1
Introductory survey

1.1 General survey

The automobile industry is the largest user of technical textiles, with about 20 kg in each of the 45 million or so cars made every year world-wide (see Tables 1.1 and 1.2). Despite production overcapacity, and near market saturation in the developed world of Western Europe, the USA and Japan, car production is set to increase for the foreseeable future especially in the developing countries of the world. Significant new markets are opening up in Eastern Europe, South America and the Pacific Rim countries. Total world car production growth has been generally static in the years 1997 to 1999, but by 2004 analysts predict a growth of about 12% on 1999 figures.

Mobility is a fundamental requirement of all human activity whether it falls into either of the two categories of work or play. Cars embody personal freedom and for some an expression of individuality. Despite environmental issues, more and more crowded roads and ever increasing costs of motoring, people are not going to give up their cars. Statistics released by the US Department of Transportation in early 1998 revealed that motor vehicles were the preferred form of travel in long distance trips up to 2000 miles and 80% of all journeys of 100 miles or more were taken in motor vehicles, i.e. cars, trucks or vans.

Of special relevance to textile manufacturers, car interiors have become more important within recent years for a variety of reasons. People are spending more time in their cars, commuting longer distances to work on a daily or weekly basis. They have more leisure time and higher disposable incomes for more days out to visit places of interest, friends and relations as well as trips to the supermarket and out-of-town shopping centres. For business people the car is a place of work, being able to communicate with colleagues and customers by mobile telephone. The car in fact has become an office, a living room and a shopping bag on wheels! From the point of view of the original equipment manufacturers (OEMs), changing the car interior design of an existing model is an economical way to revamp a

Table 1.1 World personal vehicle sales ('000 units)

	1996	1997	1998	1999	2000	2001	2002	2003	2004
North America									
USA: Car	8527	8272	8160	7992	7547	7360	7596	7810	8057
USA: LT	5709	5985	6498	6674	6144	6234	6534	6709	6867
Canada: Car	661	739	746	755	720	657	665	703	725
Canada: LT	428	550	565	580	565	511	519	573	574
Mexico: Car	179	303	430	428	469	486	469	443	447
Mexico: LT	99	137	163	165	181	184	185	210	215
Total	15602	15987	16561	16593	15626	15433	15969	16448	16885
Latin America	1679	1864	1502	1295	1504	1671	1784	1886	1984
Western Europe	12859	13459	14431	14524	14508	14873	15029	14681	14271
Germany	3496	3528	3736	3841	3869	3929	3977	3925	3794
Italy	1725	2396	2369	2086	2017	2215	2241	2104	2041
France	2132	1713	1944	2055	2125	2207	2236	2187	2108
UK	2025	2171	2247	2119	2065	2100	2143	2098	2136
Spain	963	1069	1262	1376	1419	1399	1387	1374	1298
Eastern Europe	1878	2300	2253	2117	2285	2527	2735	3006	3204
Japan	4669	4492	4094	4155	4332	4691	4899	5170	5342
Asia/Pacific	3088	3082	2172	2448	2836	3171	3452	3740	4041
Other	3893	4062	4184	4409	4866	5158	5220	5328	5354
World	43668	45246	45198	45542	45957	47523	49089	50260	51081

Source: SMMT, National Sources, J.D. Power-LMC.
Note: The total for sales in 'Other' countries also includes a statistical balancing item to compensate for inconsistencies and inadequancies in national data, and equate world sales to world production.
LT, Refers to light trucks used as personal transport vehicles in North America.
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Table 1.2 World light commercial vehicle sales ('000 units)

	1996	1997	1998	1999	2000	2001	2002	2003	2004
North America									
USA	862	857	904	911	807	821	866	889	910
Canada	83	100	102	104	98	86	85	93	93
Mexico	14	22	28	28	29	29	29	33	34
Total	958	979	1034	1043	934	936	981	1015	1037
Latin America	316	359	328	301	322	382	432	446	471
Western Europe	1317	1426	1605	1634	1634	1646	1650	1625	1603
Germany	174	188	214	207	206	222	216	214	193
Italy	144	141	172	167	156	150	150	145	140
France	331	312	347	366	389	396	390	367	359
UK	207	228	241	221	203	198	204	204	205
Spain	129	160	183	198	214	222	230	239	241
Eastern Europe	292	359	366	346	399	484	572	635	669
Japan	2334	2189	1720	1636	1746	1846	1963	1942	1957
Asia/Pacific	2129	1938	1485	1601	1782	2006	2209	2363	2482
Other	353	369	371	365	405	440	464	477	487
World	7699	7619	6910	6926	7223	7740	8271	8502	8707

Source: SMMT, National Sources, J.D. Power-LMC.
Light commercial vehicles are those of less than 6-t GVW, and figures for countries outside North America include vehicles which would be classified in North America as 'light trucks'.
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model that is not selling well. Consumer researchers in the USA believe that the car interior will become a focal point for brand recognition.[1] Textile design and colour will inevitably be an essential tool in creating these distinctive interiors.

Textiles provide a means of decoration and a warm soft touch to the seats and the interior of the car, but they are also used in more functional applications. Carpets and textile headliners not only contribute to the overall comfort and decor of the interior, but they also play an important part in damping of sound and vibration. The use of textiles in tyres contributes to the performance, road handling and tyre durability. Reinforcing textile yarns are essential for high-pressure hoses and belts. Non-woven fabrics are used extensively in air and oil filters, bonnet liners and as production aids during manufacture. Fibre composites in place of heavier metal components are helping to reduce the weight of the car, and in many cases simplifying production methods together with other advantages. Seat belts, airbags and associated safety devices are contributing to road safety and saving lives. In addition to the major components there are numerous other textile items such as sewing threads, fastening devices, tie cords, flocked fabric on window seals and even in the battery as electrode separators. Many of these applications have only become possible within the last two or three decades as newer high-performance materials such as aramids became available. Specialist variants of aramids and other fibres have been developed for particular applications and this process is continuing.

