PP/EPDM	98.2	74.2	0.0	0.0	172.3
PVC	70.1	15.8	0.0	42.4	128.3
SUBTOTAL commodity plastics	559.4	203.2	76.6	61.7	900.9
• ABS	103.6	11.8	0.0	0.0	115.4
Other styrenics	9.9	4.9	0.0	0.0	14.8
PMMA	14.5	20.8	0.0	0.0	35.3
• PA	28.6	34.3	97.1	22.9	182.9
• PC	6.0	53.8	2.4	3.6	65.8
• PET and PBT	3.3	27.3	10.9	21.8	63.3
POM	10.9	3.3	8.7	5.5	28.4
• PPO	24.0	26.2	4.4	2.2	56.8
Other mid-performance ETPs	2.2	1.1	2.2	1.1	6.6
SUBTOTAL mid-performance ETPs	203.0	183.5	125.7	57.1	569.3
SUBTOTAL high-performance ETPs	0.0	0.0	2.1	1.0	3.1
SUBTOTAL thermoplastic blends	762.4	386.7	204.4	119.8	1,473.3
UP	0.0	43.6	21.8	32.7	98.1
Epoxy + phenolic	1.0	3.0	7.9	3.0	14.9
PU	403.5	120.0	39.3	2.2	565.0
Other thermosets	0.0	1.0	1.0	1.0	3.0
SUBTOTAL thermosets	404.5	167.6	70.0	38.9	681.0
TOTAL	1,166.9	554.3	274.4	158.7	2,154.3

Table 9.15 Western Europe projected plastics consumption 2007 (000 tonnes)

	Interior	Ext. structure glazing	Fuel/engine compartment	Electrics and electronics	Total
PE	32.9	2.8	47.0	13.1	95.8
PP	367.8	113.6	28.1	5.6	515.1
PP/EPDM	101.2	76.5	0.0	0.0	177.7
PVC	66.7	15.0	0.0	40.4	122.1
SUBTOTAL commodity plastics	568.6	207.9	75.1	59.1	910.7
• ABS	98.6	11.3	0.0	0.0	109.9
Other styrenics	9.4	4.7	0.0	0.0	14.1
PMMA	14.4	20.6	0.0	0.0	35.0
• PA	30.4	36.5	103.5	24.4	194.8
• PC	6.6	59.0	2.6	3.9	72.1
• PET and PBT	3.4	28.1	11.2	22.5	65.2
POM	11.2	3.4	9.0	5.6	29.2
• PPO	24.7	27.0	4.5	2.2	58.4
Other mid-performance ETPs	2.2	1.1	2.2	1.1	6.6
SUBTOTAL mid-performance ETPs	200.9	191.7	133.0	59.7	585.3
SUBTOTAL high-performance ETPs	0.0	0.0	2.2	1.1	3.3
SUBTOTAL thermoplastic blends	769.5	399.6	210.3	119.9	1,499.3
UP	0.0	45.0	22.5	33.7	101.2
Epoxy + phenolic	0.9	2.8	7.5	2.8	14.0
PU	416.2	123.7	40.5	2.2	582.6
Other thermosets	0.0	0.9	0.9	0.9	2.7
SUBTOTAL thermosets	417.1	172.4	71.4	39.6	700.5
TOTAL	1,186.6	572.0	281.7	159.5	2,199.8

Table 9.16 Summary of 1998 West European plastics usage in cars, with projections for 2003 and 2007 (000 tonnes)

Plastic	1998	2003	2007
PE	102	100.7	95.8
PP	458	499.5	515.1
PP/EPDM	158	172.3	177.7
PVC	130	128.3	122.1
SUBTOTAL commodity plastics	848	900.8	910.7
• ABS	117	115.5	109.9
Other styrenics	15	14.8	14.1
PMMA	34	35.3	35.1
• PA	160	182.8	194.8
• PC	55	65.7	72.1
• PET and PBT	58	63.3	65.2
POM	26	28.4	29.2
• PPO	52	56.7	58.5
Other mid-performance ETPs	6	6.5	6.7
SUBTOTAL mid-performance ETPs	523	569.0	585.6
SUBTOTAL high-performance ETPs	3	3.1	3.4
SUBTOTAL thermoplastic blends	1,374	1,472.9	1,499.7
UP	90	98.2	101.2
Epoxy + phenolic	15	14.8	14.1
PU	518	564.9	582.6
Other thermosets	3	3.0	2.8
SUBTOTAL thermosets	626	680.9	700.7
TOTAL	2,000	2,153.8	2,200.4

Japan

Table 9.17 Japan, estimated plastics consumption 1998 (000 tonnes)

	Interior	Ext. structure glazing	Fuel/engine compartment	Electrics and electronics	Total
PE	10	8	15	9	42
PP + PP/EPDM	185	65	10		260
PVC	60	9		28	97
SUBTOTAL commodity plastics	255	82	25	37	399
• ABS + other styrenics	48	5			53
PMMA	3	10			13
• PA	8	12	20	5	45
• PC	3	11	3	1	18
• PET and PBT		10	6	4	20
POM	1	1	3		5
• PPO	8	2	2	1	13
Other mid-performance ETPs		1	1	1	3
SUBTOTAL mid-performance ETPs	71	52	35	12	170
SUBTOTAL high-performance ETPs	1	1	1	1	4
SUBTOTAL thermoplastics	327	135	61	50	573
UP		3	2		5
Phenolic/epoxy		2	2	5	9
PU foam	110	12	2	1	125
SUBTOTAL thermosets	110	17	6	6	139
TOTAL	437	152	67	56	712

Table 9.18 Japan, projected plastics consumption 2003 (000 tonnes)

	Interior	Ext. structure glazing	Fuel/engine compartment	Electrics and electronics	Total
PE	10.0	8.0	15.5	9.0	42.5
PP + PP/EPDM	195.0	70.0	15.0		280.0
PVC	57.0	8.0		28.0	93.0
SUBTOTAL commodity plastics	262.0	86.0	30.5	37.0	415.5
• ABS + other styrenics	47.0	5.0			52.0
PMMA	3.0	11.0			14.0
• PA	8.5	12.5	20.0	5.0	46.0
• PC	3.0	13.0	2.0	2.0	20.0
• PET and PBT		10.5	6.0	4.0	20.5
POM	1.0	1.0	3.5		5.5
• PPO	8.0	2.5	2.0	1.5	14.0
Other mid-performance ETPs		1.2	1.1	0.9	3.2
SUBTOTAL mid-performance ETPs	70.5	56.7	34.6	13.4	175.2
SUBTOTAL high-performance ETPs	1.0	1.0	1.0	1.0	4.0
SUBTOTAL thermoplastics	333.5	143.7	66.1	51.4	594.7
UP		3.2	2.0		5.2
Phenolic/epoxy		2.0	2.0	4.5	8.5
PU foam	115.0	12.0	2.0	1.0	130.0
SUBTOTAL thermosets	115.0	17.2	6.0	5.5	143.7
TOTAL	448.5	160.9	72.1	56.9	738.4

Table 9.19 Japan, projected plastics consumption 2007 (000 tonnes)

	Interior	Ext. structure glazing	Fuel/engine compartment	Electrics and electronics	Total
PE	9.1	8.8	17.3	9.8	45.0
PP + PP/EPDM	231.0	70.0	10.0	1.0	312.0
PVC	52.9	7.9		24.7	85.5
SUBTOTAL commodity plastics	293.0	86.7	27.3	35.5	442.5
• ABS + other styrenics	46.0	4.5			50.5
PMMA	3.2	13.0			16.2
• PA	7.0	12.2	23.0	6.0	48.2
• PC	3.8	14.0	3.2	2.0	23.0
• PET and PBT		10.2	6.4	5.0	21.6
POM	1.2	1.0	3.8		6.0
• PPO	8.5	3.2	2.0	2.0	15.7
Other mid-performance ETPs		1.0	1.5	0.9	3.4
SUBTOTAL mid-performance ETPs	69.7	59.1	39.9	15.9	184.6
SUBTOTAL high-performance ETPs	1.0	1.0	1.0	1.0	4.0
SUBTOTAL thermoplastics	363.7	146.8	68.2	52.4	631.1
UP		3.5	2.0		5.5
Phenolic/epoxy		1.8	1.8	4.4	8.0
PU foam	120.0	15.0	2.3	2.0	139.3
SUBTOTAL thermosets	120.0	20.3	6.1	6.4	152.8
TOTAL	483.7	167.1	74.3	58.8	783.9

Table 9.20 Summary of 1998 plastics use in Japanese cars and projections for 2003 and 2007 (000 tonnes)

	1998	2003	2007
PE	42	42.5	45.0
PP + PP/EPDM	260	280.0	312.0
PVC	97	93.0	85.5
ABS + other styrenics	53	52.0	50.5
PA	45	46.0	48.2
Other thermoplastics	76	81.2	89.9
PU	125	130.0	139.3
Other thermosets	14	13.7	13.5
TOTAL	712	738.4	783.9

Comments:

It is anticipated that the increase in total plastics consumption by the Japanese car industry between 1998 and 2007 will be approximately 10%.

We now consider the areas of the car and some of the principal plastics which show growth.

Areas of the car

All areas of the car are expected to show a largely similar increase in the use of plastics. The two highest are "interior" and "fuel/engine compartment". These average 11%.

The area "exterior structure incl. glazing" averages 10%. The increase in the use of plastics in "electrical and electronics" applications is expected to be not less than 5% to 2007.

Individual plastics

Polycarbonate is forecast to exhibit the highest growth to 2007 with an increase of approximately 28%. This estimate is based on the increasing use of polycarbonate in headlamp lenses and the anticipated developments in automotive glazing, as well as in polycarbonate blends for exterior components.

Polymethyl methacrylate PMMA is forecast to exhibit an increase of approximately 25% to 2007 partly on account of recent changes in styling and design of tail light assemblies.

Polypropylene and polypropylene/EPDM blends will both show steady growth of not less than 25% over the period under review. The growth will be divided between body panels, bumpers and interior components.

PVC is forecast to reduce by approximately 12%, this being initially due to a reduction in low voltage cabling and wiring and also to material substitution by TPOs in interiors.

ABS and other styrenics are forecast to decline by approximately 5% due largely to replacement in interior parts by polypropylene and TPOs.

Polyphenylene oxide PPO is likely to maintain a slow but steady growth as are PBT/PET, PA and POM. None of these polymers is likely to exceed a 15% growth to 2007.

Polyurethane foams are also expected to show a growth of not less than 10% to 2007.

Unsaturated polyester (UP) will show slightly under 10% growth to 2007.

Other Countries

South Korea

Table 9.21 Current and projected use of plastics in cars, South Korea. (000 tonnes)

	1998	2003	2007
PE	12.2	12.5	13.8
PP + PP/EPDM	55.8	63.1	74.2
PVC	16.1	15.8	16.7
ABS + other styrenics	16.4	16.6	18.3
PA	15.1	16.9	19.9
Other thermoplastic	25.3	27.9	32.4
PU	42.9	47.1	53.8
Other thermosets	11.3	12.2	13.9
TOTAL	195.1	212.1	243.0

Table 9.22 Current and projected use of plastics in cars, Other Pacific Rim countries (000 tonnes)

	1998	2003	2007
PE	5.3	6.7	11.9
PP + PP/EPDM	26.8	42.5	95.3
PVC	10.6	13.3	23.6
ABS + other styrenics	5.8	8.3	17.8
PA	6.0	7.5	13.4
Other thermoplastic	9.7	13.2	25.3
PU	13.6	20.6	44.1
Other thermosets	1.2	1.5	2.7
TOTAL	79.0	113.6	234.1

Latin America

Table 9.23 Current and projected use of plastics in cars, Latin America (000 tonnes)

	1998	2003	2007
PE	11.9	15.2	19.3
PP + PP/EPDM	72.1	101.4	139.3
PVC	15.2	19.4	24.5
ABS + other styrenics	15.4	19.7	24.9
PA	18.7	27.6	39.2
Other thermoplastic	27.4	39.1	54.3
PU	60.6	85.3	117.1
Other thermosets	12.6	17.5	23.8
TOTAL	233.9	325.2	442.4

Eastern Europe

Table 9.24 Current and projected use of plastics in cars, Eastern Europe (000 tonnes)

	1998	2003	2007
PE	12.9	18.0	21.9
PP + PP/EPDM	77.6	120.3	158.7
PVC	16.4	23.0	28.0
ABS + other styrenics	16.6	23.3	28.4
PA	20.2	32.7	44.6
Other thermoplastic	29.5	46.3	61.9
PU	65.3	101.1	133.4
Other thermosets	13.6	20.8	27.1
TOTAL	252.1	385.5	504.0

Rest of World

Table 9.25 Current and projected use of plastics in cars, Rest of World (000 tonnes)

	1998	2003	2007
PE	8.2	9.5	13.1
PP + PP/EPDM	38.9	47.9	68.2
PVC	11.1	12.2	15.7
ABS + other styrenics	11.3	12.5	16.5
PA	10.1	12.8	18.7
Other thermoplastic	17.0	21.0	30.4
PU	29.5	35.7	49.6
Other thermosets	7.9	9.5	13.2
TOTAL	134.0	161.1	225.4

Table 9.26 Estimated use of plastics in cars, all areas, 1998 with projections to 2007 (000 tonnes)

Totals by Region	North America	Western Europe	Japan	Eastern Europe	Latin America	South Korea	Other Pac. Rim.	Rest of World	Total
1998									
PE	120	102	42	12.9	11.9	11.5	4.6	8.2	313.1
PP + PP/EPDM	379	616	260	77.6	72.1	71.0	28.3	38.9	1,542.9
PVC	130	130	97	16.4	15.2	26.5	10.6	11.1	436.8
ABS + other styrenics	180	132	53	16.6	15.4	14.5	5.8	11.3	428.6
PA	120	160	45	20.2	18.7	12.3	4.9	10.1	391.2
Other thermoplastic	239	234	76	29.5	27.4	20.8	8.3	17.0	652.0
PU	310	518	125	65.3	60.6	34.1	13.6	29.5	1,156.1
Other thermosets	133	108	14	13.6	12.6	3.8	1.6	7.9	294.5
TOTAL	1,611	2,000	712	252.0	234.0	194.5	77.7	134.0	5,215.2
2003									
PE	120.2	100.7	42.5	18.0	15.2	12.1	6.2	9.5	324.4
PP + PP/EPDM	379.7	671.8	280.0	120.3	101.4	79.7	40.8	47.9	1,721.6
PVC	117.8	128.3	93.0	23.0	19.4	26.6	13.6	12.2	433.9
ABS + other styrenics	165.8	130.3	52.0	23.3	19.7	14.8	7.6	12.5	426.0
PA	125.9	182.8	46.0	32.7	27.6	13.1	6.7	12.8	447.6
Other thermoplastic	244.2	258.9	81.2	46.3	39.1	23.1	11.8	21.0	725.6
PU	295.7	564.9	130.0	101.1	85.3	37.0	18.9	35.7	1,268.6
Other thermosets	133.3	116	13.7	20.8	17.5	3.9	2.0	9.5	316.7
TOTAL	1,582.6	2,153.7	738.4	385.5	325.2	210.3	107.6	161.1	5,664.4
2007									
PE	132	95.8	45.0	21.9	19.3	13.8	12.4	13.1	353.3
PP + PP/EPDM	416.9	692.8	312.0	158.7	139.3	95.4	86.1	68.2	1,969.4
PVC	119.4	122.1	85.5	28.0	24.5	26.1	23.6	15.7	444.9
ABS + other styrenics	170.2	124	50.5	28.4	24.9	15.4	13.9	16.5	443.8
PA	146.3	194.8	48.2	44.6	39.2	14.7	13.3	18.7	519.8
Other thermoplastic	273.3	270.2	89.9	61.9	54.3	27.5	24.8	30.4	832.3
PU	312.3	582.6	139.3	133.4	117.1	42.6	38.5	49.6	1,415.4
Other thermosets	144.2	118.2	13.5	27.1	23.8	4.1	3.7	13.2	347.8
TOTAL	1,714.6	2,200.5	783.9	504.0	442.4	239.6	216.3	225.4	6,326.7

9.3.2 Plastics usage forecasts (by value)

It is only possible to give usage in value terms very approximately. Prices of specialist grades are usually a matter of negotiation between supplier and customer, but are obviously much higher than those of general purpose grades. However, reductions are often given for purchases in bulk: again these are usually a matter of negotiation between the parties involved.

Over a period of time, polymers, being commodities traded worldwide, will tend to be priced at approximately the same rate in the different main regions (North America, Europe and the Far East): changes in price are frequently not simultaneous.

It is only practicable to give prices of general purpose grades of the various polymers: for the reasons given above, these must be regarded as very approximate.

In mid-1998 they were as follows:

Table 9.27 US dollar prices per tonne of main thermoplastics and thermosets, Mid 1998.

Commodity thermoplastics	
PE	880
PP	575
PP/EPDM	575
PVC	525
HIPS	925
Engineering thermoplastics	
ABS	1,990
SMA	2,475
PMMA	1,860
PA*	3,070
PC	3,400
PET and PBT**	3,225
POM	2,750
Modified PPO	3,900
High performance thermoplastics	
LCP	22,800
PEEK	72,600
PEI	14,100
PES	12,550
Thermosets	
UP	1,250
Phenolic	3,000
PU	4,000
Vinyl ester	3,150

*Average price of PA66 grades.

**Average price of PET and PBT grades.

Sources: Plastics Industry Europe (PIE);
Plastics Technology.

Table 9.28 North America, estimated plastics usage 1998 with projections to 2003 and 2007 (US $m)

	1998	2003	2007
PE	105.6	105.8	116.2
PP + PP/EPDM	217.9	218.3	239.8
PVC	68.3	61.9	62.7
ABS + other styrenics	358.3	329.8	338.8
PA	368.4	386.6	449.1
Other thermoplastic	783.0	802.4	899.4
PU	1,240.0	1,183.0	1,249.2
Other thermosets	215.3	215.6	230.5
TOTAL	3,356.8	3,303.4	3,585.7

Table 9.29 Western Europe, estimated plastics usage 1998 with projections to 2003 and 2007 (US $m)

	1998	2003	2007
PE	89.8	88.6	84.3
PP + PP/EPDM	354.3	386.3	398.4
PVC	68.3	67.3	64.1
ABS + other styrenics	262.7	259.2	246.6
PA	491.2	561.2	598.1
Other thermoplastic	654.6	738.9	782.1
PU	2072	2,259.8	2,330.5
Other thermosets	166.5	176	177.3
TOTAL	4,159.4	4,537.3	4,681.4

Table 9.30 Japan, estimated plastics usage 1998 with projections to 2003 and 2007 (US $m)

	1998	2003	2007
PE	37	37	40
PP + PP/EPDM	150	161	179
PVC	51	49	45
ABS + other styrenics	105	103	100
PA	138	141	148
Other thermoplastic	284	300	326
PU	500	520	557
Other thermosets	33	33	31
TOTAL	1,298	1,344	1,426

Table 9.31 Estimated values of plastics used in cars, all areas 1998 with projections for 2003 and 2007 (US $m)

Totals by Region ($m)	North America	Western Europe	Japan	Eastern Europe	Latin America	South Korea	Other Pac. Rim.	Rest of World	Total
1998									
PE	105.6	89.8	37	11.3	10.5	11.6	4.0	7.2	277.0
PP + PP/EPDM	217.9	354.3	150	44.6	41.5	46.7	16.4	22.4	893.8
PVC	68.3	68.3	51	8.6	8.0	15.9	5.6	5.8	231.5
ABS + other styrenics	358.3	262.7	105	33.1	30.7	32.7	11.4	22.5	856.4
PA	368.4	491.2	138	61.9	57.5	43.0	15.0	30.9	1,205.9
Other thermoplastic	783.0	654.6	284	82.5	76.6	88.4	31.0	56.6	2,056.7
PU	1,240.0	2,072.0	500	261.1	242.4	155.7	54.5	118.2	4,643.9
Other thermosets	215.3	166.5	33	21.0	19.5	10.3	3.6	12.9	482.1
TOTAL	3,356.8	4,159.4	1,298	524.1	486.7	404.3	141.5	276.5	10,647.3
2003									
PE	105.8	88.6	37	15.9	13.4	11.9	5.4	8.3	286.3
PP + PP/EPDM	218.3	386.3	161	69.1	58.3	51.7	23.5	27.6	995.8
PVC	61.9	67.3	49	12.0	10.2	15.7	7.2	6.4	229.7
ABS + other styrenics	329.8	259.2	103	46.4	39.1	33.1	15.0	24.9	850.5
PA	386.6	561.2	141	100.5	84.7	45.3	20.6	39.2	1,379.1
Other thermoplastic	802.4	738.9	300	132.3	111.6	96.4	43.8	66.3	2,291.7
PU	1,183.0	2,259.8	520	404.5	341.2	167.0	75.9	142.7	5,094.1
Other thermosets	215.6	176	33	31.5	26.6	10.6	4.8	15.3	513.4
TOTAL	3,303.4	4,537.3	1344	812.2	685.1	431.7	196.2	330.7	11,640.6
2007									
PE	116.2	84.3	40	19.3	16.9	13.9	11.0	11.5	313.1
PP + PP/EPDM	239.8	398.4	179	91.2	80.1	62.0	49.4	39.2	1,139.1
PVC	62.7	64.1	45	14.7	12.9	15.6	12.4	8.2	235.6
ABS + other styrenics	338.8	246.6	100	56.5	49.6	34.7	27.6	32.9	886.7
PA	449.1	598.1	148	137.0	120.2	51.3	40.9	57.4	1,602.0
Other thermoplastic	899.4	782.1	326	179.1	157.2	113.0	90.0	96.4	2,643.2
PU	1,249.2	2,330.5	557	533.7	468.4	193.1	153.7	198.6	5,684.2
Other thermosets	230.5	177.3	31	40.6	35.6	10.7	8.6	21.1	555.4
TOTAL	3,585.7	4,681.4	1,426	1,072.1	940.9	494.3	393.6	465.3	13,059.3

Applying these dollar prices to the tonnages given previously for North America, West Europe and Japan the above amounts are obtained in value terms. Values are in constant 1998 prices.

Forecast values of usage assume that the relative prices of the various polymers and resins will remain the same in 2003 and 2007 as they were in 1998. This assumption will almost inevitably be proved false, but on the evidence now available we do not think that any change in relative prices will be serious enough to invalidate our forecasts. It is possible that the relative prices of some high value, high performance plastics will fall in relation to commodity plastics and engineering plastics, but the tonnages and values involved are currently very small and likely to remain so.

9.3.3 Conclusions

The projections made in the previous tables and narrative have been drawn up after a considerable amount of original research and cross-checking of estimates. However there is inevitably some uncertainty as with any projections of this type. That said it is possible to draw the following tentative conclusions:

1. In 1998 total usage of plastics in cars was of the order of 5,200,000 tonnes. This weight of polymers is likely to increase to a total of approximately 6,325,000 tonnes by 2007. This is equivalent to approximately a 21% growth over the period 1998 to 2007.

2. The value of plastics used in cars worldwide in 1998 was a little over US$10.5 billion. This value is likely to grow by approximately 22.5% between 1998 and 2007 to a little over US $13 billion.

3. In terms of weight and value, Western Europe continues to be the largest user of plastics in cars followed by North America and then Japan. All these regions will show only moderate growth overall to 2007.

   The developing areas of Eastern Europe, Latin America and India are likely to achieve higher growth to 2007 but in each case from a much lower base.

   In South East Asia use of plastics in cars in China and South Korea is likely to continue to grow. In other areas including Indonesia, Malaysia, the Philippines and Taiwan sustained growth is less likely, largely because of instability and the consequent uncertainty of the future.

4. There will be a steady and sustained growth of PP and its blends both in the form of homopolymer or copolymer and with EPDM. Polypropylene based GMT and LFT will also enjoy further growth. We calculate that over the period 1998-2007 polypropylene will grow by not less than 27% on a global basis.

5. Polyethylene will also exhibit steady growth largely due to the use of HDPE in fuel tanks. On a global basis it is likely that polyethylene will increase by not less than 10% to 2007.

6. Of the engineering thermoplastics, polyamides are likely to show sustained growth both in the engine compartment and in fuel systems, in exterior/structural applications alloyed with PPO and in electronic components. Globally we expect the growth in these polymers to 2007 to be not less than 30%.

7. Other engineering thermoplastics mainly PBT, PPO, POM, PC and PMMA are also likely to show sustained growth. Globally we expect these to average slightly more than 25%.

8. Thermosetting plastics are likely to enjoy less growth than thermoplastics over the period 1998-2007. Globally polyurethanes will increase

slightly over 20% whilst other thermosets mainly unsaturated polyesters will increase by slightly under 20%.

9. ABS and other styrenics are likely to show modest growth on a global basis of under 5% to 2007.

10. PVC, although under pressure in some regions of the world, is likely to increase by approximately 2% to 2007 on a global basis.

10 Profiles of Major Car Producers

10.1 Introduction

10.1.1 A review of 35 marques

The following section provides information on the world's principal car and light vehicle manufacturers. The information is presented in a series of profiles, arranged in alphabetical order by marque, starting with Alfa Romeo and ending with Volvo. The full list of 35 marques is as follows. Where the company is a subsidiary, the parent is identified in brackets:

- Alfa Romeo (Fiat Group)
- Audi (Volkswagen Group)
- BMW
- Chrysler (DaimlerChrysler)
- Citroën (PSA Peugeot Citroën)
- Daewoo
- Daihatsu
- Fiat (Fiat Group)
- Ford
- General Motors
- Honda
- Hyundai
- Isuzu
- Jaguar (Ford)
- Kia (Hyundai)
- Lancia (Fiat Group)
- Mazda
- MCC Smart (DaimlerChrysler)
- Mercedes-Benz (DaimlerChrysler)
- Mitsubishi
- Nissan
- Perodua
- Peugeot (PSA Peugeot Citroën)
- Porsche
- Proton

- Renault
- Rover (BMW)
- Saab (General Motors)
- SEAT (Volkswagen Group)
- Skoda (Volkswagen Group)
- Subaru
- Suzuki
- Toyota
- Volkswagen (Volkswagen Group)
- Volvo (Ford)

10.1.2 Automotive industry trends

The accelerating pace of rationalisation and consolidation within the worldwide vehicle manufacturing sector has resulted in several significant developments during 1999, such as Ford's takeover of the Volvo Car Corporation and Renault's purchase of a sizeable minority stake in Nissan. This follows the significant structural changes in the worldwide vehicle manufacturing sector which occurred during 1998 when, for example, DaimlerChrysler was formed and Hyundai acquired Kia.

Mergers and takeovers are hardly a recent characteristic of the automotive industry, but they have assumed a new urgency in the context of recent activity. The aforementioned merger of Daimler-Benz and Chrysler promises significant cost savings, not least with regard to product development and component procurement, and hence an enhanced competitive position for the combined business in world markets. It follows that other companies are re-examining their strategies and determining the moves required to ensure long term survival.

The expectation is that further consolidation moves will take place during the next two years as the global car manufacturing sector becomes centred on a limited number of companies with extensive international operations. Many senior executives in the vehicle manufacturing sector believe that the corporate moves which occur during the next two years will determine the vehicle industry's long term structure, leading to the formation of a strictly limited number of major organisations. At one extreme it is contended that there will be only six groups - two American, two European (maybe German) and two Japanese.

If this holds true, clearly there are serious implications for a number of current major players, notably Fiat in Italy, PSA Peugeot Citroën and Renault in France, and Nissan in Japan. For planning purposes, it would probably be more realistic to assume that there will be around ten independent groups, all of which will have their headquarters in North America, Western Europe or Japan. This implies that Korean vehicle producers will eventually form alliances or, more likely, become part of wider international groupings.

An important trend is for some of the smaller vehicle manufacturers to seek alliances with larger groups in the attempt to benefit from enhanced economies of scale. Mitsubishi, for example, has made no secret of its desire to form international link-ups and is hoping that the joint venture with Volvo in the Netherlands (NedCar) will continue after the original agreement comes to an end in 2004. Volvo has indicated that joint production may continue but that it does not intend to continue sharing a vehicle platform with Mitsubishi. Similarly Fiat is understood to be exploring opportunities for co-operation with other vehicle manufacturers.

In addition, the management upheavals at BMW in February 1999 have raised a questionmark over the long term independence of the German group, with suggestions that the Quandt family (which owns 46% of BMW shares) may be persuaded to sell their stake to another vehicle producer such as Ford or Volkswagen.

10.2 Production

Attempting to define car production by manufacturer is becoming increasingly involved. Many vehicle producers have established operations away from their domestic base and hence differences may arise because some sources refer purely to a manufacturer's domestic production, while others refer to the complete spectrum of operations.

The position may be complicated because sometimes the foreign operations are assemblers in their own right while others are dependent on CKD (completely knocked down) kits which are exported from the base country. In the latter case, these are usually counted as "domestic" output although they may also be counted at the point of assembly with the obvious pitfall of double counting.

Other complications arise over the definition of a car since some statistics include light 4x4s and specialist vehicles like MPVs and SUVs, and in North America it is usual to include light vans since these vehicles constitute around 50% of the region's "car" market.

It is not unknown for a manufacturer's figures in its annual report and other published material to differ from officially recorded production figures, although any difference is usually minimal. The point to note, though, is that the recording of car production figures is an inexact science and there will typically be one or two different versions of what should be the same number.

The figures in Table 10.1 are sourced from national trade associations supplemented where necessary from industry sources. They provide an indication of car production by marque and by country for the two-year period 1997-98. Since the objective is to give an indication of the relative size and significance of each company the figures are presented to the nearest thousand.

Table 10.1 Global car production by major company, 1997–98 (000 units)

	1997	1998
Alfa Romeo	161	200
Audi	558	608
BMW	679	709
Chrysler	2,865	3,062
Citroën	613	699
Daewoo	990	939
Daihatsu	374	437
Fiat	2,351	1,976
Ford	6,547	6,483
General Motors	7,903	7,259
Honda	2,257	2,281
Hyundai	976	587
Isuzu	85	133
Jaguar	44	50
Kia	467	281
Lancia	177	174
Mazda	688	701
MCC Smart	—	20
Mercedes-Benz	743	885
Mitsubishi	1,452	1,210
Nissan	2,528	2,270
Perodua	63	45
Peugeot	1,262	1,303
Porsche	32	40
Proton	215	94
Renault	1,833	2,089
Rover	486	466
Saab	86	85
SEAT	679	744
Skoda	321	368
Subaru	438	480
Suzuki	1,157	1,226
Toyota	4,401	4,223
Volkswagen	2,809	3,082
Volvo	376	389

10.3 Profiles

This section provides profiles of the 35 marques identified earlier. Each profile conforms to a similar pattern and includes a description of the marque's activities and scope of operation, an indication of the possible model development programme during the period to 2007 and, where appropriate, the current use of plastics. Contact details are provided in Chapter 12 but are not duplicated here.

Special mention should be made of the section on the "Model range and development programme 1998-2007". This provides details of the marque's current model range and indicates the likely evolution of the model range up to 2007. The information given in this section should be treated as indicative only. In some cases, notably for the first half of the forecasting period, model development programmes have been established and component producers have already been alerted to new model development programmes, but timings and model details become more tentative during the period 2002-07. The analysis in this section has been divided into nine major groups, as follows:

Segment	Category
A	minis
B	superminis
C	lower medium
D	upper medium
E	executive
F	luxury
MPV	multi-purpose vehicle (minivans/people carriers)
S	specialist sports
SUV	sport utility vehicle.

The analysis begins with Alfa Romeo.

10.3.1 Alfa Romeo

Recent developments and scope of operations

Alfa Romeo is a member of the Fiat Group and has all of its manufacturing operations in Italy. The company specialises in sports cars and sporting saloons and is able to benefit from its membership of the Fiat group by sharing vehicle platforms as well as components and systems. Even so, Alfa Romeo has a distinctive position in the marketplace and the company's standing has been improved considerably following the introduction of the 156 and 166 models which have been aimed squarely at BMW and Mercedes-Benz buyers.

The next major model development will be the replacement of the C segment 145/146 models which is expected to occur in 2001.

Model range and development programme 1998-2007

Table 10.2 Alfa Romeo's model range

Model	Segment	Introduction	Expected revision
145/146	C	1994	2001
156	D	1997	2004
166	E	1998	2005
Spider/GTV	S	1997	2004

Use of plastics

A completely integrated air intake manifold, cylinder head and cover moulded in PA6 (GF30) weighs 3.5 kg compared with an equivalent cast iron manifold weighing 7 kg. This is used in the 156 model which won the 1998 European Car of the Year award.

The 156 model also features a rocker cover in Technyl A218 MT15 V25 designed by Bosch.

10.3.2 Audi

Recent developments and scope of operations

Audi is a member of the Volkswagen Group and its car production is centred on Germany. Within the Volkswagen Group, Audi has developed a reputation for high technology, high performance models. The intention is that the marque should compete head-to-head with other German prestige brands, and especially against BMW.

Audi has been to the forefront in the use of aluminium in automotive applications. The A8 model features an aluminium body and there are plans to extend this to other smaller models. In 2000 the A2 model, a 5-door hatchback in the supermini segment, is scheduled to be launched and will also feature an all-aluminium body.

An indication of prevailing thinking is seen with the development of the Audi TT coupé which made its first appearance as a design study at the 1995 Frankfurt Motor Show. The objective was to produce a compact and functional 2+2 with an individual style.

Model range and development programme 1998-2007

Table 10.3 Audi's model range

Model	Segment	Introduction	Expected revision
A2	C	1999	2005
A3	C	1996	2002
A4	D	1993	2000/2006
Cabriolet	D	1998	2006
A6	E	1997	2003
A8	F	1994	2001
TT/TTS	S	1998	unknown
Allroad	SUV	2000	unknown

Use of plastics

Exterior and Interior

The rear window wiper drive housing for the A4 model is made of high stress resistant PET (45% GFR Impet 2700 GV1/45).

The A6 front end is a hybrid component made of Durethan BKV130 and various metal parts. The engine brackets, mountings for radiator, headlamps, and others are inserted in one operation. The producer is ECIA. Door liners are in Lustran and Bayblend, ABC pillars in Bayblend. Bayfill PUR for IP padding, Baydur for roofing, Bayfill EA door paddings. The last application mentioned is used for side impact protection in door interiors of A4, A6 and A8 models.

The A6 Quattro has front bumpers in an ABS + PA blend, whereas the rear ones are injection moulded in PP + EPDM + 20% talcum. The instrument panel has a carrier in an ABS + PC blend covered with a layer of PUR foam and on top a slush moulded PVC skin. The door interior trim is in ABS with the rigid part covered with a PVC foam layer.

The Audi A3 has also a skin in slush moulded PVC from Vinnolit and produced by the Magna MIS Interior Systems GmbH, Germany.

The airbag cover of the A4 is made from injection moulded TPO from Solvay, weighs 300 g and is produced by TRW-Mürdter, Germany.

The luxury A8 model has bumper cores made in steam chest moulded EA EPP particle foam with a density of 70 kg/m^3 and are produced by Ruch Novaplast GmbH & Co KG.

Engine and fuel system

In the case of the fuel system, the airflow sensor is a PBT moulding.

The fuel tank of the Audi A6 Quattro is blow moulded in HDPE resin and online internally fluorinated.

10.3.3 BMW

Recent developments and scope of operations

BMW's principal assembly operations are located in Germany where the company has two main factories. In addition, the company has set up an assembly operation in the US where the Z3 sports model is produced, and there are assembly operations in Egypt, Indonesia, South Africa and Thailand.

BMW acquired Rover Group from BAe in 1994 in a move which effectively doubled the size of annual vehicle output. At the time this was heralded as a positive development and there was the expectation that significant cost savings would be generated through the pooling of R&D effort and component procurement. In the event, this did not take place to any serious extent and losses have continued at the UK operation.

More recently, the future of BMW has come under threat due to continuing poor performance of its Rover subsidiary. A boardroom row at the start of February 1999 saw the departure of Bernd Pischetsrieder, chairman, and his replacement by Joachim Milner. As a consequence, the future of the Rover subsidiary is uncertain, although a new investment package has been agreed with financial support from the British government.

In 1998, BMW made an unsuccessful attempt to take over Rolls-Royce Motors, but was outbid by Volkswagen. Nevertheless, BMW has purchased the right to use the Rolls-Royce brand on motor vehicles, although an agreement with Volkswagen means that the latter will produce and distribute Rolls-Royce cars until 2003. The intention is that by then BMW will have established a new manufacturing operation in the UK to produce Rolls-Royce models.

Over recent decades, BMW has established an enviable reputation as a producer of high performance, luxury saloons from mid-range (3 Series) through to large (7 Series). More recently, there has been a move towards the development and production of niche models such as the Z3 sports model and smaller compact models as seen in the 3 Series Compact. In 1998 the fifth generation of the 3 Series was introduced.

Model range and development programme 1998–2007

Table 10.4 BMW's model range

Model	Segment	Introduction	Expected revision
3 Compact	C/D	1993	1999/2004
3 Series	D	1998	2004
5 Series	E	1996	2003
7 Series	F	1994	2001
8 Series	F	1989	1999
Z3	S	1995	2003

Use of plastics

Interior

The instrument panel for the BMW 5 Series is totally polyurethane and consists of a R-RIM PU hard foam substrate (armature) covered by integral skin PU foam. The top layer is a polyurethane "colofast" skin which is sprayed on.

Exterior

Body panels and fenders are in SMC in the case of the BMW 3 Series.

Engine

The acoustic engine cover is moulded in PA6 to give sound deadening in the BMW 3 Series.

A noise insulator between engine and passenger compartment in the 3 Series as well as the transmission tunnel noise absorber and the bonnet cover is made of high temperature resistant Basotect, a melamine-formaldehyde foam from BASF.

The fuel system airflow sensor is moulded from PBT.

10.3.4 Chrysler

Recent developments and scope of operations

Chrysler is a member of DaimlerChrysler, the group which was formed in 1998 following the merger between Chrysler Corporation and Daimler-Benz. At the Frankfurt Motor Show in September 1999 DaimlerChrysler announced a three-year $54 billion investment programme in new projects and products. This is expected to result in the introduction of 34 new car and commercial vehicle models during the next three years.

Within North America, Chrysler is the smallest member of the US "Big Three", the others being General Motors and Ford. However, the corporation's ability to benefit from the economies of scale enjoyed by its larger competitors has been improved following the aforementioned merger with Daimler-Benz.