The 20 kg of textiles in an average car is made up approximately from 3.5 kg seat covers, 4.5 kg carpets, 6.0 kg other parts of the interior and tyres and 6.0 kg glass fibre composites.[2] This is possibly conservative when absolutely all textile-containing items are included, and is likely to increase further when at least one airbag, and in the future possibly as many as four or more airbags or related safety devices, are installed as standard items. The weight of fibre in composites could also increase to replace heavier metal in the quest to make cars lighter and more efficient. In addition, in the effort to improve recycling of car interior components some polyurethane foam could be replaced with polyester, or some other fibre. This fibre itself could be a recycled material and this has already happened in some current production cars. In recent years there has been a revival of interest in natural fibre such as jute, sisal and kapok for use in automobiles, especially in composites.

1.1.1 The beginning

The motor industry has come a long way since Karl Benz of Mannheim in Germany built the first successful petrol-engined car in 1885, which some regard as the beginning of the commercial motor industry.[3,4] This vehicle was in fact a three-wheeler, the first successful four-wheeled, petrol-engined car was produced by Gottlieb Daimler in 1886. Apparently the two founding fathers never met and did their work independently of each other. The closing years of the nineteenth century was an exciting period of new developments, and by the turn of the century there was an embryonic motor industry in the USA as well as Europe. The first successful American car was produced in 1893. In Britain the 'red flag' law, which required a man walking in front of cars carrying a red flag, hindered progress. This law was not fully repealed until 1896, after which date a vast number of companies seeing the potential in this new transportation industry began to build cars, many with engines imported from the continent. There were about 32 car manufacturers in Coventry alone at the beginning of the twentieth century, among them was Rover which began production in 1904. The General Motors Company (which became General Motors Corporation), was founded in September 1908 and within about a year included, the Buick, Olds(mobile), Cadillac and Oakland (later Pontiac) companies.

The first reliable world figures show that France led the world in 1903, making half of the world's total output of about 62 000 vehicles, with the

USA making about 11 000 vehicles in second place.[3] Apparently, restrictive traffic regulations in Germany checked the growth of the industry in the country which had been the pioneer. However, the motor industry did not really take off until Henry Ford introduced mass-production-line assembly in 1908 at Detroit, and in 1913 at Old Trafford, Manchester, to make his Model T Ford. Until this time car parts were in general, made individually by hand with skilled labour. Ford invested in large machine tools that could stamp out parts by the thousand all exactly the same without the need for skilled operatives. However, these new tools were extremely expensive and so very large numbers of cars needed to be built and sold to recoup the cost. Other car makers soon copied Ford's system and the modern motor industry was born.[4,5]

1.1.2 The new beginning

The Toyoda family founded the Toyota Motor Company in 1937 but it was not until the 1950s that they and other Japanese companies developed their 'lean production' methods, which were later to be adopted throughout the world. This development was the start of another significant landmark in the international automotive industry – competition from Japanese car manufacturers. The Japanese brought new methods and cultures to the mass production of motor cars and their appearance on the international scene in the 1960s significantly intensified worldwide competition.

1.1.3 The present day

Today the same principles apply; the cost of development of a new model and making tools for mass production are so expensive that cars must sell in large numbers quickly against the international competition, first to recover the development costs, and then to make a profit. However, today the numbers required are so large that cars, especially those made in Europe must sell in more than one country to make a profit. The automotive industry has become a global industry and car makers must manufacture on a global scale to compete. The concept of the 'global car', a single model which could sell all over the world has been the subject of discussion, including discussion on the actual definition of the term. It would allow production on an enormous scale with all the benefits of very long production runs and reduced unit development costs. However, it is likely to need regional or national features, especially in the interior trim and some writers believe a 'global car', in the strict definition of the term is not possible. A more practical approach is rationalising and limiting the number of 'platforms' – the basic engineering structure of the car – and most OEMs are doing this. For example, Volkswagen currently build 33 car models on

11 platforms but by the year 2005 are expected to be building 55 models on only four platforms.[6]

Competition between individual OEMs has become extremely intense and is intensifying further as they strive to increase their share of the market by producing cars with better value for money and with more marketable designs both exterior and interior. At the same time production costs are being continually reduced. Development of new models, designs and more economical production methods and materials have become essential. Development times-to-market are becoming shorter and shorter, to respond more quickly to market demands. A three-year minimum was once the norm but some OEMs claim they can reduce this, in some cases, to less than one year.

Although large-scale production is essential for economy, the customer is demanding more choice, both in actual appearance and interior design of the vehicle as well as accessories and more practical features. In fact different classes of vehicle have appeared to satisfy different customer life styles and individual requirements. Specialist vehicles described by the new terminology such as 'recreational vehicle' (RV), 'sports utility vehicle' (SUV) or 'multi-purpose vehicle' (MPV) have appeared. In the USA pick-up trucks now sell in numbers that are comparable with saloon cars (see Table 1.1). To compete effectively each OEM must be represented in each of these categories and each category may have its own variants. OEMs are striving to reduce costs by economies of scale of production and at the same time cater for a wide diversity of individual customer requirements.

In the effort to reduce production costs OEMs have become assemblers of components produced outside their own factory by specialist suppliers who also make the same components, e.g. seats for other OEMs. These direct, 'Tier-1 suppliers' cut production costs by making the components in very large volume, by bulk-buying of components and raw materials – anywhere in the world and by combining small individual items together into larger single modules that can be installed quickly into the car on the production line. This system of 'outsourcing' is now a standard feature of the automobile and other industries, and is being developed further, involving even larger unit modules. An example of a large module is a modern headliner which can incorporate a number of items such as a sun-roof, light units and assist handles.