In North America, Chrysler produces a full range of car and light truck models and is widely regarded as the "inventor" of the MPV (known as minivan in North America). Chrysler also owns the Jeep brand.

Chrysler has an important and growing presence in South America. In Argentina it opened a plant near Cordoba in 1997 for the product of a sport utility model with an annual capacity of around 10,000 units. There is a small assembly plant in Austria where Voyager MPVs and Jeeps are assembled for European markets.

Model range and development programme 1998–2007

Table 10.5 Chrysler's model range

Model	Segment	Introduction	Expected revision
Neon	D	1996	1999/2003
300M	E	1998	2002/2006
New Yorker	F	1997	2001/2005
Viper	S	1994	unknown
Voyager	MPV	1997	unknown

Use of plastics

Exterior and Interior

Chrysler has replaced the metal instrument panel carrier of its Dakota model by a PC/ABS blend moulded by Textron, obtaining considerable weight savings and ease of assembling other plastic parts.

The 1999 models Concorde and LHS feature slush moulded TPU instrument panel skins, replacing PVC. The improved heat resistant material is from Bayer and converted by Textron Automotive.

The 1999 Chrysler Jeep Cherokee has a unique doubled-walled blow moulded PP load floor and spare tyre cover. Long glass fibre reinforced PP from Composite Products Inc is used.

The 1999 Jeep Grand Cherokee Laredo is the first to have a mould-in colour metallic 2.5 mm thick fascia made from Deflex TPO from Solvay Engineered Polymers. The air intake grille is made in Luran S778 T, an ASA polymer from BASF.

10.3.5 Citroën

Recent developments and scope of operations

Citroën is part of the PSA Peugeot Citroën Group and has the majority of its operations in France. The company produces a wide range of European models covering 3- and 5-door superminis, small and mid-range hatchbacks, coupés, estate cars, executive saloons and MPVs. In the A segment, the company is represented by the Saxo, available in 3- and 5-door format. A new "retro" version of the 2CV is expected to be launched in 2000. The Xsara was introduced in 1997.

Citroën used to enjoy a reputation for unorthodox cars which had a certain "character" but lately the models have been fairly mainstream. Vehicle platforms and many components are shared with Peugeot.

Model range and development programme 1998–2007

Table 10.6 Citroën's model range

Model	Segment	Introduction	Expected revision
AX/Saxo	A	1996	2002
New 2CV	A	2000	no plans
Xsara	C	1997	2003
Xantia	E	1989	2000
XM			
Evasion/Synergie	MPV	1994	2001
Xsara MPV	MPV	1999	2004

Use of plastics

The Citroën Xantia has a bumper beam compression moulded from long fibre thermoplastic LFT produced with a hybrid technology.

The air entry ducts in the Citroën Xantia and Saxo are made of recycled ABS. The front facade of the Xantia is SMC with 5% production waste from the Xantia's tailgate.

The Berlingo features interior door panels made from vacuum formed extruded PP foam sheet using Montells Profax SD resin.

10.3.6 Daewoo

Recent developments and scope of operations

Daewoo has emerged as one of the two survivors of the shake-up in the Korean vehicle industry (the other being Hyundai). Daewoo's operations include SsangYong, and the company is also assuming the ownership of Samsung's vehicle manufacturing facilities. This deal has been brokered by the Korean government which has been anxious to ensure that the country's vehicle manufacturing sector is able to achieve the economies of scale required to compete internationally.

In addition to significant car assembly facilities in Korea, Daewoo is establishing an extensive global assembly network. Indeed, the company's target is to produce as many cars in these foreign locations as in its domestic facilities in Korea. In 1998 Daewoo assembled cars in Egypt, India, Poland, Romania, Russia, Ukraine, Uzbekistan and Vietnam. Rumours persist that the company will set up manufacturing operations in Europe when financial conditions improve, perhaps in the UK where it already has important design and engineering facilities.

Model range and development programme 1998–2007

Table 10.7 Daewoo's model range

Model	Segment	Introduction	Expected revision
Matiz	A	1998	2002
Lanos	C	1997	2003
Nubira	C	1998	2004
Leganza	D	1997	2003
Shiraz	E	2000	2005

Use of plastics

Engine

The 1998 Daewoo Matiz uses Capron GF PA66 for its air intake manifold. Future models will have Capron GF PA6 for this technical part because of the higher burst strength and less warpage obtainable with PA6.

Exterior

For the Lanos, the headlamp bezel uses PBT.

10.3.7 Daihatsu

Recent developments and scope of operations

Daihatsu's operations are concentrated in Japan where the company is a producer of niche models. Vehicles produced include minicars and minitrucks as well as recreational 4-wheel-drive models.

Model range and development programme 1998–2007

Table 10.8 Daihatsu's model range

Model	Segment	Introduction	Expected revision
Cuore	A	1997	2002
Charade	B	1993	2001
Move	MPV	1997	2003
Fourtrak	SUV	1990	unknown
Terios	SUV	1997	unknown

10.3.8 Fiat

Recent developments and scope of operations

Fiat is Italy's largest car marque and is one of the largest in Europe. The model range is concentrated in the low/medium sectors which account for the majority of demand in its domestic market. The company has invested heavily in recent years to modernise its model range and upgrade its production facilities with the result that market appeal has improved and unit costs have declined. Even so, the company is keen to establish a partnership with another vehicle producer and its name has been linked with a number of possible suitors. In 1999, Fiat attempted to merge with the Volvo Group but this was scuppered when Volvo's car operations were sold to Ford.

Towards the end of 1999 it was announced that Fiat had reached a preliminary co-operation agreement with Mitsubishi for the joint development and production of an SUV model. Fiat is handling the styling while Mitsubishi will provide the platform and mechanical parts. Production is scheduled to commence in Italy in 2001. This could be the precursor to a closer relationship since the two companies have agreed to hold discussions aimed at establishing additional co-operation at the technical level.

Meanwhile, Fiat has continued to invest heavily in its model development programme and 1999 saw the introduction of a new version of the Punto.

Fiat has been active in establishing a growing international presence in recent years, largely through the development of the Palio and Siena world cars, its models for emerging markets. New investment has included a plant in Cordoba, Argentina, for the production of Palio. Annual output is scheduled to build up to about 180,000 units.

Model range and development programme 1998–2007

Table 10.9 Fiat's model range

Model	Segment	Introduction	Expected revision
Seicento	A	1998	2003
Punto	B	1993	1999/2005
Bravo/Brava	C	1995	2001/2006
Marea	C/D	1995	2003
Barchetta	S	1995	2001
Coupé	S	1995	2002
Multipla	MPV	1998	unknown
Ulysee	MPV	1994	2001
Fuoristrada	SUV	2001	unknown

Use of plastics

Interior

A research programme at Fiat has concluded that, for ecological reasons and to promote car recyclability, the interior should be made of PP with PP foam covered with TPO foil. This construction is particularly suited to instrument panel assemblies, door trim and centre consoles.

The Fiat Palio has inner door liners in R-RIM polyurethane. The airbag cover is in Deflex TPO from Solvay.

Engine compartment

Some Fiat models will have an air inlet manifold in Zytel 7276, a new enhanced burst strength PA from DuPont moulded by Magneti Marelli.

10.3.9 Ford

Recent developments and scope of operations

Ford is the world's second largest car producer after General Motors. Annual output in North America (including light trucks) amounts to more than 4 m units a year, while European output totals around 1.5 m. In Europe, Ford has car assembly facilities in Belgium (Mondeo), Germany (Focus), Spain (Ka, Fiesta and Focus) and the UK (Fiesta and Escort).

In addition, Ford has an extensive network of international operations, principally in Latin America and the Far East.

During the past few years Ford has demonstrated two important characteristics. The first has been to organise its vehicle manufacturing operations on a global (as opposed to regional) basis. This is seen in the Ford 2000 project which aims to merge North American and European operations into one group as a first step towards welding the entire global network into a single entity. This has important ramifications for component and system suppliers because the aim is to achieve significant reductions in design and development costs, along with lower unit costs for purchased parts.

Secondly, Ford has extended its scope of operations through acquiring other car producers. In part, this reflects two key objectives: the desire to add upmarket brands; and the policy of extending international reach. With regard to the former, Jaguar was acquired at the start of the 1990s and subsequently Aston Martin has joined the group. At the start of 1999 Ford made an agreed bid for the Volvo Car Corporation. In the case of the latter, Ford has made a number of moves in the Far East, including a failed attempt to acquire Kia. This is not the end of the story, though, since it is widely believed that the future of both major Korean producers (Hyundai and Daewoo) rests with an alliance with one of the principal global vehicle producers. Elsewhere in the Far East, Ford has an important shareholding in - and management control of - Mazda.

International expansion remains a top priority. In India, Ford is expected to become the majority shareholder in its 50/50 joint venture with Mahindra & Mahindra for the production of Escorts. During 1999, assembly of the Fiesta model began and Ford plans to invest around US$400m in the Indian operation during the next few years.

Despite the slow pace of development and serious problems in the national economy, it is probable that Ford will establish a substantial presence in Russia during the period 2000-2004. The intention is to assemble Escort and Transit vans from CKD kits, but to build up local content to around the 50% level. Initial plans point to an annual assembly target of 100,000 units, but clearly this has the potential to expand noticeably long term.

Model range and development programme 1998–2007

Table 10.10 Ford's model range

Model	Segment	Introduction	Expected revision
Ka	A	1996	2002
Fiesta	B	1994	2000/2006
Puma	B	1997	2003
Escort	C	1990	Run-out by 2000
Focus	C	1998	2004
Mondeo	D	1993	2000/2006
Cougar	D	1998	2004
Scorpio	E	1995	Run-out 1999
LS	E	1999	2004
Focus	MPV	2000	unknown
Galaxy	MPV	1995	2000/2004
Maverick	SUV	1993	2001
Explorer	SUV	1997	2001

Use of plastics

Exterior and interior

The radiator grille of the Fiesta is made in Novodur P3TF, a high temperature-resistant ABS from Bayer and covered by a film according to the film back moulding technique.

Ford has led the way with the adoption of a composite front end for the 1998 Focus model. Bayer's patented hybrid technology is used. In this case, GF Polyamide 30 plus profiled steel plate give a 40% weight saving over an equivalent front end made completely of metal. Parts integration is also an advantage with this hybrid construction.

Ford continues to make use of SMC in a number of models, particularly in North America. These include a grille opening reinforcement on the Contour and Mercury Mystique models and a grille opening panel on the Crown Victoria. SMC is also used for right and left fender extensions and rear applique for the Escort; upper and lower radiator supports for the Taurus; right and left fender extensions for the Tracer; and the hood for the Mustang and A and C pillars for the Mustang Coupé.

The Lincoln Continental uses Hivalloy W, a modified PP from Montell for the B-pillar components designed for the side-impact airbag systems.

Engine

Vinyl ester resin based SMC is being used for heat shields on the 1998 Taurus.

The Ford Zetec 1.8/2-litre engines have air inlet modules in polyamide made by the test core technique.

Air cleaner housings for Ford engines are moulded from post-consumer carpet recycled material which is PA66 MF 25%. The material comes from a DuPont carpet recycling plant.

Fuel rails and water pumps fitted to Ford's 6-cylinder engines use polyphenylene sulphide (PPS).

Interior

HVAC duct vent doors on a number of US models including Taurus, Mercury Sable and Lincoln use recycled PET GF 45 PET Resin. As well as being more environmentally friendly, it is claimed that the recycled material gives a cheaper and more directionally stable vent door.

Electrical

PBT is used for the relay box in Ford's MPVs.

10.3.10 General Motors

Recent developments and scope of operations

General Motors is the world's largest car producer with substantial manufacturing capacity in North America, Western Europe and other regions. In North America, the corporation produces vehicles under the Buick, Cadillac, Chevrolet, Oldsmobile, Pontiac and Saturn marques, while in Europe the main brands are Opel and Vauxhall.

General Motors has an extensive network of manufacturing operations and alliances worldwide.

Model range and development programme 1998-2007

Table 10.11 General Motors' European model range

Model	Segment	Introduction	Expected revision
Unknown	A	2000	2004
Corsa	B	1993	2000
Tigra	B	1994	2000
Astra	C	1998	2004
Vectra	D	1995	2001/2007
Omega	E	1994	2001
Sintra	MPV	1996	unknown
Frontera	SUV	1991	2001
Monterey	SUV	1994	2003

Use of plastics

Exterior

In Europe the Opel/Vauxhall Astra has HVAC parts made by Delphi Automotive in high crystalline PP (HCPP). This gives a weight reduction of 10% compared with conventional materials.

The headlamps supplied by Hella feature lenses moulded in polycarbonate with a weight saving of 1.5 kg per car.

The radiator grille of the Opel Corsa is made of Luran S778T, an ASA polymer from BASF. The producer is Delphi.

The rocker cover in the Opel Astra is moulded in Polyamide 66.

The Frontera has an SMC roof.

Exterior

The front and rear fascias of the Oldsmobile Aurora and Buick Park Avenue are made from TPO, moulded and painted by Conix. The Buick Park Avenue has EA EPP foam cores in the front and rear bumper shells as collision energy absorbers, which are also moulded by Conix. EA EPP will also be used for the year 2000 Saturn LS front and rear bumpers. Noryl GTX (a PA/PPO blend) from GE Plastics is used for the present Saturn fenders and some vertical parts.

The Pontiac Firebird and Chevrolet Camaro have fenders in RIM PUR and SMC doors, roof and spoiler.

Interior

The Opel Astra has the HVAC parts made by Delphi Automotive in High Crystalline PP (HCPP) presenting a weight reduction of 10%. The headlamps supplied by Hella feature lenses made in PC with a weight saving of 1.5 kg.

The C-pillar trim of the Astra is in two coloured 20% talc filled propylene, moulded by Victor Reinz Thermoplast, Germany, part of the Dana group, in a two cavity mould and completely robotized.

The 1999 Chevrolet Silverado features a 1 kg clutch pedal and bracket assembly moulded in Ultramid B3G8 from BASF, with a 65% weight reduction over a similar metal module. The other advantage is the quick mounting.

10.3.11 Honda

Recent developments and scope of operations

Honda is Japan's third largest car producer, after Toyota and Nissan. Although Honda's operations remain centred on Japan, the company is internationally-minded and, among Japanese vehicle manufacturers, has been at the forefront in developing on a global basis. In particular, there are important assembly facilities in the USA, while in Europe the company has established an assembly operation in the UK. In 1998 the company commenced operations in India and China.

Europe has been identified as a priority region for expansion, both in terms of sales and production. Honda has announced a reorganisation of its European sales and distribution network together with further investment in its UK car assembly facility.

Model range and development programme 1998–2007

Table 10.12 Honda's model range

Model	Segment	Introduction	Expected revision
'J' series	A	1999	2003
Civic	C	1994	2000
Accord	D	1998	2003
Prelude	D	1997	2002
Legend	E	1996	2001
NSX	S	1990	unknown
SSX	S	2000	no plans
Shuttle	MPV	1995	2003
CRX	SUV	1997	2003

Use of plastics

Engine

The Civic from 1994 onwards has been equipped with an air intake manifold injection moulded in PA6. This represents the first time that a plastic air intake manifold had been used by a Japanese car maker.

10.3.12 Hyundai

Recent developments and scope of operations

Hyundai's operations are centred primarily in Korea. Along with Daewoo, it is one of two Korean vehicle manufacturers to survive the recent Asian downturn. Towards the end of 1998 the company took over the troubled Kia group, but now faces the task of rationalising this company's operations into its own. It is probable that there will be a consolidation of platforms.

Model range and development programme 1998–2007

Table 10.13 Hyundai's model range

Model	Segment	Introduction	Expected revision
Atos	A	1998	2003
Accent	C	1994	2002
Lantra	C/D	1995	2001
Sonata	D	1998	2003
Coupé	S	1995	unknown

Use of plastics

Engine

The use of PA66 for the cylinder head has replaced the design in aluminium that was previously used. This change from metal to plastic gives a 45% weight saving coupled with a 15% cost saving. There is also a 3dB improvement in engine noise shielding while still meeting the tough performance required from this part.

An integrated rocker cover/air cleaner is injection moulded in PA66. It is fitted to the engine used on the 1998 Atos model. There is a weight reduction of 20% plus a system cost saving of 20%. The integration reduced the part count by 35%.

10.3.13 Isuzu

Recent developments and scope of operations

Isuzu used to be a car producer but now concentrates on SUVs (and commercial vehicles). General Motors has an equity holding in Isuzu and there is the expectation that links between the two companies will become closer including the sharing of vehicle platforms.

Model range and development programme 1998-2007

Table 10.14 Isuzu's model range

Model	Segment	Introduction	Expected revision
Trooper	SUV	1993	unknown

10.3.14 Jaguar

Recent developments and scope of operations

Jaguar's entire production is centred on the UK. The company was taken over by Ford in 1991, since when it has benefitted from a substantial investment programme which is resulting in new models and a rapid build-up in output. The intention is that Jaguar should provide more of a challenge to the BMW and Mercedes-Benz marques in the future.

An important aspect of current strategy is to produce a growing range of smaller models. The S-Type - aimed at BMW 5 Series and Mercedes-Benz E-class buyers - was launched earlier in 1999 and has received a favourable reception in the marketplace. A smaller model - codenamed X400 - is currently being developed and is expected to enter production in 2001 at Ford's Halewood plant in the UK.

In view of these developments, it is anticipated that Jaguar's annual production will rise to 150,000-200,000 units during the first half of the next decade.

Model range and development programme 1998-2007

Table 10.15 Jaguar's model range

Model	Segment	Introduction	Expected revision
X400	D	2001	no plans
S-Type	E	1999	unknown
XJ6/XJ8	F	1994	unknown
XK8	S	1997	unknown

Exterior

The front and rear bumpers of the Jaguar XK6 and XK8 (European versions) are made from GMT-PP.

Interior

The load floor of the Jaguar XK6 and XK8 models is made from GMT-PP.

Engine

The radiator support panels on Jaguar XK6 and XK8 models are made from GMT-PP.

10.3.15 Kia

Recent developments and scope of operations

In 1998, the Korean vehicle producer Kia was taken over by Hyundai as part of a restructuring of the Korean automotive sector. Various other vehicle producers were interested in acquiring Kia - including Ford - but in the end there was a "Korean solution".

Model range and development programme 1998–2007

Table 10.16 Kia's model range

Model	Segment	Introduction	Expected revision
Pride	A	1991	2002
Mentor	C	1994	2003
Sportage	SUV	1996	2002

10.3.16 Lancia

Recent developments and scope of operations

Lancia is a member of the Fiat Group and produces a range of cars based on Fiat Auto platforms. Recent years have seen the marque eclipsed somewhat by Alfa Romeo within Fiat's "specialist" grouping but this is set to change over the next few years as Fiat relaunches Lancia with new models. A new Dedra was introduced in 1999 and a new MPV is scheduled for launch in 2001.

Lancia's biggest volume model is the Ypsilon which is expected to be replaced in 2001.

Model range and development programme 1998–2007

Table 10.17 Lancia's model range

Model	Segment	Introduction	Expected revision
Y	A	1995	2001/2007
Delta	C	1994	1999/2005
Dedra	C/D	1999	2005
k	E	1994	1999
Z	MPV	1994	2001

The Lancia Kappa has an IP skin made from calendered PVC/ABS foil supported by PUR foam.

10.3.17 Mazda

Recent developments and scope of operations

Ford took over the management control of Mazda in 1996, since when the company has made a determined effort to simplify its model range. As a result, the company has abandoned the minicar market and rationalised its product line-up through the deletion of low volume models.

It is inevitable that Mazda's model development programme will become more and more integrated into that of Ford. Future Mazdas are likely to be based on Ford platforms and there will be other areas of co-operation including component sharing and some production processes.

Model range and development programme 1998–2007

Table 10.18 Mazda's model range

Model	Segment	Introduction	Expected revision
121	B	1996	2000/2005
323	C	1993	1999/2004
626	D	1997	2002/2007
Xedos 6	D	1994	unknown
Xedos 9	E	1994	unknown
MX-5	S	1998	no plans

10.3.18 MCC Smart

Recent developments and scope of operations

The MCC project started out as a joint venture between the Swiss-based watch company Swatch and Volkswagen. However, Mercedes-Benz took over from Volkswagen as the technical partner at an early stage and subsequently has assumed full financial and managerial control for the venture.

The operation made a shaky start due to the twin effect of adverse publicity concerning the Smart car's safety coupled with the model's unconventional appearance. However, the tempo improved noticeably by the end of 1999 with the result that sales were running at an annual rate of around 100,000 units by the end of the year and it is anticipated that sales will rise to 130,000 in 2000.

Further variants are planned including a convertible and diesel-engined version.

Model range and development programme 1998-2007

Table 10.19 MCC's model range

Model	Segment	Introduction	Expected revision
Smart	A	1998	2005

Use of plastics

The Smart car's bodywork is made from eleven injection moulded panels of a coloured PC/PBT alloy and is twice coated with UV rays and scratch resistant layers. The instrument panel, the door and armrest, as well as the console and headlamp housing, are all made in PP.

There is a moulded clamp on the chassis made of Xenoy XD 1573 PC/PBT blend.

In addition, there is a moulded 22 litre petrol tank in HDPE by Solvay Automotive.

10.3.19 Mercedes-Benz

Recent developments and scope of operations

Although the Mercedes-Benz marque remains rooted firmly in its German base, two important developments have occurred which point to a more international approach in the future. The first has been the merger with Chrysler Corporation to form DaimlerChrysler, and the second has been the growth in foreign assembly operations including India and Mexico. A significant development has occurred with the establishment of an assembly operation in the US which is the sole production location for the company's M-class model.

Mercedes-Benz has established a reputation for producing well engineered large, medium and sporting cars. A significant move in recent years, though, has been an entry into the small car sector with the A-class. After a poor initial reception due to safety fears, Mercedes-Benz fitted an electronic stability programme to the A-class and the model has now established a strong position in its segment.

The huge investment programme mentioned under the Chrysler entry applies to Mercedes-Benz too, with the result that there will be an intensive model development programme over the next three years leading to new models and variations of existing ones.

Model range and development programme 1998–2007

Table 10.20 Mercedes-Benz's model range

Model	Segment	Introduction	Expected revision
A-class	B/C	1998	2005
C-class	D	1992	2000
CLK	E	1997	2001
E-class	E	1996	2003
S-class	F	1998	unknown
S/CL	F	1999	unknown
Maybach	F	2001	unknown
SLK	S	1996	2001
SL	S	1989	2000
V-class	MPV	1996	2001
M-class	SUV	1998	unknown

Use of plastics

Interior

The Mercedes-Benz S-class uses calendered ASA sheet as a replacement for PVC in the instrument panel skin. The model also features an instrument panel with carrier in GF ABS/PC covered by PU foam and a vacuum formed two colour ASA foil, with leather look.

Mercedes-Benz cars are equipped with door inner trim panels made by Johnson Controls, Wuppertal, Germany, in Bayer's "Fibropur", an innovative 60% flax-sisal fibre mat reinforced PUR composite. This is less expensive, has a lower weight (1.3-1.6 kg/m^2) and is more environmentally friendly than glass fibre reinforced PUR.

Exterior

A prestigeous SMC application is the bootlid of the Mercedes-Benz S CL 500 Coupé. The two piece moulding is produced by Mitras, Germany, under licence from Budd Co of Troy, Michigan, US.

Engine compartment

The Mercedes-Benz A-class has an air inlet module with cylinder head in Bayer polyamide produced by Mann & Hummel, Ludwigsburg, Germany.

10.3.20 Mitsubishi

Recent developments and scope of operations

Mitsubishi's major assembly facilities are in Japan but the company also has operations in North America and Europe. The company has established a reputation for technical innovation as seen in its innovative GDI (gasoline direct injection) technology, but it has lacked the scale of larger Japanese companies to make a bigger impact in international markets. To remedy this Mitsubishi has established a series of co-operative arrangements with other companies including Chrysler, Volvo and, more recently, Fiat.

Model range and development programme 1998-2007

Table 10.21 Mitsubishi's model range

Model	Segment	Introduction	Expected revision
Colt	A	1996	2003
Charisma	D	1996	2002
Galant	E	1997	2003
3000GT	S	1992	unknown
Spacerunner	MPV	1990	1999
Shogun	SUV	1994	unknown

Use of plastics

The 1999 Mitsubishi Galant is the first model worldwide to feature a section plastic rear bumper beam in Azdel (GMT). This is compression moulded in the in-car position from Azdel C 467 - a polypropylene-based laminate with 46% mineral and chopped glass content. It is 35% lighter, 25% cheaper and requires 20% less assembly time than an identical roll formed steel bumper. It is the 1999 winner of the SPE award.

10.3.21 Nissan

Recent developments and scope of operations

In common with other major Japanese vehicle producers, Nissan has embarked on a strong programme of international expansion during the past 20 years. Large scale assembly facilities have been established in the US and the UK.

Recently Nissan has been affected by a poor financial performance which has resulted in Renault taking a sizeable (37%) minority shareholding in the Japanese company. It is expected that this will lead to co-operation in a number of functions including design and product development. In particular, it is likely that the two companies will share platforms and components.

Model range and development programme 1998–2007

Table 10.22 Nissan's model range

Model	Segment	Introduction	Expected revision
Micra	A	1992	2000
Almera	C	1995	2000
Primera	D	1996	2001
QX	E	1995	unknown
200SX	S	1994	unknown
Serena	MPV	1993	unknown
Terrano	SUV	1994	unknown
Patrol	SUV	1989	unknown

Interior

The load floor of the Nissan Primera is of polypropylene-sandwich construction.

The Nissan Primera has an instrument panel with a PP carrier with Bayfill PUR foam.

The Nissan Almera in 2000 will have a foamless instrument panel with a soft feel TPO UV resistant coating.

10.3.22 Perodua

Recent developments and scope of operations

Perodua is Malaysia's second "home grown" car producer (the first being Proton) and started car assembly in 1994. There are links with Daihatsu and the company produces a version of the Daihatsu Micra 660cc minicar. The company has not been so badly affected by the recent adverse market conditions in Asia due to the "budget" nature of its output.

For the last two years output has fallen well short of capacity with the result that plans to expand, drawn up before the Asian economic and financial crisis, have been deferred.

Model range and development programme 1998–2007

Table 10.23 Perodua's model range

Model	Segment	Introduction	Expected revision
Nippa	A	1997	2002

10.3.23 Peugeot

Recent developments and scope of operations

Peugeot is a member of PSA Peugeot Citroën and has the majority of its operations based in France, although in Europe it also produces cars in Spain and the UK. There has been speculation that the company would seek an alliance with another vehicle producer but so far there do not seem to have been many discussions. However, an important part of Peugeot's strategy for maintaining international competitiveness centres on the formation of a series of alliances on specific projects. For example: it is co-operating with Renault on various topics and has a successful joint venture with Fiat in the light vehicle sector. Towards the end of 1999 it entered into a second joint venture with Ford for the manufacture of diesel engines. Peugeot is one of Europe's leading producers of diesel-powered cars.

Peugeot has been an major supplier of small cars to the European marketplace and has developed and produced some very popular models over the years. In 1998 the company launched the 206 model which has become a strong seller in European markets.

As noted earlier, Peugeot's focus tends to be France and the company has developed few international markets compared with other major European car producers. There are a few small-scale assembly operations in South America and there is a presence in China.

Model range and development programme 1998–2007

Table 10.24 Peugeot's model range

Model	Segment	Introduction	Expected revision
106	A	1991	2001
206	B	1998	2004
306/307	C	1993	2000
406	D	1995	2002
606	E	1999	2006
806	MPV	1994	2001
307	MPV	2001	no plans

Use of plastics

Exterior

The 1999 Peugeot 206 has a front end moulded from long fibre thermoplastic (LFT).

The 1999 Peugeot 806 has a front bumper beam made from GM Tex.

The 1998 Peugeot 406 Coupé has a thin wall painted bumper moulded from PC/PBT.

The Peugeot 406 Estate has a rear window wiper arm moulded from the 45% GFR PBT/PET blend Celanex 542. The wiper yokes were specifically designed to fit the wiper arms. The three yokes of the wiper blade frame are made from 30% GFR PET Celanex 2302 GVI/30. The individual yokes are joined together with a specially designed snap connection.

The Peugeot 306 bumper is manufactured from recycled polypropylene which comes from old battery trays and bumpers.

10.3.24 Porsche

Recent developments and scope of operations

Porsche has established an enviable reputation as a producer of high performance sports cars. Two models are produced - the 911 and more recently introduced Boxster with production split approximately 50/50. Production at the end of 1999 was running at record levels.

There have been suggestions recently that the company will establish an assembly presence outside its German base, possibly in North America, but this has not happened so far. However, the company has an arrangement with the Finnish company Valmet for the assembly of Boxster models.

Porsche is broadening its model range through the introduction of an SUV model which is currently being developed jointly with Volkswagen. The new model will be produced at a purpose-built factory at Leipzig, Germany, where output is scheduled to commence during the last quarter of 2001. Output of the Porsche version is anticipated to be 20,000 units a year.

Model range and development programme 1998–2007

Table 10.25 Porsche's model range

Model	Segment	Introduction	Expected revision
Boxster	S	1997	unknown
911	S	1997	unknown
Unknown	SUV	2001	no plans

Use of plastics

Interior

TPO skin laminated to EPP foam was chosen for the cover of the instrument panel and for door trim for the Boxster

The Porsche 996 Coupé has a similar interior material choice.

Engine

The air intake manifold for the Boxster's engine is injection moulded in PA66 GFR 35. This weighs only 1.4 kg which is approximately 50% lower than a comparable aluminium intake manifold.

10.3.25 Proton

Recent developments and scope of operations

Proton is based in Malaysia and commenced car production in 1985. It has strong links with Mitsubishi and also assembles a Citroën model, based on the AX. Prior to the Asian economic and financial crisis which developed towards the end of 1997, Proton had plans for a substantial expansion in capacity but these have been put on hold for the time being. Part of the expansion plan envisaged the construction of a massive new complex which would have been known as Proton City.

Instead the priority now is on new model development in order to increase the appeals of its products in the marketplace. Export markets have been developed but Proton is very dependent on its domestic market for sales.

Proton purchased Lotus, the UK specialist sports car producer and engineering consultancy, in 1996. This was a deliberate move aimed at reducing the company's dependence on Mitsubishi and Citroën for technical assistance.

Model range and development programme 1998–2007

Table 10.26 Proton's model range

Model	Segment	Introduction	Expected revision
Compact	A	1995	2003
Persona	C	1996	2003

10.3.26 Renault

Recent developments and scope of operations

Renault is France's largest car producer and is assuming an increasingly international stance. Undoubtedly the most far reaching development recently has been the company's decision to take a 37% equity stake in Nissan, a move which almost certainly will lead to ever-closer ties between the two companies, notably with regard to component sharing and joint model development. It is probable that a common platform for small cars will be developed and that this will form the basis for the next generation Clio/Twingo as well as for the next Micra.

Model range and development programme 1998–2007

Table 10.27 Renault's model range

Model	Segment	Introduction	Expected revision
Twingo	A	1993	2000
Clio	B	1998	2005
Mégane	C	1996	2003
Laguna	D	1994	2000
Safrane	E	1992	2001
Spider	S	1996	unknown
Scenic	MPV	1996	2003
Espace	MPV	1997	2004
Unknown	SUV	2001	unknown

Use of plastics

Exterior

The Clio 2 and Mégane Scenic have fenders in conductive high temperature resistant Noryl GTX, and alloy of PPO and PA. These are in-line paintable. The use of this material results in a 3.2 kg weight saving and there is good resistance to small collisions.

The front end of the Clio is moulded in SMC, and the same applies to exterior body panels of the Renault Espace.

Interior

The light guide housing of the instrument panel for the Clio and Mégane is moulded in PBT.

10.3.27 Rover

Recent developments and scope of operations

Rover has suffered a chequered existence in both the private and public sectors for several decades. After a lengthy period in public ownership, the company was returned to the private sector when BAe acquired the operation from the British government. In 1994 BAe sold Rover to BMW and there was hope that a new era of stability and expansion would follow. However, at the start of 1999 Rover's future once more looked under threat due to continuing heavy losses and concern that BMW would not be prepared to make the necessary investment to modernise Rover's product range and assembly facilities.

Rover's assembly operations are located solely in the UK, with cars produced at Cowley (near Oxford) and Longbridge (a suburb of Birmingham). 4-wheel-drive Land Rover vehicles are produced at Solihull (near Birmingham).

Rover's recent financial performance has been affected adversely by a variety of factors including the deletion of the 100 model (former Metro) from the range, a loss of competitiveness in the UK market due to an ageing model range and the high value of sterling which has hindered exports.

Model range and development programme 1998–2007

Table 10.28 Rover's model range

Model	Segment	Introduction	Expected revision
Mini	A	1988	2000
200	C	1995	2002
400	C/D	1995	2002
75	E	1999	unknown
Riley	E	2000	unknown
MGF	S	1995	unknown
Range Rover	SUV	1994	2001
Freelander	SUV	1997	unknown
Defender	SUV	1988	2000
Discovery	SUV	1989	2003

Use of plastics

The Rover 75 has an SMA/ABS CADON instrument panel (armature) developed by SAG Industries. The roof headliner is a self-supporting compression moulded item which is manufactured from Baynat specialised rigid foam.

The engine cover is moulded from Durethan polyamide, mineral filled to give good vibration dampening.

The Land Rover Freelander 4x4 has front fenders made from Noryl GTX. These can be painted at the company's paint shop during assembly. There is a 50% weight saving compared with traditional materials.

The characteristics of new plastics mean that exceptional finish quality can be obtained. Azdel is used in a number of applications including the rear bumper beam, load floor locker and engine undertray.

Valox PBT is used for the door handles and tailgate handle.

Cycolac ABS is used for the centre console.

10.3.28 Saab

Recent developments and scope of operations

Saab's position has been uncertain in recent years due to the combination of a low and declining production level and its location in a high cost producing area. As a consequence the company has notched up serious financial losses. Saab is 50% owned by General Motors which also has management control. It is probable that General Motors will exercise its right to acquire the other 50% from its joint venture partner, Investor and that Saab will become a 100% subsidiary.

Lately, though, Saab's fortunes appear to have been improving. It is reported that the operation has returned to profitability and car output in 1999 was expected to reach the 120,000 units level. For 2000 the sales target is 150,000 units.

New models are expected to be developed based on the current 9-3 and 9-5 platforms.

Model range and development programme 1998–2007

Table 10.29 Saab's model range

Model	Segment	Introduction	Expected revision
9-3	D	1998	2005
9-5	E	1996	2003

10.3.29 SEAT

Recent developments and scope of operations

SEAT, based in Spain, is a member of the Volkswagen Group and, like Skoda, has been transformed by the Volkswagen link. The association has brought engineering knowhow, investment funds, assembly work and the ability to benefit from the economies of scale far superior to what it could have expected as an independent company.

Model range and development programme 1998–2007

Table 10.30 SEAT's model range

Model	Segment	Introduction	Expected revision
Arosa	A	1998	2005
Ibiza	C	1993	1999/2005
Cordoba	C/D	1994	1999/2005
Toledo	D	1998	2004
Alhambra	MPV	1996	2003

10.3.30 Skoda

Recent developments and scope of operations

Skoda is part of the Volkswagen Group and has benefitted significantly in recent years from heavy investment in new product development and manufacturing facilities. Substantial expansion is envisaged over the next few years which is forecast to increase annual output to around the 500,000 units level.

Skoda's latest models and, in particular, the Octavia have won praise for their quality and specification, and there appears a good chance that the company will reach its planned target. A new model, the Fabia, has already entered production. This model is an all-new supermini which is positioned between Felicia and Octavia and is the first model to be built on Volkswagen's latest small car platform. There are rumours that Skoda is planning to develop a completely new model which would be positioned above Octavia.

Model range and development programme 1998–2007

Table 10.31 Skoda's model range

Model	Segment	Introduction	Expected revision
Fabia	A	1999	2006
Felicia	B	1994	1999
Octavia	D	1998	2004

10.3.31 Subaru

Recent developments and scope of operations

Subaru is owned by Fuji Heavy Industries and specialises in the production of mini and recreational vehicles.

Model range and development programme 1998–2007

Table 10.32 Subaru's model range

Model	Segment	Introduction	Expected revision
Justy	A	1996	2003
Impreza	D	1994	2002
Legacy	E	1998	2004
Forester	SUV	1997	unknown

Use of plastics

Exterior

The Subaru 66L Platform, produced at its Lafayette facility in the US, is equipped with a unique blow moulded PP bumper which is able to withstand a collision at 8 mph and −30°C ambient temperature.

Engine

The air intake manifold of the Sambardias engine is injection moulded in GFR PA6.

10.3.32 Suzuki

Recent developments and scope of operations

Suzuki is another of Japan's small vehicle manufacturers which specialises in niche vehicles. It is heavily committed to the US market.

There is an important relationship with General Motors which owns a 10% equity stake. This was raised from just over 3% in 1998 and is indicative of the growing links between the two companies. Among the areas of co-operation, General Motors and Suzuki are developing jointly a new small car which will replace the Wagon-R and provide General Motors with an A segment contender in the European market. This model is known as the Opel Agila and will be produced at Opel's newest plant at Gliwice in Poland.

Although Suzuki is one of Japan's smallest car producers, it has performed strongly in both domestic and export markets and has a key position in the Indian automotive industry through the Maruti joint venture with the Indian government.

Model range and development programme 1998–2007

Table 10.33 Suzuki's model range

Model	Segment	Introduction	Expected revision
Swift	A	1991	2002
Alto	A	1997	2003
Baleno	C	1995	2001
Wagon R	MPV	1997	unknown
Vitara	SUV	1996	unknown
X-90	SUV	1996	unknown

Use of plastics

The exterior mirror of the Swift model uses PBT/PET 30 GF (Celanex 2302 GV1/30 black 10/900).

10.3.33 Toyota

Recent developments and scope of operations

Toyota is Japan's largest car producer and the third largest in the world. The majority of output is carried out in Japan but in addition there is an extensive network of assembly operations elsewhere in the world, notably in the company's major markets of North America and Europe.