An important feature of modern 'lean' production is just-in-time (JIT) delivery. With JIT delivery, ideally, no warehouse is necessary, which simplifies stock control, administration and helps cash flow. The Tier-1 suppliers have also become global manufacturers, and need to be close geographically to the OEM plants they supply to facilitate JIT delivery. In turn, their suppliers, the Tier-2s also ideally, need to be close to their customers. OEMs are continually applying pressure to cut costs, indeed one major OEM in 1995 announced their requirement of 3–6% annual cuts to the year 2000, i.e. 20% compounded from their Tier-1 suppliers.[7] The 'cost down' has become a regular feature of the auto industry. To achieve even further cost savings a process of consolidation is taking place among Tier-1s, Tier-2s and the OEMs themselves. The Lear Corporation is buying up interior component companies with the intention of eventually being able to offer entire car interiors to an OEM at an agreed price.[8,9] The trend is for OEMs, Tier-1s and others in the industry, to reduce the number of suppliers to simplify administration and reduce cost. In 1996 there were 400 Tier-1 suppliers, but by the year 2010 they are expected to number only 20, and some analysts believe there will be far fewer.[10] However OEMs expect more from the select few to supply JIT at the right price and right quality. Reliability and quality are so important that audition of suppliers is becoming standard practice in the industry. QS9000 quality standard, the requirement for suppliers to the American 'Big Three' of General Motors, Ford and Chrysler is becoming the requirement or basis of requirements for other OEMs. Long-term business relationships between suppliers and customers based on confidence and mutual understanding is now the preferred method of doing business, especially when a Japanese OEM is involved.

1.1.4 New challenges

Probably the most important challenge that the motor industry faces today is the effect on the environment. More and more green countryside is being converted to traffic-choked roads, but more importantly, cars are burning up non-renewable fossil fuels, causing air pollution and global warming in the process. Attempts have been, and are being made, to make cars lighter so the engine has less work to do and thus save fuel. In addition, at the end of a car's life the end-of-life vehicles (ELVs) are presenting problems in the disposal of the non-metallic parts, many of which at present go into landfill sites. Recycling of some materials is being done but there is still a long way to go. Attempts are being made to replace certain components such as polyurethane foam with polyester non-woven fibre (the seat cover is also polyester), to facilitate recycling by commonization of materials, i.e. using as few chemical types as possible. Solutions to environmental problems however usually increase cost, and government legislation, sometimes following action from environmental pressure groups, is often necessary to make things happen. EU Directives that are likely to change the way cars are made in the immediate future are imminent. These aspects are discussed in some detail in Chapter 8.

Similar to environmental issues, safety devices, such as seat belts and airbags, add to production costs and government action has been necessary for widespread installation. As a result airbags and associated safety devices have become probably the largest single growth area in technical textiles at the present time. Half a million persons are killed on the roads worldwide every year and road accidents are becoming one of the top three causes for premature death. The governments of the world are applying pressure to reduce this by a number of methods, including making the car safer. Very recently, there has been a move to make cars less harmful to pedestrians in the event of an accident. Softer exterior front ends are being considered and possibly textiles may find a use here.

The car seat cover is perhaps the most familiar automotive textile to the layman, who may not appreciate the considerable technical input necessary, to develop a fabric which must stand up to rigorous use (and abuse), and still last the life of the car. In recent years the design and colour of the car interior, especially the seat have become extremely important in attracting the buyer's attention. During the mid-1990s a number of technical magazines appeared devoted entirely to automotive interiors, (see Chapter 11). The seat must be comfortable in all senses of the word both physically to the touch and also visually. Comfort has assumed more importance as people spend more time in cars for business, domestic, social and leisure activities. Comfort also helps prevent stress and fatigue and therefore contributes to road safety, and textiles have an important contribution to make in this area. This aspect is discussed in some detail in Chapter 6.

1.2 Material survey – fibres

1.2.1 Early seat covers

Many of the earliest cars were open top, and the first car seat covers were leather or leather imitations. Before the era of synthetic fibres, wool and cotton were used and when rayon and other man-made fibres became available, they were also used, sometimes in combinations to give coloured, toned effects. In the 1940s many car seats were covered in fabrics made from fibres spun from a copolymer of vinyl and vinylidene chloride (Saran in the USA, Velon or Tygan in the UK). This material was pigment dyed in the melt and had very high lightfastness and was also easy to clean. Also at this time just after World War II, nylon began to be used, sometimes in blends with other fibres such as cotton. A textiles encyclopaedia first written in the late 1950s, lists the main requirements of a car seat fabric in order of importance as; cleanability, durability, slideability, colour fastness and wrinkle-resistance.[11] The term slideability, refers to one notable disadvantage of the thick velours which were used in the earlier days, i.e. they were hard to clean and difficult to move about on. A notable absence from this list is ultra-violet (UV) light degradation resistance.

In the 1950s PVC-coated fabrics became widely used for apparel, domestic furniture and car seat covers. They were available in many attractive colours and could be embossed and 'vinyl' became much used as a fashion material. A further development produced 'expanded vinyl', which had a soft touch and closely resembled real leather. PVC car seat covers were very widely used in regular production cars until the early 1970s when rising living standards began to demand more comfort in cars. PVC seats were hot and sticky, especially in hot weather. Milliken and Fords themselves produced knitted PVC fabric made from threads obtained by slitting sheets of PVC film. This material was noticeably more breathable and comfortable than continuous PVC sheet.

Nylon, which was already being used in some car seats, began to be used more widely in different constructions and colours. However durability standards were rising as competition began to be more intense. Another factor, the 1973 Arab-Israeli war had a very significant effect on the industry at this time, causing the price of petrol to more than double almost overnight in the western world. The exterior styling of cars had already become important to attract customers but now, because of rising fuel costs, cars had also to be more aerodynamic with low air drag coefficients. These factors led to slanting glass and larger windows, which in turn let in more sunlight. Glass is transparent to visible light, which has the effect of heating up the car interior. The heat is retained in the car like a greenhouse and on sunny days in the tropics the temperature can easily exceed well over 100 °C. In addition to dry heat the relative humidity can vary from 0 to 100%. These conditions are very severe for any material, especially textiles and many of the nylon car seats covers used at this time degraded, losing colour and tensile strength and abrasion performance. These experiences have deterred many OEMs to this day from using nylon as car seat covers in large volume production cars despite improvements in UV and light protection and the fact that in certain constructions the abrasion properties of nylon are probably the highest of any fibre. Earlier cars generally had smaller windows in which the glass was more or less vertical, and the conditions inside on sunny days were probably not as hot as in modern cars. In addition customers were possibly less demanding regarding the car interior, and competition between the car companies was also possibly less intense than today.

1.2.2 Modern seat covers

The most important requirements of car seat cover fabric are high abrasion resistance and resistance to UV degradation. The fabric must last the life of the car, well over ten years and must appear in first class condition, to maintain a good resale value, for at least two years. Most car buyers are not mechanically minded and if the car seats look worn, they will assume that the engine and the rest of the car is also worn. The abrasion properties of fabrics depend to a certain extent on construction and the type of yarn, degree of texture, fineness of filaments etc. but also very significantly on the fibre type. Cotton and other cellulosic-based yarns such as viscose rayon and the new lyocell yarns have significantly lower abrasion resistance than nylon, polyester, acrylic and polypropylene. Acrylic has the highest light and UV resistance but falls down on abrasion compared to the other synthetic fibres. The material which has risen to prominence during the 1970s and 1980s and is now used in over 90% of all car seats world-wide is polyester. Even this fibre however requires to have UV light-absorbing chemicals added to the dyebath to pass modern rigorous standards of durability.

Polyester is helped by the fact that glass filters out the UV light radiation which harms it most, see Table 1.3 – other fabric properties appear in Tables 1.4 and 9.1. The excellent UV degradation resistance of polyester combined with very good abrasion resistance and relatively inexpensive price ensure that it will keep its prominent position among the available fibres. Other properties of polyester which make it ideal for car seat covers

Table 1.3 Light durability of some natural and synthetic fibres exposed simultaneously

Durability in Florida: months required to reach loss in strength indicated

	Initial tenacity g/den	Outdoors (direct sunlight)		Behind glass	
		50% Loss	80% Loss	50% Loss	80% Loss
Acrylic, semidull	2.1	13.6	36 (72%)	19	36 (63%)*
Polyester, bright	4.2	3.7	7.9	24	36 (75%)*
Polyester, semidull	3.1 (spun)	4.0	9.1	36	36 (49%)*
Polyester, dull	4.2	3.6	8.0	20	36 (79%)*
Nylon, bright	5.3	9.5	17.0	10.3	20.7
Nylon, semidull	5.4	3.2	6.5	4.5	8.2
Nylon, dull	5.1	3.1	5.1	4.1	7.7
Rayon, bright	1.6	2.6	6.3	3.0	14.2
Acetate, bright	1.0	5.1	11.8	8.1	27
Cotton, deltapine	1.8	2.9	5.8	4.9	14.0
Flax, Irish	3.5	0.9	2.5	4.5	5.0
Wool, worsted	0.7	2.3	3.2	4.5	7.6
Silk	4.2	—	—	0.8	3.9

* Loss per cent indicated after 36 months.
Source: Faris BF, (Dupont) in '*Automotive Textiles*' (Edited by M Ravnitsky), SAE PT-51 1995. Copyright held by Society of Automotive Engineers Inc Warrendale, PA., USA. Reprinted with permission.

Table 1.4 Summary of properties of main fabrics used in automotives

	% Moisture regain at 65% RH	Acids	Resistance to alkalis	Solvents	Advantages	Disadvantages	Major applications
Polyester	0.4	Good	Moderate	Good	High abrasion. Good UV resistance. Relatively inexpensive	Low moisture absorbancy. Uncomfortable seats in summer. Limited compressed resilience – not used in tufted carpets	Seat cover fabric. Interior trim face material. Carpets (needle-punched). Functional non-woven applications. Seat belts. Tyre cords
Polyamide 6 and 66	4.0	Moderate	Good	Good	Good resilience and elasticity recovery. Good thermal absorption (for airbags)	UV resistance poor unless stabilized	Airbags, Carpets (tufted). Tyre cords

Table 1.4 (cont.)

	% Moisture regain at 65% RH	Acids	Resistance to alkalis	Solvents	Advantages	Disadvantages	Major applications
Polypropylene	0	Good	Good	Moderate	Inexpensive. Lightweight	Colouration limited. Low melting point. Low moisture absorbency	Interior trim face material (not seats) Carpets (needle-punched). Functional non-woven applications.
Acrylic	2.0	Good–moderate	Moderate	Good	High UV resistance. Soft handle	Moderate abrasion	Car roofs
Wool	12+	Good	Poor	Good	Comfortable Resilient	Relatively expensive. Low resistance to UV	Seat cover fabric in luxury cars

Notes: 1. Other fibre properties appear in Table 9.1.
2. All synthetic fibres have good soil resistance and good resistance to micro-organisms compared with natural fibres. Polyester, polyamide and polypropylene tend to retain oil soiling.
3. Polyester not used in airbags because of poor thermal energy absorption.

include, high tear strength, resistance to mildew, low water absorbency, allowing it to be kept clean relatively easily, excellent resilience and crease resistance. The latter property is helped by lamination to polyurethane foam. However, the low water absorbency in hot weather can result in thermal discomfort, and ways of improving this have been explored. Some acrylic fibres have been used, and a small quantity is still used, mainly in Italian cars. Acrylic fibre has excellent UV degradation resistance, is available in a variety of colours and has a soft handle but abrasion resistance is not especially good. The exceptional UV degradation resistance, especially when spun dyed, makes acrylic eminently suitable for car roof covers and for hoods for convertibles.

Wool is also used in car seat covers and has acceptable abrasion resistance in certain constructions but it is expensive and is generally used only in up-market cars. Wool is a hygroscopic fibre absorbing water vapour, and for this reason provides better thermal comfort than polyester. Wool can be made flame retardant to a high standard by the Zirpro process, which makes it very attractive for use in passenger-carrying vehicles, trains and aircraft.