Like Honda, Toyota is aiming to secure a strong increase in its European sales. It is looking to boost market share from 3 to 5%, implying a volume increase from 600,000 to 800,000 units. Part of the plan involves a substantial expansion in its European assembly capacity.

Toyota is also planning to build up Lexus, its luxury car brand.

Toyota is one of the few companies to have introduced a technically advanced car which features a non-conventional power unit. The Prius is powered by a low emission internal combustion engine with an electric motor. It has been on sale in Japan since 1997 and is scheduled to be launched in Europe in 2000.

Model range and development programme 1998–2007

Table 10.34 Toyota's model range

Model	Segment	Introduction	Expected revision
Starlet	A	1996	2003
Yaris	B	1999	2005
Corolla	C	1997	2003
Paseo	C	1997	2003
Avensis	D	1998	2004
Camry	E	1996	2002
Celica	S	1998	unknown
MRS	S	1999	unknown
Picnic	MPV	1997	unknown
Previa	MPV	1994	unknown
Landcruiser	SUV	1996	2005
RAV4	SUV	1994	2003
Lexus IS200	D	1998	2005
Lexus GS300	E	1998	2004
Lexus LS400	F	1998	2004

Engine

Several models have a fuel pump unit moulded in POM resin from Duracon, Ticona, Japan.

Interior and exterior

The Toyota Avenis has an armrest with integrated electric window opening system made by Johnson Controls, Wuppertal, Germany in ABS foil with back moulding of ABS.

The Crown has a hubcap produced by Tokai Rica, Japan, with in mould decoration technique. Toyota uses ABS for wheel covers.

The latest Toyota Previa model, an MPV, has a large dashboard in ppe/ps as well as interior trim parts (chosen because of its heat distortion temperature of 118°C necessary because of the flat windscreen.

The Toyota Avenis and Corolla both have instrument panels moulded in Bayblend PC/ABS and covered with Bayfill PUR foam. The top skin is made from slush moulded PVC plastisol.

10.3.34 Volkswagen

Recent developments and scope of operations

Volkswagen is one of Europe's largest car manufacturers and has established a wide European and international manufacturing network. As already covered in this chapter, members of the group include Audi, SEAT and Skoda, but in addition the company has acquired a number of exotic brands including Bentley, Bugatti and Lamborghini. The company seems determined to compete with BMW and Mercedes-Benz in the large luxury car market and may produce its own version of a luxury model.

More than any other European-based car producer, Volkswagen has established a comprehensive international production network.

Model range and development programme 1998–2007

Table 10.35 Volkswagen's model range

Model	Segment	Introduction	Expected revision
Lupo	A	1998	2004
Polo	B	1995	2000/2005
Beetle	C	1998	no plans
Golf	C	1997	2003
Vento	C/D	1998	2004
Passat	D	1997	2001
W12	S	2000	unknown
Sharan	MPV	1995	2002
Golf MPV	MPV	1999	2005
unknown	SUV	2002	no plans

Use of plastics

The Passat has a front end moulded from long fibre thermoplastic (LFT).

Interior and exterior

The airbag module of the VW Lupo is supplied by Autoliv and made in a PA66 + 33% GF housing and a cover in Hytrel DYM 350 both from DuPont. The complete cockpit of the Lupo is assembled by SAI-Siemens GmbH in a plant near Wolfsburg and supplied directly on the Lupo assembling chain. For the major part PP is used.

The technical front end of the VW Golf is produced by Rütgers Automotive in GMT PP.

The VW Golf and Passat have instrument panels with an injection moulded SMA carrier with PUR semi rigid foam and a slush moulded PVC skin.

The door interior liners of the Golf are in Vinnolit PVC paste which is converted by Benecke-Kaliko, Germany.

The interior doors of the Passat B5 have a rigid carrier in injection moulded ABS and subsequently covered with a PVC foil. Producer: Peguform, Germany.

The Passat has the upper and lower A and B pillars as well as the upper parts of the C and D columns in the new High Crystalline PP, substituting PP talcum filled.

The spare wheel of the Passat is in 20 kg/m^3 steam chest moulded EA EPP particle foam and produced by Rucj Novaplast GmbH & Co KG.

The integrated children seats for the Passat and Audi A6 are 17 kg in weight with 2 seats made in PUR foam, a metal frame and a PP shell.

The New Beetle, produced in Mexico, has an integrated front part produced by Plastic Omnium with a bumper shell in TPO from Solvay and the fenders in Noryl GTX from GE Plastics. Also an airfilter made by Mann & Hummel in a combination of PUR/PA/paper.

The New Beetle has the head lamp lenses in 500 g injection moulded PC and made scratch resistant with a Sicralan MRL coating by GFO Gesellschaft für Oberflachen Technik mbH.

The VW Bora has 900 g head rest frames in metal with PUR foam and PE parts produced by Grammar AG, Germany.

Engine

The intercoolers in the 66 and 81 kW engines, fitted in the current Audi A3 and Volkswagen Golf diesel versions, have a PA46 end cap. This has replaced aluminium because of the plastic material's lower weight, lower part cost and better performance.

10.3.35 Volvo

Recent developments and scope of operations

Volvo's car operations are centred at Gothenburg in Sweden. However, the company also has assembly facilities in Belgium where the V70 is produced and, until recently, cars were produced in Canada too. In the Netherlands

Volvo has a joint venture with Mitsubishi called NedCar. The two companies share a common platform but produce their own distinctive models, in Volvo's case the S40 and V40 models.

In early 1999 the Volvo Car Corporation was acquired by Ford and Volvo is now part of Ford's Premier Auto Group. For the moment it is hard to discern the influence of Ford but there is clearly much potential for cost savings and this is likely to become more and more apparent over time. In particular it is likely that Volvo's cars will incorporate an increasing amount of Ford componentry.

Model range and development programme 1998–2007

Table 10.36 Volvo's model range

Model	Segment	Introduction	Expected revision
S40/V40	D	1995	2002
70 series	E	1992	1999
80/90	E	1998	2005

Use of plastics

Exterior

The Volvo 850 has a front end in long fibre thermoplastic (LFT).

Interior

The Volvo 850 Estate has a rear seat squab which is moulded in GMT by Volvo in-house.

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11 Profiles of Major Suppliers of Plastic Components to the Car Industry

Aeroquip Group

Address:	3000 Strayer, Maumee, OH 43537-0050 USA
Tel:	+1 419 867 2200
Fax:	+1 419 867 2395
Internet:	http://www.aeroquip.com
Senior Vice President:	Howard Selland
Employees:	7000
Activities and products:	The Aeroquip Group are active in the design, manufacture and distribution of components and systems to the Industrial, Aerospace and Automotive Industries. Aeroquip makes all pressure ranges of hoses, adapters, fittings, couplings and other fluid connectors. In April 1999, Eaton Corporation acquired Aeroquip-Vickers, Inc.

Aeroquip Automotive

Group V.P. Aeroquip Automotive:	Daniel E. Kimmet
Employees (end 1997):	2759 (was 4088 end 1996)
Activity and products:	Focus on fluid connectors for air conditioning, power steering, oil and transmission cooler components and assemblies. Further exterior trim such as spoilers, decorative bumper strips and roof mouldings. Direct OEM Sales. The interior trim business was sold in 1997.
Plant locations:	The business group has five manufacturing locations in the USA, four in Europe and one in Brazil.
Quality:	The company is exercising the Six Sigma quality goal, which means less than 3.4 failures per million opportunities. This has been extended to suppliers. Aeroquip was nominated by GM a Supplier of the Year for 1997.

Divestments:

Aeroquip sold its automotive plastic interior components operation in Chesterfield and Port Huron, MI; Chihuahua, Mexico; Beienheim, Germany, and Kendallville, IN. Sold plastic interior parts facilities in Spring Arbor, MI and Roedelheim, Germany. This improved considerably operating margins.

Acquisitions:

Aeroquip Inoac Company, a joint venture of Aeroquip and Inoac Corp acquired Aeroquip's automotive plastic exterior parts operations in Atlanta, GA, and Livingston, TE.
Aerotech South Africa, the largest supplier of hose assemblies and fittings in South Africa. A new plant for automotive fluid connectors was opened in Wolfsburg, Germany.

Joint Ventures:

The Aeroquip Inoac Company is a 51/49 joint venture of Aeroquip and Inoac Corporation of Japan. Its goal is to expand Aeroquip's automotive components business especially with the Japanese transplants in the USA.

Financial performance in millions US$

Year (End 31/12)	1997	1996	1995
Group sales	2112.3	2032.9	1884.0
Group net income	100.9*	102.7	94.9
Automotive sales	454.1	503.8	494.0
Auto operating Income	19.0*	35.1	24.1

*After a special charge of US$30 million (US$18.5 million net) because of the divestitures.

Automotive sales declined in 1997 due to the exit from the automotive plastic interior parts business. Some eight facilities were either sold or closed, because of the focus on hose and attached fittings business.
For the first nine months of 1998 the Automotive sales declined by US$32.3 million or 9.4%, (US$310.3 million vs. US$342.6 million) compared to the period ending 30/09/1997 because of the same reason. Strong sales for fluid connectors for air conditioning and power steering in Europe are noted.

Customer base:

This includes Audi, BMW, Mercedes-Benz, Ford Motor Co, GM Corporation, Jaguar Ltd, Rover, VW which are supplied with fluid connectors. VW has named Aeroquip one of the top suppliers partly because of the global position and the production of both hose and fittings.

Benecke-Kaliko AG

Address:	Benecke Allee 40, D-30419 Hannover, Germany
Tel:	+49 511 6302-0
Fax:	+49 511 6302-206
Internet:	http://www.centitech.de/ctcompany/benecke
	The company is owned 50.1% by Goppinger-Kaliko GmbH, a wholly owned subsidiary of Continental AG, Hannover and 49.9% by DG-Bank AG.
Executive Directors:	Dr Meyer, Chairman, Mr. Kepper, Director
Sales Europe:	Mr Engelmann
Sales Overseas:	Mr Hinrichs
Purchasing:	Mr Schumacher
Employees in 1998:	2,602
Sales volume 1998:	DM 748 million
Participations:	Sandusky Ltd. 14%
	Sansui-Benecke LTDA 50%
	Bamberger-Kaliko GmbH 100%
	Beneform GmbH 100%
	Benoac Fertigteile 80.4%

Products:

Calendered PVC, ASA and TPO foil for car interior trim and seat upholstery (around 270,000 m/day) which are produced in the plants of Hannover and Eislingen. Car interior roof covers, thermoformed (around 9,000/day) are produced in the Uberherm and Peine plants. Slush moulded PVC skins for dashboards (around 1300/day) are produced by Benoac in the Peine facility.

These products are used in the manufacturing of instrument panels, glove box covers, door and pillar trim, seat upholstery, sunvisors, headrests, luggage compartment linings, middle consoles, door watershields, roofing, curtains, pillartrim. The technologies available are: calendering, extrusion, lamination, coating, printing, laquering, thermoforming, compression moulding, rotational moulding, Tramico process.

Plant locations:

Benecke-Kaliko AG, D-73054 Eislingen
Benoac Fertigteile GmbH, D-31224 Peine
Bamberger Kaliko GmbH, D-96052 Bamberg

Benecke-Kaliko's Beneform division has sold two plants for automotive headliners, one in Peine, Lower Saxony and one in Überherm, Saarland to Johnson Controls Headliner (formerly Happich). The two plants have sales of US$60 million/year.

Customers are the Tier one, (system) and module suppliers and the car producers. The products are used by nearly all car manufacturers in Europe: VW/Audi/Seat/Skoda group, Fiat/Alfa/Lancia, BMW/Rover, Mercedes-Benz, Ford/Jaguar, PSA, Renault, Saab, Volvo, Mazda, Mitsubishi, Nissan, Suzuki, Toyota, Opel, Porsche.

Breed Technologies Inc

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Tel:	+1 941 668 6000
Fax:	+1 941 668 6007
Internet:	http://www.breedtech.com
Chairman & CEO:	Johnnie C Breed
President & Chief Operating Officer:	Charles J Speranzella, Jr.
Executive Vice-President (Operations Worldwide):	Robert M Rapone
Executive Vice-President & Chief Financial Officer:	J F Gallagher
Treasurer:	Robert J Salterelli
Secretary:	Lizanne Guptill
Employees:	16,300

Breed Technologies Inc. was founded in 1987 by Allen K Breed as a manufacturer of crash sensor systems with one facility and 65 employees which now has grown to a tier one sub-system supplier with more than 50 locations worldwide in 11 countries. The company claims that its customers include the top OEMs and their products are fitted as standard equpment to over 400 vehicle models. Breed's customers include General Motors, Fiat, Ford, Chrysler and Suzuki. By acquiring established businesses in the areas of seatbelts, steering wheels and electronics, and forming a strategic partnership with Siemens AG, the company is becoming a global leader in the design, development and manufacture of full automotive occupant protection systems and components. Acquisitions during the last two financial years include:

H S Technik and Design, which develops advanced technology for seatbelt systems for US$4.1 million.

SRS, the largest independent supplier of seatbelt systems and the third largest independent supplier of airbag systems in the USA for $710 million.

Custom Trim, located in Canada and Mexico who produce leather wrapped steering wheels and other leather wrapped automotive products for approximately US$70 million.

The company is structured into four divisions - airbags and inflators, seatbelts, steering wheels and electronics, and its subsidiaries include Vaisala Technologies (VTI Hamlin), the Finnish micro-machined silicon sensor producer, Momo, the Italian steering wheel producer, Italtest the Italian Electronic company which produces printed circuit boards for the automotive industry, Gallino, the Italian manufacturer of steering wheels and automotive interior parts, Force Imaging Technologies, the US designer of ultra-thin printed sensors, and the steering wheel division of United Technologies Automotive which is now renamed United Steering Systems.

Pecentage of net sales per product group

	1996	1997	1998
Electronics and sensors	70.1%	33.6%	14.9%
Airbags and inflators	22.9	9.4	24.1
Steering wheels	4.5	33.4	25.1
Seatbelt systems	–	–	23.1
Interiors and plastics	–	22.9	12.4
Other	2.5	0.7	0.4

Breed has announced the first airbag contract with a Chinese car maker. They are to supply First Auto Works with SRS-40 airbag systems which are also supplied to Ssangyong of Korea and to Proton of Malaysia. At the same time, Breed announced a new supply agreement with Sungwoo Corporation of Korea to deliver driver and passenger side non-azide inflators for a utility vehicle developed by Hyundai.

The company claim to be the world's largest independent manufacturer of steering wheels, supplying steering wheels to OEMs in North America, Europe and Asia. The company's products range from wheels trimmed with high quality wood and leather for luxury and high performance cars to moulded plastic steering wheels for lower-priced, high volume vehicles.

The steering systems divisions manufacturing facility in Italy utilises integral skin polyurethane foam, painted urethane rigid foam, polypropylene and PVC to manufacture a full range of steering wheels for European and other global customers as well as leather wrapped and wooden steering wheels for the high end of the market.

Breed's principal customers are Fiat, GM, DaimlerChrysler and Ford and in the fiscal year 1998 these companies purchases accounted for the following percentages of Breed's net sales:-

Fiat	20%
GM	19%
Chrysler	19%
Ford	16%

The company competes with independent suppliers and partially or fully integrated manufacturers of occupant protection systems and other automotive components. Their principal competitors in the integrated occupant protection system market are TRW, Autoliv, Delphi and Takata; in the market for electronics and sensors are TRW, Bosch, Autoliv, Temic, Delphi, Nippondenso, and Ford Visteon; in the market for inflators and airbags are Autoliv, Takata, TRW, OEA, and Tally all of which operate on a worldwide basis and Temic which offers inflator products in Europe. Competitors for the sale of steering wheels are TRW, Autoliv Centoco, Toyoda Gosei and Neton in North America and in Europe with Autoliv, Dalphi Metal, Delphi and Petri. In the seatbelt sector the competitors are Autolive, Takata and TRW.

The company operates primarily in North America and Europe. Net sales in these two areas during the last three financial years were as follows:

	North America	Europe
1996	75%	25%
1997	48%	52%
1998	60%	37%

Breed Technologies currently owns 355 United States patents and 505 foreign patents. They have also trademarked eight names in the USA and 176 in various other countries.

Financial performance (in US$ millions)

	1995	1996	1997	1998
Net sales	400.9	431.7	794.9	1385.3
Operating income	104.8	92.8	50.6	(324.2)
Net earnings	72.3	63.0	14.8	(368.6)

More recently, Breed has experienced severe financial difficulties and in September 1999 filed for Chapter 11 protection from its creditors. The company's position has been worsened by the departure of engineering and technical staff who have been concerned over the company's future prospects.

Breed's financial problems are believed to stem from an ambitious acquisition programme involving 11 operations since the mid-1990s. In particular, the company appears to have over-reached itself as a result of purchasing AlliedSignal's Safety Restraint Systems division for US$710 million in 1997.

On another negative note, Breed's joint venture with Siemens for the production of smart airbags and safety restraint systems (called BSRS Restraint Systems) is to be dissolved after two years due to Breed's inability to meet the financial obligations involved with the venture.

The company's prinicipal facilities (in excess of 25,000 sq. ft.) are located as follows:

AMERICA

Corporate Headquarters, Manufacturing and engineering:	Lakeland FL
Distribution and administration:	Brownsville, TX
Technical centre, engineering, sales, Customer support and R&D:	Farmington Hills, MI
Manufacturing:	Grabill, IN Maryville, TN Greenville, AL El Paso, TX
Manufacturing, sales and engineering:	Lake Mills, WI
Manufacturing Warehouse:	Knoxville, TN
Administration, R&D:	Sterling Heights, MI

CANADA

Manufacturing:	Waterloo, ON

ENGLAND

Manufacturing:	Birmingham Diss Carlisle

ITALY

Manufacturing:	Torino (3 sites) Tregnano Milan (2 sites) Frosinone
Administration, sales and distribution:	Milan

HUNGARY

Manufacturing:	Aszar

MEXICO

Manufacturing:	Valle Hermosa Matamoros (2 sites) Aqua Pricta (2 sites) Juarez Tamaulipas

Dynamit Nobel AG

Address:	Kaiserstrasse 1, D-53840 Troisdorf, Germany
Tel:	+49 2241 89-0
Fax:	+49 2241 891540
Internet:	http://www.dynamitnobel.com
Chairman:	Dr Fritz Lehnen
Chairman, Supervisory Board:	Dr Karl Josef Neunkirchen, Executive Chairman Metallgesellschaft AG.

Sales by division:

	DM million
Explosives	795
Plastics	1322
Advanced ceramics	559
Speciality chemicals	1189
Pigment chemicals	630
Total sales 1997/1998:	4,482 million

Total profit of group:	DM268 million
Employees (1998):	16,028

Business Areas:

Dynamit Nobel GmbH Explosivestoff-und Systemtechnik, Troisdorf. With eight subsidiaries. Products: explosives and industrial products, ammunition for sports and industrial use, defence technology, special chemistry.

Chemetal GmbH, Frankfurt am Main with 29 companies.
Products: polymer compounds and additives, fine chemicals, surface treatment electroplating, foundry technology.

CeramTec AG: innovative ceramic engineering, Plochingen, Germany, with 10 subsidiaries. Products: Structural ceramics, functional ceramics.

Sachtleben GmbH, Duisburg, Germany, pigment business.
Products: pigments and extenders, functional anastases, water chemicals.

Dynamit Nobel Kunststoff GmbH, Wissenburg, Germany

Address:	Jahnstrasse 18, D-91781 Weissenburg.
Tel:	+49 9141 991-0
Fax:	+49 9141 991-275
Management:	Dr Dieter Putz, Chairman, Klaus Uwe Broderson, Bernd Graf

Financial Performance:

	1994/95	1995/96	1996/97	1997/98
Sales in million DM	847	918	1030	1322
Net profit in million DM	N/A	28	21	54

Products; system supplier of: Bumper systems, fenders, frontends, radiator grilles, air inlet grilles, exterior parts, body panels (Smart car), cockpit modules and dashboards. Subsidiary Menzolit-Fibron is a supplier of: SMC/BMC compounds inclusive of new generation "Low pressure SMC", GMT and LFT and moulded parts for car and commercial vehicle production, electrical/electronics sector and sanitary and construction industry.

Subsidiaries:

Dynamit Nobel Iberica SA, San Andreu de la Barca, Barcelona, Spain
Dynamit Nobel France, Hambach, France
Phoenix Kunststoff GmbH, Hamburg, Germany
Phoenix-ICAS Schuhfabrieken GmbH, Sterbfritz
Menzolit-Fibron GmbH, Bretten Germany, 58.5% owned
Menzolit SA, Vineuil, France
Menzolit-Fibron AS, Dolayoba, Turkey
Menzolit-Fibron SRO, Trnava, Slovakia

Phoenix Kunststoff GmbH with sales of DM 160 million and with two production plants at Sterbfritz and Reinsdorf was acquired in July 1997 to strengthen the position as a leader in Europe of painted bumper systems and external plastic panels.

Menzolit-Fibron GmbH

Address: Menzolit-Fibron GmbH, H Beuttenmuller Strasse 11-13, D-75015 Bretten, Germany
Tel: +49 7252 509-0
Fax: +49 7252 302-0
E-Mail: marketing@menzolit-fibron.de
Internet: http://www.menzolit-fibron.de
Chairman: Klaus Uwe Broderson
Joint ventures and collaborations

Menzolit-Fibron has a co-operation with US Cambridge Industries Inc, Madison Heights, MI, market leader in the USA in SMC mouldings to the car industry. Menzolit CV is a joint venture between M-F and French Cray Valley (Total group) combining the activities in BMC e.g. for car headlamp reflectors. M-F has a further co-operation with Rodgers Engineering, Addison, IL., a leader in BMC production and processing in the USA. Synergy potential is expected in headlamp reflectors. A further joint venture with Inapal Plasticos Portugal (70-30%) produces SMC structural front ends (headlamps, radiator, fan and crash elements for the VW Sharan, Ford Galaxy and Seat Alhambra).

Menzolit-Fibron reported a breakthrough as it developed and successfully supplied the structural front end of the VW Passat in LFT - PP (long fibre thermoplastics) replacing GMT - PP of the previous model. Ecological benefits like recyclability of the production scraps (1 kg per part) are claimed.

The company also supplies the SMC hardtop, in three parts, of the new Rover Freelander. The hardtop is covered with a black, slightly textured paint. M-F has now developed "low pressure" SMC materials which need only a processing pressure of max. 5 bar at temperatures of 70°C or lower against 50-100 bar and 140°C for standard SMC. Further, M-F supplies nearly all SMC parts for the Mercedes Actros truck produced at the Worth site.

Main automotive customers of Menzolit-Fibron are: VW/Audi/Seat, DaimlerChrysler, Ford, Opel, BMW, Nissan. Bumper systems are produced for: VW Golf, Audi A6, Ford Ka, Ford Puma. For the Smart car an entire interchangeable plastic outer panelling is supplied from coloured PBT/PC compounds in loco produced by Dynamit Nobel SAS, Hambach, France.

Further plant locations of Dynamit Nobel Kunststoff GmbH.

Germany:

Pappenheim
Langenaltheimer Strasse 5
D-91788 Pappenheim
Tel: +49 9141 88-0
Fax: +49 9141 88-161

Essen
Westuferstrasse 7
D-45356 Essen
Tel: +49 201 3617-0
Fax: +49 201 3617-222

Sterbfritz
Icastrasse 7-9
D-36391 Sinntal-Sterbfritz
Tel: +49 6664 88-0
Fax: +49 6664 88 124

Reinsdorf
An der Kreisstrasse 22
D-38372 Buddenstedt
Tel: +49 5352 53-0
Fax: +49 5352 53 209

Spain:

Dynamit Nobel Iberica SA

Barcelona
Carretera Nacional 11, KM 593
Apartado de Correos 100
Sant Andreu de la Barca
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Tel: +34 93 631 1900
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Tudela
Carretera de Corella, KM 250
E-31500 Tudela
Tel: +34 948 412444
Fax: +34 948 412310

Valencia
Parque Industrial Rey D. Juan Carlos 1
Parcella 2.9 a 2.11
E-46440 Almussafes (Valencia)
Tel: +34 96 179 7029
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France:

Dynamit Nobel France SAS
Hambach
Europole de Sarreguemines
F-57931 Hambach Cedex
Tel: +33 387 28 2370
Fax: +33 387 28 2371

Faurecia

Address:	276 Rue Louis Blériot, F-92641 Boulogne Cedex, France
Tel:	+33 1 41 22 70 00
Fax:	+33 1 41 22 70 07
Internet:	http://www.faurecia.com
Chairman & CEO:	Daniel Dewavrin
Employees:	30,000 in 25 countries

Activities and products: Faurecia is a merger (effective January 1st, 1998) between French automotive suppliers Bertrand Faure and Ecia. Ecia was 68% owned by the PSA (Peugeot-Citroen) Group. PSA still holds 55.1% of the shares in Faurecia and 70.6% of the voting rights.

It claims to be the fifth largest automotive system and module supplier in Europe and the second largest in car interior parts. With group sales of FF 25 billion (US $4.1 billion), 68% of sales come from automotive seating, 10% from interior modules, 14% from exhaust systems and 8% from front-end modules. The company claims a 30% share of the European automotive seat market. Annual sales of cockpits amount to FF 1.1 billion (US$ 180 million).

Strategy/Objectives Faurecia expects a growth of 50% in seating over the next five years, taking business away for the 30% production in Europe which is still captive. The company wants to grow in B and C cockpits which it believes will increase by up to ten times in the next ten years.

Door panels is another focus point through the joint venture with Treves.

The company is also heavily involved in electronically assisted steering, which is now being widely introduced into lower market models.

Plant and other locations: Faurecia is present in 100 locations in 25 countries. These include: Argentina, Brazil, Canada, China, Czech Republic, France, Germany, India, Italy, Japan, Poland, Portugal, Slovenia, South Africa, Spain, Sweden, Turkey, UK, Uruguay, USA.

Participations, Majority owned are: Cesa, Eesa, ECTRA, EAK, Ecia GmbH, Hills Precision Components Ltd. UK, Silenciadores P.C.G.S.A., Madrid, Peugeot Motorcycles, all consolidated.

Venture/Co-operations: During the second half of 1998 Faurecia established a 50/50 joint venture with French interior trim supplier Treves, called Trecia, in door panels. Trecia expects to achieve annual sales of US$ 41.7 million (FF 254 million). It supplies about half of PSA's door panels and around 6% of the European market. Treves already has a 50/50 joint venture with Plastic Omnium, called Tredel, in door panels for the Peugeot 406 and 206.
Ecia had strengthened its position in seating in 1996 by taking over ECSA (Etudes et Construction de Sieges pour l'automobile) from Johnson Controls.

Financial performance Euro millions:

Period	1st half 1999	1st half 1998
Sales	1,449.8	1,376.8
Operating income	80.2	93.9
Net income	30.8	30.8
R&D	152.7	113.2

Some 42.2% of sales was generated in France, 30% in Germany, 10% in Spain, 5.6% in the UK and 3.9% in North America.
New business generated during the first half of 1998: for the new Toyota "Yaris" to be produced in the new plant in Valenciennes, France, Faurecia will supply the seats, exhaust system and instrument panel components. Also the seats and exhaust systems for the GM Delta and Epsilon programmes.

Customer base:

The first half 1999 sales came from:
34.8% PSA group
23.9% VW group
18.2% Renault
5.8% BMW/Rover
4.4% Ford/Jaguar
Minor percentages with Japanese customers GM/Opel, DaimlerChrysler, Fiat.

Johnson Controls

Address:	5757 N Green Bay Avenue, PO Box 591, Milwaukee, WI 53201, USA
Tel:	+1 414 228 1200
Fax:	+1 414 228 2070
Internet:	http://www.johnsoncontrols.com

Chairman & CEO:	James H Keyes
Employees:	around 95,000 worldwide
Facilities:	275 worldwide (Automotive Systems Group)

Johnson Controls, based in Milwaukee, Wisconsin, is one of the world's leading suppliers of automotive seating and interior systems. Other automotive products include batteries.

There have been a number of important acquisitions in recent years as Johnson Controls, in similar fashion to its principal competitors, has pursued a strategy of taking over smaller companies to add to its geographic reach and product offerings. As an example, the Michigan-based Prince company was purchased in 1997 for US$1.3 billion thereby adding considerably to Johnson Controls' ability to offer complete interior systems. This move and others mean that the company has changed over the past decade from being principally a supplier of seats to a supplier of complete interior systems to include overhead systems, door systems, floor consoles, on-board electronics and instrument panels.

During the year to end September 1999 Johnson Controls achieved a sales turnover of US$16,139 million, an increase of 28% compared with the previous year. Net income rose by a similar percentage to US$387 million.

Automotive systems accounted for US$12,075 million, equivalent to 75% of total sales and an increase of 30% over the previous year. The company reports that this strong advance reflects new contracts for seating and interior systems, along with existing contracts for models which enjoyed strong demand during the year. It is estimated that Johnson Controls will supply interior products for more than 22 million vehicles in 1999.

Around 33% of the automotive group's sales growth can be attributed to the acquisition (in July 1998) of Becker Group, a major European supplier of instrument panels and door systems.

Major automotive customers include DaimlerChrysler, Fiat, Ford, General Motors, Honda, Mazda, Mitsubishi, Nissan, Renault, Toyota and Volkswagen.

In July 1999 Johnson Controls finalised the acquisition of two manufacturing facilities from Benecke-Kaliko in Germany. The two operations produce vehicle headliners and are based at Peine and Uberherrn. They supply the Audi, Mercedes-Benz, Opel and Volkswagen marques. This deal is significant because it involves roof-reinforcing technologies which will facilitate Johnson Controls integrating products such as head protection airbags into headliner systems and interior pillars.

Lear Corporation

Address: 21557 Telegraph Road, PO Box 508, Southfield, MI 48086-5008, USA
Tel: +1 248 447 1500
Fax: +1 248 447 1722
Internet: http://www.lear.com/
Chairman & CEO: Ken Way
Employees: 65,316

Lear Corporation, based in Southfield, Michigan, is one of the world's largest suppliers of vehicle seats and interior systems. Its origins go back to 1917 when it was founded in Detroit as American Metal Products. The company merged with Lear Siegler in 1996 and went through several name changes until it became Lear Corporation in 1996. It was not until 1994 that it became a public company. Since then it has experienced substantial growth, both organically and through a major acquisition programme.

The corporation produces seats, headliners, instrument panels, consoles, flooring and door modules and is one of the few component groups able to supply complete vehicle interior systems.

During the year to the end of December 1998 Lear Corporation achieved sales of US$9.1 billion, an increase of 23% over the previous year. This strong showing stems from the impact of acquisitions together with the launch of interior programmes for around 30 new light vehicles worldwide.

Among significant purchases are Delphi's seating operations in September 1998, ITT Automotive Seat Subsystems in August 1997, Dunlop Cox in June 1997, Keiper in May 1997, Borealis in December 1996 and Masland in July 1996. In February 1999 two flooring and acoustics operations were taken over in Italy and Poland, and this was followed in May 1999 by the purchase of United Technologies Automotive (UTA) for US$2.3 billion.

The two businesses of Lear Corporation and UTA are complementary which means that Lear is now able to make a convincing case to customers concerning the supply of complete vehicle interiors. UTA brings competences in instrument panels, headliners and electrical and electronic systems.

More recently, Lear Corporation's name has been linked with Visteon. Together the two companies have an annual turnover of around US$30 billion which would place the combined group on a par with Delphi, the world's largest automotive components group.

Lear has formed a new division called Lear Electronics and Electrical Division, based in Dearborn, Michigan. The new operation will concentrate on developing and producing electronic products and integrating then into vehicle interior systems.

Lear has extended its presence in Europe following the winning of a contract to supply PSA Peugeot-Citroën with seats for the next generation Peugeot 106 and Citroën Saxo models which are scheduled for introduction within the next three to four years. Annual production of the two models is expected to reach 500,000 units.

Magneti Marelli

Headquarters: Viale Aldo Borletti 61/63, 1-20011 Corbetia, Milan, Italy
Tel: +39 02 972001
Fax: +39 02 97200755
Internet: http://www.marelli.it/Magneti

Magneti Marelli is a Tier One supplier of parts and systems to the global vehicle industry, although it has close links with Fiat. One of the main objectives in recent years has been to widen its customer base and correspondingly reduce its dependence on Fiat which holds a major equity stake in Magneti Marelli.

During the second half of 1999 Magneti Marelli has effected a number of far reaching changes in its strategic direction with the twin aim of boosting its sales from the US$ 4.2 billion in 1999 to US$5.5 billion in 2002, and raising its margins significantly from the 5% level achieved in 1998 to more like 18%.

The new strategy involves bolstering its position in three business sectors: cockpit modules, suspension modules and vehicle servicing. In addition, the company is divesting certain non-core operations (such as rotating machines) and has pooled its lighting interests in a new venture with Bosch.

It is expected that chassis systems will become Magneti Marelli's largest systems group with annual sales in excess of US$1.4 billion. In 1998 interior and body systems accounted for sales of US$800 million.

Mitras Kunstoffe GmbH

Mitras Automotive Division

Address: Moosbürger Strasse 20, D-92637 Weiden, Germany
Tel: +49 961 89660
Fax: +49 961 89662
Joint Presidents: Professor Dr Rudi Noppen (Mitras Automotive)
Rudolf Ignaszak (Mitras Composites Systems)
Sales Manager: Andreas Scholl
Employees: 1,700 (total group)
Activity: The company is a Tier 1 and Tier 2 supplier of systems and modules to the automotive industry, including producers of cars, commercial goods vehicles and passenger carrying commercial vehicles. SMC/BMC parts are produced by compression and injection moulding operations.
Products: Products manufactured include hard tops, sunroof frames, bumper beams, seatback shells, front-end mounting supports, noise shields, oil sumps and complete driver cab panelling.
Plants and operations: Mitras Composites is based at the same location. There are 12 production sites in Europe including Stratinor in France, Fiberpachs in Spain and Mitras Automotive in the UK. There is also a site in the Czech Republic. Among the quality standards to which the operations conform are ISO 9001, QS 9000 and VDA61.
Collaboration: There is a collaborative agreement with Budd Co of Troy, Michigan, USA on thermoset automotive parts.
Turnover: Total annual group turnover amounts to DM350 million, of which automotive represents DM190 million. Exports account for around 40% of total turnover.
Customers: Among the company's vehicle manufacturing customers are BMW Group (BMW, Rover), DaimlerChrysler (Mercedes-Benz), Fiat, Ford, GM, Isuzu, Paccar (DAF and Leyland), Porsche, PSA Peugeot Citroën, Renault, Volkswagen Group (Audi, Seat, Volkswagen) and Volvo. Component and systems producing customers include Faurecia, Keiper Recaro, Meritor and Webasto.

Contact points:

Mitras Composites System Division

Address: Moosbürger Strasse 20, D-92637 Weiden, Germany
Tel: +49 961 89 501
Fax: +49 961 89 280
Managing Director: Dr Klaus Ahlhorn

Stratinor

Address: 35, Rue Santos - Dumont, F-87000 Limoges, France
Tel: +33 55 303070
Fax: +33 55 313067
Sales/Customer Service: Guy Audran

Fiberpachs SA

Address:	Poligono Industrial "La Xarmada", E-08739 Pacs Del Penedes, Barcelona, Spain
Tel:	+34 3 890 3599
Fax:	+34 3 890 3754
General Manager:	Cesar Alvarez

Mitras Automotive UK

Address:	Winsford Industrial Estate, Winsford, CW7 3PZ, UK
Tel:	+44 1606 550339
Fax:	+44 1606 550639
Managing Director:	Keith Worral

Peguform GmbH

Address:	Schlossmattenstrasse 18, 79268 Boetzingen, Germany
Tel:	+49 7883 61-0
Fax:	+49 7663 61-166
E-Mail:	Contact@peguform.do
Executive Board:	Werner Deggim: Sales, Product Development, Strategy, Q-Management, International Operations, Dieter Bella: Finance, Controlling, Purchasing, Human Resources, Gerhard Ruf: Operations (Ger.) Logistics (Ger.) Process Development.
Employees:	8,500 (Germany 4,000)
Structure:	The Peguform Group consists of Peguform GmbH, whose headquarters is located in Germany, and the subsidiaries Peguform France SA (100%), Peguform Iberica SA (Spain) (100%), Peguform Bohemia a.s. (Czech Republic) (100%) and Peguform Hella Mexico SA de CV (70%/30% Hella KG). In March 1999, Peguform was purchased by Venture Holdings Trust from Klockner Werke.
Peguform Iberica subsidiaries:	Cefa SA (Spain) 50%, Peguform do Brasil Ltda (100%), Peguform Argentina SA (100%), although the last is dormant.
Peguform France subsidiaries:	Hengfen Automotive Equipments Co. Ltd. (China) (51%) which is not active.
Activities:	Peguform produces high-performance plastic systems for car exteriors and interiors. It is a full service functions, systems and parts developer, manufacturer and supplier to the automotive industry worldwide. Exterior Systems: bumpers, exterior trim, body panels, hatchback doors. Interior systems: dashboards, door panels, interior trim. Market leader: bumpers
Customers:	Audi, BMW, Citroën, DaimlerChrysler, Ford, Kia, Matra, Mitsubishi, NedCar, Nissan, Opel, Peugeot, Porsche, Renault, Saab, Seat, Skoda, Toyota, Volvo, VW.
Plants:	Peguform GmbH (Germany): Boetzingen, Goettingen, Neustadt, Oldenburg Peguform France: Burnhaupt, Noeux-les-Mines, Pouance, Vernon Peguform Iberica (Spain): Palencia, Polinya, Vigo, Zaragoza (joint venture) Peguform do Brasil (subsidiary of Peguform Iberica): Curitiba Peguform Bohemia: Liban, Liberec Peguform Hella Mexico: Puebla (joint venture)
R&D Centres:	Boetzingen Germany, Vernon France.
Sales:	(Billion DM) Financial Year 95/96:1.5: 96/97:1.7 97/98: 2.0 (Automotive 97%)

Peguform GmbH

Address:	Schlossmattenstrasse 18, D-79268 Botzingen, Germany
Tel:	+49 7663-610
Fax:	+49 7663 6115

Peguform France

Address:	Zone Ind. Le Virolet, F-27950 Saint Marcel Vernon, France
Tel:	+33 23271 2500

Peguform Iberica

Address: Citra B-142 Sentmenat 18-20, E-08213 Polinya, Barcelona, Spain
Tel: +34 93-745-2300

Peguform Bohemia

Address: Kubelikova 604, PO Box 101, CZ-46078 Liberec 6, Czech Republic
Tel: +42 048 523 1111

Rutgers Group

Head Office: Rutgers AG, Rellinghauser Strasse 3, D-45128 Essen, Germany
Telephone: +49 201 17702
Fax: +49 201 177 2050
Chairman: Professor Dr Gerhard Neipp
Deputy Chairman and Chairman of the General Works Council Teerbau GmbH: Heinz Fickholt
Deputy Chairman and Chairman of the Group Works Council Rutgers AG: Willi Lauth
Officer with Statutory Authority at Rutgers Automotive AG Essen: Johannes-Bernhard Fryder

Rutgers Automotive AG

Address: Rutgers Automotive AG, Westuferstrasse 7, D-45356 Essen, Germany
Tel: +49 201 3609 525
Fax: +49 201 3609 411
Employees: 2,563 (in 1997)

Rutgers Automotive AG supplies friction lining plastic components and systems and acoustic components to the automotive industry and has facilities in Italy, Belgium, Spain, Mexico, Brazil and China. Under the brand name of Pagid Rutgers Automotive supplies the principal car manufacturers including VW (Golf, Passat and Polo), Audi (A3 and A4), Opel (Astra), Saab (9-5) and Mercedes-Benz (E-class).

Rutgers manufactures heavy duty structural and functional components made of GMT and SMC at its German locations at Kongen and Peine as well as at the joint venture company FPK SA in Bilbao, Spain at a new manufacturing plant. Rutger Kunststofftechnik De Mexico SA de CV was built in N. Puebla, Mexico where in future all GMT components for VW De Mexico will be produced. Rutgers supplies an estimated 90% of VW front-ends. The German works in Kongen and Peine have firm contracts up to the year 2003.

Rutger Automotive financial performance DM (millions):

	1996	1997
Sales	598	641
Results before income tax	40.7	37.7

Plastic Omnium

Head office: Compagnie Plastic Omnium, 1 rue du Parc, F - 92593 Levallois Cedex, France

Tel: +33 1 40876400

Fax: +33 1 47393217

Internet: http://www.plasticomnium.com

Chairman & CEO: Jean Burelle

Employees: over 9,000 on four continents

Plastic Omnium is owned 52% by the Burelle family; the rest is publicly traded.

Activities and products: Plastic Omnium operates five divisions

- Recycling/communal systems: containers for household refuge (90 to 2,400 litre); plastics recycling by Zarn in USA and Scotra in France with around 10,000 tons a year handled.
- 3 P Performance Plastics Products: conversion of high performance polymers for, among others, the automotive industry. Includes fluropolymers PTFE, PFA, PVDF, FEP, PCTFE and high performance plastics PAA, PEI, PES, PSU, PEEK, LCP. Nine production plants and 22 offices in Europe, USA and Asia.
- Industry: injection moulded plastics and composite parts for the automotive, household and office markets. With the acquisition of Reydel Consoles, door panels and instrument panels were added to the product line. In 1998 daily production amounted to 16,000 bumpers, 30,000 external parts, 45,000 under the bonnet parts and 120,000 parts for car interiors.
- Blow moulding: one of the largest producers of blow moulded fuel tanks mainly in HDPE internally fluorinated. In 1997, over 2 500 000 fuel tanks were produced. Also filling pipes, air ducts, lacquered spoilers and blow moulded containers for households and hospitals.
- Medical: supplies the medical and pharmaceutical industry.

Acquisitions/ co-operations:

Plastic Omnium Industrial bought the majority of Reydel in July 1995 to strengthen the interior parts business with slush moulding and foaming. Reydels customers included Nissan and Fiat.
Plastic Omnium and the US Becker Group formed a joint venture in North America to produce external automotive parts in the USA, Canada and possibly Mexico. The joint venture is called P&B Automotive LLC and Plastic Omnium sold its Anderson, SC plant to this joint venture, excluding the fuel tank business.

With Solvay a joint venture factory for the production of plastic fuel tanks is being built in Brazil. Solvay supplies Renault, Chrysler and GM in South America.

At the end 1997 a 50/50 joint venture with Valeo was established to produce integrated cockpits on a global scale. With this joint venture a 20% market share in Europe for dashboards and consoles is claimed.

Strategy/objectives: In Europe, some 80% of fuel tanks are made in plastic and there are three main suppliers: Solvay, Plastic Omnium and Walbro. At present in the USA plastic fuel tanks account for approximately 20% of the market, and hence

Plastic Omnium sees strong growth prospects. As a result, the company aims to increase its fuel tank share in the USA from 8%, as GM, Ford and DaimlerChrysler are changing from metal to plastic.

An important part of Plastic Omnium's strategy is to grow in North America by securing plastic fuel tank contracts with US producers and transplants. The main site is in Anderson, SC.

Sale performance in 1998 in US$ millions

Total sales 1998 US$ 9,080 million

Segment	Exterior parts	Interior parts	Fuel systems	Urban medical
Sales	2,841	2,558	1,557	839

Region	France	Rest of Europe	North America	Other regions
Sales (US$ millions)	3,893	3,713	1,235	239

Customers:

- Renault plants in Europe, Asia and Africa
- Various Opel models
- Fiat Group
- Volkswagen in Mexico with front and rear fascias and fenders (in PPO/PS and in-line painted) for the New Beetle
- The Anderson SC plant supplies BMW Z3 roadstar plant in Spartanburg, SC, with fuel systems, bumper fascias
- Fuel systems for GM minivan and the Corvette

New ownership:

In 1999 the Interior Automotive Components business of Plastic Omnium was sold to Visteon for US$493 million.

SAI Automotive AG

Head Office: SAI Automotive AG, Friesstrasse 26, D-60388 Frankfurt am Main, Germany
Tel: +49 69 4108-0
Fax: +49 69 4108 278
Internet: http://www.sai-automotive-ag.de
Main plant site and central functions: Sommer Allibert Industrie Kunststofftechnik GmbH, Daimlerstrasse 1, Building 14, D-76744 Worth, Germany
Tel: +49 7271 130-0
Fax: +49 7271 130 711
Chairman: Marc Assa
Employees (end 1998): 14,253

SAI AG is a holding company quoted on the Frankfurt stock exchange with a share capital of DM 127.6 million of which 63% is held by the French Sommer Allibert Group.

Plant locations: Apart from Frankfurt and Worth, the company has production sites in Germany, France, UK, Spain, Portugal, Luxembourg, Czech Republic, USA, Brazil, Argentina and Mexico.

The main business is as a global supplier of car interior systems. These include complete cockpits in a 50/50 joint venture with Siemens, instrument panel modules, and complete door modules made to SAI's patented design. With the complete takeover of Lignotock GmbH there is increased interest in woodfibres for instrument and door panels. The company is preparing for an entry in the car acoustics sector with applications under the bonnet, interior carpeting, luggage compartment linings, interior roofing.

Joint ventures and acquisitions: In 1996, the Mercedes-Benz plastic parts operation at Worth, Germany was acquired. Existing collaboration with Lignotock GmbH was extended in 1997 with the acquisition of the remaining 90% of the shares.

At the end of 1997, two French automotive suppliers were taken over from the Sommer Allibert Group: Allibert Industrie SNC and Sommer Industrie SNC. A 50/50 joint venture with Siemens AG under the name of SAS Autosystemtechnik GmbH & Co. KG has been formed to produce and sell complete car cockpits inclusive of all wiring.

(DM million)	1995	1996	1997	1998
Sales in Germany	540	759	864	1,205
Outside Germany	693	942	1624	2,562
Total sales	1,233	1,701	2,488	3,767
Net profit	36.7	40.8	41.0	96.5
Investments	104	166	384	249

2002 sales objective: DEM 5 billion

Typically 28.2% of the company's sales are from door panels, 19.3% from instrument panels, 29.2% from systems and equipment and 9.6% from acoustic parts.

The sharp increase in sales in 1997 and 1998 is due to the complete takeover of Lignotock GmbH early in 1997 and the consolidation of the two acquired French companies at the end of 1997. Another factor was the purchase of a 50% stake in Trimtec Autopecas, Brazil. Organic growth resulted in additional sales of DM400 million specifically in USA, UK, Belgium and Czech Republic.

Customers:

The sales by car producer for 1997 was as follows:

Mercedes-Benz	16%	PSA	7.0%
Ford	16.4	GM	5.9
Volvo	11.9	VW	20.8
BMW/Rover	11.1	Others	11.1

SAI currently has cockpit contracts for Brazil-produced Renault Scenic, to which will be added the Clio and Kangooby 1999 and 2000. Other contracts include VW Polo, Lupo, Seat Arosa, Skoda Octavia produced in Germany and Argentina, and also the Volvo S70/V70 made in Belgium. The Audi A3 and A4 produced in Brazil started to be supplied at the end of 1998 and mid-1999 respectively. At present six cockpit system plants are operational worldwide and another six are in preparation. The geographical focus will be Central and South America.

New projects involving door modules include the Ford Focus for the 2001, model year, Ford C212 multi-activity vehicle for 2002 and the next generation Ford Fiesta.

The tendency with several car manufacturers is towards woodfibre filled polypropylene. SAI has developed "Lignoprop" for such applications.

TRW

Address: World Headquarters: 1900 Richmond Road, Cleveland, Ohio 44124, USA

Tel: +1 216 291 7000
Fax: +1 216 291 7629
Internet: http://www.trw.com

Chairman & CEO: Joseph T Gorman

Employees: 78,000

TRW is a global manufacturing and service company with an emphasis on advanced technology. Customer groups include automotive, space, defence and information systems.

The largest part of the group is automotive which has experienced substantial expansion as well as a restructuring during 1999. One of the most important developments has been the takeover of LucasVarity which was completed in May 1999. Since July TRW has closed two manufacturing facilities, reduced excess manufacturing capacity and divested a non-core business. Also, management has been streamlined through the elimination of a layer and the business has been reorganised into eight global product lines.

Net sales in 1998 amounted to US$11.9 billion, an increase of 10% over 1997. However, turnover in 1999 will be boosted noticeably by the incorporation of LucasVarity and TRW is well advanced in its target of achieving annual sales of US$20 billion by the early part of the next decade. During 1998 automotive sales increased by 2% to US$7.2 billion.

TRW produces a large number of mechanical products including engine parts and steering systems but its involvement in plastics stems from its leading position in the global safety systems market.

Visteon

Address: 5500 Auto Club Drive, Dearborn, MI 48126, USA
Tel: +1 313 396 5145 (info number for outside USA)
Tel: 1 888 284 7836 (info number for inside US and Canada)
Internet: http://www.risteon.com
President: Craig Muhlhauser
Employees (1998): 77,000 in 21 countries
Activities and products: Visteon Automotive Systems was launched in September 1997 at the Frankfurt Motor Show. The company is, with 1997 sales of around US$17 billion, the second largest global system supplier to the automotive industry. It is a wholly owned subsidiary of Ford and may be floated as an independent company on the stock exchange in the near future. The company operates through seven system divisions:

- Chassis systems - from corner modules to full frames; steering and drive systems
- Climate control systems
- Electronic systems with ICES voice-activated control modules and VIVID driver information systems as new developments; also Adaptive Airbag Systems and Remote Keyless Entry
- Exterior systems - Integrated Front End Systems with the Rear End System in development
- Glass systems - integrated float glass production; back-lights and side-lights; deep centre-sag windshields
- Interior systems - instrument panels, cockpits door panels
- Powertrain control systems - integrated systems, modules and components for enhancing powertrain performance, fuel economy and emission control.

Strategic objectives:

- To reduce its dependence on Ford to the point where "outside" customers account for 20% of sales by 2002, against 12% in 1999. This is to be achieved by creating new, and expanding existing, marketing and sales structures throughout the world. Much of the sales increase will come from Europe.
- Increase sales by a minimum of 7% per year, and achieve operating profits of 5% of sales, and a 10% return on assets.

Acquisitions:

- At the end of 1998 Visteon bought Zekel Innovation - a US developer of in-car navigation systems.
- The company formed a joint venture with Pi Technology, a UK software and technology specialist
- Two plants were acquired in Poland in the second quarter of 1998.

Quality: All 49 manufacturing sites are compliant with industry standard QS9000. Some 24 plants around the world have completed certification for ISO 14001, the standard for environmental management. All facilities were scheduled to comply by the end of 1998..

New systems/products: Visteon has developed the Information, Communication, Entertainment, Safety and Security (ICES) system, which integrates audio, climate control, emergency services, mobile phone and e-mail as well as voice control and on-board navigational technology.

The super integrated cockpit with a magnesium support structure has 25-30% less weight, 10-20% cost reduction and 30-50% fewer parts. Some 35 patents and 250 disclosures form the basis of this product.
In plastic interior parts the group in Europe uses natural fibre reinforces PP instead of talcum or glass fibre filled.
Visteon's super integrated modular rear package tray incorporates interior trim, audio and electrical and electronical capabilities. This system is designed for long-term reliability and reduced NVH (Noise, Vibration, Harshness) levels.

Year to Year comparison in US$ millions:

Year	1998	1997	1996
Sales	17,800	17,200*	16,200
Net profit	703	518	339
Net profit margin %	3.9%	3.0	2.1

*81% of 1997 revenue was obtained in North America, 15% in Europe and 4% in South America and Asia. Cost reductions exceeding $400 million were put through in 1997.

The Super-integrated cockpit was launched at the Paris Motor Show in 1998.

Visteon has taken over the Interior Automotive Components business of Plastic Omnium for US$493 million. Visteon claims that the acquisition gives it market leadership in Europe for interior systems with an annual turnover of more than US$3 billion. Visteon states that its intention is to offer integrated cockpit systems, including electronic and climate control systems. The move also brings a sizeable amount of business with other vehicle manufacturers including Fiat, Honda, Nissan and SEAT as well as the French producers. As a result, Visteon's non-Ford European business now amounts to an estimated 20%.

In early October Visteon agreed to purchase a majority interest in Duck Yang Industry, Korea's (and Asia's) largest producer of instrument panels with an annual output of around 1.4 million units. Based in Ulsan, the company moulds instrument panels and other interior plastic parts for Hyundai. The move is regarded as significant insofar as this is Visteon's first interior parts operation in Korea and strengthens the company's position in the global instrument panel market. Duck Yang also produces vibration pads, armrests, glove box doors and consoles.

In mid-October 1999 Visteon announced a restructuring which is widely seen as a step towards full independence from its parent, Ford. Business units have been combined and key management staff reorganised with the aim of making the company a leader in systems integration. With regard to its plastics interests, Visteon has integrated all functions into a single operation called Interior Systems. This includes the former Exterior Trim division as well as the Bumpers and Lighting business units. The new division is headed by Steve Delaney.

At the same time, Visteon is implementing a cost cutting programme with the target of reducing annual expenditure by US$400 million.A large part of this is expected to be achieved through demands for lower prices of bought-in parts.

Plant and Sales office locations:

The company has 81 plants in 18 countries, including 49 wholly-owned facilities and 32 joint ventures and 36 sales, engineering and technical centres.

Regional sales offices are in:

- Yokohama, Nagoya and Hiroshima, Japan
- Coventry, UK
- Cologne, Germany
- Sao Paulo, Brazil
- Mexico City, Mexico
- Paris, France
- Wolfsburg, Germany
- Troy, MI and Dearborn, MI, USA

These offices are divided over four marketing regions:

- North America
- South America
- Europe + Middle East & Africa
- Asia Pacific

Asia Pacific: Headquarters:

Yokohama, Japan.

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12 Directory of Major Car Manufacturers

This directory provides contact details including address, telephone number, fax number and (where available) website for the 35 marques identified in Chapter 10. Where the marque is owned partly or wholly by another group, the identity of the parent or stakeholder is indicated in brackets.

12.1 Alfa Romeo (Fiat Group)

Address: 20020 Arese, Milan, Italy
Tel: +39 2 93391
Fax: +39 1 2 931 5564
Internet: http://www.alfaromeo.com

12.2 Audi (member of Volkswagen Group)

Address: 85045 Ingolstadt, Germany
Tel: +49 841 890
Fax: +49 841 89 2817
Internet: http://www.audi.com

12.3 BMW

Address: 80788 Munich, Germany
Tel: +49 89 38951
Fax: +49 89 3895 5858
Internet: http://www.bmw.com

Principal manufacturing subsidiary

Address: BMW Manufacturing Corp, Spartanburg, SC 29304-4100, USA
Tel: +1 864 989 6000
Fax: +1 864 989 6051

12.4 Chrysler (DaimlerChrysler)

Address: 1000 Chrysler Drive, Auburm Hills, MI 48326-2766, USA
Tel: +1 810 576 5741
Fax: +1 810 956 3747
Internet: http://www.chryslercorp.com

Principal manufacturing subsidiaries

Address: Chrysler Argentina, Avenue del Libertador 498, Piso 27, 1001 Capital Federal, Argentina
Tel: +54 819 1300
Fax: +54 819 1336

Address:	Eurostar Automobilwerk, Walter-P Chrysler Platz 1, 8041 Graz- Thondorf, Austria
Tel:	+43 316 4080
Fax:	+43 316 4084 377

Address:	Chrysler do Brasil, Av Das Nacoes Unidas 12551, 23 Andar, 04578-903 Sao Paulo, Brazil
Tel:	+55 11 3043 7910
Fax:	+55 11 3043 7922

Address:	Chrysler Canada, 2450 Chrysler Center, Windsor, Ontario N8W 3X7, Canada
Tel:	+1 519 973 2000
Fax:	+1 519 973 2226

Address:	Chrysler de Mexico, Lago Alberto 320, Colonia Anahuac, 11320 Mexico DF, Mexico
Tel:	+52 5 729 1000
Fax:	+52 5 729 1479

12.5 Citroën (PSA)

Address:	62 Boulevard Victor Hugo, 92208 Neuilly, Paris, France
Tel:	+33 1 4748 4141
Fax:	+33 1 4748 4320
Internet:	http://www.psa-peugeot-citroen.com

Principal manufacturing subsidiary

Address:	Citroën Hispania, Dr Esquerdo 62, 28007 Madrid, Spain
Tel:	+34 91 585 1100
Fax:	+34 91 585 1367

12.6 Daewoo

Address:	199 Chungchun-dong, Puk-gu, Inchon 403-714, Korea
Tel:	+82 32 520 2114
Fax:	+82 32 524 4362

12.7 Daihatsu

Address:	1-1 Daihatsu-cho, Ikeda, Osaka 563, Japan
Tel:	+81 727 51 8811
Fax:	+81 727 53 6880

12.8 Fiat (Fiat Group)

Address:	Corso G Agnelli, 10135 Turin, Italy
Tel:	+39 11 683 1111
Fax:	+39 11 683 7591
Internet:	http://www.fiat.com

Principal manufacturing subsidiaries

Address:	Fiat Auto Argentina, C.M. della Paolera, Piso 25, 1001 Capital Federal, Argentina
Tel:	+54 310 4949
Fax:	+54 310 4999
Address:	Fiat Automoveis, Rodovia Fernao Diais, 32501-000 Betim MG, Brazil
Tel:	+55 31 529 2111
Fax:	+55 31 529 3098

12.9 Ford

Address:	The American Road, Dearborn, MI 48121-1899, USA
Tel:	+1 313 322 3000
Fax:	+1 313 446 7011
Internet:	http://www.ford.com

Principal manufacturing subsidiaries

Address:	Ford Argentina, Henry Ford y ruta Panamericana, 1617 General Pacheco, Buenos Aires, Argentina
Tel:	+54 756 5500
Fax:	+54 756 5400
Address:	Ford Motor Company of Australia, Campbellfield, VIC 3061, Australia
Tel:	+61 39 359 8211
Fax:	+61 39 359 8200
Address:	Ford Werke, Henry Fordlaan, 3600 Genk, Belgium
Tel:	+32 89 616111
Fax:	+32 89 619070
Address:	Ford Brasil, Avenue do Taboao 899, 09870-900 Sao Bernado do Campo - SP, Brazil
Tel:	+55 11 754 8855
Fax:	+55 11 754 8311

Address:	Ford Motor Company of Canada, The Canadian Road, Oakville, Ontario L6J 5E4, Canada
Tel:	+1 905 845 2511
Fax:	+1 905 844 8085

Address:	Ford Werke, 50725 Cologne, Germany
Tel:	+49 221 900
Fax:	+49 221 901 2986

Address:	Ford Motor de Mexico, 06000 Mexico DF, Mexico
Tel:	+52 5 326 6000
Fax:	+52 5 511 5297

Address:	Ford Espana, Paseo de la Castellana 135, 28046 Madrid, Spain
Tel:	+34 91 336 9100
Fax:	+34 91 579 1423

Address:	Ford of Britain, Eagle Way, Brentwood, Essex, CM13 3BW, UK
Tel:	+44 1277 253000
Fax:	+44 1277 252896

12.10 General Motors

Address:	100 Renaissance Center, Detroit, MI 48243-7301, USA
Tel:	+1 313 556 5000
Fax:	+1 313 556 5108
Internet:	http://www.gm.com

Principal manufacturing subsidiaries

Address:	General Motors Argentina, Avda Eduardo Madere 900, Piso 14, Buenos Aires, Argentina
Tel:	+54 319 2700
Fax:	+54 319 2799

Address:	General Motors - Holden's, PO Box 1714, Melbourne, VIC 3001, Australia
Tel:	+61 39 647 1111
Fax:	+61 39 647 2550

Address:	Opel Belgium, Noorderlaan 401 Haven 500, 2030 Antwerp, Belgium
Tel:	+32 3 540 4111
Fax:	+32 3 540 4852

Address:	General Motors do Brasil, Avenue Goias 1805, 09550-900 Sao Caetano do Sul - SP, Brazil
Tel:	+55 11 741 7700
Fax:	+55 11 741 7217

Address:	General Motors of Canada, 1908 Colonel Sam Drive, Oshawa, Ontario L1H 8P7, Canada
Tel:	+1 905 644 5000
Fax:	+1 905 644 3830

Address:	Adam Opel, 65423 Rüsselsheim, Germany
Tel:	+49 6142 660
Fax:	+49 6142 664859

Address:	General Motors de Mexico, Lago Victoria 74, Colonia Granada CP 11520, Mexico
Tel:	+52 5 625 3000
Fax:	+52 5 625 3335

Address:	Opel Espana, Paseo de la Castellana 91, 28046 Madrid, Spain
Tel:	+34 91 456 9200
Fax:	+34 91 456 9307

Address:	Vauxhall Motors, Griffin House, Osborne Road, Luton, LU1 3YT, UK
Tel:	+44 1582 21122
Fax:	+44 1582 427400

12.11 Honda

Address:	1-1, 2-chome, Minami-aoyama, Minato-ku, Tokyo 107, Japan
Tel:	+81 3 3423 1111
Fax:	+81 3 3423 0217
Internet:	http://www.honda.com

Principal manufacturing subsidiaries

Address:	Honda UK Manufacturing, Swindon, Wiltshire, SN3 4TZ, UK
Tel:	+44 1793 831183
Fax:	+44 1793 831177

Address:	Honda of America Manufacturing, 24000 Honda Parkway, Marysvlle, Ohio 43040, USA
Tel:	+1 513 642 5000
Fax:	+1 513 642 6543

12.12 Hyundai

Address:	140-2 Ke-dong, Chongro-gu, Seoul100-793, Korea
Tel:	+82 2 746 1114
Fax:	+82 2 741 0470
Internet:	http://www.hmc.co.kr

12.13 Isuzu

Address:	26-1 Minami -Oi, 6-chome, Shinigawa-ku, Tokyo 140, Japan
Tel:	+81 3 5471 1111
Fax:	+81 3 5471 1090
Internet:	http://www.isuzu.com

12.14 Jaguar (Ford)

Address:	Browns Lane, Allesley, Coventry, West Midlands, CV5 9DR, UK
Tel:	+44 1203 402121
Fax:	+44 1203 407075
Internet:	http://www.jaguar.com

12.15 Kia (Hyundai)

Address:	15 Yoido-dong, Youngdeungpo-gu, Seoul 150-706, Korea
Tel:	+82 2 788 1114
Fax:	+82 2 788 1434
Internet:	http://www.kia.co.kr

12.16 Lancia (Fiat Group)

Address:	Via Vincenzo Lancia, 10141 Turin, Italy
Tel:	+39 11 33311
Fax:	+39 11 3331 12580

12.17 Mazda

Address:	3-1 Shinchi, Fuchu-cho, Aki-gun, Hiroshima 730-91, Japan
Tel:	+81 82 282 1111
Fax:	+81 82 287 5225
Internet:	http://www.mazda.com

12.18 MCC (DaimlerChrysler)

Address:	Contact through Mercedes-Benz, Stuttgart

12.19 Mercedes-Benz (DaimlerChrysler)

Address:	70322 Stuttgart, Germany
Tel:	+49 711 170
Fax:	+49 711 172 2244
Internet:	http://www.daimler-benz.com

Principal manufacturing subsidiary

Address:	Mercedes-Benz of North America, PO Box 100, Tuscaloosa, AL 35403, USA
Tel:	+1 205 507 3300
Fax:	+1 205 507 3700

12.20 Mitsubishi

Address:	33-8, Shiba 5-chome, Minato-ku, Tokyo 108, Japan
Tel:	+81 3 5232 7165
Fax:	+81 3 5232 7747

12.21 Nissan

Address:	17-1 Ginza, 6-chome, Chuo-ku, Tokyo 104-23, Japan
Tel:	+81 3 3543 5523
Fax:	+81 3 3546 2269
Internet:	http://www.nissan.com

Principal manufacturing subsidiaries

Address:	Nissan Motor Ibérica, Panama 7, 08034 Barcelona, Spain
Tel:	+34 93 290 8080
Fax:	+34 93 290 7033

Address:	Nissan Motor Manufacturing UK, Washington Road, Sunderland, Tyne and Wear, SR5 3NS, UK
Tel:	+44 191 415 0000
Fax:	+44 191 415 1077

Address:	Nissan Motor Manufacturing Corp USA, 983 Nissan Drive Smyrna, TN 37167, USA
Tel:	+1 615 459 1400
Fax:	+1 615 459 1102

12.22 Perodua

Address:	MY-4800 Rawang, Mukim Serendah, Malaysia
Tel:	+60 3 691 5708
Fax:	+60 3 691 5698

12.23 Peugeot (PSA)

Address:	75 Avenue de la Grande Armee, 75116 Paris, France
Tel:	+33 1 4066 5511
Fax:	+33 1 4066 5414
Internet:	http://www.psa-peugeot-citroen.com

Principal manufacturing subsidiaries

Address:	Peugeot Espana, Carreterra de Villaverde, 28041 Madrid, Spain
Tel:	+34 91 347 2000
Fax:	+34 91 347 2244

Address:	Peugeot Motor Company, Aldermoor House, PO Box 227, Aldermoor Lane, Coventry, West Midlands, CV3 1LT, UK
Tel:	+44 1203 884000
Fax:	+44 1203 884001

12.24 Porsche

Address:	Porschestrasse 42, 70435 Stuttgart, Germany
Tel:	+49 711 8270
Fax:	+49 711 827 5111
Internet:	http://www.porsche.com

12.25 Proton

Address:	MY-40990 Shah Alam, PO PKNS Complex, Malaysia
Tel:	+60 3 511 1055
Fax:	+60 3 511 1252
Internet:	http://www.proton.com

12.26 Renault

Address:	34 Quai du Point du Jour, 92109 Boulogne Billancourt, Paris, France
Tel:	+33 1 4104 6469
Fax:	+33 1 4104 6790
Internet:	http://www.renault.com

Principal manufacturing subsidiary

Address:	FASA-Renault, Avda de Burgos 89, 28050 Madrid, Spain
Tel:	+34 91 374 2200
Fax:	+34 91 766 5709

12.27 Rover (BMW)

Address:	International House, Bickenhill Lane, Bickenhill, Birmingham, B37 7HQ, UK
Tel:	+44 121 781 6000
Fax:	+44 121781 0253
Internet:	http://www.rovergroup.com

12.28 Saab (General Motors)

Address:	S-461 80 Trollhattan, Sweden
Tel:	+46 520 85000
Fax:	+46 520 36296
Internet:	http://www.saab.com

12.29 SEAT (Volkswagen Group)

Address:	Sector A, Calle 2, 1-25, Zona Franca, 08040 Barcelona, Spain
Tel:	+34 93 402 8500
Fax:	+34 93 403 6900
Internet:	http://www.seat.com

12.30 Skoda (Volkswagen Group)

Address:	Vaclava Klementa 869, 293 60 Mlada Boleslav, Czech Republic
Tel:	+420 326 811111
Fax:	+420 326 811932
Internet:	http://www.skoda.com

12.31 Subaru

Address:	7-2 Nishi Shinjuku, 1-chome, Shinjuku-ku, Tokyo 160, Japan
Tel:	+81 3 3347 2111
Fax:	+81 3 3347 2338

12.32 Suzuki

Address:	300 Takatsuka, Hamamatsu City, Shizuoka 432-91, Japan
Tel:	+81 53 440 2079
Fax:	+81 53 445 0040
Internet:	http://www.suzuki.com

12.33 Toyota

Address:	4-18 Koraku 1-chome, Bukyo-ku, Tokyo 112, Japan
Tel:	+81 3 3817 7111
Fax:	+81 3 3817 9017
Internet:	http://www.toyota.com

Principal manufacturing subsidiaries

Address:	Toyota Motor Manufacturing UK, Burnaston, Derbyshire, DE1 9TA, UK
Tel:	+44 1332 282121
Fax:	+44 1332 282801
Address:	Toyota Motor Manufacturing USA, 1001 Cherry Blossom Way, Georgetown, Kentucky 40324, USA
Tel:	+1 502 868 2067
Fax:	+1 502 868 3060

12.34 Volkswagen (Volkswagen Group)

Address:	38436 Wolfsburg, Germany
Tel:	+49 5361 90
Fax:	+49 5361 92 8282
Internet:	http://www.vw.com

Principal manufacturing subsidiaries

Address:	Volkswagen do Brasil, Rua Volkswagen 291, Parque Jabaquara, 04344-900 Sao Paulo - SP, Brazil
Tel:	+55 11 5582 5122
Fax:	+55 11 5582 5163
Address:	Volkswagen de Mexico, 116 Autopista Mexico-Puebla, Puebla, Mexico CP 72008, Mexico
Tel:	+52 2 230 8110
Fax:	+52 2 248 7192

12.35 Volvo (Ford)

Address:	S-40508 Gothenburg, Sweden
Tel:	+46 31 590000
Fax:	+46 31 544064
Internet:	http://www.volvo.com

Principal manufacturing subsidiary

Address:	Volvo Cars, John Kennedylaan 25, 9000 Gent, Belgium
Tel:	+32 9 250 2111
Fax:	+32 9 251 6264

13 Directory of Representative Plastic Components Suppliers

This chapter identifies a representative sample of plastics processors in North America, Europe and the Far East.

As a rule, the companies listed conform to three key characteristics:

- they are significant players in their particular product group(s);
- automotive components account for a substantial proportion of output;
- they are recognised suppliers of the vehicle manufacturing sector.

In compiling the following listing, a variety of sources have been used including trade association membership details, major national, regional and global component directories and the extensive database of Dick Mann Associates.

This chapter is divided into three sections which correspond to the main plastic component regions of North America, Europe and Asia. North America is subdivided into Canada and the US, Europe into Belgium, Czech Republic, Denmark, France, Germany, Italy, The Netherlands, Norway, Poland, Portugal, Spain, Sweden, Switzerland and the UK, and Asia into China, Japan, Korea, Malaysia, Singapore, Taiwan and Thailand.

13.1 North American manufacturers of plastic automotive components

CANADA

ABC Group

Address:	100 Ronson Drive, Rexdale, ON M9W 1B6
Tel:	+1 416 246 0530
Fax:	+1 416 246 1997
Products:	blow moulded and injection moulded automotive components including instrument panels, interior and exterior trim, bumpers, spoilers, windscreen water bottles, coolant recovery bottles
Contact:	G Elgner, executive VP & general manager

Camoplast Inc

Address:	425 Tenth Avenue, PO Box 1070, Richmond, QC J0B 2H0
Tel:	+1 819 826 5911
Fax:	+1 819 826 5061
Products:	body, HVAC and trim components
Contact:	J P Grouix, general manager

Canadian General-Tower Ltd

Address:	52 Middleton Street, Cambridge, ON N1R 5T6
Tel:	+1 519 623 1630
Fax:	+1 519 740 2977
Products:	headliners, instrument panels, seats, interior and exterior trim, PVC sheet and film products for flooring
Contact:	N A Towle, VP automotive products

Centoco Plastics Ltd

Address:	2466 Central Avenue, Windsor, ON N8W 4J3
Tel:	+1 519 948 2300
Products:	steering wheels, air bag modules
Contact:	A Toldo, president

Gecamex Technologies Inc

Address:	1 Seneca Drive, PO Box 460, Leamington, ON N8H 3W5
Tel:	+1 519 326 2616
Fax:	+1 519 326 1576
Products:	miscellaneous auto parts
Contact:	Paul Muller, marketing manager

Kautex Corporation

Address: 2701 Kautex Drive, Windsor, ON N8W 5B1
Tel: +1 519 974 6656
Fax: +1 519 974 6588
Products: fuel tanks and other blow moulded parts
Contact: G J Ulicny, sales manager

Schlegel Canada Ltd

Address: 514 South Service Road, PO Box 218, Oakville, ON L6J 5A2
Tel: +1 905 845 6657
Fax: +1 905 845 3112
Products: automotive door and sealing systems, injection moulded parts
Contact: C Hall, sales manager

Scott Douglas Plastics Ltd

Address: PO Box 65, Ingersoll, ON N5C 3K1
Tel: +1 416 485 1943
Products: HVAC components
Contact: D A Douglas, president

Tarxian Corporation

Address: 505 Finley Avenue, Ajax, ON L1S 2E2
Tel: +1 810 524 3001
Fax: +1 810 524 3273
Products: roof panels, rain gutters, handles, interior body parts
Customers: all principal North American car producers
Contact: R J Zarboni, president

Ventra Group Inc

Address: PO Box 126, 1 Mitten Crt, ON N1R 5S9
Tel: +1 519 658 6777
Fax: +1 519 658 5422
Products: injection moulded auto lenses, interior trim
Contact: H Law, VP & general manager

Windsor Plastic Products

Address: 6845 Hawthorne Drive, ON N8T 3B8
Tel: +1 519 944 5445
Products: grilles and other injection moulded and foam moulded components
Contact: K Elliott, president,
Plants: US (two), Canada (one)

Woodbridge Group

Address: 4240 Sherwoodtowne Boulevard, Missisauga, ON L4Z 2G6
Tel: +1 905 896 3626
Fax: +1 905 896 9262
Products: PU foam seating and other automotive products
Contact: T R Beamish, chairman & CEO
Plants: Canada (nine), US (nine)

USA

3M Automotive Engineered Plastics Division

Address: 3M Center 223-1S-02, St Paul, MN 55144
Tel: +1 612 736 2964
Fax: +1 612 736 4387
Products: lenses, reflectors, connectors, protective trim, insignia
Customers: all major vehicle manufacturers
Contact: L DeSimone, chairman & CEO
Plants: US (82), rest of world (107)

Acadia Polymers Inc

Address: 38701 Seven Mile Road, Livonia, MI 48152
Tel: +1 734 953 0555
Fax: +1 734 953 0355
Products: precision polymeric seals, vibration isolation parts
Contact: G Robertson, general manager

ADAC Plastics Inc

Address: 3801 36th Street SE, Grand Rapids, MI 49588-8375
Tel: +1 616 957 0311
Fax: +1 616 583 5217
Products: body exterior and interior trim, lighting, electrical/electronic components
Contact: K G Hungerford, president

Advance Dial Company

Address: 940 Industrial Drive, Elmhurst, IL 60126-1131
Tel: +1 630 993 1700
Fax: +1 630 993 0372
Products: injection moulded components
Contact: Tay Ziganto, marketing and sales manager
Plants: US (four)

Advanced Composite Products Inc

Address: 116 South 18th Street, Harrisburg, PA 17104
Tel: +1 717 232 8237
Fax: +1 717 232 5417
Products: composite electric pick up components
Contact: K N Hitt, president

Advanced Thermoforming Inc

Address: 6210 Product Drive, Sterling Heights, MI 48312
Tel: +1 810 939 1720
Fax: +1 810 795 8977
Products: external and internal trim components

Advent Molded Products Inc

Address: 21438 N 7th Avenue, Phoenix, AZ 85027
Tel: +1 602 582 4411
Fax: +1 602 582 5883
Products: PU foam rebound bumpers and thermoplastic springs

Allied Plastics Inc

Address: 3005 Ranchview Lane N, Minneapolis, MN 55447-1463
Tel: +1 612 862 4500
Fax: +1 612 862 4544
Products: seat consoles, interior trim, plastic accessories
Contact: D Fransden, CEO

Allison Corporation

Address: 630 W Mount Pleasant Avenue, Livingston, NJ 07039
Tel: +1 201 992 3800
Fax: +1 201 992 3095
Products: seat covers and cushions, interior and exterior trim
Contact: S Seltzer, president

Amesbury Group Inc

Address: 159 Walker Road, Statesville, NC 28677
Tel: +1 704 873 8743
Fax: +1 800 873 7453
Products: HVAC, headliners, instrument panels, seating, interior trim
Contact: M S Barnes, president & CEO

Amoco Torlon Products Ltd

Address: 5300 Fulton Industrial Boulevard, PO Box 43488, Atlanta, GA 30336-2426
Tel: +1 404 346 8253
Fax: +1 404 346 8255
Products: drive train components

Anchor Industries Inc

Address: 1100 Birch Drive, Evansville, IN 47733
Tel: +1 812 867 2421
Fax: +1 812 867 1429
Products: supports, cushions, bumpers, grommets, brake, clutch and accelerator pedals
Contact: Judy Dreher, sales manager

AOTEC Inc

Address: PO Box 8007, 25 Case Street, Southbridge, MA 01550
Tel: +1 508 765 2217
Fax: +1 508 765 0281
Products: instrument panels, exterior and interior trim, mirrors
Contact: W J Dhooghe, president