The manufacturers of polypropylene fibres are trying very hard to have their material accepted for car interior trim.[11–15] It is less expensive than polyester, is claimed to be more easily recycled and is significantly lighter in weight. However at present its disadvantages outweigh the advantages. The most serious problem is that it cannot be dyed commercially in a dyebath, and the only commercially available coloured polypropylene yarns have been spun dyed during manufacture. Spun-dyed (also referred to as producer, solution or melt-dyed) yarns are only available in bulk quantities which goes against the present day requirements of flexibility and rapid response to colours in vogue, at a particular moment in time. Much research is being conducted to enable polypropylene to be dyed in dyebaths.[15] Other disadvantages of polypropylene yarns for use in car seats are the low melting point and limited abrasion resistance. It has even lower moisture absorbency than polyester and is therefore even more likely to be thermally uncomfortable in hot weather especially when next to the skin. Polypropylene however is used in non-woven fabrics as headliners, carpets and other areas of the car. Chemical stabilizers have improved the stability of polypropylene fibre to light and thermal degradation.[13,14]

1.2.3 Modern seat covers – the fabric producers' view

A prime requirement of any textile seat or door panel base fabric, is the ability to apply both a visual and aesthetic sense to the product. This may seem somewhat self-evident but many fabrics have been developed which meet many of the needs of the OEM and Tier-1 stylists, but which are inflexible when it comes to surface decoration, and fabrics have suffered as a result of this. In addition base fabrics should be capable of design and colour variations on short development time scales.

One such product is double-needle-bar Raschel fabrics (DNBR), see Section 3.3, which is in many ways an ideal product with a pile surface, high production rates, low cost, some stretch for ease of engineering etc., but it lacks the ability to have large surface patterns applied easily and efficiently, without dramatically affecting cost. The result of this over recent years has been the fact that this technology has lost out to more 'design friendly' processes such as circular-knitted products.

Similar comments could be made of loop-raised tricot fabrics, where fabric aesthetics rather than surface pattern predominate. New ways of applying design to fabric such as ink-jet printing, however, mean that such fabrics could again come to the fore as print substrates and compete favourably with jacquard technologies which are at the moment dominant in the production of figured fabrics.

1.2.4 Seat cover laminates

The seat cover fabric must always appear uncreased, and for this reason it is usually laminated to polyurethane foam, with a thickness varying from about 2 to 10 mm. In addition it must resist soiling, be easily cleanable without ever being put into a washing machine. The lamination to polyurethane foam also imparts a soft touch to the fabric and when the seat cover is made up, deep attractive sew lines are formed. To help the seat cover slide along the sewing machine surface during sewing, and to assist sliding when the made-up cover is pulled over the seat structure, a scrim fabric is laminated to the other side of the polyurethane foam. The scrim also helps control the stretch properties of the seat cover especially when knitted fabrics are used. Thus the cover 'fabric' is usually in the form of a triple laminate for seats, but when used for door casings a bilaminate, i.e. without the scrim, is used. At the present time the most important technical requirements of a car seat covering fabric are cost, UV degradation resistance, lightfastness, abrasion resistance and soil resistance. The latter is a natural property of polyester, which can be improved by a fluorocarbon after-treatment if necessary.

The polyurethane foam to which the cover fabric is laminated can be of two general types, polyester polyurethane foam and polyether polyurethane foam. Polyester polyurethane foam has poorer hydrolysis resistance compared to polyether polyurethane foam and is generally used in northern Europe but not in more humid parts of the world. Some OEMs specify polyether polyurethane for all their fabric. In addition there are flame-retardant (FR) grades of both types to different standards of flame retardation, the higher the standard, of course, the higher the cost. Polyether polyurethane foam needs to be modified slightly with certain additives to make it flame laminateable.

1.2.5 Textiles in other areas of the car

The decorative and soft touch properties of textiles are used in most other areas of the car interior, summarized in Table 1.4. The more functional uses of textiles generally demand very specific properties such as high tenacity and low shrinkage (important for tyres), high modulus (important for composite structures) and high temperature resistance (for belts and hoses). Specialist fibres have been developed and have found ready applications in the motor industry. In addition, textiles play a vital part in composites and rubber-based products, which have brought tremendous benefits – increasing performance and durability and saving weight. Non-woven fabrics are used extensively for both functional and decorative applications in the car and the amount used is increasing slowly but steadily to replace more expensive covering materials and in other numerous applications, see Section 3.6. The use of non-woven material to replace polyurethane foam has been explored extensively but so far with only limited success. The use of fibres in composites is likely to increase as more success is achieved in replacing heavy metals with lighter plastic/fibre combinations. Natural fibres, which are a replaceable natural resource are being examined carefully for this application and some technical advantages have been identified.

1.3 Material survey – plastics

Some mention must be made of plastics and their properties because automotive textiles are almost invariably joined to or used in conjunction with plastics; indeed synthetic fibres are themselves plastics and have the properties of plastics. Table 1.5 summarizes the main materials used in car interiors. Textiles are now processed using techniques originally designed for plastics alone such as the various moulding procedures. The durability requirements of plastics inside the car are of course similar to those of textiles. In some cases they are even higher. For example, the dashboard in virtually all cars is mostly plastic, and it is directly under the windscreen – the hottest part of the car. The use of plastics in car manufacture has grown very considerably over the last 25 years and will continue to grow, especially in the form of composites. Several 'all plastic' concept vehicles have appeared over the years. Plastics have allowed freedom of design and

Table 1.5 Summary of materials used in car interiors

Component	Decorative cover face material	Intermediate or soft touch	Carrier or rigid structure
Seats	Polyester fabric (woven/knitted), Wool, Wool/polyester blends (woven), Leather	Polyurethane foam, Polyester non-woven	Cushion/squab, of polyurethane foam, Metal frame
Door panels	Polyester fabric, PVC, PVC/ABS foil, TPO foil, Polyurethane foil, Leather	Polyurethane foam, Polyester non-woven, PO foam, PP foam	Wood fibre, PO/wood fibre, PP/natural fibres, PP/glass fibre, PP/talc, PU/glass fibre, PU/natural fibres
Headliner	Polyester non-woven, Knitted nylon/Polyester, PVC foil	Polyurethane foam, Polyester non-woven, PO foam, PP foam	Semi rigid PU foam/fibre glass, Resinated shoddy fibre, Cardboard
Parcel shelf (Package tray/ hat rack)	Non-woven polyester, Non-woven Polypropylene	— —	Wood fibre, Resinated shoddy fibre, Polypropylene PU/glass fibre
Sunvisor	Polyester fabric, PVC foil	Polyurethane foam, Polyester nonwoven PO foam	Semi rigid PU foam, Cardboard, Metal frame
Carpet	Nylon fibre, Polypropylene fibre	— —	Polyester non woven/SBR latex binder, Polyethylene for mouldability, Acoustic barrier of EPDM, Resinated shoddy fibre/PU foam, PU foam
Dashboard (Instrument panel)	PVC/ABS, PVC, TPO, Polyurethane foil	(Expanded) PVC, PP foam	PVC, PVC/ABS, Polyurethane, PU/glass fibre, PP/talc Metal
Bootliner (Trunkliner)	Polyester non-woven, Polypropylene non-woven	— —	— —
Bonnetliner (Hoodliner)	Polyester non-woven Polypropylene non-woven	Polyurethane foam	Resinated shoddy fibre, Fibreglass, Polyurethane foam
ABC pillars	PVC/ABS, PVC, PU or TPO foil	Polyurethane foam, PP foam, Polyester non-woven	PP, PVC/ABS
Airbag	Nylon 66, 6, 46 woven	—	—
Seat belt	Polyester woven	—	—