Arrow Molded Plastics Inc

Address: 800 Independence Drive, Napoleon, OH 43545
Tel: +1 419 592 3333
Fax: +1 419 599 2077
Products: injection moulded and PU auto components
Contact: T Nash, CEO
Plants: US (five), Canada (one)

ASC Inc (American Sunroof Co)

Address: 1 Sunroof Center Drive, Southgate, MI 48195 3044
Tel: +1 313 285 4911
Fax: +1 313 246 0505
Products: sunroofs, body panels, miscellaneous mouldings and trim
Contact: H C Prechter, chairman & CEO
Plants: US (three)

ATC Lighting and Plastics Inc

Address: 107 North Eagle Street, Geneva, OH 44041
Tel: +1 440 466 7670
Fax: +1 440 466 0186
Products: body, electrical/electronic, fuel system, interior trim and seating components

Automotive Industries Inc

Address: 4508 IDS Center, Minneapolis, MN 55402
Tel: +1 612 332 6828
Fax: +1 612 443 2012
Products: sun visors, interior trim, air ducting and other injection and blow moulded parts
Customers: Ford, Chrysler, GM, Diamond Star, Mazda, Isuzu, Nissan
Contact: T C Rhea, VP trim operations
Plants: US (16)

Auto Style Plastics Inc

Address:	5015 52nd Street SE, Grand Rapids, MI 49512
Tel:	+1 616 940 9500
Fax:	+1 616 940 9575
Products:	bumpers, loadfloors and other RIM components
Contact:	P Bayley, marketing director
Plants:	US (six)

Avtech Plastic Products

Address:	34203 James J Pompo, Fraser, MI 48026-3475
Tel:	+1 810 293 4510
Fax:	+1 810 293 9021
Products:	body, passenger restraint, seating and trim components

Bace Manufacturing Inc

Address:	3125 E Coronado Street, Anaheim, CA 92806
Tel:	+1 714 630 6411
Products:	bezels and other injection moulded components
Contact:	M Noggle, CEO
Plants:	US (four)

Bailey Manufacturing Corporation

Address:	700 Lafayette Road, Seabrook, NH 03874
Tel:	+1 603 474 3011
Fax:	+1 603 747 8949
Products:	exterior SMC plastic components
Customer:	Ford
Contact:	R R Philips, president
Plants:	US (four)

Blue Water Plastics Inc

Address:	1515 Busha Hwy, Marysville, MI 48040-0129
Tel:	+1 810 364 4550
Fax:	+1 810 364 4556
Products:	HVAC systems, functional components, seat backs, injection moulded interior and exterior trim
Customers:	Ford (largest)
Contact:	C C Haas, president
Plants:	US (seven), Mexico

BMC Industries Inc

Address:	2 Appletree Square, Minneapolis, MN 55425
Tel:	+1 612 851 6000
Fax:	+1 612 851 6050
Products:	polycarbonate and other plastic auto lenses
Contact:	P B Burke, president & CEO

Bostik Inc

Address: 211 Boston Square, Middleton, MA 01949
Tel: +1 978 777 0100
Fax: +1 978 750 7319
Products: headliners, instrument panels, seating, interior trim
Contact: W F Fulton, VP marketing
Plants: US (two)

Brooklyn Products Inc

Address: 171 Wamplers Lake Road, Brooklyn, MI 49230
Tel: +1 517 592 2185
Fax: +1 517 592 3759
Products: door panels, seat and visor inserts
Contact: R Linenfelser, president & CEO

Bryan Custom Plastics

Address: 918 S Union Street, PO Box 568, Bryan, OH 43506-2246
Tel: +1 419 636 4211
Fax: +1 419 636 5528
Products: injection moulded components
Contact: Tom Kling, VP & general manager
Plants: US (three)

Buffalo Molded Plastics Inc

Address: Maple Street Extension RR7, Andover, OH 44003
Tel: +1 440 293 5900
Fax: +1 440 293 5064
Products: injection moulded auto parts
Contact: John O'Neill
Plants: US (two)

Cadillac Products

Address: 5800 Crooks Road, Troy, MI 48098-2830
Tel: +1 248 879 5000
Fax: +1 248 879 6428
Products: door liners, instrument panels and consoles, large vacuum formed auto products
Customer: Chrysler
Contact: M K Williams II, joint president
Plants: US (six)

Cambridge Industries

Address: 555 Horace Brown Drive, Madison Heights, Dearborn, MI 48071-1847
Tel: +1 248 616 0500
Fax: +1 248 616 0532
Products: SMC bumpers, bonnets, roofs, doors, floorpans; BMC valve covers, radiator parts, body panels, RTM panels, SRM floorpans; instrument panels, GMT load floors, seats, HDPE fuel tanks, interior trim, bearing cages, gears
Contact: R Crawford, president
Plants: US and Canada (11 in total)

Capsonic Group Inc

Address: 460 Second Street, Elgin, IL 60123
Tel: +1 847 888 7300
Fax: +1 847 888 7543
Products: braking, electrical/electronic and interior trim, door systems and trim, seats and seating components, instrument panels and consoles, lighting components, ducting
Contact: A J Hoffmann, president

Cascade Engineering Inc

Address: 5175 36th Street, Grand Rapids, MI 49512-2009
Tel: +1 616 949 4800
Fax: +1 616 949 4114
Products: injection moulded components
Customer: Chrysler
Contact: J Oosting, VP sales

Central Decal Co Inc

Address: 6901 High Grove Boulevard, Burr Ridge, IL 60521-7583
Tel: +1 630 325 9892
Fax: +1 630 325 9860
Products: name plates, exterior trim
Contact: H Kaplan, president

Chestnut Ridge Foam Inc

Address: Route 981 North, PO Box 781, Latrobe, PA 15650
Tel: +1 412 537 9000
Fax: +1 412 537 9003
Products: moulded PU seating
Contact: Carl Ogburn, VP sales & marketing

CIP USA

Address: 350 Griswood Road, Port Huron, MI 48060
Tel: +1 800 203 5540
Fax: +1 810 982 2950
Products: mirrors and brackets

Collins and Aikman Automotive Division

Address: PO Box 580, Albemarle, NC 28002
Tel: +1 704 983 5166
Fax: +1 704 983 8304
Products: door systems and trim, interior trim
Contact: T E Hannah, president & CEO

Colonial Diversified Polymer Products

Address: 2055 Forrest Street Extended, Dyersburg, TN 38024-3616
Tel: +1 901 287 3602
Fax: +1 901 287 3691
Products: body, electrical/electronic, HVAC, passenger restraint components

Conix Corporation

Address: 500 Town Center Drive, Dearborn, MI 48126
Tel: +1 313 390 2090
Fax: +1 313 390 9880
Products: body panels, bumper covers, fascias
Contact: Jack McBride, VP sales and engineering
Plants: US (one), Canada (two), Belgium (one)

Continental Plastics Co

Address: 33525 Groesbeck Highway, Fraser, MI 48026-1587
Tel: +1 810 294 4600
Fax: +1 810 294 3317
Products: interior and exterior trim components
Contact: A Catenacci, president

Cooper Automotive

Address: 1050 Wilshire Drive, Troy, MI 48084
Tel: +1 248 649 9393
Fax: +1 248 649 2255
Products: automotive lamps and fittings, wipers, brake system parts, steering system parts
Customer: Chrysler
Contact: D A White, senior VP planning
Plants: US (eight)

C-Plastics Corporation

Address: 243 Whitney Street, Leominster, MA 01453
Tel: +1 978 534 6876
Fax: +1 973 537 8238
Products: injection moulded pipes, lenses, housings, decorative trim, instrument cluster components

Donnelly Corporation

Address: 414 E 40th Street at Industrial Parkway, Holland, MI 49423-5368
Tel: +1 616 786 7000
Fax: +1 616 786 7762
Products: glass-related and moulded products for the automotive industry
Contact: D J Viola, CEO
Plants: US (nine), Ireland (one)

Drossback USA

Address: PO Box 219, 65 Aurora Industrial Parkway, Aurora, OH 44202
Tel: +1 216 562 4005
Fax: +1 216 562 4065
Products: convoluted tubing in PE, PP, PA and other thermoplastics

Dynacast Inc

Address: 1401 Front Street, Yorktown Heights, NY 10598
Tel: +1 914 245 0064
Fax: +1 914 245 7185
Products: body parts, door systems and trim, seats and seating components, exterior and interior trim components, instrument panels and consoles, mirrors
Contact: Tim Hayter, general manager
Plants: US (five), others worldwide

Dynamec Inc

Address: 12209 Chandler Drive, Walton, KY 41091-9675
Tel: +1 606 485 1700
Products: seats
Contact: Jacques Lemorvan, president

Eagle-Picher

Address: 2424 John Daly Road, Inkster, MI 48141
Tel: +1 313 278 5956
Fax: +1 313 278 3546
Products: injection moulded and thermoset components
Contact: Roger Schwartz, VP automotive sales

Engineered Plastics Products Group

Address: 4655 N Elston Avenue, Chicago, IL 60630
Tel: +1 800 535 2889
Fax: +1 312 286 1443
Products: injection moulded components
Contact: R A Molitor, president

Exel Industries Inc

Address:	27335 West Eleven Mile Road, Southfield, MI 48034
Tel:	+1 248 352 3399
Fax:	+1 248 352 2831
Products:	injection moulded automotive components
Customers:	all major automotive manufacturers
Contact:	J J Lohman, chairman & CEO
Plants:	US (ten)

Findlay Industries Inc

Address:	4000 Fostoria Road, Findlay, OH 45840
Tel:	+1 419 422 1302
Fax:	+1 419 422 0385
Products:	seats, interior trim, headliners, door panels, instrument panels, consoles, passenger restraint systems
Contact:	R Fernandez, VP sales and marketing
Plants:	US (12), Mexico (two), Canada (one), Poland, (one), Germany (four), Spain (two)

Flambeau Corporation

Address:	801 Lynn Avenue, Baraboo, WI 53913-2746
Tel:	+1 608 356 5551
Fax:	+1 608 356 5260
Products:	blow moulded rear seat assemblies, HDPE fuel tanks, windscreen washer system components
Customers:	GM (largest)
Contact:	Bill Flint, director of marketing and sales
Plants:	US (six)

Foamade Industries

Address:	2555 Auburn Court, Auburn Hills, MI 48326-3220
Tel:	+1 248 852 6010
Fax:	+1 248 853 3442
Products:	flexible foam and film fabricators: gaskets and seals, air filters, water deflectors, vacuum formed parts, NVH insulation
Contact:	Alan Piette, VP operations

Foamex International Inc

Address:	400 Galleria Officenter, Suite 214, Southfield, MI 48034
Tel:	+1 248 204 9400
Fax:	+1 248 204 9444
Products:	door systems and trim, seats and seating components, interior trim, headliners
Contact:	A Farace, chairman & CEO

Freudenberg-NOK

Address: 47690 E Anchor Court, Plymouth, MI 48170
Tel: +1 734 451 0020
Fax: +1 734 451 0125
Products: valve covers
Customer: Chrysler

GE Automotive

Address: 25900 Telegraph Road, PO Box 5011, Southfield, MI 48086
Tel: +1 313 965 7775
Fax: +1 810 351 8533
Products: electrical/electronic, HVAC, passenger restraint components

Gem Manufacturing Corp

Address: 7752 W 60th Street, Summit, IL 60501
Tel: +1 312 427 3176
Fax: +1 312 427 2795
Products: bumpers, interior and exterior lights, wind deflectors

Grand Rapids Plastics Inc

Address: 4050 Roger B Chaffee Boulevard, Grand Rapids, MI 49518-8069
Tel: +1 616 531 6110
Fax: +1 616 247 1017
Products: exterior and interior trim, instrument panels and consoles, bumpers, body parts
Contact: A J Bott, president

GT Products Inc

Address: 315 S First Street, PO Box 1404, Ann Arbor, MI 48106
Tel: +1 313 761 7666
Fax: +1 313 761 9360
Products: fuel pumps, sensors, valves, pressure switches
Contact: A Turner, president

GT Styling

Address: 1500 Superior Avenue, Coata Mesa, CA 92627
Tel: +1 714 548 1960
Fax: +1 714 548 1455
Products: grilles, speakers, decorative trim, panels
Contact: Doug Turner, manager

Guardian Automotive Trim Inc

Address:	601 N Congress Avenue, Evansville, IN 47716-5109
Tel:	+1 802 234 9941
Fax:	+1 802 234 9940
Products:	electrical/electronic, fuel system, passenger restraint, seating components

Harvard Industries

Address:	60665 Northwestern Highway, Farmington Hills, MI 48334
Tel:	+1 248 626 4320
Fax:	+1 248 932 8150
Products:	body parts, exterior and interior trim, door systems and trim, instrument panels and consoles, mirrors
Contact:	D L Kuta, senior VP marketing

Hawtal Whiting Inc

Address:	41155 Technology Park Drive, Sterling Heights, MI 48314-4155
Tel:	+1 810 726 3444
Fax:	+1 810 726 3455
Products:	body parts, bumpers, exterior and interior trim, door systems and trim, seats and seating components, headliners, instrument panels and consoles, lighting components, mirrors
Contact:	D Jones, president

Hettinga Technologies

Address:	2123 N W 111th Street, Des Moines, IA 50325-3788
Tel:	+1 515 270 6900
Fax:	+1 515 270 1333
Products:	lenses and lighting systems, seating, steering and trim components
Contact:	Heannine S Hettinga, president & CEO

Himont Inc

Address:	2801 Centerville Road, Wilmington, DE 16439
Tel:	+1 392 996 6000
Products:	PP components: safety bumpers, spoilers, side protection, instrument panels, interior trim, door panels
Contact:	P Morrione, president & CEO

Hoechst Celanese Corporation

Address:	1195 Center Road, Auburn Hills, MI 48321-7007
Tel:	+1 248 377 2700
Fax:	+1 217 377 2981
Products:	body, drivetrain, electrical/electronic, engine and fuel system components

Hoffer Plastics Corporation

Address: 500 N Collins Street, South Elgin, IL 60177
Tel: +1 708 741 5740
Fax: +1 708 741 3086
Products: injection moulded components
Contact: W Hoffer Sr, VP sales
Plants: US (two)

Holley Automotive Division (subsidiary of Coltec)

Address: 19955 E 9 Mile Road, Warren, MI 48090-2003
Tel: +1 810 497 4000
Fax: +1 810 497 4104
Products: plastic automotive parts
Contact: R H Allen, president

Huntington Foam Corporation

Address: 11 Industrial Park Drive, Brockway, PA 15824-0248
Tel: +1 814 265 8930
Fax: +1 814 265 8627
Products: bumpers, door systems and trim, interior trim, headliners, instrument panels and consoles

Huron Plastics Group Inc

Address: 1362 N River Road, St Clair, MI 48061-0429
Tel: +1 810 329 4711
Fax: +1 810 329 3700
Products: body, drivetrain, electrical/electronic, fuel system, engine, passenger restraint, seating, trim and wheel parts
Customer: GM
Contact: W T Mattick, VP sales and marketing
Plants: US (five)

ITW Deltar Special Products Division

Address: 21577 S Harlem Avenue, Frankfort, IL 60423
Tel: +1 708 720 3800
Fax: +1 708 720 3810
Products: plastic components and fasteners for the auto industry
Contact: J D Nichols, chairman & CEO
Plants: US (20)

John W Gillette & Co

Address: 26999 Woodward Avenue, Huntingdon Woods, MI 48070-1365
Tel: +1 810 542 2000
Products: armrests, ducting
Contact: Bill Roberts, president
Plants: US (two)

Kenco Plastics Inc

Address: 31500 Northwestern Highway, Farmington Hills, MI 48334-2568
Tel: +1 248 855 4050
Fax: +1 248 851 4001
Products: blow moulded electrical/electronic, fuel system, HVAC, engine, seating and trim components
Contact: E Warens, president

Key Plastics Inc

Address: 21333 Haggerty Road, Suite 200, Novi, MI 48375
Tel: +1 248 449 6100
Fax: +1 248 449 6199
Products: interior and exterior trim components
Contact: G Mars, president
Plants: US (six), France, Portugal, UK

Klefel Technologies Inc

Address: Scott Road, PO Box 968, Hampton, NH 03842 0968
Tel: +1 603 919 3900
Fax: +1 603 926 1387
Products: thermoformed interior parts and trim

Kryptonics Inc

Address: 740 Pierce Avenue, Louisville, CO 80027
Tel: +1 303 665 5353
Fax: +1 303 665 7395
Products: PU engine mounts and vibration isolators, front and rear suspension bushes, steering bushes and isolators
Contact: L Vinson, VP marketing

Kuss Filtration

Address: 1331 Broad Avenue, Findlay, OH 45840
Tel: +1 419 425 7257
Fax: +1 419 425 7200
Products: filters and fuel systems, windscreen washers and air conditioning systems
Customers: Chrysler, Ford, GM
Contact: F Cramer, sales manager

Lacks Enterprises Inc

Address: 5460 Cascade Road SE, Grand Rapids, MI 49546
Tel: +1 616 949 6570
Fax: +1 616 285 2367
Products: radiator grilles, exterior components
Customers: Chrysler, GM
Contact: D McNulty, sales and marketing
Plants: US (four)

Laydon Company

Address: 4911 E Main Street, Brown City, MI 48416
Tel: +1 810 346 2952
Fax: +1 810 346 2900
Products: sun visors, brackets arms, handles, mirrors, fan gratings

Lear Corporation

Address: 21557 Telegraph Road, Southfield, MI 48086-5008
Tel: +1 248 447 1500
Fax: +1 248 447 1524
Products: seating systems, seat backs, pans
Customers: Chrysler, Ford, GM and most major vehicle manufacturers
Contact: K L Way, chairman

Leon Plastics Inc

Address: 4901 Clay Avenue, Grand Rapids, MI 49501-0350
Tel: +1 616 531 7970
Fax: +1 616 531 3393
Products: injection moulded interior trim, armrests, consoles, instrument panels, glovebox doors
Contact: D A Schiedmantel, marketing and sales manager
Plants: US (two)

Leslie Metal Arts Inc (Lescoa)

Address: 3035 32nd SE, Grand Rapids, MI 49512
Tel: +1 616 949 1250
Fax: +1 616 949 1540
Products: instrument panels
Customers: GM (largest)
Contact: D Tassell, president

Libralter Plastics Inc

Address: 3175 Martin Road, Walled Lake, MI 48390
Tel: +1 248 669 4900
Fax: +1 248 669 5912
Products: injection moulded automotive components
Contact: T Barr, president
Plants: US (four)

Lowell Engineering Corporation

Address: 6153 Bancroft SE, Alto, MI 49302
Tel: +1 616 868 6122
Fax: +1 616 868 7169
Products: mirror components
Customers: Chrysler, Hyundai
Contact: P M Johnson, marketing director

Master Molded Products Corporation

Address: 1000 Davis Road, Elgin, IL 60123-1383
Tel: +1 847 695 9700
Fax: +1 847 695 9707
Products: body, electrical/electronic components
Contact: J J Weinhart, president

McGowan Manufacturing Company

Address: 25 Michigan Street, Hutchinson, MN 55350
Tel: +1 320 587 2222
Fax: +1 320 587 7966
Products: interior trim, mouldings, panels
Contact: W G McGowan, president

Mid-American Products Inc

Address: 1623 Wildwood Avenue, PO Box 983, Jackson, MI 49204
Tel: +1 517 789 8116
Fax: +1 517 788 6035
Products: under bonnet (hood) components
Customer: GM
Contact: J Hughey, general manager

Molded Fiber Glass Companies Inc

Address: 2925 Manufacturing Place, Ashtabula, OH 44004-0675
Tel: +1 800 456 5263
Fax: +1 440 992 2695
Products: GRF products including exterior body panels, seats and other components
Customer: GM
Contact: J B Kane, sales manager
Plants: US (three)

Molded Rubber and Plastic Corporation

Address: 13161 W Glendale Avenue, Butler, WI 53007
Tel: +1 414 781 7122
Fax: +1 414 781 5353
Products: exterior body panels, fans and other moulded plastic auto components
Contact: Ken Simatic, VP manufacturing

Molmec Inc

Address: 2655E Oakley Park Road, Walled Lake, MI 48390
Tel: +1 248 669 7840
Fax: +1 248 669 8280
Products: steering wheels and connectors, name plates
Contact: R C Leland, executive VP
Plants: US (four)

Moon Roof Corporation of America

Address: 28117 Groesbeck Highway, Roseville, MI 48066
Tel: +1 810 772 8730
Fax: +1 810 777 8228
Products: roof linings and similar products: specialist in RIM, RRIM and SRIM PU, polyurea and high density foam urethane

Morton International

Address: 3350 Airport Road, Ogden, UT 84405-1563
Tel: +1 801 625 4800
Fax: +1 801 625 4800
Products: airbags, air bag modules
Contact: S J Stewart, chairman & CEO
Plants: US (six)

Motor Wheel Corporation

Address: 4000 Collins Road, Lansing, MI 48910
Tel: +1 517 337 5700
Fax: +1 517 337 5899
Products: automobile wheels, brake systems and parts
Contact: D M Cyrill, VP sales
Plants: US (four), Canada (one)

MTD Products Inc

Address: PO Drawer 360900, Cleveland, OH 44136
Tel: +1 330 225 2600
Fax: +1 330 273 4617
Products: bumper beams and load floors

Naltex

Address: 220 E St Elmo Road, Austin, TX 78745-1218
Tel: +1 512 447 7000
Fax: +1 512 447 7444
Products: extruded thermoplastic netting for spring silencers, protective covers for door assemblies, wall supports for filter systems, protective screens for defroster units, seat backs

Neaton Automotive Products Manufacturing Inc

Address: 975 S Franklin Street, Eaton, OH 45320-9421
Tel: +1 937 456 7103
Fax: +1 937 456 1437
Products: injection moulded components
Contact: Akio Seto, president & CEO

Norton Performance Plastics Corporation

Address: 150 Dey Road, Wayne, NJ 07470-4670
Tel: +1 973 696 4700
Fax: +1 973 696 4700
Products: body, electrical/electronic, fuel system components
Contact: J Hensel, managing director

Nyx Inc

Address: Livonia, MI 48150-2006
Tel: +1 313 421 3850
Products: large injection moulded automotive components
Contact: Chain Sandhu, president

OEM/Miller Corporation

Address: 1300 Dahner Drive, Aurora, OH 44202
Tel: +1 330 562 2900
Fax: +1 330 562 7635
Products: flexible plastic hose for automotive wiring harnesses

O'Sullivan Corporation

Address: 1944 Valley Avenue, PO Box 3510, Winchester, VA 22601
Tel: +1 540 667 6666
Fax: +1 540 722 2695
Products: calendered and injection moulded interior trim
Contact: J T Holland, president
Plants: US (five)

Parker Hannifin Corporation

Address: 6035 Parkland Boulevard, Cleveland, OH 44124-4141
Tel: +1 216 896 3000
Fax: +1 216 896 4035
Products: hose clips, control panels, filters, gaskets, seals
Contact: F J Myers, general marketing manager
Plants: US (43), others worldwide

Performance Marketing Inc

Address: 201 N Sullivan, Santa Ana, CA 92703
Tel: +1 714 835 2126
Fax: +1 714 835 9653
Products: steering wheels, head and arm rests, mats, wind deflectors
Contact: D Lueck, manager

Phillips Plastics Corporation

Address: 1201 Hanley Road, PO Box 29, Phillips, WI 54016
Tel: +1 715 386 4320
Fax: +1 715 386 4326
Products: injection moulded components
Contact: Bob Buckley, VP manufacturing
Plants: US (ten)

Pine River Plastics Inc

Address: 1111 F W Moore Highway, PO Box 477, St Clair, MI 48079-0477
Tel: +1 810 329 9005
Fax: +1 810 329 9388
Products: interior and exterior trim components
Contact: T L Acton, CEO
Plants: US (three)

Plastic Engineered Components Inc

Address: 14 W 23833 Stone Ridge Drive, Waukesha, WI 53188-1137
Tel: +1 414 523 3200
Fax: +1 414 523 3201
Products: injection moulded components
Contact: E W Mentzer, president
Plants: US (four)

Plastic Molding Corporation

Address: 2181 Grand Avenue, Cincinnati, OH 45214-1593
Tel: +1 513 921 5040
Fax: +1 513 921 5883
Products: braking, electrical/electronic, fuel system and suspension components
Contact: C Corato, senior VP marketing

Plastic Products Company Inc

Address: 30355 Akerson Street, Lindstrom, MN 55045
Tel: +1 612 257 5980
Fax: +1 612 257 3955
Products: injection moulded components
Contact: Frank E Messin, executive VP
Plants: US (five)

Plastomer Corporation

Address: 37819 Schoolcraft Road, Livonia, MI 48150-5031
Tel: +1 734 464 0700
Fax: +1 734 464 4792
Products: HVAC, seating and trim components
Contact: W Baughman III, president

PMP Composites Corporation

Address:	572 Whitehead Road, Trenton, NJ 08619
Tel:	+1 609 587 1188
Fax:	+1 609 587 3463
Products:	body panels
Customer:	GM

Polycel Structural Foam

Address:	680 County Line Road, Somerville, NJ 08876
Tel:	+1 908 722 7457
Fax:	+1 908 722 5254
Products:	structural foam components

Powerflow Inc

Address:	1639 Bailey Avenue, PO Box 905, Buffalo, NY 14212-2090
Tel:	+1 716 892 1014
Fax:	+1 716 892 0331
Products:	splash guards, window vents, grilles
Contact:	Doug Ward, chairman

Premix Inc

Address:	PO Box 281, North Kingsville, OH 44068
Tel:	+1 440 224 2181
Fax:	+1 440 224 2766
Products:	body panels, spoilers, bumpers and other thermoset parts
Customer:	GM
Contact:	N McCarthy, VP marketing
Plants:	US (three)

Puget Corporation

Address:	20101 Mildred Street W, Tacoma, WA 98466
Tel:	+1 206 564 3632
Fax:	+1 206 565 6984
Products:	injection moulded components
Contact:	Bill Lofton, president & CEO
Plants:	US (two)

Rehau Inc

Address:	PO Box 1706, 1501 Edwards Ferry Road, Leesburg, VA 20177
Tel:	+1 800 247 9445
Fax:	+1 800 627 3428
Products:	bumpers, plastic tubing, extruded and injection moulded parts
Contact:	H Wagner, president

Renesol Corporation

Address:	PO Box 1424, Ann Arbor, MI 48016
Tel:	+1 418 484 5282
Fax:	+1 418 484 2511
Products:	moulded flexible PU seating and interior trim

Resinoid Engineering Corporation

Address:	7557 N St Louis Avenue, Skokie, IL 60075-4033
Tel:	+1 847 673 1050
Fax:	+1 847 673 2160
Products:	braking, electrical/electronic and fuel system components
Contact:	G Sedlacek, sales manager

Rochester Gauges Inc

Address:	PO Box 29242, Dallas, TX 75229
Tel:	+1 972 241 2161
Fax:	+1 972 260 1403
Products:	fuel sensors, float gauges and switches
Contact:	H Ross, executive VP

Scottburg Plastics Inc

Address:	1250 S Bond, PO Box 454, Scottsburg, IN 47170-9000
Tel:	+1 812 752 6224
Fax:	+1 812 752 3600
Products:	body and trim components
Contact:	J Wolf, president & CEO

Security Plastics Inc

Address:	14427 NW 60th Avenue, Miami Lakes, FL 33014
Tel:	+1 305 623 5440
Fax:	+1 305 557 1431
Products:	electrical/electronic, engine, passenger restraint and seating components
Contact:	N H Cohan, chairman

Sentinel Products Corporation

Address:	70 Airport Road, Hyannis, MA 02601-1416
Tel:	+1 508 775 5220
Fax:	+1 508 771 1554
Products:	PE film, foam seating products, trim components
Contact:	J D Bambara, president
Plants:	US (four)

Shawnee Products

Address: 501 Lake Shore Drive, PO Box 280, Kuttawa, KY 42055-6206
Tel: +1 502 388 2253
Fax: +1 502 388 9621
Products: trim components
Contact: G Lester, VP sales

Sherwood RTM Corporation

Address: 4043 Beck Avenue, PO Box 211, Louisville, OH 44641
Tel: +1 330 875 7151
Fax: +1 330 875 7153
Products: glass fibre parts produced by resin transfer moulding (RTM)
Contact: Greg Brookes, sales manager

Siegel-Robert Inc

Address: 12837 Flushing Meadows Drive, St Louis, MO 63131-1830
Tel: +1 314 965 2444
Fax: +1 314 965 2383
Products: exterior and interior trim, door handles, bezels, body parts, instrument panels and consoles
Customer: Chrysler
Contact: H B Anderson, CEO

Solvay Automotive

Address: 2565 W Maple Road, Troy, MI 48084-7114
Tel: +1 248 435 3300
Fax: +1 248 435 3957
Products: blow moulded components, including seat backs and fuel tanks
Customers: Chrysler (fuel tanks), Ford (seat backs)
Contact: N Johnston, president

Spartan International Inc

Address: 1845 S Cedar Street, Holt, MI 48842-1760
Tel: +1 517 694 3911
Fax: +1 517 694 7952
Products: exterior trim and mouldings
Contact: B Krauss president

Spaulding Composites Company

Address: One Monogram Place, PO Box 1745, Rochester, NH 03866-1748
Tel: +1 603 332 0555
Fax: +1 603 332 5357
Products: engine transmission components
Contact: Janet Guertin, sales manager
Plants: US (four)

Sperry Rubber and Plastics Company Inc

Address:	9146 US Navy Highway 52, Brookville, IN 47012-9657
Tel:	+1 765 647 4141
Fax:	+1 765 647 3302
Products:	body and trim components

Steere Enterprises Inc

Address:	289 Commerce Street, Tallmadge, OH 44278
Tel:	+1 330 633 4926
Fax:	+1 330 633 3921
Products:	clean air ducting
Customer:	Chrysler
Contact:	J Johnson, sales and marketing manager

Strongwell

Address:	400 Commonwealth Avenue, PO Box 580, Bristol, VA 24203
Tel:	+1 545 645 8000
Fax:	+1 545 645 8312
Products:	reinforced polyester, vinyl ester and epoxy components
Contact:	E Street, corporate marketing manager

Talon Automotive Group

Address:	900 Wilshire Drive, Suite 203, Troy, MI 48084
Tel:	+1 248 362 7600
Fax:	+1 248 362 7612
Products:	body parts, bumpers, door systems and trim, seats and seating components, interior trim, headliners, instrument panels and consoles

Tech Group Inc

Address:	14677 N 74th Street, Scottsdale, AZ 85260
Tel:	+1 480 948 6130
Fax:	+1 480 951 4882
Products:	injection moulded components
Contact:	S K Ohlmann, president & CEO
Plants:	13 worldwide

Teleflex Fluid Systems

Address:	1 Firestone Drive, Suffield, CN 06078-2611
Tel:	+1 860 668 1285
Fax:	+1 860 668 2353
Products:	fuel lines
Customers:	Ford, GM
Contact:	D S Boyer

Thermoplastics Inc

Address: 1400 S Industrial Drive, Mishawaka, IN 46544
Tel: +1 219 256 0277
Fax: +1 219 255 2579
Products: injection moulded body components
Contact: T Kellar, president

Thermotech

Address: 1202 Fifth Street S, Hopkins, MN 55343
Tel: +1 612 933 9400
Fax: +1 612 933 9412
Products: injection moulded components
Contact: R Radunz, president
Plants: US (three)

Thomson Industries Inc

Address: 2 Channel Drive, Port Washington, NY 11050
Tel: +1 516 883 8000
Fax: +1 516 883 9039
Products: sleeve bearings
Contact: L T Kontonickas, VP sales and marketing

Thompson International

Address: 801 John C Watts Drive, Nicholasville, KY 40356
Tel: +1 606 887 2446
Fax: +1 606 887 6299
Products: hub caps, automotive trim
Customer: Volkswagen (hub caps)
Contact: M Bennet, plant manager
Plants: US (four)

Titeflex Corporation

Address: 170 Tapley Street, Springfield, MA 01104
Tel: +1 413 739 5631
Fax: +1 413 781 7593
Products: plastic hose and pipe
Contact: Jas Marlatt

Toledo Molding and Die Corporation

Address: 1429 Coining Street, Toledo, OH 43612-2932
Tel: +1 419 470 3950
Fax: +1 419 470 3976
Products: interior trim, instrument panels and consoles, lighting components, injection moulded auto components
Contact: M Harbaugh, executive VP
Plants: US (three)

Trend Plastics Inc

Address:	1480 Attebury Lane, San Jose, CA 91531
Tel:	+1 408 432 9600
Products:	injection moulded components
Contact:	B Cavallini, president
Plants:	US (two)

Triple S Plastics Inc

Address:	14320 Portage Road, PO Box E, Vicksburg, MI 49097-9704
Tel:	+1 616 649 0545
Fax:	+1 616 649 3427
Products:	body, electrical/electronic, engine, seating and trim components
Contact:	V Valentine Jr, president

Truck-Lite Company Inc

Address:	310 E Elmwood Avenue, Falconer, NY 14733
Tel:	+1 716 665 6214
Fax:	+1 716 665 6403
Products:	interior and exterior light fittings
Contact:	R E Ives, VP marketing

UFE Inc

Address:	1850 S Greeley Street, Stillwater, MN 55082-0007
Tel:	+1 651 351 4100
Fax:	+1 651 351 4272
Products:	injection moulded braking, electrical/electronic, exhaust, fuel system, engine, passenger restraint, seating, steering and suspension components
Contact:	M N Kellogg, president
Plants:	US (three), Singapore (one)

Ultra Tool and Plastics Inc

Address:	500 Commerce Drive, Amherst, NY 14228-2390
Tel:	+1 716 691 6223
Fax:	+1 716 691 7888
Products:	body, engine and trim components
Contact:	R Ljungberg, president and CEO

Uretech International Inc

Address:	21200 Luckey Road, Luckey, OH 43443
Tel:	+1 419 833 4511
Fax:	+1 419 833 8318
Products:	PUR wheel styling
Customer:	Chrysler
Contact:	S Murray, CEO

Venture Industries Corporation

Address: 33662 James J Pompo Drive, Fraser, MI 48026-3466
Tel: +1 810 293 9060
Products: injection moulded interior trim panels
Customer: GM
Contact: Larry Winget, president

Victor Plastics Inc

Address: 2135 B Avenue, Victor, IA 52347
Tel: +1 319 647 3151
Fax: +1 319 647 3329
Products: injection moulded components
Contact: J Kubu, president
Plants: US (three)

Walbro Corporation

Address: 6242 Garfield Avenue, Cass City, MI 48726-1325
Tel: +1 517 872 2131
Fax: +1 517 872 2301
Product: fuel tanks
Contact: F E Bachiero, CEO

Webasto Sunroofs Inc

Address: 2700 Product Drive, Rochester Hills, MI 48309
Tel: +1 248 853 2270
Fax: +1 248 853 2279
Products: sunroofs
Customers: Ford (largest)
Contact: K Adams, VP operations

Webster Plastics

Address: 83 Estates Drive West, Webster, NY 14580
Tel: +1 716 425 7000
Fax: +1 716 425 7238
Products: transmission components
Customer: Ford
Contact: J Czop, sales manager

Wellman Automotive Inc

Address: 1 Progress Road, Shelbyville, IN 46176
Tel: +1 317 398 4411
Fax: +1 317 392 5461
Products: fan components

Wickes Manufacturing Company

Address:	3340 Ocean Park Boulevard, Santa Monica, CA 90405
Tel:	+1 310 452 0161
Products:	bumper systems and other automotive components
Customer:	GM

Windsor Plastics

Address:	601 N Congress Avenue, Evansville, IN 47716-5109
Tel:	+1 812 473 6151
Fax:	+1 812 473 6320
Products:	grilles, other injection moulded passenger restraint and trim components
Contact:	E Lehmann, president & CEO
Plants:	US (four)

Worthington Custom Plastics Inc

Address:	1111 W Long Lake Drive, Troy, MI 48099
Tel:	+1 248 641 5959
Fax:	+1 248 641 9678
Products:	radiator grilles, other exterior and interior components
Contact:	J Biafore, VP Sales
Plants:	US (seven)

Zehrco Plastics

Address:	5502 Washington Avenue, Ashtabula, OH 44004
Tel:	+1 440 998 5774
Fax:	+1 440 992 2430
Products:	GFR, SMC and BMC auto components
Contact:	J Danner Jr, CEO

13.2 European manufacturers of plastic automotive components

Belgium

OVP-Overpelt-Plascobel NV

Address: Fabriekstraat 145, B-3900 Overpelt
Tel: +32 11 660711
Fax: +32 11 660712
Products: moulded plastic parts
Contact: I Marechal, general manager

Philips Plastics Lommel

Address: A Philipstraat 4, B-3920 Lommel
Tel: +32 11 559815
Fax: +32 11 559983
Products: moulding of thermoplastics and thermosets up to 7 kg and 5 kg, respectively
Contact: S Glasbergen, general manager

Recticel NV SA

Address: Plejadenlaan 15, B-1200 Brussels
Tel: +32 2 7751811
Fax: +32 2 7751990
Products: PUR foam for seats and PUR skins for instrument panels

Solvay Automotive (SAGEM)

Address: Rue du Prince Albert 33, 1050 Bruxelles
Tel: +32 2 509 6111
Fax: +32 2 509 7240
Products: fuel tanks, spoilers, consoles, bumpers, seat trim
Contact: A Collard, marketing director
Plants: Brazil, France (2), Germany, Spain (2), UK, US

Stuctuplas Deprez

Address: Oudelepersestraat 75, B-8870 Izegem
Tel: +32 51 331611
Fax: +32 51 487744
Products: exterior trim parts
Contact: H van Ermen, managing director

Vitalo NV

Address: Bruggesteenweg 7, B-8760 Meulebeke
Tel: +32 51 487721
Fax: +32 51 487744
Products: injection and compression moulding; dashboard parts, watershield foams, acoustic linings
Contact: P Lichtherte, general manager

CZECH REPUBLIC

Delphi Packard Electric Systems

Address: Mladaboleslavska 692, 29421 Bela pod Bezdezem
Tel: +420 326 92513
Fax: +420 326 92512
Products: power and signal systems
Contact: Mr Miracky, marketing director

G M sro

Address: Smetanovo nabr. 498, 682 24 Vyskov
Tel: +420 507 21358
Fax: +420 507 21746
Products: injection moulded automotive components
Contact: Ing Eduard Casek