TPO, thermoplastic polyolefin; ABS, acrylonitrile–butadiene–styrene; PP, polypropylene; PU, polyurethane; PO, polyolefin; PE, polyethylene; EPDM, ethylene – propylene – diene monomer rubber.

styling as more creative shapes can be produced in plastic compared with metal or wood.

The versatility of plastics has also allowed significant weight reductions, and more economical production methods, by permitting the integration of several parts and processes. An example is in-mould lamination to the décor material, which can be a textile or a foil, without adhesives. This single process replaces the separate production of the rigid part which then, in another separate process, needs to be joined to the face décor material. This technology is becoming more sophisticated, enabling more complex shapes and parts to be produced faster, more economically and with more consistent quality. However the production volume must justify the tooling costs. More mention will be made of this subject in Chapter 6. The Association of Plastic Manufacturers in Europe (APME) has pointed out that 100 kg of plastic in a modern car will have replaced between 200–300 kg of conventional material. Over the life span of the car, this results in very considerable savings of oil, which is estimated at 12 million tonnes per year in Western Europe.[16] Carbon dioxide and other exhaust emissions are also substantially reduced.

Plastics can be broadly divided into two types; thermoplastics, which soften and eventually melt when heated and thermosets, which do not soften or melt when heated. All plastics are made from long-chain linear polymer molecules but in the case of thermoset plastics, the molecules are cross-linked, which makes the whole stucture more rigid and prevents them moving when heated. With thermoplastics, the long-chain molecules are free to move about more when heated above certain temperatures specific to the particular molecular length and chemical nature. Thermoplastic properties of some plastics are useful in that they allow the material to be used as hot-melt adhesives and in certain cases allow the material to be joined by welding techniques.

In general terms for a given chemical type of thermoplastic, the shorter the molecular length, the lower the melting point, and the longer the molecular length, the higher the melting point. Adhesives are generally shorter-chain-length molecules and melt at relatively low temperatures, for example polyester fibre melts at about 260 °C, but there are polyester-based adhesives which melt as low as 100 °C. The thermoplastic nature influences the ease with which recycling can take place; if thermoplastic, the material can be melted down and reprocessed into the same or another useful article. Thermoset plastics are not as easily recycled, and for this reason thermoplastics are generally preferred over thermoset materials – if there is a choice. Thermoset plastics are harder, more rigid and more heat resistant but the vast majority of plastics are thermoplastic.

The main plastics used in combination with fabric are, polyurethane foam, and adhesives based on polyurethane, polyethylene, polypropylene, polyamide and polyester. Covering materials (coverstock), inside the car, other than textiles and leather, are thermoplastic films (sometimes called foils), made from PVC, PVC/ABS, polyurethane, and polypropylene. Plastics are also used in rigid components of the car interior such as the dashboard, pillars, door casings and the rear parcel shelf. There are of course very many other applications of plastics and advanced plastic materials in all other areas of the car. Tables 1.4 and 1.5 summarize the textiles and polymer types used in the car interior.

It is important to realize that a 'plastic' generally consists of the plastic itself plus several additives. Amongst these are UV radiation and heat stabilizers, antioxidants, fillers to improve the mechanical properties, fillers for economy, flame-retardant chemicals, reinforcement fibres (turning the plastic into a 'composite' – see Chapter 9), pigments and other compounds necessary to confer further special properties or to assist with processing. Sometimes it is necessary to add materials specially to make all the various ingredients compatible with each other. When fibres are added or when the compound is to be coated onto a fabric, coupling or bonding agents – also called adhesion promoters – may also be required. Plastic compounding or mixing of components is a specialized process and if not carried out correctly, it can cause production problems and variations in quality. In addition, volatile compounds can cause fogging in cars, see Chapter 5. Furthermore there are many variants of each chemical type and the terms 'polyurethane' or 'polyester' in fact refer to families of polymers of related chemical constitution and not just a single type.

1.4 Material survey – natural and synthetic rubbers

These materials are closely related to plastics and are used in combination with textiles in many parts of the car. Similar to plastics there are various types to suit different applications and they are versatile in that they can be blended together and additives can be mixed in to provide specific properties. The largest application by far for rubber is the tyre, which accounts for about 50% of all rubber production in the world. However there is not enough natural rubber available and so this has to be supplemented with synthetic rubbers especially styrene butadiene rubber (SBR). A number of specialist rubbers which are widely used in transportation applications are nitrile rubber, butyl rubber, polychloroprene, the best known of which is Neoprene (DuPont) and chlorosulphonated polyethylene, the best known of which is Hypalon (DuPont). These more specialist materials are used widely in fabric-coating applications, which are described in more detail in Chapters 7 and 9.

1.5 Requirements from suppliers

OEMs and also their suppliers, the Tier-1s and -2s, in fact everyone associated with car construction or the supply chain require unfailing reliability in terms of delivery on time, quality and suitability for efficient use. Suppliers must also be prepared to accept and respond to fluctuations in the market place. A selection of OEMs, Tier-1s and textile producers in the auto industry appears in Table 1.6. A new potential supplier's past performance is examined, and his facilities inspected and audited to reassure the purchaser of his ability to produce quality goods at the required time. The supplier is expected to conform to a recognized quality procedure such as ISO 9000. These procedures are very wide ranging, covering all management functions including, sales and marketing, production, research and development and personnel.