Gumotex AS

Address: Mladeznicka 3, 69575 Breclav
Tel: +420 627 314111
Fax: +420 627 322909
Products: seat parts, sun visors, foam sets, interior trim
Contact: J Kaluzik, managing director

Mechanika Prostejov vd

Address: Za Dvorakovou ul, 796 86 Prostejov
Tel: +420 508 25611
Fax: +420 508 23391
Products: miscellaneous automotive parts
Customer: Skoda

Meritor LVS Liberec AS

Address: Jestedska 90, 460 08 Liberec
Tel: +420 48 48 5229 111
Fax: +420 48 48 5432
Products: window regulators, seat recliners and adjusters, door handles
Contact: automotive marketing

Petri Parts sro

Address: Hlavni Ulice, 57374 Dolni Kalna
Tel: +420 438 942901
Fax: +420 438 942902
Products: plastic injection moulded parts for interior and exterior trim, complete door panel systems, interior panels with textile coverings, steering wheels, airbag modules
Contact: automotive marketing

Plastik HT AS

Address: Masarykova 194, 346 21 Horsovsky Tyn
Tel: +420 188 2711
Fax: +420 188 2594
Products: injection moulded automotive components
Contact: Jiri Heriam, marketing director

DENMARK

Indu-Plast Production ApS

Address: Vesterbro 67, 8970 Havadal
Tel: +45 864 705 11
Fax: +45 864 708 62
Products: vacuum formed & pressed instrument panels and front grilles
Contact: C Steen, director

FRANCE

A R C Industrie

Address: Chemin du Moulin à Vent, F-33640 Portets
Tel: +33 56 67 06 99
Fax: +33 56 67 07 55
Products: bodywork, chassis and suspension components

A T M C (Ateliers Materiaux de Synthese) Sarl

Address: ZI Chef de la Baie, Ave du Président Wilson, F-17043 La Rochelle Cedex
Tel: +33 5 46 43 53 23
Fax: +33 5 46 43 00 58
Products: composite automotive parts
Customer: Renault
Contact: Michel Golla, commercial director

Azoulay SA (Ets)

Address:	ZI 6 rue Robert Schuman, F-77330 Ozoir-la-Ferrière
Tel:	+33 1 64 40 05 67
Fax:	+33 1 64 40 03 93
Products:	body panels and other composite components
Customer:	Renault
Contact:	Maz Azoulay, chairman

Bailly Comte Vercars

Address:	Zac Les Echavagres, F-38163 St Marcelin
Tel:	+33 78 53 67 21
Fax:	+33 78 53 90 22
Contact:	C Roizant, general manager
Products:	valves, gears, PU axles, hydraulic reservoirs, tank caps
Customers:	Peugeot, Volvo, GM, Opel, Citroën, Renault, NedCar
Contact:	F Haiblet, marketing manager

Boilin Plastique SA

Address:	Allee Lorrain, F-21660 Ropuvray
Tel:	+33 3 80 64 71 23
Fax:	+33 3 80 64 77 77
Customers:	Renault
Contact:	P Margueron, commercial director

Bourbon Fabi Automobile

Address:	29 rue du Boeuf, F-78300 Poissy
Tel:	+33 1 30 65 97 55
Fax:	+33 1 30 74 10 00
Products:	lighting consoles, wheel covers, air vents, emblems
Customers:	Renault, Citroën, Peugeot, Honda
Contact:	J Remonnay, marketing manager
Plants:	France (3)

Britax Geco SA

Address:	88 avenue de Fontainebleu, F-77310 Saint Forgeau Ponthierry Cedex
Tel:	+33 1 60 65 22 00
Fax:	+33 1 60 65 22 39
Products:	external cladding, bumpers, licence plates, mirrors, sun roofs, radiator grilles, internal trim, instrument panels
Customers:	Renault, Peugeot, Citroën, RVI
Contact:	J-C Descroy, marketing manager

Cipa Industrie SA

Address:	10 rue Charlemagne, BP, F-88500 Bruyères
Tel:	+33 29 50 18 44
Fax:	+33 29 50 22 30
Products:	rear view mirrors
Contact:	J M Darbous, managing director

Draftex Industries SA

Address:	8 rue Edmond Poillot, Parc les Propylées, BP 839, F-28011 Chartres Cedex
Tel:	+33 2 37 24 22 00
Fax:	+33 2 37 24 44 69
Products:	window seals, plastic parts
Contact:	R Gresson, commercial director

Dreux-Renault SA

Address:	ZI Nord, BP 217, F-28104 Dreux Cedex
Tel:	+33 2 37 50 32 30
Fax:	+33 2 37 50 32 01
Products:	plastic components
Customers:	Volvo, NedCar, Renault
Contact:	D Bargary, marketing manager
Plants:	France (2)

EACP

Address:	Z1, Place Royale, F-78230 Le Pecq
Tel:	+33 1 34 51 81 81
Fax:	+33 1 34 51 83 60
Products:	wings and other thermoplastic interior and exterior components
Customers:	Renault, PSA, Volkswagen, GM
Contact:	J Guillot, chairman
Plants:	A total of 8 in France, Spain, Czech Republic, UK and US

EMC Européenne de Materiaux Composites

Address:	9 rue du Mont-Doré, F-75017 Paris
Tel:	+33 1 42 93 49 80
Fax:	+33 1 40 08 02 52
Products:	thermoset components
Customers:	Renault
Contact:	J-F Pagel, managing director
Plants:	France (4)

GE Plastics France

Address:	ZI Ste Guénault, BP 67, F-91002 Every Cedex
Tel:	+33 1 60 79 69 00
FAX:	+33 1 60 77 56 53
Products:	moulded plastic components
Customers:	Renault, Peugeot, Citroën, Ford, Fiat, GM, Volvo, BMW, Mercedes-Benz, Seat, VW, Audi
Contact:	P Goreaud, sales manager

General Motors France SA

Address:	56-68 avenue Louis Roche, F-92231 Gennevilliers Cedex
Tel:	+33 1 46 91 67 00
Fax:	+33 1 40 80 72 24
Products:	miscelleaneous plastic parts
Contact:	J Simonnet, CEO

Griffine Enduction Division Automobile

Address:	34-41 rue du Capitaine Guynemer, F-92090 Paris La Défense Cedex
Tel:	+33 1 46 91 67 00
Fax:	+33 1 47 74 98 47
Products:	vinyl for dashboards and seats; interior and exterior trim
Customers:	Renault, Peugeot, Fiat, Volvo, DAF, Alfa Romeo, Lancia, Rover, Citroën, Ford, Honda, BMW, VW
Contact:	Pierre Grange, automobile manager
Plants:	France (2)

Hutchinson Département Piéces de Carosserie

Address:	59 rue Marius Aufan, F-92300 Levallois Perret
Tel:	+33 1 40 89 54 27
Fax:	+33 1 40 89 54 54
Products:	PU RIM body parts; bumpers, grilles, steps, wings, spoilers
Customers:	Renault, Iveco, Citroën, Peugeot, Volvo
Contact:	L Valla, sales manager

Inoplast SA

Address:	ZI de Désirat/Champagne BP 3, F-07340 Andance
Tel:	+33 4 75 69 45 45
Fax:	+33 4 75 34 28 29
Products:	moulded thermoplastic and thermoset automotive components
Customers:	all French automotive manufacturers, Volvo, Fiat
Contact:	Alain Marion, managing director

Le Profil International

Address:	1 rue Charles Edouard Jeanneret, F-78306 Poissy
Tel:	+33 1 39 22 3300
Fax:	+33 1 39 11 30 40
Products:	door frames, door inserts, consoles, bodyside mouldings, mudshields, bumpers, dashboard, interior trim
Customers:	BMW, Ford, Peugeot, Citroën, Renault, VW
Contact:	J Pasquereau, marketing manager
Plants:	France (4), UK (1), Spain (1)

Lhotellier Montrichaud

Address:	Saint-Julien-de-Chédon BP 17, F-41401 Montrichaud Cedex
Tel:	+33 2 54 71 12 12
Fax:	+33 2 54 71 12 12
Products:	thermoset automobile parts formed using low pressure SMC, RTM and thermoforming
Contact:	Bernard Schillewaert, director of industrial products division

Manzoni Bouchot SA

Address:	ZI du Plan d'Acier BP 9, F-39206 St Claude Cedex
Tel:	+33 1 84 41 35 00
Fax:	+33 1 84 45 60 96
Products:	rear view mirrors
Contact:	C Manzoni, commercial director

MBS Composites

Address:	42 rue Dutemple, F-62800 Liévin
Tel:	+33 21 44 87 87
Fax:	+33 21 29 44 22
Products:	composite components including mass production bumpers, leaf springs made from epoxy prepregs, engine airlets and monocoques for racing cars
Customers:	Bugatti, Renault, Peugeot, Citroën
Contact:	M Ganseman, managing director

Mecaplast SA

Address:	4-6 Avenue Prince Héréditaire Albert BP 689, F-98014 Monaco Cedex
Tel:	+377 92 05 52 52
Fax:	+377 92 05 68 69
Products:	interior trim, panels, hub caps, door handles, window winders, loudspeaker grilles, air vents, thermoplastic cylinder head covers
Customers:	Renault, Rover, Citroën, GM, Ford
Contact:	D Theron, marketing manager
Plants:	8 in Europe

Nobel Plastiques

Address: 41 rue des Trois Fontanot BP 206, F-92002 Nanterre
Tel: +33 1 46 95 3800
Fax: +33 1 46 95 38 02
Products: interior trim, sun roof, roof panel, parcel shelf and window trims. Bumpers and bumper trim, SMC grilles and mud guards
Customers: Renault, PSA, GM, VW, Ford, Seat, Rover, Volvo, Mercedes-Benz
Contact: P Garat, commercial director
Plants: France (2), Spain, Germany, Sweden, UK

Peugeot Citroën Industrie

Address: 9 avenue du Maréchal Juin, F-92336 Meudon la Forêt
Tel: +33 46 29 63 13
Fax: +33 46 29 63 94
Products: plastic moulding, prototype modelling
Customers: PSA, Renault, Rover, Jaguar
Contact: Emile Urbain, marketing manager
Plants: France (5)

Plas-Elec

Address: Rue des Campanules, F-77185 Lognes
Tel: +33 1 64 62 50 40
Fax: +33 1 60 17 02 47
Products: miscellaneous plastic components
Contact: G Schneider, chairman

Plastohm SA

Address: Rue Grange Morin, ZI Arnas, F-69400 Villefranche sur Saône
Tel: +33 4 74 81 74 81
Fax: +33 4 74 73 04 75
Products: control buttons, rear seat locks, window catches
Customers: Peugeot, GM, Renault, Citroën, PSA, Valeo, Bosch, Rockwell, SKF, Wabco
Contact: P Jenin, sales director
Plants: France (5)

Proner-Comatel

Address: 10 rue Maison Rouge, F-77437 Lognes Cedex 02
Tel: +33 16 60 06 80 00
Fax: +33 1 60 06 80 20
Products: plastic connectors
Customers: Peugeot, Renault
Contact: M Mathieu, managing director

Recticel SA

Address: 6 boulevard du Général Leclerc, F-92115 Clichy
Tel: +33 1 45 19 22 00
Fax: +33 1 45 19 22 01
Products: PU and PE foam seats, extruded or cold-cure moulded foam for seating, window encapsulation and interior trim
Customers: Citroën, Renault, Ford, Matra, GM, Alpine
Contact: J-P Hui Bon Hoa
Plants: France (6), Belgium

Solvay Automotive de France

Address: ZI du point-du-Jour, Avenue d'Angers BP 847, F-53032 Laval Cedex
Tel: +33 2 43 49 66 00
Fax: +33 2 43 53 27 01
Products: fuel tanks, body trim parts, bodyside mouldings, brake oil reservoirs, bumper armatures, reservoir tanks
Customers: Alpine, Chausson, Ford, Matra, Peugeot, Renault, Volvo, Honda, Citroën, Nissan, Jaguar, Land Rover
Contact: J Nanoux, marketing manager
Plants: France (4), UK

Sotira

Address: Zone Industrielle, F-53170 Meslay du Maine
Tel: +33 2 43 64 64 64
Fax: +33 2 43 98 70 72
Products: GFR body panels, spoilers, bumpers, sill panels made using ICS (RTM) process
Customers: Rover, Citroën, Peugeot, RVI, Ford, VW, Jaguar
Contact: J-L Guezennec, commercial director

Stradour Industries

Address: BP4, F-32730 Villecomtal-sur-Arros
Tel: +33 5 62 64 84 22
Fax: +33 5 62 61 81 06
Products: composite bodywork, bumpers and other components
Customers: Alfa Romeo, Peugeot, Renault, VW
Contact: Carlo Cappello, commerical director

Stratime Cappello Systems

Address: ZI, F-02600 Villiers Cotterêts
Tel: +33 3 23 96 06 50
Fax: +33 3 23 96 09 30
Products: RTM composite automobile components
Contact: Carlo Cappello, commerical director

Stratinor

Address: ZI Magre 35 rue Santos Dumont, F-87000 Limoges
Tel: +33 5 55 31 84 48
Fax: +33 5 55 31 30 67
Products: thermoset automotive components
Contact: Guy Audran, commercial director

Taracell France

Address: ZI du Pont d'Aspach BP 28, F-68520 Burnhaupt-le-Haut
Tel: +33 3 89 83 13 00
Fax: +33 3 89 48 78 43
Products: PP foam products
Contact: Thierry Floureux, sales manager

Webasto Systèmes Carrosserie

Address: ZI le Guittion, F-85700 Les Châteliers Châteaumur
Tel: +33 2 51 66 71 71
Fax: +33 2 51 92 27 19
Products: sunroofs and fittings

GERMANY

AIK Faserverbundtechnik GmbH

Address: Otto Hahn Strasse 5, D-34123 Kassel
Tel: +49 561 5801 0
Fax: +49 561 5801 252
Products: fibre reinforced composites
Contact: Roland Runge, director

A Kayser Automotive Systems GmbH

Address: Hullerser Landstrasse 43, D-37574 Einbeck
Tel: +49 5561 7902-0
Fax: +49 5561 7902 90
Products: valves, filters, tubing
Contact: Dipl. Kfm Dr Klaus Ammermann, managing director

AKT Altmärker Kunststoff-Technik GmbH & Co KG

Address: Stendaler Chaussee 3-5, D-39638 Gardelegen
Tel: +49 3907 540
Fax: +49 3907 6356
Products: plastic parts for car interiors: consoles, air bag housings; radiator grilles, exterior trim
Contact: Dieter Heyer, director

Alkor GmbH Kunststoffe

Address: Morgensternstrasse 9, D-81479 München
Tel: +49 89 74917-0
Fax: +49 89 791 4613
Products: calendered and extruded films and foils for construction, packaging. TPO and PVC/ABS foils for instrument and door panel skins, headliners, parcel shelves
Plants: Germany (3)

Backhaus & Co GmbH

Address: Waldheimstrasse 8, D-58566 Kierspe
Tel: +49 2359 906-0
Fax: +49 2359 906 197
Products: articles from reinforced and filled phenolic resins for the automotive sector by injection moulding
Contact: Norbert Schmidt, managing director

BMW AG

Address: Ohmstrasse 2, D-84030 Landshut
Tel: +49 871 702 2000
Fax: +49 702 2845
Products: system supplier to the car industry: cockpits, consoles, interior linings, bumpers and other exterior parts
Customers: BMW, DaimlerChrysler and Porsche
Contact: Dr Bernd Woite

BWR Fahrzeugsysteme GmbH

Address: Werkstrasse 2, D-76437 Rastatt
Tel: +49 8222 599-0
Fax: +49 7222 599 237
Products: thermoplastic and thermoset composites
Contact: Dr Georg Falkenstein

Carl Freudenberg

Address: Zwischen den Dämmen, D-69469 Weinheim
Tel: +49 6201 80-0
Fax: +49 6201 69300
Products: various plastic and rubber parts for the automotive industry
Contact: Dr Reinhard Freudenberg, CEO

ContiTech Holding GmbH

Address: Büttnerstrasse 25, D-30165 Hannover
Tel: +49 511 938-02
Fax: +49 511 9382766
Products: technical products from plastics and elastomers, upholstery, hoses, seals and roofing
Plants: Germany (17), France, Italy, Spain, Slovak Republic, Sweden, Mexico

C F Maier Kunstharzwerk GmbH

Address: Wiesenstrasse 37-43 and 24-44, D-89551 Königsbronn
Tel: +49 7328 81-0
Fax: +49 7328 81 210
Products: long fibre reinforced components
Contact: Dipl. Ing. Markus Maier, director

Delphi Automotive Systems

Address: Stahlstrasse 42-44, D-65428 Rüsselsheim
Tel: +49 6142 914-414
Fax: +49 6142 914 400
Products: instrument panels, airbag modules, steering wheels, door linings, door modules, seat systems, headlamp systems, brake lights

Dunlop Tech GmbH

Address: Birkenhainer Strasse 77, D-63450 Hanau
Tel: +49 6181 68-04
Fax: +49 6181 68-1283
Products: hot and cold cure foam articles, elastic wheel covers, tanks, fenders
Contact: Ulrich Weinreuter, director

EAH Naue GmbH & Co KG

Address: Brandenburger Ring 2-4, D-32339 Espelkamp
Tel: +49 5772 48-0
Fax: +49 5772 1411
Products: polyester foam and foam laminates; upholstery, car interiors
Contact: Friedrich Wilhelm Naue, managing director

Elastogran GmbH

Address: Landwehrweg, D-49448 Lemförde
Tel: +49 5443 12-0
Fax: +49 5443 122201
Products: raw materials, semi-finished and finished PUR foam and RIM and R-RIM products; TPE-U
Contact: Gerhard Hellmann, managing director

EMPE Werke Ernst Pelz GmbH & Co KG

Address: Dieselweg 10, D-82538 Geretsried
Tel: +49 8171 381-0
Fax: +49 8171 381 211
Products: plastic interior trim
Contact: Peter F Strohmeier, director

Ensinger GmbH & Co

Address: Rudolf Diesel Strasse 8, D-71154 Nufringen
Tel: +49 7032 819-0
Fax: +49 7032 819 100
Products: injection moulded parts and extruded precision profiles in engineered plastics, GF-thermoplastics and thermosets
Contact: Klaus Ensinger, director

FS Fehrer GmbH & Co KG

Address: Heinrich Fehrer Strasse 1-3, D-97381 Kitzingen
Tel: +49 9321 302-0
Fax: +49 9321 302 348
Products: upholstery foam products; structural and interior trim parts as well as upholstery modules for car interiors
Contact: C Fehrer, managing director

Filterwerk Mann & Hummel GmbH

Address: Hindenbergstrasse 45, D-71638 Ludwigsburg
Tel: +49 7141 98-0
Fax: +49 7141 98 2545
Products: complete air intake manifolds, oil filter modules, air-oil and fuel filters
Contact: W Witte, managing director

Fritzmeier Composite GmbH & Co

Address: Heimatweg 1, D-83052 Bruckmühl
Tel: +49 8062 9020
Fax: +49 8062 902 39
Products: roofing, sleeping cabins and spoilers for commercial vehicles, interior decorative panels for cars, trucks in PUR, technical parts in SMC, RTM and GF-T; carbon fibre technology
Contact: Helmuth Maier

Gefinex GmbH

Address: Rote Erde 6, D-33803 Steinhagen
Tel: +49 5204 1000-0
Fax: +49 5204 1000 75
Products: energy absorbing PP foam parts made by steam chest moulding; extrusion of PP foams and vacuum forming for car interiors: bumper cores, door crash pads, pillar covers, sun visors, kneebolsters, roofing, parcel trays; direct lamination of EPP parts

Grammer AG

Address: Köferinger Strasse 9-13, D-92245 Kümmersbruck
Tel: +49 9621 880-0
Fax: +49 9621 880 130
Products: PE, PP, PUR foam products; seat systems; car interior parts

Greiner GmbH

Address: Galgenbergstrasse 9, D-72622 Nürtingen
Tel: +49 7022 501-0
Fax: +49 7022 501311
Products: seals and foam products for the car industry
Contact: Manfred Frik, director

Hella KG Hueck & Co

Address: Rixbecker Strasse 75, D-59557 Lippstadt
Tel: +49 2941 38-1
Fax: +49 2941 38 7133
Products: front and rear lamp systems
Contact: Dipl. Ing. R Röpke
Plants: Germany (4), Austria, Finland, Spain, UK, USA, Portugal, Philippines, Australia, New Zealand

HT Troplast AG

Address: Kaiserstrasse, D-53840 Troisdorf
Tel: +49 2241 85-0
Fax: +49 2241 85 2793
Products: PE and polyolefin foams in rolls and blocks; polyvinylbutyral (PVB) films for glazing
Contact: Werner Heep, director

Hugo Görner GmbH

Address: Friedrichstrasse 100, D-73430 Aalen
Tel: +49 7361 9595-0
Fax: +49 7361 6094
Products: rear-, brake- and head-light lenses in plastics, metalised plastics, injection moulded plastic parts
Contact: Hans Dieter Meier, managing director

Hübner Gummi- und Kunststoff GmbH

Address: Agathofstrasse 15, D-34123 Kassel
Tel: +49 561 5701-0
Fax: +49 5701 158
Products: PUR integral foam, R-RIM/RIM integral foam
Contact: Dipl. Ing. Reinhard Hübner, director

IBS Brocke GmbH

Address: Bergstrasse 29, D-51597 Morsbach
Tel: +49 2294 697-0
Fax: +49 2294 697 155
Products: technical plastic parts for car interiors, in-mould decorated pillar trim, glove box modules, window frames, engine covers with noise absorption, luggage compartment linings
Contact: Dr Berthold Schmitz, director
Plants: Germany (5)

Illbruck Automotive GmbH & Co KG

Address: Sägerbäume 9, D-38448 Wolfsburg
Tel: +49 5363 40010
Products: PUR foam parts for sealing and acoustical applications; EPP particle foam parts, such as door crash pads and car toolboxes
Contact: Frank Schwarze

ISL Schaumstoff-Technik GmbH

Address: Industriestrasse 17, D-68519 Viernheim
Tel: +49 6204 706 135
Fax: +49 6204 706 160
Products: crash pads, child's seats, bumper cores, head rests, parcel shelves in EA, EPP and EPE foams
Contact: Georg Heinlein, managing director

Johnson Controls Interiors GmbH

Address: Konsum Strasse 45, D-42285 Wuppertal
Tel: +49 202 34-0
Fax: +49 202 34 1872
Products: door panels, instrument panels, middle consoles, sun visors, door seals, laminated parts
Contact: Bernd Lattemann, director
Plants: Germany (6), France, UK, Hungary (2), Spain, Costa Rica, Sweden

Kautex Textron GmbH

Address: Kautexstrasse 52, D-53229 Bonn
Tel: +49 228 488-0
Fax: +49 28 488 371
Products: sandwich plastic fuel tanks
Contact: Dr Wolfgang Theis, director

Köver GmbH & Co KG, Metall- und Kunststoffverarbeitung

Address: Estetalstrasse 45-47, D-21614 Buxtehude
Tel: +49 4161 728-0
Fax: +49 4161 728 155
Products: thermoplastic automotive parts
Contact: Mr Wotz, managing director

Magna Exterior/Interior Systems GmbH

Address: Feldstrasse 12, D-63179 Obertshausen
Tel: +49 6104 706-0
Fax: +49 6104 706 411
Products: system supplier of instrument panels; PP- PUR- and PVC foam products
Contact: Thomas Saalwächter, managing director
Plants: Germany (5), UK, Belgium

Magna Zippex Autotechnik GmbH

Address: Eugen Zipperle Strasse 12, D-74374 Zaberfeld
Tel: +49 7046 201-0
Fax: +49 7046 201 101
Products: seals, sun visors, encapsulated windows
Contact: Hans Peter Glatt, director

M Faist GmbH & Co KG

Address: Michael-Faiststrasse 11-15, D-86381 Krumbach
Tel: +49 8282 93-0
Fax: +49 8282 93-299
Products: NVH products
Contact: Micheal Faist, managing director

Mannesmann VDO AG

Address: Sodener Strasse 9, D-65824 Eschborn (Frankfurt)
Tel: +49 6196 87-0
Fax: +49 6196 8 6571
Products: cockpit and fuel modules, air intake manifolds, air conditioning control parts

Menzolit-Fibron GmbH

Address: Herman Beutenmüller Strasse 11-13, D-75015 Bretten
Tel: +49 7252 509-0
Fax: +49 7252 509 196
Products: glass fibre reinforced UP resins
Contact: Harald Mischo

Mitras Industries

Address: Werkstrasse 2, D-76437 Rastatt
Tel: +49 7222 599-0
Fax: +49 7222 599237
Products: parts in SMC/BMC
Contact: Dr Georg Falkenstein

Olho-Technik OHG

Address: In den Fichten 24, D-32584 Löhne
Tel: +49 5731 4807-0
Fax: +49 5731 41433
Products: technical and decorative plastic parts and systems; air grilles, locks, switches, gears
Contact: Werner Oleff, director

Peguform GmbH

Address: Schlossmattenstrasse 18, D-79268 Bötzingen
Tel: +49 7663 61-0
Fax: +49 7663 61-155
Products: system supplier; front and rear systems, instrument panels
Contact: Werner Deggim, director
Plants: Germany (4), France (4), Spain (4), Czech Republic (4), Brazil

Petri AG

Address: Bahnweg 1, D-63743 Aschaffenburg
Tel: +49 6021 65-0
Fax: +49 6021 98583
Products: steering wheel air bags, air bag modules and systems, steering wheel shrouds
Contact: Alexander Petrie, director
Plants: Germany, Brazil, USA, Czech Republic, Poland, Romania, South Africa

Philippine GmbH & Co Technische Kunststoffe AG

Address: Max Schwarz Strasse 23, D-56112 Lahnstein
Tel: +49 2621 173-0
Fax: +49 2621 173 80
Products: PUR integral and semi rigid foams; energy absorbing parts in EPP and EPE particle foams; PUR foams for car energy management; Vulkolan PUR products
Contact: Klaus Eckhardt

Phoenix AG

Address: Hannoversche Strasse 88, D-21079 Hamburg
Tel: +49 40 7667-1
Fax: +49 7667 2211
Products: car parts in PUR foams, hoses, metal rubber parts, coated textiles
Contact: Dr Ludwig Horatz, director
Plants: France, Spain, Italy, Belgium, The Netherlands, UK, Sweden, Austria, USA

Plastic Omnium GmbH

Address: Max Planck Strasse 27, D-61184 Karben
Tel: +49 6039 4804-0
Fax: +49 6039 7000
Products: fuel tanks and fuel systems, air ducts, bumpers, door panels
Contact: Werner Probst, managing director

Recticel Automobil Systeme GmbH

Address: Rolandsecker Weg 30, D-53619 Rheinbreitbach
Tel: +49 2224 1802-0
Fax: +49 2224 1802 21
Products: Colo-Fast LM, aliphatic PUR instrument panel spray skin, PUR foam products for seating and car interior parts, window encapsulation
Contact: Rafael Thientont, managing director

Rehau AG + Co

Address: Rheniumhaus, D-95111 Rehau
Tel: +49 9283 77 2798
Fax: +49 9283 77 7725
Products: bumper systems, spoilers, decorative exterior trim, hoses, grilles, water tanks
Contact: Wolfgang Faber, automotive director

Reitter & Schefenacker GmbH & Co KG

Address: Eckenerstrasse 2, D-73730 Esslingen an Neckar
Tel: +49 711 3154-0
Fax: +49 711 3154 102
Products: exterior and interior mirrors, rear light systems, interior lighting, Bose car sound systems
Contact: Dr Alfred R Schefenacker, director
Plants: Germany (4), Hungary, USA

Rhein-Bonar Kunststoff-Technik GmbH

Address: PO Box 1425, D-68757 Hockenheim
Tel: +49 6205 2099-0
Fax: +49 6205 2099 54
Products: instrument panels, air ducts, air filter housings, interior trim, water tanks, hydraulic oil containers, plastic fuel tanks in polypropylene, polyethylene and polyamide
Contact: Kevin D Barber, managing director

Rieter Automotive Germany GmbH

Address: Im Mittelbruch, D-64380 Rossdorf Gunderhausen
Tel: +49 6071 491-0
Fax: +49 6071 491 218
Products: NVH foam products
Contact: Dr Pittman, managing director

Robert Bosch GmbH

Address: Alte Bundesstrasse 50, D-71332 Waiblingen
Tel: +49 7151 503-1
Fax: +49 7151 503563
Products: electric/electronic components and systems

Rütgers Automotive AG

Address: Westuferstrasse 7, D-45356 Essen
Tel: +49 201 3609-1
Fax: +49 201 3609 343
Products: brake and coupling liners
Contact: RA Christian H Molson, director

Schade GmbH & Co KG

Address: Königstrasse 57, D-58840 Plettenberg
Tel: +49 2391 62-0
Fax: +49 2391 62-100
Products: door modules, window seals, exterior decorative trim
Contact: Jürgen von der Heyden, director

Seeber Systemtechnik KG

Address: Flosshafenstrasse 40, D-67547 Worms
Tel: +49 6241 844-0
Fax: +49 6241 844 113
Products: injection moulded plastic parts for interiors

TRW Automotive GmbH

Address:	Hefner-Alteneck Strasse 11, D-63743 Aschaffenburg
Tel:	+49 6021 314-0
Fax:	+49 6021 314 1299
Products:	steering wheels, air bag covers, dashboard parts
Customers:	Lear Seat, Johnson Control, Recaro
Contact:	Thomas Penn, sales manager

Varta-Plastic GmbH

Address:	Industriestrasse 6, D-63607 Wächtersbach
Tel:	+49 6053 81-410
Fax:	+49 6053 81 500
Products:	wheel arch linings, parcel shelves, air ducting, window seals, consoles, luggage compartment lining systems
Customers:	BMW, VW, Skoda, Grammer, Johnson Controls, Magna, Lear Seating, VDO, Karmann, Mann & Hummel
Contact:	Bernd Renners, managing director

Veritas AG

Address:	Stettiner Strasse 1-9, D-63558 Gelnhausen
Tel:	+49 6051 821-0
Fax:	+49 6051 821 190
Products:	fuel line systems
Contact:	Peter Lorenz, marketing director

Waco Wachendorff GmbH & Co KG

Address:	Kradepohlsmühlenweg 16, D-51469 Bergisch Gladbach
Tel:	+49 2202 209-0
Fax:	+49 2202 209 171
Products:	car interior linings
Contact:	Dipl. Ing. Manfred Lindenberg, director

Walbro Automotive GmbH

Address:	Hertzstrasse 24, D-76275 Ettlingen
Tel:	+49 7243 108-0
Fax:	+49 7243 108 268
Products:	blow moulded HDPE fuel tanks
Contact:	Mr Schmeer, managing director

Walter Alfmeier GmbH & Co

Address:	Industriestrasse 5, D-91757 Treuchtlingen
Tel:	+49 9142 70 0
Fax:	+49 9142 70156
Products:	fuel supply systems, fuel tanks, filters, valves
Contact:	Ute Gebhardt, managing director

Wayand GmbH Kunststofferzeugnisse

Address: Zur Oberacht 3, D-55743 Idar- Oberstein
Tel: +49 6784 992-0
Fax: +49 6784 992 106
Products: grilles, spoilers, bumpers, instrument housings, engine covers
Contact: Hans-Jürgen Wayand, managing director

WOCO Industrie Technik GmbH

Address: Sprudelallee 19, D-63628 Bad Soden-Salmünster
Tel: +49 6056 78-0
Fax: +49 6056 78 212
Products: technical precision parts on thermoplastics and rubber

Woodbridge Foam GmbH

Address: Hessenring 32, D-64546 Mörfelden-Walldorf
Tel: +49 6105 200 60
Fax: + 49 200 660
Products: upholstery in PUR foam; foam backed parts, energy absorbing foam parts

ITALY

B M Industria Bergamasca Mobile SpA

Address: Via Kennedy 28, I-24060 Bagnatica (Bergamo)
Tel: +39 035 585426
Fax: +39 035 585409
Products: injection moulded plastic parts

Gruppo Plastico Industriale Srl

Address: Via della Liberta 30, I-10095 Grugliasco (TO)
Tel: +39 011 787373
Fax: +39 011 7803313
Products: injection moulded automotive components
Customers: Fiat, Alfa Romeo
Contact: L Aghemo, president

IAO Industrie Riunite SpA

Address: Str Torino 23, I-10043 Beinasco (TO)
Tel: +39 011 3972600
Fax: +39 011 3101074
Products: plastic and mechanical components; bumpers, instrument panels, steering wheels, car interior and exterior parts, modular and integrated door systems, rear lamps, suspension system parts
Contact: G Malvassora, managing director

ICS SpA (Industria Componenti Stampati)

Address: Via Bergamo, 24040 Canonica d'Adda (BG)
Tel: +39 02 909 4881
Fax: +39 02 909 4165
Products: injection moulded automotive components
Customers: Fiat, VW, Ford
Contact: M Aglialoro, marketing manager

Ilpca SpA

Address: Viale del Industria 37, I-21023 Megesso (Vaeresr)
Tel: +39 0332 787111
Fax: +39 0332 787358
Products: slush moulded PVC instrument panel skins
Contact: Mr Molenia, marketing

ITIB SpA

Address: Via Romiglia 9, I-25050 Paderno Franciecorte Brescia
Tel: +39 030 6858500
Fax: +39 030 6858559
Products: fuel hoses, fuel tanks and other containers

Lander SpA

Address: Via Rovigo 1, I-35010 Vigonza (Padova)
Tel: +39 04962 9622
Fax: +39 04962 9633
Products: composite auto components

Lys Fusion SpA

Address: Via Beauviermoz 22, I-11020 Hone (AO)
Tel: +39 0125 803321
Fax: +39 0125 803325
Products: injection moulded automotive components
Customer: Fiat
Contact: G Cantarini, chairman

Magneti Marelli SpA

Address: Viale Aldo Borletti 61/63, I-20011 Milano
Tel: +39 0297 227111
Fax: +39 0297 227355
Products: fuel delivery systems, exhaust systems, lighting, mirrors, instrument panels, electronics and aftermarket spare parts
Plants: 76 subsdiaries, 21 affiliates with 45 production sites

Pianfei SpA

Address: Via la Pira 25, I-10028 Trofarello Torino
Tel: +39 011 649 9632
Fax: +39 011 649 7517
Products: door trim, body trim, body panels, headliners
Customers: Fiat, BMW, DaimlerChrysler

Plastal ZCP

Address: Via Giuseppe Verdi 30, I-31046 Oderzo
Tel: +39 0442 8171
Fax: +39 0442 817202
Products: grilles, fenders, wheel trim, instrument panels, door panels, interior
Contact: Romeo Del Rosso, sales and marketing manager
Plants: Sweden (3)

Royalite Plastics Srl

Address: Via 4 Novembre 49, I-200212 Cuggiono
Tel: +39 02 972361
Fax: +39 02 97236257
Products: PVC/ABS foil for instrument panel skins and other interior linings
Contact: Natale Osnaghi, managing director

Saiag Plast SpA

Address: Via Asse Attiezato, I-03013 Ferentino
Tel: +39 0775 34591
Fax: +39 0775 348677
Products: bumpers, dashboards, handles, steering columns, shelves
Customers: BMW, Valeo, Renault, Behr, Saab
Contact: C Valetto, managing director
Plants: Italy (3)

Sistema Compositi

Address: Via Casilina, Km 57.5, Castellacio di Paliano (Frosinone)
Tel: +39 07755 38101
Fax: +39 07755 38143
Products: composite body panels
Contact: Mario Sarosso, CEO

Upca SpA

Address: Viale del Industria 37, I-21023 Megesso (Varese)
Tel: +39 0332 787111
Fax: +39 0332 787358
Products: slush moulded PVC instrument panel skins
Contact: Mr Molenria, marketing

The Netherlands

Caligen Europe BV

Address: Konijnenberg 59, NL-4825 BC Breda
Tel: +31 76 5780300
Fax: +31 76 5783051
Products: PUR foams; roof coverings, headrests, seals, seats, engine and luggage linings

Dynoplast BV

Address: Einsteinstraat 22, NL-6902 PB Zevenaar
Tel: +31 316 590100
Fax: +31 316 523983
Products: injection moulding; IMD; 2-component moulding; airbag covers

Helvoet BV

Address: Sportlaan 13, NL-3220 AA Hollevoetsluis
Tel: +31 181 331333
Fax: +31 181 331374
Products: moulder of engineering plastic, rubber and TPE parts

McKechnie Vehicle Components

Address: Noord Esmarkerrondweg 419, NL-7533 BL Enschede
Tel: +31 53 432 0046
Fax: +31 53 431 6922
Products: semi-finished and finished products for the car industry

Polynorm Automotive NV

Address: Amersfoortseweg 9, NL-3750 GM Bunschoten
Tel: +31 33 2989579
Fax: +31 33 2989007
Contact: W Spierings, managing director

van Nitrik Kunstoffprodukten BV

Address: Bosweg 2, NL-4645 RB Putte
Tel: +31 164 608800
Fax: +31 164 604190
Products: injection moulding of plastic and rubber parts
Contact: J J Tiedinga, general manager

Wientjes BV

Address: Produktieweg 9, NL-9300 AA Roden
Tel: +31 591 669666
Fax: +31 505 014890
Products: SMC/BMC and thermoplastic semi-finished and finished parts
Contact: B E M Wientjes, managing director

NORWAY

Dynoplast

Address:	PO Box 779 Sentrum, N-0106, Oslo
Tel:	+47 22 31 7000
Fax:	+4722 31 7856
Products:	truck interior parts, expansion tanks, fuel tanks, sunroof components, under-bonnet components, washer reservoirs

Hydro Raufoss Automotive

Address:	Plastics Department, PO Box 15, N-2831 Raufoss
Tel:	+47 61 15 1800
Fax:	+47 61 15 2052
Products:	bumper systems

Norsk Extruding

Address:	PO Box 115, N-3671, Notodden
Tel:	+47 35 01 1100
Fax:	+47 35 01 1658
Products:	cable clamps, body parts, hoses and tubing, interior trim, tanks and containers

Trelleborg Viking

Address:	PO Box A, N-3051, Mjondalen
Tel:	+47 32 23 2100
Fax:	+47 32 23 2299
Products:	blow moulded plastic parts, bumper systems