There are certain aspects which are peculiar to the automotive industry, and to meet these, the three major American car makers, General Motors, Ford and Chrysler collaborated to produce QS 9000. This quality-assurance document is based on the ISO 9000 series, but tailored to meet these special requirements. Quality is discussed at length in Chapter 5. Supplier quality requirement manuals are now issued by customers, which detail the actual procedures and mechanisms of doing business. In response many suppliers now declare that their aim is to provide total customer satisfaction and indeed aspire to exceed customer expectations.

OEMs expect their suppliers to become long-term partners who not only deliver quality goods JIT but are also capable of correcting any problems of supply or quality quickly and efficiently. Non-conformance and concession forms are issued if performance properties are not entirely within specifications. Documented action plans should be in place for multidisciplinary teams to tackle problems should they arise, so that the causes are located quickly, corrective action is taken promptly and more importantly, re-occurrence is prevented. Techniques such as failure mode and effects analysis (FMEA) and statistical process control (SPC) are expected to be in operation.

OEMs and their suppliers operate supplier merit systems, whereby suppliers' performance is assessed and reviewed at least annually. Awards and certificates are made to those companies whose performance has been outstanding in terms of quality and delivery JIT. These annual awards encourage and reward the efficient suppliers but also act as a 'league table', so that those companies who do not rank high can strive to improve their performance over the coming year.

The prices OEMs pay for the goods are expected to be the lowest possible and the supplier is expected to continuously strive to lower this even

Table 1.6 Some major producers in automotive textile engineering

1.6.1. Original equipment manufacturers (OEMs) car makers

General Motors	Fiat
Ford	PSA Peugeot/Citroen
Toyota	BMW
DaimlerChrysler	Porsche
Renault/Nissan	Mitsubishi
Volkswagen	Daewoo
Honda	Hyundai

1.6.2. Heavy goods vehicles (over 6 tonnes gross vehicle weight) manufacturers

DaimlerChrysler (Freightliner)	ERF
Navistar (formerly International Harvesters)	MAN
RVI, Renault (Mack)	General Motors (Bedford)
Ford	Isuzu
Volvo/Scania	Dongfeng
Paccer (DAF, Forden, Kenworth, Peterbilt)	Hino
Iveco, Fiat (Magirus Deutz, Unic)	Mitsubishi

1.6.3. Some Tier-1 suppliers

Company	Main activity involving textiles
Delphi	Seating, airbags
Visteon	Seating
Johnson Controls	Seating, headliners, door panels
Lear	Seating, headliners, door panels, floor systems
Magna	Seating, door panels
Textron Automotive	Seating, door panels
Ikeda Bussin	Seating
Collins & Aikman	Floor systems, door panels, interior trim
Treves	Seating, door panels, floor systems
Sommer Allibert	Door panels, headliners, interior trim
Faurecia	Seating, door panels
Rieter	Floor systems, interior trim
Autoliv	Airbags, seat belts
TRW	Airbags, seating
Toyoda Gosei	Airbags
Toyko Seat	Seating, door panels, headliners

1.6.4. Some automotive fabrics suppliers

Woven/knitted Fabrics	Non-woven fabrics
Collins & Aikman	Freudenberg
Guildford Mills	Cosmopolitan
Milliken	Lohmann
Joan	Fibertex
Viktor Achter	Lantor
Achter and Abels	Fiberduk
De Witte	US Nonwovens
Aunde	National Nonwovens
Borgstena	Texidel
Axelsons	Dexter
Deutsche Bobinet	Libeltex
Eybl	BFF Nonwovens
Thiery	Sandler
Fidivi	Sommer
Kawashima	
Seiren	
Suminoe	
Trèves	

Compiled from various sources including:
1. '*Automotive & Transportation Interiors*' Special Report August 1999.
2. *FT Auto*, 3 December 1999.
3. Wilkens C, 'Automotive Fabrics', *Knitting International* August 1995, 52.

further without compromising quality in any way. Furthermore the supplier is expected to improve his product and to work with the OEM to find more economical ways of achieving the same objective with alternative or more advanced methods or materials. Everyone is expected to strive for zero defects and to be constantly looking for ways to improve performance and to shorten delivery times further.

Suppliers, especially the Tier-1s are also expected to innovate and research new products and develop more cost-effective processes. They are therefore expected to have research, development and design teams and facilities, together with market researchers and analysts to keep up to date with new concepts in a constantly and rapidly changing world. Development times to market must be as short as possible and ways of shortening them further should be constantly researched. The Tier-1s may develop products for different OEMs, which may ultimately compete with each other in the marketplace, and of course confidentiality must be respected. However, if a fabric company develops a new fabric or design they may be required to make all the information available to one of their competitors so that the OEM or Tier-1 can have two suppliers.

The environment is being taken seriously by OEMs and from 2006 they will be responsible for taking back all scrap cars for dismantling, recycling and disposal. OEMs will be seeking for contributions and assistance in this task and will look favourably on suppliers who are able and willing to do this. Already some major OEMs require a recycled content in components supplied. It is in order to create a positive image for the industry as a whole that the OEMs and their suppliers strive for a cleaner environment, and the ideal of 'sustainable development'. Many companies already have successfully registered for ISO 14001. These aspects are discussed in Chapter 8.

In the modern automotive industry, suppliers are expected to be capable of supplying JIT anywhere in the world, and to provide prompt technical service and sales support anywhere in the world. Needless to say they are expected to exhibit confidence, management stability, efficiency and professionalism, a positive, forward proactive approach and to be innovative and constantly searching for increased productivity and quality. The automotive industry pioneered the modern methods of mass production, i.e. assembly line manufacturing and JIT delivery. It has become a truly global industry and many see it as a future model for other industries. There are regular special requirements conferences held to inform, discuss and develop new concepts and procedures necessary to be an efficient supplier to the automotive industry. Modern communications technology is revolutionizing ways of conducting business and there are exciting new possibilities offered by the internet to improve efficiency and reduce costs.