POLAND

Ferroplast Wytwaranie Czosi

Address:	Zamennych Zbigniew Rybieki, Swidwinnek 2, 78 200 Swidwin
Tel:	+48 961 52456
Fax:	+48 961 52749
Products:	miscellaneous automotive components
Contact:	Marian Starzak, president

Magneti Marelli Poland

Address:	U1 Gen M Zaruskeigo 11, 41-200 Sosnowiec
Tel:	+48 32 3 163840
Fax:	+48 3 1636618
Products:	fuel and oil pumps, injection systems, exterior parts, radiator, grilles, rear view mirrors, seats, window activators, on-board, instrumentation, lighting, control systems and air conditioning

Petri Parts Spols ka zo.o

Address: 58-405 Krzeszow
Tel: +48 7574 12039
Fax: +48 7574 441 20
Products: plastic injection moulded parts for interior and exterior trim, complete door panel systems, interior panels with textile coverings, steering wheels, airbag modules
Contact: automotive marketing

Pollena Warszawska Fabryka

Address: Tworzyw Sztuchnych, Marylywska 58, 03-042 Warszawa
Tel: +48 22 114471
Fax: +48 22 112769
Products: miscellaneous automotive components
Contact: Bogtan Samalak, director

Rieter Automotive Poland

Address: 01 Owslara 60 A, 40-780 Katowice
Tel: +48 32 252 1064
Fax: +48 252 7064
Products: insulating materials, sound deadeners, felts, interior trim, rear shelves
Contact: automotive marketing

TRW Polska SP zo.o

Address: Czestochowa, U1 Krotka 30, 42-201 Czestochowa
Tel: +48 34 361 8891
Products: steering systems
Contact: automotive marketing

PORTUGAL

Inapal-Industria SA

Address: Rua Estacoa de Araujo, Leca do Balio, 4465 Sao Mamedo de Infesta
Tel: +351 2943 9977
Fax: +351 2944 9901
Products: seat frames, bumpers, GFR parts, pedals
Customer: VW
Contact: A Bardosa Leo, managing director

Simoldes Plasticos Lda

Address:	AP 113, ZI, 3721 Oliveira de Azameis Codex
Tel:	+351 5668 5351
Fax:	+351 5668 6637
Products:	door panels, door pans, cable protectors, other trim, under engine fairing
Customer:	Renault
Contact:	J Pedro S Ramalho, marketing manager

Textil Manuel Goncalves SA

Address:	Campleos, 4800 Guimaroes
Tel:	+351 5357 4001
Fax:	+351 535 74011
Products:	PVC based interior trim coated fabrics, unsupported fabrics
Contact:	Carlos Pinheiro Vieira, technical director

SPAIN

Alcala Industrial SA

Address:	Aptdo 69, 28806 Alcala de Henares (Madrid)
Tel:	+34 91 888 1800
Fax:	+34 91 888 1858
Products:	bumpers, polyester and PVC mouldings
Customers:	Ford, PSA, Nissan, Seat, Suzuki
Contact:	F A Mella, general manager
Plants:	Spain (3)

Arto Iberica SA

Address:	Pol Ind Can Jardi, C Verdi 82 Apartado 51, 08191 Rubi (BA)
Tel:	+34 93 588 5502
Fax:	+34 93 697 0668
Products:	rear view mirrors, plastic gears, interior lights, other interior trim
Customers:	Seat, Renault
Contact:	J Gonzales Oliva, commercial director

Asientos Majosa SA

Address:	Valdemuel S/N, Epila (Zaragoza)
Tel:	+34 97 681 7055
Fax:	+34 97 681 7280
Products:	foam seats and seatbacks
Customers:	Ford, Opel, VW, Nissan

Autotex SA

Address:	Pl Can Trias, Miguel Servat S/N Apt 394, 08220 Terrassa (Barcelona)
Tel:	+34 93 780 5133
Fax:	+34 93 788 1889
Products:	interior trim, door panels, headliners, sound proofing, padding
Customers:	Renault, Opel, Ford, Seat
Contact:	E Salvador, marketing manager
Plants:	Spain (4)

Carrocera Castrosua

Address:	Ctra de la Coruna km 59.9, 15890 Santiago de Compostela (La Coruna)
Tel:	+34 98 158 2411
Fax:	+34 98 158 2469
Products:	exterior and interior trim, bumpers, door panels, dashboards
Contact:	J Castro, managing director

Catalana de Enfeltrados SA

Address:	Ausias March 16-18, 08010 Barcelona
Tel:	+34 93 302 7595
Fax:	+34 93 302 2329
Products:	headliners, trim parts, door panels, parcel shelves
Contact:	M Melero, marketing manager

Dalphi-Metal Espana SA

Address:	Campo de las Naciones, 280420 Madrid
Tel:	+34 91 721 1314
Fax:	+34 91 721 0605
Products:	polypropylene, polyurethane, steering wheels, airbags, eurobags
Customers:	Ford, Renault, PSA, Volvo, VW, Opel
Contact:	J M G Ponte, sales and marketing director

Delphi Componentes SA

Address:	Pl El Sequero, 26509 Agoncillo (La Rjoja)
Tel:	+34 94 148 8100
Fax:	+34 94 146 8200
Products:	exterior trim, radiator grilles, spoilers, head restraints, seat and seat accessories, dashboards, air conditioning equipment, heaters
Contact:	Juan Quadra, managing director

Ficosa International SA

Address:	Gran Via Carlos III 98-5a, 08028 Barcelona
Tel:	+34 93 330 9814
Fax:	+34 93 490 1063
Products:	mirrors, sun visors, fuel tanks and caps, door handles
Contact:	J M Pujol, president
Plants:	Spain (6), Portugal, France

Iberofan Plasticos SA

Address:	PL Miralcampo-Parceefa 15 & 17, 19200 Azuqueca de Henares (Guadalajaroo)
Tel:	+34 949 26 3642
Fax:	+34 949 26 4833
Products:	seats, plastic gears, bushings, consoles, tanks
Customers:	Renault, Ford
Contact:	F Catalan, managing director

Iberplasticos SA

Address:	Ctra Madrid-Barcelona Km 26, Aptdo 99, 28814 Alcala de Henares (Madrid)
Tel:	+34 91 889 0700
Fax:	+34 91 880 7861
Products:	bumpers, licence plates, radiator grilles, interior trim, ashtrays, consoles
Customers:	GM, Ford, Renault
Contact:	R Regulez Pardo, sales director

Indepol SA

Address:	Ctra Santpedor a Navareles Pol Ind, 08251 Santpedor (Barc)
Tel:	+34 93 827 2672
Fax:	+34 93 827 2681
Products:	exterior trim, fenders, handles, levers, foam, seat parts, soundproofing
Customers:	Renault, Ford
Contact:	Automotive marketing

Industrias Regard SA

Address:	L1011 208, 08005 Barcelona
Tel:	+34 93 309 9816
Fax:	+34 93 300 4064
Products:	cable terminals, headlight trims, plastics bushings and plastic gears, moulded polyurethane foam parts, plastic tubes, locks and locking mechanism
Contact:	Automotive marketing

ITT Automotive Spain

Address:	Ctra Andalucia Km 10, 28021 Madrid
Tel:	+34 91 795 2662
Fax:	+34 91 797 2785
Products:	electrical systems, wiper systems, rearlights, electronic switches, sensors
Contact:	J M Gonzales, managing director

ITW Espana SA

Address: Ctra de Ribes Km 31.7, 08520 Les Franqueses (Barcelona)
Tel: +34 93 844 3125
Fax: +34 93 849 7194
Products: door panels, plastic exterior and interior trim, boots, plastic clips, bushings and gears, moulded plastic parts, door handles, grab handles
Contact: J Baltz, managing director

Laboratorios Radio GH SA

Address: Ctra Valencia-Ademuz Km 28, 46160 Liria (VA)
Tel: +34 96 279 9100
Fax: +36 96 279 9106
Products: bodywork, exterior trim, mirrors, radiator grilles, door and window handles and winders, hub caps, consoles
Customers: Ford, SEAT
Contact: Glavez Martinez, managing director

Megaplast SA

Address: Ctra Bilbao-Galdacano 22, 48004 Bilbao
Tel: +34 94 473 0277
Fax: +34 94 412 8350
Products: grilles, hub caps, interior trim, dashboards, steering columns, plastic gears, bushings, moulded parts for air conditioning
Customers: Renault, Peugeot
Contact: M Garcia Alcaraz, commercial director

Meier S Coop Ltda

Address: Pol Ind Arabieta S/N, Aptdo 103, 48300 Gernika (Bizcaia)
Tel: +34 94 625 1450
Fax: +34 94 625 1454
Products: ashtrays, interior trim, consoles, hub caps
Customers: Peugeot, GM, VW, SEAT, Nissan
Plants: Spain (2)

Saifa-Keller SA

Address: Calie San Franscico 81, Aptdo 75, 08221 Terassa (Barcelona)
Tel: +34 93 784 2311
Fax: +34 93 786 295
Products: insulators, trim parts, roof liners, sound proofing, engine encapsulation
Customers: PSA, Renault, Suzuki, DAF, Mercedes-Benz, Ford, SEAT, Nissan
Contact: J Aurell, commercial director
Plants: Spain (5)

Sociedad General de Hules SA

Address: C Disputacion 240, 08007 Barcelona
Tel: +34 93 318 6252
Fax: +34 93 318 6582
Products: fuel tanks and other plastic parts

Todornold SA

Address: Ctra Capellades-Motorelli Km 17.3, 08783 Masquefa (Barcelona)
Tel: +34 93 772 5271
Fax: +34 93 772 5873
Products: door panels, instrument panels, trim, internal bodywork, parcel shelves, sound proofing
Customers: SEAT, PSA, BMW, Ford
Contact: C Raventos Soler, commercial director

Trilla SA (Industrias Plasticas)

Address: Balmes 12-16, Aptdo 45, 08291 Ripollet (Barcelona)
Tel: +34 93 692 1250
Fax: +34 93 691 8802
Products: body panels, bumpers, mirrors, radiator grilles, interior trim, instrument panels
Customer: SEAT
Contact: Francisco Almazan, technical director

SWEDEN

Borealis Industrier AB

Address: Salsmaastargatan 32, SE-42246 Hisingsbacke
Tel: +46 31586770
Fax: +46 31522632
Products: composites external cladding, bumpers, mirrors, sunroofs, radiator grilles, interior trim, instrument panels (RTM)
Customers: Saab, Volvo
Contact: Thos Bernttson, marketing manager

Celsius Applied Composites AB

Address: Vehicle Components Unit, SE-58013 Linköping, Nobymalmsvägen 1
Tel: +46 13 209700
Fax: +43 13 209709
Products: engine spark plug covers and other components in polyester and epoxy fibre composites
Customer: Volvo

Fagerdala Industri AB

Address:	PO Box 54, SE-13922 Värmdö
Tel:	+46 8 571 45200
Fax:	+46 8 571 45940
Products:	EPP and EPE foam products and parts for interior trim, bumper cores, head rests, liners
Contact:	Mikael Magnusson, managing director
Plants:	Sweden (1), Germany (1)

Gislaved Folie AB

Address:	Jornsgatan 8, PO Box 518, SE-33200 Gislaved
Tel:	+46 371 80660
Fax:	+46 371 14366
Products:	PVC/ABS, TPO, skins for instrument and door panels, roof liners, sun visors
Contact:	Lage Kellander, marketing director

Perstorp Components Europe Skaraplast

Address:	SE-42122 Gothenberg
Tel:	+46 314 50520
Fax:	+46 314 73598
Products:	injection moulded parts
Contact:	R Nystrom, marketing manager

Plastal ZCP AB

Address:	PO Box 163 Lindhagagatan 6, SE-272 24 Simrishama
Tel:	+46 414 18700
Fax:	+46 414 13360
Products:	bumpers and other interior and exterior parts
Customers:	Volvo, Saab
Contact:	P Ohlmann, managing director

Sanoform AB

Address:	PO Box 336, SE-57324 Tranas
Tel:	+46 140 18040
Fax:	+46 140 13897
Products:	body panels, hard tops, spoilers
Contact:	M Blikaz, managing director

SWITZERLAND

Alveo AG

Address: Bahnofstrasse 7, CH-6002, Luzern
Tel: +41 228 92 92
Fax: +41 228 92 00
Products: chemically and physically cross linked semi-finished polyolefin foams for sound and vibration damping. Protection against water ingress and energy absorbing grades.
Contact: M W King, sales and marketing manager

Angst & Pfister AG

Address: Thurgauerstrasse 66, CH-8052 Zurich
Tel: +41 1 306 6111
Fax: +41 1 302 1871
Products: engine components, fans and other plastic components
Contact: P Puippe, managing director

Symalit AG

Address: Hardstrasse 5, CH-5600 Lenzburg
Tel: +41 628 858 150
Fax: +41 628 858 383
Products: glass mat thermoplastic sheet
Customers: DaimlerChrysler, BMW, Audi, VW, Ford, PSA, Opel, Renault, Alfa Romeo, Volvo, Fiat, Rover
Contact: A Krawanja, vice president

UNITED KINGDOM

ABCD Plastics

Address: PO Box 44 Hainge Road, Tivdale Road, Warley, West Midlands B69 2PA
Tel: +44 121 557 3747
Fax: +44 121 557 3747
Products: polyurethane mouldings
Contact: MR Thorne, managing director

Automold

Address: Brunel Way, Stroudwater Business Park, Stonehouse, Glos GL10 3SX
Tel: +44 1453 752661
Fax: +44 1453 853501
Products: electrical, wiper, battery trays, PU mouldings, interior trim
Contact: M Hoddy, managing director

Autoplas International

Address: 90 Main Road, Hawkwell, Hockley, Essex SS5 4JH
Tel: +44 1702 202796
Fax: +44 1702 203499
Products: hub caps, grilles, visors, spoilers, fascia panels and similar products for aftermarket
Contact: A J Stratton, sales manager
Plants: UK, Spain

BI Composites

Address: Green Lane, Bridgtown, Cannock, Staffs, WS11 3JW
Tel: +44 1543 466201
Fax: +44 1543 574157
Products: thermoplastic and thermoset automotive parts produced by vacuum forming, foam moulding SRIM, high frequency welding etc
Contact: M Birrell

Birkbys Plastics

Address: Headlands Road, Liversedge, WF15 6QA
Tel: +44 1924 403721
Fax: +44 1924 400051
Products: injection moulded components
Contact: I S Rendell, marketing manager

Brecknell Willis Composites

Address: Chard, Somerset, TA20 2DE
Tel: +44 1460 68111
Fax: +44 1460 66057
Products: thermoset body panels
Contact: M C Casemore, sales and marketing manager

Britax (PMG)

Address: Bessingby Industrial Estate, Bridlington, North Humberside, YO16 4SJ
Tel: +44 1262 670161
Fax: +44 1262 605666
Products: vehicle lighting, wiper motors, switches, rotating beacons, light bars, truck mirrors
Contact: R J Bentley, sales director

Britax Vega

Address: Kingswood Road, Hampton Lovett Industrial Estate, Droitwich, Worcestershire, WR9 0QH
Tel: +44 1905 794441
Fax: +44 1905 794466
Products: headlamps, rear lamp clusters, number plates
Contact: L A Morgan, managing director

Brose

Address: Colliery Lane, Exhall, Coventry, CV7 9NW
Tel: +44 1203 645645
Fax: +44 1203 645355
Products: window regulators, seat adjusters, door modules
Contact: W Suttor, managing director

Bundy International

Address: Lambourn Court, Abingdon Business Park, Abingdon, Oxfordshire, OX14 1UH
Tel: +44 1235 555207
Fax: +44 1235 553227
Products: fluid carrying systems, tubing, flexible hoses, connectors
Contact: J Langston, chief executive

Carello Lighting

Address: Walkmill Lane, Bridgtown, Cannock, Staffs
Tel: +44 1453 462525
Fax: +44 1453 512535
Products: headlamps, fog lamps, signal lamps and rear lamps
Contact: J Pozzo, director

Cobb, Slater Precision Injection Moulding

Address: Cosim Works, Darley Dales, Derbyshire, DE4 2GG
Tel: +44 1629 732344
Fax: +44 1629 733446
Products: injection moulded components
Contact: J Baverstock, sales manager

Collins & Aikman Plastics

Address: Apollo Way, Tachbrook Park, Leamington Spa, Warwickshire, CV34 6RW
Tel: +44 1926 422241
Fax: +44 1926 421454
Products: air vents, instrument panel parts, door handles
Contact: J Everard, managing director

Concargo

Address: Oldmixon Crescent, Weston Super Mare, Avon, BS24 9AH
Tel: +44 1934 628221
Fax: +44 1934 417623
Products: thermoset auto components
Customer: Ford
Contact: N D Brown, managing director

Concept Mouldings

Address: Unit 51 Imex Business Park, Upper Villiers Street, Wolverhampton
Tel: +44 1902 716227
Products: console components, arm rests, body side mouldings
Customer: Rover

Dunlop Cox

Address: Glaisdale Parkway, Bilborough, Nottingham, NG8 4GP
Tel: +44 115 901 2200
Fax: +44 115 928 9688
Products: seating and seat components, including seat slides, height adjusters, recline mechanisms
Customers: GM, Rover, Jaguar, Saab, Volvo
Contact: I Harrison, managing director

Dunlopillo UK

Address: Harrogate, North Yorkshire, HG3 1JL
Tel: +44 1423 872411
Fax: +44 1423 879232
Products: seat mouldings, headrests, armrests
Customers: Rover, Peugeot, Vauxhall, Ford, Rolls-Royce, Jaguar
Contact: M Newlyn, marketing director

Elta Plastics

Address: Elta House, Yarn Road, Stockton-on-Tees, Cleveland, TS18 3RX
Tel: +44 1642 672299
Fax: +44 1642 611004
Products: injection moulded interior trim and engine parts
Contact: A E Morton, technical sales manager

Excel Plastics

Address: Unit 24, Milton Park, Milton, Abingdon, Oxfordshire, OX14 4HG
Tel: +44 1235 864466
Fax: +44 1235 865586
Products: injection moulded exterior badges and interior trim components
Contact: R J Speechley, managing director

Faurecia (Hills Precision)

Address: PO Box 200, Humber Road, Stoke, Coventry, CV1 3LU
Tel: +44 1203 635533
Fax: +44 1203 535075
Products: fascia panels, steering wheels, seats, door trim pads, consoles, fans, cowls, other trim components
Contact: W J Furner, managing director

Foggini-Key UK

Address: Bayton Road, Bayton Road Industrial Estate, Exhall, Coventry, CV7 9EL
Tel: +44 1203 585000
Fax: +44 1203 585001
Products: interior trim, panels, instrument panels, sun shades, driving mirrors, air conditioning components
Contact: automotive marketing department

Griflex Econopac

Address: Woking Business Park, Albert Drive, Sheerwater, Woking, Surrey, GU21 5RX
Tel: +44 1483 715981
Fax: +44 1483 764569
Products: extrusions including bumper trims, body side mouldings
Customers: Rover, Ford, GM, Jaguar, Nissan, Peugeot
Contact: R A Stott, general manager

Hellerman Insuloid

Address: Sharston Works, Leestone Road, Wythenshawe, Manchester, M22 4RH
Tel: +44 161 945 4181
Fax: +44 161 998 8551
Products: pipe and cable clips, ties and binding systems, grommet strips, customised auto components for chassis, trim, electrical, brake, engine and environmental control uses
Customers: Ford and others

Holden Hydroman

Address: Porthouse Industrial Estate, Bromyard, Herefordshire, HR7 4N
Tel: +44 1885 483000
Fax: +44 1885 482276
Products: exterior body components
Contact: J McGladdery, managing director

Johnson Controls Automotive UK

Address: Holyhead Road, Wednesbury, West Midlands, WS10 7DD
Tel: +44 121 502 7200
Fax: +44 121 556 9345
Products: PU foam for seating, headrests, armrests, bolsters
Contact: P Jones, Commercial Manager

Lear Corporation Interior Systems Division

Address: Vaughan Trading Estate, Sedgley Road, Tipton, DY4 7WN
Tel: +44 121 520 7202
Fax: +44 121 522 3521
Products: interior trim, headliners

Linecross Plastics

Address:	Station Road, South Luffenham, Oakham, Rutland, LE15 8NG
Tel:	+44 1780 720720
Fax:	+44 1780 721481
Products:	thermoformed trim panels and other interior and exterior panels
Customer:	Ford
Contact:	R J Lewis, chairman

Linpac GPG

Address:	Luton Road, Dunstable, Bedfordshire, LU5 4LN
Tel:	+44 1582 664225
Fax:	+44 1582 664255
Products:	plastic injection moulders and finishers
Contact:	O Lancaster

Lorival Plastics

Address:	William Street, Little Lever, Bolton, BL3 1AR
Tel:	+44 1204 41400
Fax:	+44 1204 795725
Products:	battery components and accessories, injection moulded and foam moulded parts
Customer:	Rover
Contact:	A J Bent, UK operations director
Plants:	UK (2)

L T Homer

Address:	Stirling Road, Shirley, West Midlands, B90 4NB
Tel:	+44 121 705 2271
Fax:	+44 121 711 3271
Products:	fuel tanks, plastic rotational mouldings
Contact:	G A Guy, managing director

Magna Exterior Systems

Address:	Ledson Road, Wythenshawe, Manchester, M23 9WP
Tel:	+44 161 998 5353
Fax:	+44 161 945 3947
Products:	automotive exterior body components
Contact:	D Rider, technical director

Magna Interior Systems

Address:	Bircholt Lane, Maidstone, Kent, ME15 9XT
Tel:	+44 1622 625061
Fax:	+44 1622 625070
Products:	dashboards and other interior systems components
Contact:	M Raines, business manager

McKechnie Plastics Components

Address:	Stamford Bridge, York, YO4 1AL
Tel:	+44 1759 71441
Fax:	+44 1759 71517
Products:	miscellaneous injection moulded plastic components
Customers:	Ford, Rover, Jaguar
Contact:	B V Mann, operations director
Plants:	UK (2)

MIP Textron UK

Address:	Bewdley Road, Stourport-on-Severn, Worcestershire, DY13 8QT
Tel:	+44 1299 827676
Fax:	+44 1299 827033
Products:	interior trim, instrument panels, rear shelves, armrests, other reinforced plastic and PU mouldings
Contact:	R Lindoe, sales and marketing director

Permali UK

Address:	Hydroglas Works, Bristol Road, Gloucester, GL1 5TT
Tel:	+44 1452 528671
Fax:	+44 1452 597409
Products:	reinforced polyester body panels, bumpers etc. Reinforced PU and SMC mouldings for panels, trim and bumpers
Customers:	Lotus, Volvo, Scania, Case, NACCO
Contact:	M W Mallorie, technical and sales director

Plastic Omnium

Address:	Unit 1, Tweedale Industrial Estate, Telford, Shropshire
Tel:	+44 1952 582583
Fax:	+44 1952 588660
Products:	injection moulding bumper systems, fuel systems

Polymer Engineering

Address:	Quakers Coppice, Crewe Gates Farm Industrial Estate, Crewe, Cheshire, CW1 6FA
Tel:	+44 1270 583723
Fax:	+44 1270 580846
Products:	RTM moulded exterior body panels
Customers:	Aston Martin, Rolls-Royce
Contact:	N G Clarke, managing director

Polynorm Plastics (UK)

Address: PO Box 9, Washway Lane, St Helens, Merseyside, WA10 6FE
Tel: +44 1744 743333
Fax: +44 1744 743300
Products: GMT and SMC mouldings and assemblies
Contact: G Mannus, managing director

Railko

Address: Boundary Road, Loudwater, High Wycombe, Bucks, HP10 9QU
Tel: +44 1628 537700
Fax: +44 1628 810761
Products: steering columns, steering rack support bushes, suspension elements, gear box components, window frames, sun roofs, brake and pedal box components and other moulded and extruded components
Customers: Ford, Rover, Citroën, Nissan, Vauxhall, Maserati, Alfa Romeo, Jaguar, Lotus, Volvo, Peugeot, Saab
Contact: R Holmes, managing director

Raydyot

Address: Waterfall Lane, Cradley Heath, Warley, West Midlands, B64 6QB
Tel: +44 121 559 2471
Fax: +44 121 561 1415
Products: driving/fog/rear lamps, mirrors, switches, indicators and decorative tapes

Reliant Industrial Mouldings

Address: 2 Gate Basin Lane, Tamworth, Staffs
Tel: +44 1827 250000
Fax: +44 1827 282351
Products: composite and GFR parts
Contact: J F Nash, director

Siebe Automotive UK

Address: Estover Road, Plymouth, Devon, PL6 7PS
Tel: +44 1752 775781
Fax: +44 1752 777104
Products: polyamide tubes for fuel and brake lines, hoses, flexible pipes
Contact: P Moate, managing director

Siemens Automotive Systems

Address: Halesfield 25, Telford, Shropshire
Tel: +44 1952 683600
Fax: +44 1952 580626
Products: air intake manifolds

Sommer Allibert Industry Automotive

Address: Kingfisher House, Woodbrook Crescent, Radford Way, Billericay, Essex, CM12 OEQ
Tel: +44 1277 844000
Fax: +44 1277 844030
Products: door trims, interior components including locking systems

T & D Rotomoulding

Address: Victoria Street, Pontycymmer, Bridgend, CF32 8LR
Tel: +44 1656 870415
Fax: +44 1656 870661
Products: rotationally moulded components, fenders, fuel tanks, air intake ducts, consoles, gear shift covers etc
Contact: R E Tanner, general manager
Plants: UK (2)

Textile Bonding Ltd

Address: Midland Road, Highham Ferrers NN10 8ER
Tel: +44 1933 410100
Fax: +44 1933 412252
Products: interior trim applications

Thompson Plastics Group

Address: Bridge Works, Itlings Lane, Hessle, HU13 0TP
Tel: +44 1482 646464
Products: interior components

Visteon Automotive Systems

Address: Eastwood Business Park, Harry Weston Road, Binley, Coventry
Tel: +44 1203 547300

W & H Boddington & Co

Address: Gouldhurst Road, Horsmonden, Kent, TN12 8AH
Tel: +44 1892 723033
Fax: +44 1892 723251
Products: injection moulded components
Contact: Ms D M Boddington, managing director

Wardle Storeys

Address:	Grove Mill, Earby, Lancs, BB8 6UT
Tel:	+44 1282 842511
Fax:	+44 1282 843170
Products:	vacuum forming, door linings, sun visors, noise insulation, foam and calendered sheet
Customers:	Fiat and others
Contact:	R Clare, sales and marketing director
Plants:	UK (3)

13.3 Asian manufacturers of plastic automotive components

China

Changchin No 1 Plastics Plant

Address:	32 Yitonghe, Hutong, Dongtianjie, Nanguan Dist, Changchun, Jilin 130041
Tel:	+86 431 895 0174
Fax:	+86 431 895 0173
Products:	ABS/PVC instrument panels, PVC floor linings, door panels
Contact:	Liu Mingchin, director

Chiangjiang Automotive Trim Factory

Address:	Xiaohe, Wujin County, Jiangsu 213138
Tel:	+86 519 324 1053
Products:	instrument panels, door arm rests, door handles, sun visors

Dalian No 1 Plastics Factory

Address:	90 Wuliyu, Shahekou Dist, Dalian, Liaoning 116021
Tel:	+86 411 464 3578
Products:	steering wheels and other plastic parts
Contact:	Xu Guangbang, legal representative

Donghua Instrument Panel Factory

Address:	74 Hongqi Beilu, Baoding, Hebei 071000
Tel:	+86 312 227 658
Fax:	+86 312 238 643
Products:	instrument panels, interior trim
Contact:	Wang Changsheng, legal representative

FAG Trim Factory

Address:	24 Jiutai Nanlu, Chingchin, Jilin 130031
Tel:	+86 431 237 102
Products:	seat cushions, instrument panels

FAG Trim Factory, Subsidiary Factory

Address:	Kuancheng Dist, Changchun, Jilin 130011
Tel:	+86 431 893 7294
Products:	interior decorative foams, door handles
Contact:	Han Bingyu, legal representative

Golden Dragon Rubber and Plastic Products Co Ltd

Address: Hongwen Industrial Zone, Xiamen, Fujian 361009
Tel: +86 592 506 4272
Fax: +86 592 6011 5076
Products: instrument panels, sealing strips, trims

Huachang Die Engineering Plastic Products Factory

Address: Shangbanqiao, Huaxi Dist, Guiyang, Guizhou 564100
Tel: +86 851 282 197
Products: bumpers

Hualian Automotive Parts Co Ltd

Address: Lianjianglu, Fuzhou, Fujian 35004
Tel: +86 591 3661 349
Fax: +86 591 3661 229
Products: bumpers, instrument panels
Contact: He Wunzhao, legal representative

Hubei Automobile Engineering Plastics Factory

Address: 179 Checheng Lu, Shiyan, Hubei 442055
Tel: +86 719 881 314
Fax: +86 719 881 113
Products: steering wheels, instrument panels, seats, mudguards, glove compartment doors, window regulators, door handles
Contact: Zhu Hongxun, director

JAW Trim Factory

Address: 8 Linongzhuanglu, Lixia Dist, Jinan, Shandong 250013
Products: seats, trims, steering wheels, instrument panels
Contact: Yang Beijian, general manager

Jiangnan Molding Plastics Corp

Address: Zhouzhuang, Jiangyin, Jiangsu 214423
Tel: +86 5217 221226
Fax: +86 5217 214423
Products: bumpers and other plastic parts
Contact: Cao Mingfang, president

Jiangxi Automotive Engineering Plastics Plant

Address: 9 Ganzhong Dudao, Jian, Jiangxi 343100
Tel: +86 796 442 282
Fax: +86 796 442 637
Products: bumpers, steering wheels, instrument panels, interior trim
Contact: Wang Juishang, legal representative

Jieda Soft Plastics Factory

Address: Siduan, Biandiansuo, Jiepai, Danyang, Jiangsu 212323
Tel: +86 5211 388841
Products: instrument panels
Contact: Wang Jicai, legal representative

Jinling Petrochemical Co Plastics Factory

Address: Xiaozhuang, Zhonghuamenwai, Nanjing, Jiangsu 210038
Tel: +86 25 665 2180
Products: instrument panels
Contact: Wu Duanliu, legal representative

Juliang Plastics Co Ltd

Address: 1 Huishenglu, Wuxi, Jiangsu 514035
Tel: +86 510 370 0441
Fax: +86 510 370 3864
Products: instrument panels, bumpers
Contact: Wu Haixiang, chairman

Junzilan Industry Group Corp

Address: 88 Lingdonglu, Changchun, Jilin 130031
Tel: +86 431 494 4751
Fax: +86 431 898 2827
Products: bumpers, plastic fuel tanks

Liming Chemical Industry Research Institution

Address: 5 Manglinglu, Luoyang, Henan 471001
Tel: +86 379 393 6792
Fax: +86 379 393 7056
Products: foam seating, steering wheels, instrument panels, bumpers
Contact: Zhen Baoan, director

Nanchong Engineering Plastics Factory

Address: 42 Hongqiangjie, Nanchong, Sichuan 637000
Tel: (86) 817 224 452
Products: plastic fans, timing gears, distributor box caps

Nanjing No 5 Plastics Factory

Address: 174 Jiangsulu, Nanjing, Jiangsu 21009
Tel: +86 25 663 7362
Fax: +86 25 446 2704
Products: air conditioning hoses, radiator covers, bumpers, instrument panels, interior and exterior trim
Contact: Tang Meiyu, general manager

Nanjing No 8 Plastics Factory

Address: 29 Bangtongxian, Changelu, Nanjing, Jiangsu 210006
Tel: +86 25 662 5358
Products: door handles, miscellaneous plastic parts
Contact: Fan Guansheng, legal representative

QCIVC Automotive Trim Factory

Address: Dongling Techu, Qingyang, Liaoyang, Liaoning 111011
Tel: +86 419 227 074
Products: instrument panels

Qingyang Chemical Plant

Address: Tanghutun, Liaoyang, Liaoning 111002
Tel: +86 419 23757
Products: instrument panels, door handles

Taixing Lights Factory

Address: 54 Fuxingjie, Taixing, Jiangsu 225400
Tel: +86 523 763 3161
Products: bumpers, instrument panels
Contact: Luo Yulin, legal representative

Tianjin Automotive Plastic Parts Factory

Address: 37 Liuhejie Huanghedao, Nanhai Dist, Tianjin 300102
Tel: +86 22 7372 221
Products: steering wheels, battery brackets
Contact: Wang Shirong, legal representative

Yaoguang Plastic Products Factory

Address: Fanjiacun, Hutan, Changzhou, Jiangsu 213161
Tel: +86 519 655 3039
Products: instrument panels

Zhongning Plastic Filling Factory

Address: Yangshuang, Micun, Fangzi, Weifang, Shandong 261000
Products: instrument panels
Contact: Wang Xingli, legal representative

Japan

Achilles Corporation

Address:	22-1 Daikyo-cho, Shinjuku-ku, Tokyo 160
Tel:	+81 3 3341 5111
Fax:	+81 3 3353 5322
Products:	steering wheels, seat trims and other plastic items, especially PU
Contact:	Mr Suzuki, president

Aichi Hikaku Industrial Co Ltd

Address:	2-16-22 Tabata Cho Kita-ku, J Nagoya Ahi Aichi-ken 462
Tel:	+81 52 911 2377
Fax:	+81 52 911 2380
Products:	interior trim, fuel tanks
Customers:	Nissan (fuel tanks)

Aisin Chemical Co Ltd

Address:	1141-1 Okawagahaka, Iino, Fujioka-cho, Nishikamo-gun, Aichi 470-04
Tel:	+81 565 762311
Fax:	+81 565 761101
Products:	cooling fans, piston boosters, miscellaneous plastic mouldings
Customers:	Toyota
Contact:	Tetsuo Kanagawa, president
Overseas plants:	US (1)

Alpha Corporation

Address:	1-6-8 Fukuura Kamazawa-ku, Yokohama-shi, J-Kanagawa-ken 236
Tel:	+81 45 787 8400
Fax:	+81 45 787 8425
Products:	door handles, interior trim, window knobs, bumpers, radiator grilles, mirrors
Contact:	K. Takayama, president

AOI Techcel Ltd

Address:	58-1 Aza Nishihara, Bodaiji, Hatano-shi, J-Kanagawa-ken 259-13
Tel:	+81 463 752221
Fax:	+81 463 754614
Products:	window frames, bumpers
Customers:	Nissan, Mitsubishi

Araco

Address:	25 Kamifujike, Toyota-shi, J-Aichi-ken 473
Tel:	+81 565 524141
Fax:	+81 565 512295
Products:	seats, door trim, seat adjusters
Customers:	Toyota, Daihatsu
Contact:	S Sekiya, president

Asahi Chemical Ind Co Ltd

Address: Hibiya-Mitsui Bldg, 1-1-2 Yuraku-cho, Chiyoda-k, J-Tokyo 100
Tel: +81 3 3507 2525
Fax: +81 3 3507 2496
Products: airbags
Contact: R Yumikara, president

Chiyoda Manufacturing Corp (Chiyoda Seisukusho)

Address: 126-2 Nishishinmachi, Ota-shi, Gunma 373
Tel: +81 276 318201
Fax: +81 276 313057
Products: trim boards, exterior parts, console boxes, heater ducts, tanks
Customers: Fuji
Contact: M Ooe, president

Chubu Soflan Ltd

Address: 3 Igayama Uchikoshi, Miyoshi-cho, Nishikamo-gun, Aichi 470-02
Tel: +81 5613 4 2711
Products: seat cushioning, PU bumpers
Contact: Mr Fujii, president

Daikyo Co Ltd

Address: 175-1 Oaza Hara Happanmat Su, J-Hiroshima Shi 739-01
Tel: +81 824 290113
Fax: +81 824 290938
Products: bumpers, trim, panels, console boxes, ventilators, steering wheels, radiator grilles
Customers: Mazda
Overseas plants: US (1)
Contact: S Matsunaga, president

Daikyo Webasto KK

Address: 5702-4 Yoshikawa, Happonmatsu-cho, Higashi-Hiroshima-shi, Hiroshima 737-01
Tel: +81 824 290230
Fax: +81 824 293326
Products: sun roofs, window regulators
Customers: Mazda, Hyundai, Mitsubishi, Honda, Fuji
Overseas Plants: Korea (1)
Contact: S Matsunaga, president

Daito Press Mfg Co Ltd

Address: 4-1-39 Yokotsutsumi, Tsurumi-ku, Osaka 538
Tel: +81 6 911 4751
Fax: +81 6 911 4753
Products: rearview mirrors, radiator grilles
Customers: Nissan, Mitsubishi
Contact: T Yoshida, president

Daiya Premix Co Ltd

Address: 4-1-2 Ushikawa-Dori, Toyohashi City, Aichi
Tel: +81 532 633138
Fax: +81 531 628687
Products: spoilers, other hot press moulded automotive parts
Customers: Honda (spoilers)

Delta Kogyo Co Ltd

Address: 1-14 Shinchi, Fuchu-cho, Aki-gun, Hiroshima 735
Tel: +81 82 282 8211
Fax: +81 82 282 8221
Products: seats, window regulators, sun visors, ashtrays, mirrors
Contact: T Kuroda, president

Denso Corporation

Address: 1-1 Showa-cho, Kariya-shi, J-Aichi-ken 448
Tel: +81 56625 7503
Fax: +81 566 25 4594
Products: electronic equipment and systems

Fuji Kiko

Address: 2028 Washizo, Kosai City, Shizuoka
Tel: +81 53 576 2711
Fax: +81 53 576 1103
Products: steering wheels, steering columns, seatbelts, adjusters, pedals
Customers: Nissan, Suzuki
Overseas plants: Korea (1), Taiwan (1), Sweden (1), US (1)

Fuji Seat Co Ltd

Address: 2-4-6 Higashi, Honan-cho, Toyonaba-shi, Osaka 561
Tel: +81 6 332 3331
Fax: +81 6 334 3028
Products: seats, door trim
Customers: Daihatsu

Futaba Kogyo Co Ltd

Address:	4-8-17 Ohzu, Minami-ku, Hiroshima-ku, J-Hiroshima-ken 736
Tel:	+81 82 282 221
Fax:	+81 82 282 2299
Products:	instrument panels, sun roofs, bumpers
Customers:	Toyota (bumpers)
Contact:	M Umemura, president

Hashimoto Forming Industry

Address:	320 Kamiyabe-cho, Totsuka-ku, Yokohama-shi, J-Kanagawa 245
Tel:	+81 45 811 1211
Fax:	+81 45 811 2238
Products:	window sashes, sun roofs, mouldings, radiator grilles, wheel caps, bumpers, spoilers
Customers:	Nissan, Isuzu, Fuji, Honda, Mazda, Mitsubishi
Contact:	S Ohki, president
Overseas plants:	Taiwan, UK, US (1 each)

Hayashi Telempu Co Ltd

Address:	1-4-5 Kamimaezu, Naka-ku, Nagoya-shi, J-Aichi-ken 460
Tel:	+81 52 322 2121
Fax:	+81 52 332 3219
Products:	interior trim, headliners, weather strips, sun visors
Customers:	Mitsubishi, Suzuki, Toyota, Honda, Daihatsu, Isuzu, Mazda, Fuji
Contact:	I Hayashi, president
Overseas plants:	US, Taiwan, Hong Kong, Malaysia, Germany (1 each)

Hirotani Co Ltd

Address:	1454-34 Hara, Happonmatsu-cho, Hiroshima-chi, J-Hiroshima-ken 73901
Tel:	+81 824 290311
Fax:	+81 824 290335
Products:	interior trim
Customers:	Mazda, Daihatsu

Hitachi Chemical Co Ltd

Address:	Shibaura Square Bldg, 4-9-25 Shibaura, Minato-ku, J-Tokyo 108
Tel:	+81 3 5446 9360
Fax:	+81 3 5446 9461
Products:	door trim, spoilers, panels dashboards, steering wheels, radiator grilles, interior trim
Customers:	Nissan (spoilers), Isuzu (door trim)
Contact:	T Tanno, president

Hoei Industries Ltd

Address:	2-9-10 Nishi-kamatu, Ohta-ku, J-Tokyo 144
Tel:	+81 3 3753 2111
Fax:	+81 3 3752 3661
Products:	bumpers, fuel tanks, radiator fans
Customers:	Mitsubishi (fuel tanks)
Contact:	T Kashimoto, marketing manager

Horie Metal Industry Co Ltd

Address:	2-26 Konosumachi, Toyota-shi, J-Aichi-ken 471
Tel:	+81 565 292211
Fax:	+81 565 275008
Products:	plastic fuel tanks
Customers:	Toyota
Contact:	M Tachibana, president

Howa Machinery Ltd

Address:	1900 Sukagachi, Shinkawa-cho, Nishi Kasugai-gun, Aichi Pref
Tel:	+81 52 502 1111
Fax:	+81 52 409 3777
Products:	door trim
Customers:	Nissan, Suzuki
Contact:	T Nozaki, president

Ichihama Chemical Co Ltd

Address:	1 Miyashimo-Kawara Shigo-cho, Toyota City, Aichi Pref
Tel:	+81 565 458621
Fax:	+81 565 452524
Products:	spoilers
Customers:	Toyota
Contact:	T Saeki, president

Ichikoh Industries Ltd

Address:	5-10-18 Higashi-Gotanda, Shinagawa-ku, J-Tokyo 141
Tel:	81 3 440 6281
Fax:	+81 3 449 7610
Products:	lamps, mirrors, plated plastics, hub caps, wiper blades and arms
Customers:	Nissan and most other manufacturers
Contact:	S Takada, president

Ikeda Bussan Co Ltd

Address:	771 Kosono, Ayase-shi, J-Kanagawa-ken
Tel:	+81 467 767000
Fax:	+81 467 769752
Products:	airbags, seats, interior trim
Customers:	Nissan, Mitsubishi (door trim)
Overseas plants:	US, UK, Taiwan, Malaysia
Contact:	M Nagakura, president

Ikuyo Co Ltd

Address:	2-16-5 Shibuya, Shibuya-ku, J-Tokyo 150
Tel:	81 3 3499 0194
Fax:	+81 3 3486 4825
Products:	bumpers, spoilers, weather strips, radiator grilles, door handles, consoles, hub caps
Customers:	Mitsubishi
Contact:	M Sakai, president

Inoac Corp/Inoue MTP

Address:	Chubu Gomu Kaikan, 2-13-4 Meieke Minami, Nakamura-ku, Nagoya-shi, J Aichi Ken 450
Tel:	+81 52 581 2938
Fax:	+81 52 581 4726
Products:	PU foam, seating, armrests and accessories, body panels, instrument panels, bumpers, spoilers
Customers:	Toyota, Mitsubishi, Suzuki, Mazda
Contact:	S Inoue, chairman/president

Ishihara Plastic Industrial Co Ltd

Address:	2723-2 Yaba, Ohta-shi, Gunma 373
Tel:	+81 276 461231
Fax:	+81 276 461238
Products:	miscellaneous plastic components
Contact:	H Ishihara, president

Ishizaki Honten Co Ltd

Address:	2-7-6 Ohte-machi, Naka-ku, Hiroshima-shi, Hiroshima Pref 730
Tel:	+81 82 884 3211
Fax:	+81 82 884 1991
Products:	mirrors
Customers:	Mazda
Contact:	Takayasu Shirai, president

Ites Co Ltd

Address: 3-623 Hibarigaoka, Zama-shi, J Kanagawa-ken 351
Tel: +81 462 538111
Fax: +81 462 558340
Products: seats, interior trim, sun visors

Izumi Motor Co Ltd

Address: 704-1 Kami-ichi, Atsugi-shi, J Kanagawaka ken 243
Tel: +81 462 463702
Fax: +81 462 463702
Products: steering wheels and columns
Customers: Nissan, Mitsubishi, Mazda, Daihatsu
Contact: M Tochihara
Overseas plants: US (1)

JSP Corp

Address: Lino Bldg, 2-1-1 Uchisaiwai, Chiyoda-ku, Tokyo 100
Tel: +81 3 3503 4919
Fax: +81 3 3508 8967
Products: PS, PU and PE foam bumpers
Contact: M Uchiyama, president

Kanto Seiki Co Ltd

Address: 2-1-10 Owatari-machi, Maebashi City, Gunma Pref
Tel: +81 2725 12121
Fax: +81 2725 27680
Products: bumpers, airbag covers
Customers: Nissan
Contact: K Ebisawa, president
Overseas plants: US (1), Taiwan (2)

Kasai Kogyo Co Ltd

Address: 3316 Miyayama Samukuwa, Chokohza Gun, J-Kanagawa ken 253-01
Tel: +81 467 75 1128
Fax: +81 467 74 8791
Products: interior parts: door trim, rear shelf panels, sun visors, crash pads, dsahboards, consoles, rear quarter-trim, pillars
Customers: Nissan, Honda, Isuzu
Contact: D Kasen, president
Overseas plants: US, UK (1 each)

Kinugawa Rubber Industrial Co Ltd

Address:	330 Naganuma-cho, Chiba-shi, J Chiba-ken 263
Tel:	+81 43 259 3110
Fax:	+81 43 258 8575
Products:	bumpers
Customers:	Nissan, Fuji
Contact:	Mr Matsuura, president

Koito Manufacturing Co Ltd (Koito Seisa Kusho)

Address:	4-8-3 Takanawa, Minato-ku, J Tokyo 108
Tel:	+81 3 3447 5171
Fax:	+81 3 3447 5173
Products:	headlamps bodies and lenses, tail-light lenses, flexible circuit boards, mirrors, hub caps
Customers:	Toyota, Mazda, Nissan, Mitsubishi, Isuzu, Fuji, Daihatsu
Contact:	T Matsuura, president
Overseas plants:	US, China, Taiwan, Thailand

Kojima Press Industry Co Ltd

Address:	3-30 Shima-Ichiba-cho, Toyota-shi, J Aichi-ken 471
Tel:	+81 565 346868
Fax:	+81 565 346685
Products:	air conditioning parts, console boxes
Customers:	Toyota, Daihatsu
Contact:	T Saeki, president

Kotobuki Corp

Address:	1-2-12 Yurako-cho, Chiyoda-ku, Tokyo 100
Tel:	+81 3 3961 9811
Fax:	+81 3 3963 6750
Products:	spoilers
Customers:	Nissan
Contact:	S Fukazawa, president

Kunimatsu Kogyo KK

Address:	3-623-1 Hibarigaoka, Zama-shi, J Kanagawa-ken 228
Tel:	+81 462 538111
Fax:	+81 462 558340
Products:	seats, sun visors, ceiling liners, rear shelves, interior trim
Customers:	Isuzu
Contact:	G Kunimatsu, president

Kurabo Industries Ltd

Address:	2-4-31 Kyutaro-Machi, Chuo-ko, Osaka 541
Tel:	+81 6 266 5111
Fax:	+81 6 266 5555
Products:	PU foam products
Contact:	K Shindo, president

Kyowa Sangyo Co Ltd

Address:	3-1 Koromogahara, Toyota-shi, J Aichi-ken 471
Tel:	+81 565 324651
Fax:	+81 565 324650
Products:	sun visors
Customers:	Toyota
Contact:	Y Hachimine, president

Lonseal Corp (Lonseal Kogyo KK)

Address:	4-15-3 Midori, Sumida-ku, Tokyo 130
Tel:	+81 3 5600 1828
Fax:	+81 3 5600 1815
Products:	PVC sheet products, automotive seats
Customers:	Toyota
Contact:	Ichiro Ikemori, president

Marubishi Industry Co

Address:	1251-3 Honjyo, Komaki-shi, J Aichi-ken 485
Tel:	+81 568 799211
Fax:	+81 568 797841
Products:	seats
Customers:	Mitsubishi

Marui Industrial Co Ltd

Address:	1250 Iwase, Kamahura-shi, J Kanagawa-ken 267
Tel:	81 467 444151
Fax:	+81 467 447761
Products:	emblems, name plates, body side mouldings, exterior trim, instrument panels, radiator grilles, hub caps
Customers:	Nissan, Mazda, Mitsubishi, Honda, Fuji, Toyota
Contact:	M Kikuchi, president

Marujun Seiki Ind Co Ltd

Address:	3-22 Asanishi, Ogaki-shi, J Gifu-ken 503
Tel:	+81 584 893181
Fax:	+81 584 898060
Products:	interior and exterior door panels, dashboards, bumpers, door handles, seat adjusters
Customers:	Honda, Toyota, Mitsubishi, Suzuki
Contact:	Y Imagawa, president

Matsuyama Seisakusho Co Ltd

Address:	1-13-7 Miniowa, Taito-ku, Tokyo 110
Tel:	+81 3 3874 9651
Fax:	+81 3 3875 7852
Customers:	Honda
Products:	rearview mirrors, seat adjusters

Mazda Kasei KK

Address:	888-1 Nishiura Houfu-shi, Yamaguchi 747
Tel:	+81 835 292244
Fax:	+81 835 292584
Products:	bumpers, instrument panels, interior trim
Customers:	Mazda
Contact:	Y Mizobuchi, president

Meiwa Industry Co Ltd

Address:	Onna 33, Atsugi-shi, J Kanagawa-ken 243
Tel:	+81 462 237611
Fax:	+81 462 236163
Products:	vinyl products, door trim
Customers:	Nissan, Mazda, Daihatsu, Toyota, Honda, Isuzu
Contact:	H Miida, president
Overseas plants:	Indonesia (1)

Mitsubishi Belting Co Ltd

Address:	4-1-21 Hamazoe-dori, Nagata-ku, Kobe
Tel:	+81 78 671 5071
Fax:	+81 78 671 7301
Products:	door trim, bumpers, seats
Customers:	Mitsubishi
Contact:	Kinzo Oda, president

Mitsubishi Gas Chemical Co

Address: Mitsubishi Building, 5-2 Marunouchi-2-Chome, Chiyoda-ku, Tokyo 100-8324
Tel: +81 3 3283 5000
Fax: +81 3 3287 0833
Products: PVC window panels
Contact: Reiji Nishihawa, president

Mitsui Petrochemical Ind Ltd

Address: Kasumigaseki Bldg 2-5, Kasumigaseki 3-chome, Chiyoda-ku, Tokyo 100
Tel: +81 3 3580 3616
Fax: +81 3 3593 0028
Contact: Shigenori Koda, president

Mitsubishi Plastics Industries Ltd

Address: Mitsubishi Building, 5-2 Maronouchi-20-Chome, Chiyoda-ku, Tokyo 100-0005
Tel: +81 3 3283 4006
Fax: +81 3 3213 4095
Products: petrol tanks, bumpers, door trim
Customers: Nissan (petrol tanks); Mitsubishi (bumpers/door trim)
Contact: M Hamabe, president

Minori Industry Co Ltd

Address: 100 Ijirino, Soja-shi, Okayama 719-11
Tel: +81 8669 342301
Fax: +81 8669 342309
Products: door trim, instrument panels, floor mats

Miyagawa Kasei Ind Co Ltd

Address: 1-16-25 Konatsu, Higashiyodogawa-ku, Osaka 533
Tel: +81 6 328 4124
Fax: +81 6 324 6981
Products: bumpers, door trim, battery parts
Customers: Mazda
Contact: S Miyagawa, president

Murakami Kaimeido Co Ltd

Address: 748 Heidalyu Fujieda-shi, Fujieda-shi, J Shizuoka-ken 426
Tel: +81 546 351000
Fax: +81 546 361406
Products: mirrors
Customers: Toyota, Mitsubishi, Honda, Nissan, Suzuki
Contact: E Murakami, president

Namba Press Works Ltd

Address: 8-3-8 Kojima Ogawa, Kurashiki-shi, J Okoyama-ken 711
Tel: +81 864 741202
Fax: +81 864 741350
Products: moulded PU foams, seating, armrests, crashpads, fuel tanks
Customers: Mitsubishi
Overseas plants: US

Nanjo Sobi Kogyo Co Ltd

Address: 2-4-22 Misasa-machi, Nishi-ku, Hiroshima-shi, Hiroshima 733
Tel: +81 82 230 1202
Fax: +81 82 237 6163
Products: door trim, seat trim
Customers: Mazda

Nifco Inc

Address: 4-54 Shibaura Minato-ku, J Tokyo 100-91
Tel: +81 3 5476 4857
Fax: +81 3 5476 4861
Products: plastic fasteners, miscellaneous plastic parts
Customers: All Japanese car manufacturers
Contact: T Ogasawara, president
Overseas plants: Korea, Taiwan, Hong Kong, US

Nihon Plast Co Ltd

Address: 218 Aoshima-cho, J Fuji-shi, Shizuoka-ken 417
Tel: +81 5455 20481
Fax: +81 5455 5687
Products: steering wheels, console boxes, ventilators, instrument panels, spoilers, ducts, trim, fenders
Customers: Nissan, Mitsubishi, Honda
Contact: M Hirsue, Pres
Overseas plants: US (1)

Nippon Keikinzoku Kakoki KK

Address: 3-8-39 Tagwa 3 Chome, Yodogawa-ku, J Osaka 532
Tel: +81 6 301 1751
Fax: +816 309 5956
Products: radiator grilles, bumpers, sun visors

Nishikawa Kasei Co Ltd

Address:	2-25-31 Kabe-minami, Asakita-ku, Hiroshima-shi, J Hiroshima-ken 731-02
Tel:	+81 82 812 3121
Fax:	+81 82 815 0375
Products:	dashboards, panels, crash pads, seats console boxes, bumpers, spoilers
Customers:	Mazda
Contact:	Y Mizobuchi, president
Overseas plants:	US (1)

Nissan Shatai Co Ltd

Address:	10-1 Amanuma, Hiratsuka, Kanagawa 254
Tel:	+81 463 218001
Fax:	+81 463 218155
Products:	spoilers
Customers:	Nissan
Contact:	S Uemura, president

OM Corporation

Address:	1957 Makabe, Sojya-shi, J-Okayama-ken 719-11
Products:	bumpers, window frames
Contact:	Kochi Setu, president

PIAA Corp

Address:	3-21-1-21 Ikejiri, Setagaya-ku, J Tokyo 154
Tel:	+81 3 3413 2211
Fax:	+81 3 3414 5184
Products:	lamps, bumpers, mirrors, wiper arms and blades, hub caps

Plamex Co Ltd

Address:	5-2-11 Ikegami, Ohta-ku, Tokyo 146
Tel:	+81 3 754 2211
Products:	Miscellaneous plastic mouldings
Customers:	Honda
Contact:	M Kuroiwa

Ryobi Ltd

Address:	762 Mesaki-cho, Fuchu-shi, Hiroshima-ken 726
Tel:	+81 847 41 1111
Fax:	+81 847 436111
Products:	miscellaneous plastic components

Sekisui Chemical Co Ltd

Address: 2-4-4 Nishitenma, Kita-ku, Osaka 530
Tel: +81 6 365 4248
Fax: +81 6 365 4385
Products: bumpers, PE and PU foams
Customers: Daihatsu
Contact: K Hirota, president

Shigeru Kogyo Co Ltd

Address: 330 Oaza-Yura, Ota-shi, J Summa-ken 373
Tel: +81 276 313911
Fax: +81 276 311812
Products: mud-guards, seat trays of recycled plastic; seats, sun visors, interior trim, instrument panels
Customers: Fuji
Contact: T Shimuzu, president

Shiroki Corporation

Address: 3-7-3 Shin-Yokohama, Kohoku-ku, Yokohama-shi, J Kanagawa-ken 222
Tel: +81 45 473 4691
Fax: +81 45 473 5896
Products: window regulators, seat adjusters, other mouldings
Customers: Toyota
Contact: Y Fujimaki, president
Overseas plants: US (1)

Showa Denko KK

Address: 1-13-9 Shiba Daimon, Minato-ku, Tokyo 105
Tel: +81 3 5470 3111
Fax: +81 3 3431 6442
Products: plastic products for cars, including petrol tanks
Contact: M Murata, president

Starlite Co Ltd

Address: 4-23-7 Omiya, Asahi-ku, Osaka 535
Tel: +81 6 956 2220
Fax: +81 6 956 2714
Products: miscellaneous plastic components
Customers: Mazda
Contact: T Saigo, president

Sugihara Hosel Kogyo Co Ltd

Address:	2-3-50 Yano-shin-machi, Aki-ku, Hiroshima-shi, J Hiroshima-ken 736
Tel:	+81 82 884 2311
Fax:	+81 82 884 2277
Products:	seat trims, door trims
Customers:	Nissan, Mazda
Contact:	Y Sogihara, president

Tachi-S Co Ltd

Address:	3-2-12 Matsubara-cho, Akashima-shi, J Tokyo 196
Tel:	+81 425 468111
Fax:	+81 425 467361
Products:	car seats
Customers:	Nissan, Mitsubishi, Honda, Isuzu
Overseas plants:	US (2)

Taiyo Kogyo KK

Address:	3-20 Tajika Shodai Hirakata Shi, J Osaka 573
Tel:	+81 720 56 9111
Fax:	+81 720 56 9101
Products:	door trim, seating
Customers:	Daihatsu, Toyota
Contact:	K Nihmura, president

Takashimaya Nippatsu Kogyo KK

Address:	1-1 Maehata, Ohshima-cho, Toyota-shi, J Aichi-ken 473
Tel:	+81 565 523131
Fax:	+81 565 527204
Products:	seats, seat covers, door trim, and other automotive components
Customers:	Toyota
Contact:	T Suzuki, president

Takata Corporation

Address:	No 25 Mori Bldg, 1-4-30 Roppongi, Minato-ku, J Tokyo 105
Tel:	+81 3 3582 3222
Fax:	+81 3 3505 2278
Products:	seatbelts, baby seats, airbags, rearview mirrors
Customers:	Toyota, Nissan, Honda, Mitsubishi, Suzuki, Mazda, Daihatsu, Fuji, BMW, Chrysler
Contact:	J Takada, president
Overseas plants:	USA (5), Korea, UK

Teijin Ltd

Address: Teijin Bldg, 1-6-7- Minami-Hon-machi, Chuo-ku, J Osaka 541
Tel: +81 6 268 2615
Fax: +81 6 268 2614
Products: sun roofs
Contact: H Itagaki, president

Tokai Kasei Kogyo

Address: 4203-1 Aza-Shimohosuge, Komaki-shi, Aichi 485
Tel: +81 568 777228
Fax: +81 568 766322
Products: semi-hard PU interior trim
Customers: Toyota
Contact: M Sato, president

Tokai Rika Co Ltd

Address: 1 Aza-Noda, Oaza-Toyoda, Oguchimachi, J 480-01 Aichi-ken
Tel: +81 587 955211
Fax: +81 587 956641
Products: seatbelts, airbags, rearview mirrors, steering wheels
Customers: Toyota, Mitsubishi, Mazda, Suzuki, Daihatsu, Isuzu, Fuji
Contact: A Kisaki, president

Topre Corp

Address: Asahi Bldg, 3-12-2 Nihonbashi, Chuo-ku, Tokyo 103
Tel: +81 3 3271 0711
Fax: +81 3 3271 7045
Products: bumpers, dashboards
Customers: Honda, Nissan, Isuzu

Toray Industries Inc

Address: 2-2-1 Nihonbashi-Muro-Machi, Chuo-ku, Tokyo 103
Tel: +81 3 3245 5414
Fax: +81 3 3245 5270
Products: PMMA optical fibres, body parts
Contact: Katsunosuke Maeda, president

Toyoda Gosei

Address: 1 Nagahata Ochiai, Haruhi-Mura, Nishi-Kasogaigai-gun Aichi Pref 452
Tel: +81 52 400 5104
Fax: +81 52 400 5159
Products: airbags, steering wheels, bumpers, spoilers, weather strip
Customers: Toyota (70%), Daihatsu (bumpers)
Contact: Shoji Ban, president

Toyota Seat Co Ltd

Address: 3-7-27 Sakae-cho, Asaka-shi, J Saitama-ken 351
Tel: +81 4846 21121
Fax: +81 4846 50403
Products: seats, bumpers, door trim, dashboards, interior trim, sun visors
Customers: Honda, Isuzu
Contact: Y Yanagibashi

Yachiyo Industry Co Ltd

Address: 3-27-12 Nishiikebukuro Toshima-ku, J-Tokyo 171
Tel: +81 3 3986 0721
Fax: +81 3 3986 0796
Products: bumpers and other auto parts including sunroofs
Contact: Ahira Koyama, president

Yamakawa Industrial Co Ltd

Address: 19-1 Gomishima, Fuji-shi, J-Shizuoka-ken 416
Tel: +81 545 625121
Fax: +81 545 625121
Products: front panels, doors, fuel tanks
Customers: Nissan (fuel tanks)
Contact: Tadaomi Yamakawa, president

Yamato Kogyo Co Ltd

Address: 3825 Shimotsuruma, Yamato-shi, Kanagawa Pref 242
Tel: +81 462 74 7100
Fax: +81 462 74 8101
Products: bumpers, fuel tanks, body and electrical parts
Contact: Hiroyuki Inoue, president

Korea

Apollo Ind Co ltd

Address: 48 Hwang Seong-Dong, Gyungju-si, Gyungbuk
Tel: +686 561 42 0801
Fax: +686 561 42 6057
Products: bumpers, signal lamps, light clusters, hub caps, radiator grilles and dashboards

Che Il Plastics Co

Address: 9-2 Naicheon-Ri, Seotan-Myun, Pyungtaek-Gun, Gyunggi-Do
Tel: +686 2 742 0219
Fax: +686 333 629943
Products: fuel tanks, ducting, covers

Chung Bo Co Ltd

Address: 274-1 Baekbong-Ri, Woesa-Myun, Yongin-Gun, Gyunggi-Do
Tel: +686 335 324292
Fax: +686 335 333 594
Products: sun visors, insulation, body trim
Plants: Korea (2)

Chung Hwa Ind Co Ltd

Address: 647-3 Seonggok-Dong, Ansan-Si, Gyunggi-Do
Tel: +686 345 491 3091
Fax: +686 345 491 3097

Dae Won Industrial Co Ltd

Address: 718 Wonshi-Dong, Ansan-Shi
Tel: +686 345 495 2301
Fax: +686 3243 2350

Dong Bo Ind Co Ltd

Address: B7-L5 Namdong Ind Complex, 614 Namchong-Dong, Namdong-Gu, Incheon
Tel: +686 3243 77661
Fax: +686 3243 92095
Products: sun visors, roof linings, floor trim

Dong Yang Ehwa Ind Co Ltd

Address: 6-1 Block, Namdong Ind Complex, 614 Namchong-Dong, Namdong-Gu, Incheon
Tel: +686 3243 77661
Fax: +686 3243 92095
Products: roof linings, door linings, panels, insulation

Duck Yang Ind Co Ltd

Address: 945 Yeonam-Dong, Jung-Gu, Ulsan-Si, Gyngnam
Tel: +686 522 933414
Fax: +686 552 943130
Products: dashboards, roof linings, door linings, arm rests, head rests

Due Heung Ind Co

Address: B7-L3 Namdong Ind Complex, 614-2 Namchong-Dong, Namdong-Gu, Incheon
Tel: +686 3243 86633
Fax: +686 3243 86638
Products: cluster lights for lamps, indicator lamps, hub caps

Due Won Sun Up Co Ltd

Address:	718 Wonsi-Dong, Ansan-Si, Gyunggi-Dong
Tel:	+686 3454 952301
Fax:	+686 3454 912701
Products:	seat mouldings
Plants:	Korea (2)

Han Jin Plastic Ind Co

Address:	728 Yeonam-Dong, Jung-Gu, Ulsan-Si, Gyungnam
Tel:	+686 522 937411
Fax:	+686 522 936 566
Products:	handles, reservoirs, ducting, grilles, hub caps, dashboards

Hankook Intex Co Ltd

Address:	B606-2 Banwol Ind Complex, Ansan-Si, Gyunggi-Dong
Tel:	+686 345 491 5411
Fax:	+686 345 491 5418

H S Chemical Co Ltd

Address:	147-1 Kyo-Ri, yangsan-Up, Yangsan-Gun, Kyungnam
Tel:	+686 523 870 3331
Fax:	+686 523 370 3331
Products:	steering wheels, gears
Contact:	Cho Won-Yong, president

Il Kwang San Up SA

Address:	590-1 Yeonam-Dong, Jung-Gu, Ulsan-Si, Gyungnam
Tel:	+686 522 936 781
Fax:	+686 522 936 712
Products:	PU foam components

Jae Il Engineering Co Ltd

Address:	1355-9 Juan-Dong, Nam-Gu, Incheon
Tel:	+686 3243 25550
Fax:	+686 3243 27700
Products:	PU foam components

Jin Young Standard Inc

Address:	B6-L2 Namdong Ind Complex, Namdong-Gu, Incheon
Tel:	+686 3243 25550
Fax:	+686 3243 27700
Products:	exterior trim and other moulded components

Kang Sung Chemical Co

Address: 418-4 Shin-Ri, Taean-Gup, Hwaeseong-Gun, Gyunggi-Do
Tel: +686 344 975 1581
Fax: +686 344 975 1547
Products: seat cushions, bumpers, decorative trim

Kying Chang Ind Co Ltd

Address: 358-35 Kalsan-Dong, Taiso-Gu, Taegu
Tel: +686 5358 26040
Fax: +686 5358 42833
Products: seat covers and upholstery

Sam-A Ind Co Ltd

Address: 177 Dodang-Dong, Bucheon-Si, Gyunggi-Do
Tel: +686 3267 66111
Fax: +686 3267 53388
Products: seats, seat cushions
Plants: Korea (2)

Samdo Electric Machinery Co Ltd

Address: 2nd Manufacturing Plant, 45–55 Ehyun-Dong, Seo-Gu Daegu
Tel: +686 3286 43311
Fax: +686 3286 20076

Sam Sung Ind Co Ltd

Address: B4-L1 Namdong Ind Complex, Namdong-Gu, Incheon
Tel: +686 3243 18711
Fax: +686 3243 18654
Products: bumpers, radiator grilles

Samwon Plastic Co Ltd

Address: 537-4 Gajwa-Dong, Seo-Gu, Incheon
Tel: +686 3286 43311
Fax: +686 5229 29670
Products: arm rests, head rests, hub caps

Se Chan Ind Co Ltd

Address: 496-1 Yunam-Dong, Jing-Gu, Ulsan-Si, Daegu
Tel: +686 5229 34646
Fax: +686 5335 2138
Products: bumpers
Plants: Korea (2)

Sung Wong Metal Co Ltd

Address: Nyonggomg Complex, Daisan-Ri, Jeonggwan-Myun, Yangsan-Gun, Gyingnam
Tel: +686 5233 77 5317
Fax: +686 2454 69204
Products: interior handles

Tae Hwa Precision Ind Co Ltd

Address: 535-7 Garibong-Dong, Guru-Gu, Seoul
Tel: +686 2856 1833
Fax: +686 2868 8594
Products: bumpers, grilles

Malaysia

APM Plastics Sdn Bhd

Address: Lot 601 Pandamaran Ind Estate, PO Box 144, 42008 Port Klang, Selangor
Tel: +60 3 368 5007
Fax: +60 3 367 0518
Products: injection moulded and profile extruded auto parts
Customer: Proton
Contact: Low Kha Keong, assistant manager

CDG Plastics Sdn Bhd

Address: 19-23 Jalan Lengkuk Teluk Batu , AMJ Ind Park, 41000 Klang
Tel: +60 3 321 2888
Fax: +60 3 321 2886
Products: miscellaneous auto parts
Contact: Ho Nai Leng CEO

De Bono Industries

Address: 61 Jalem Rajah Abdullah, 50300 Kampong Baru, Kuala Lumpur
Tel: +60 3 291 1726
Fax: +60 3 291 6516
Products: miscellaneous auto parts
Contact: Noor Azmi, sales manager

Guolene Plastic Products Sdn Bhd (Injection Molding Division)

Address: Lot 33A, 6 ½ mile, Jalan Kepong Ind Area, Mukim Batu, 52000 Kuala Lumpur
Tel: +60 3 511 6588
Fax: +60 3 511 6605
Products: plastic automobile parts
Contact: Yip Kong Lam, CEO

Hicom-Tech See Manufacturing Malaysia Sdn Bhd

Address: Lot 75A and 76, Jalan Sementa 27/91, 40000 Shah Alam, Selangor Darul Ehsan
Tel: +60 3 511 6077
Fax: +60 3 511 6091
Products: bumpers, instrument panels, other auto parts
Contact: Albert Lim How Ghee, managing director

Hil Industries Berhad

Address: Lot 3, Jalan Ladah Sulah, 16/11 Section 16, 40000 Shah Alam, Selangor Darul Ehsan
Tel: +60 3 550 0501
Fax: +60 3 550 0493
Products: hub caps and other auto parts
Customer: Proton
Contact: Tony Chow, marketing director

Industrial Quality Management Sdn Bhd

Address: Lot 4, Jalan Piandang, Section 24, 40300 Shah Alam
Tel: +60 3 542 2697
Fax: +60 3 542 2751
Products: miscellaneous automotive parts
Contact: Hamdan Bin Yunus

Mah Sing Plastics Industries Sdn Bhd

Address: Lot 54, Jalan E1/2, Taman Ind Estate, Batu 8 Jalan Kepong, 52100 Kuala Lumpur
Tel: +60 3 221 8888
Fax: +60 3 222 2833
Products: miscellaneous automotive parts
Contact: Mr Leong Hoy Kum, CEO

Nylex (Malaysia) Berhad

Address: Persiaran Selangor, Shah Alam Ind Estate, 40200 Shah Alam
Tel: +60 3 559 1706
Fax: +60 3 550 7264
Products: PVC leather cloth for car interior furnishing
Contact: Heah Koh Soon, managing director

Raya Plastik Industri Sdn Bhd

Address: 10 Kawasan Miel, Phase 9, Jalan Piandang 24/34, Sct 24, 40000 Shah Alam, Selangor Darul Ehsan
Tel: +60 3 541 7780
Fax: +60 3 541 7812
Products: miscellaneous automotive parts
Contact: Azman B Hamzah

Rieter Asia Pacific

Address: UOA Centre, 19-8-2/3 19 Jalan Pinan Maz, 50450 Kuala Lumpur
Tel: +60 3264 3280
Fax: +60 3 264 3251
Products: interior trim, sound deadening and other insulating materials

Teck See Plastic Sdn Bhd

Address: 8 Hala Rapat Baru 24, Kinta Jaya Light Ind Area, 31350 Ipoh, Perah
Tel: +60 5 3131 981
Fax: +60 3 757 4612
Products: battery cases
Contact: Tan Ong Hock, CEO

Toyo Plastic (Malaysia) Sdn Bhd

Address: 15th KM Jalang, Lot 56 Tasek Ind Estate, 31400 Ipoh
Tel: +60 5 547 5818
Fax : +60 5 546 2676
Products: extruded sheets, lighting panels, vacuum formed auto parts
Contact: Albert Chan Kwong Sung, managing director

Trisen Mfg Sdn Bhd

Address: 8 Jalan Kilang Midan, Taman Midah, Cheres, 56000 Kuala Lumpur
Tel: +60 3 971 4934
Fax: +60 3 971 5435
Products: miscellaneous automotive parts
Contact: Ju Long Ming, director

SINGAPORE

Delphi Automotive Systems S Pte Ltd

Address: 238880 Singapore, Wheelock Place 501, Orchard Road 18-00
Tel: +65 7359939
Fax: +65 7309598
Products: automotive systems and components
Contact: Carl Rausch, managing director

Federal-Mogul Pte Ltd

Address: 628504 Singapore, PO Box 0401, Jurong Town, 916114
Tel: +65 8630188
Fax: +65 8630005
Products: automotive systems and components
Contact: K T Chee, general manager

TAIWAN

Auto Parts Ind Ltd

Address: 7F, 10, Lane 235 Pao Chiao Road, Hsintien City, Taipei Hsien
Tel: +886 2 2698 1199
Fax: +886 2 2918 2299
Products: bumpers
Contact: Frank Gong, marketing manager

Autotime Ind Inc

Address: PO Box 44-256, Taipei City 106
Tel: +886 2 2733 4148
Fax: +886 2 1735 1892
Products: handles
Contact: Stanley Kio, managing director

Chen Chung Plastics Co

Address: #Ln 1002, Feng Lin 2nd Road, Ta Liao Hsiang, Kao Hsiung, Kaohsiung Hsien 831
Tel: +886 7 781 1114
Fax: +886 7 781 2209
Products: bodywork components
Contact: Kuo-Chung Chiao, general manager

Chi Fa Plastics Works Co Ltd

Address: #11-2, Ln 363 Fu Hsing Road, Sec 3, Taiching City 400
Tel: +886 4 228 4186
Fax: +886 4 228 3156
Products: bezels
Contact: Chi Shen Lu, general manager

Chung Fu Ching Ent Co

Address: #214 Ta Hu Road, Ying Ko Chen, Taipei, Taipei Hsien 239
Tel: +886 2 670 2785
Fax: +886 2 678 1731
Products: bodywork components
Contact: C T Wang, sales manager

Conjoin Kdy Ind Co Ltd

Address: #165 Hai Shan Road, Loochoo Hsiang, Taoyuan, Taoyuan Hsien 338
Tel: +886 3 324 4933
Fax: +886 5 696 1474
Products: grilles, bodywork components
Contact: Jenner Lin, sales manager

Evergreen Auto Body Parts Mfr

Address:	#15 Ln 375 Chung Hua Road, Shulin, Taipei Hsien 238
Tel:	+886 2 683 9115
Fax:	+886 2 683 9116
Products:	bodywork parts

Legion Mold Tool & Mfg Co Ltd

Address:	#92 Kuang Fu N Road, Hukou Hsiang, Hsinchu, Hsinchu Hsien 303
Tel:	+886 3598 1491
Fax:	+886 3595 2194
Products:	grilles
Contact:	Kegion Lao, CEO

Long Chih Ind Co Ltd

Address:	PO Box 22783, Taipei City 105
Tel:	+886 22 683 2345
Fax:	+886 22 785 1079
Products:	grilles
Contact:	Song Tien Nuang, CEO

Pro Fortune Ind Co Ltd

Address:	1F, 14-4 Hai Wei, Hsipan Vill, Sanchu Hsiang, Taipei Hsien
Tel:	+886 22 636 4268
Fax:	+886 22 636 1149
Products:	bumpers
Contact:	Wen-Pin Lee, marketing manager

Pro-Glory Ent Co Ltd

Address:	2201, Ln 333 Hsin Shu Road, Hsinchuang City, Taipei Hsien
Tel:	+886 2 204 1652
Fax:	+886 2 202 0294
Products:	bumpers, spoilers, exterior trim, air conditioning components
Contact:	Y C Su, marketing manager

Tong Yang Ind Co Ltd

Address:	#98 An Ho Road Sec 2, Tainan City 709
Tel:	+886 6 256 0511
Fax:	+886 6 255 5337
Products:	grilles, bodywork, dashboards, headlamp housings
Contact:	Kao Wu, general manager

Wei Liang Ent Co Ltd

Address: #16 An Ho Road Sec 2, Tainan City 709
Tel: +886 6 335 1000
Fax: +886 6 355 1006
Products: dashboards

Yue Ki Ind Co Ltd

Address: #23 Wen-Hwa Road Hain-chu Ind Park, RC Hsinchu City 300 Hhsien
Tel: +886 3598 1226
Fax: +886 3598 2225
Products: bumpers, seats, shock absorber rings

THAILAND

CM Industry Co Ltd

Address: 203 Moo 10 Sukhapibal 6, Poochosamingprai Road, Samutprakarn 10130
Tel: +66 2 384 4191
Fax: +66 2 384 2682
Products: injection moulded auto parts
Contact: Prajit Tongpiputn, marketing manager

Narong Industry Co Ltd

Address: 358/1 Moo 17, Theaparuk Road, Bangplee Ind Est, Samutprakam
Tel: +66 313 10181
Fax: +66 315 1583
Products: rear lamp lenses, mirrors, number plates, emblems and other small injection moulded auto parts
Contact: Anuwat Komkrichwarakool, marketing manager

Polymer Industrial Co Ltd

Address: 25/1 Moo 2 Phetkasem Road, Omyai, Samprem, Nakhon Pathom 73160
Tel: +66 2 420 1193
Fax: +66 2 420 2954
Products: bumpers and spoilers
Contact: Dackewar Chintamez, managing director

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Acknowledgements to Tables

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