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2
Interior design

2.1 Interior design

2.1.1 The background

The importance of interior design to the potential sales volume of passenger cars has always been a major consideration to the automobile stylist. However, despite the fact that textiles had for a long time played a part in automobile manufacture it was not until the early to mid-1970s that these same companies began to realize the role that well-designed textile fabrics could play in the design of attractive interiors.

The reason for this was probably twofold. First, cars were largely designed by engineers, who, although talented, were not usually trained in any textile technology and so they relied upon their suppliers to alert them to developments. They tended to develop tried and trusted products due probably, then as now, to the 'huge cost of getting it wrong'.

The second reason was that up until this time the textile industry had not come to regard the automobile industry as a major market for aesthetically designed fabrics. This again was probably due to problems with performance in that the existing technologies struggled to produce products which could withstand the critical requirements of abrasive wear and high lightfastness. The products that could meet the criteria were usually unexciting fabrics, probably piece dyed, which offered little design potential.

Three major developments in the early 1970s conspired to change this situation. The first was the oil crisis of 1973–4 when the Middle East oil producers precipitated an artificial shortage of oil world-wide which in turn increased prices dramatically. This caused a swift reaction in Europe and Japan, not as quickly reflected in the US, to 'downsize' the product and make smaller, cheaper and more fuel-efficient cars. The laws of aerodynamics ensured that gradually, many of them began to assume similar shapes to reduce drag factors to a minimum. This in turn encouraged design-

2.1 Air texturized continuous filament yarn.

ers to look for new ways to differentiate the product, and interior trim design assumed a new importance.

It was also around this time that, in Europe, ways of improving the abrasion and lightfastness of textile fabrics had led to the development of continuous filament air-textured yarns. These yarns were produced by interlacing the filaments under the influence of air jets and had the effect of producing a yarn where the filaments were looped around the yarn axis with these loops being fixed due to the interlacing effect, illustrated in Fig. 2.1 [See Chapter 3 for a fuller description].

The development of high lightfast dyes was also under way by specially selecting disperse dyes for polyester which could either be produced through the yarn package-dyed method or by applying the dye to the polyester chips before extrusion to produce 'spun-dyed' filaments which could be combined in various ways to make 'colour-spun' air-textured yarns.

The technical suitability of polyester for the automotive market together with the expansion of world-wide production which tended to stabilize prices and the development of suitable yarns and fabrics created an ideal situation. The result of these developments was to create a market for more adventurous trim fabrics at a time when the technology to produce them to the necessary quality and performance standards was just coming on stream.

It was at this time that textile companies began to realize the potential of the car market which, unlike the majority of businesses they were used to supplying, was free of any preconceived ideas about what constituted a good design but was eager to see all new design ideas and developments of every type. A new business was opening up for the traditional fabric designers and suppliers, a business which they were soon to find was unlike any other they had experienced in terms of its quality and performance requirements. Many producers dipped their toe in the water but most quickly withdrew it when they discovered the high entry cost in terms of the investment required in different technologies, up-front development cost, quality issues, and very long time scales involved to recoup this investment.

Courtaulds Automotive Products (CAP), which was formed in 1978, was among the early entrants into this area and was one of the first to make concentrated efforts to design specific ranges for interior trim in innovative yet technically sound fabrics. The use of coloured yarns to produce these fabrics established a trend which was to see enormous growth due the vast increase in design and colour potential offered. World-wide presentations mounted by CAP and other participants in the early days ensured that the message was spread far and wide.

Early design ideas were based largely around apparel and suiting design with colour and weave and simple dobby effects comprising a large part of many collections. The Japanese companies in particular were eager to see what Europe was offering in terms of design and colour, in what eventually turned out to be a precursor to their involvement in setting up manufacturing plants in Europe and particularly the UK.

Free-form jacquard designs followed, first in flat woven structures and then in pile structures, as the technology was developed. The range of fabric technologies from which the interior-trim designer could select was suddenly mushrooming with new products becoming ever more sophisticated due to the continuing development of alternative fibres, yarns, dye-stuffs and fabrics. Some succumbed to the temptation to go overboard with the design of interior fabrics sometimes to the detriment of the interiors, others trod a more cautious and sophisticated path and used design to best effect rather than simply to attract attention.

Eventually design 'styles' started to emerge with the more conservative, perhaps understated and often self-coloured designs appearing in the more expensive up-market models – often these designs were based on geometric principles. Other companies in the mass market began to experiment with larger-scale motifs and frequently used campaign models (these are often variants on existing models using exterior and interior design to either lift flagging sales or experiment with new ideas) to try out bold colourations. In this area particularly, the effect that different cultural approaches to design and colour had on the trim material, soon became apparent. The trained observer in Europe was able to tell which companies had retained design control in their native land whether it be Japan, America etc and which had delegated responsibility to stylists living and trained in Europe.

2.1.2 The challenge for the textile supplier

This evolving situation began to pose serious problems for both the supplier and also the car company. The textile manufacturer and supplier, in order to meet the expanding requirement, had to invest much more heavily in true textile design studios with full customer-support facilities dedicated to the requirements of the automotive industry, this in turn put pressure on finding and training qualified designers and establishing training systems.

The development of CAD helped improve work flow and reaction times to customer requirements but again demanded ever more qualified personnel. The automotive company expectations increased in direct proportion to the ability to meet them. What is just possible today, is normal tomorrow, and unacceptable the day after!

Eventually the OEMs became aware that in order to fully appreciate and realize the potential of textile design for interiors they had to know more about it so they started to employ qualified textile designers and technicians. Stopping short usually of designing actual fabric they created ever more sophisticated design briefs for their suppliers, who in turn had to satisfy the requirements of the stylist while at the same time keeping a sharp eye on what the trim engineer wanted, in terms of fabric physical properties, and the laboratory, in terms of test procedures and results. It was and certainly still is the conflicts created by these three areas which present the fabric designer and supplier with the greatest challenge, and, it must be said, greatest dilemma.

2.1.3 Design support – hardware and software requirements

It is tempting to say that all these problems are in the past and all is now plain sailing. Unfortunately this is not the case and the dilemmas still exist, although advances in technology have meant certain issues such as lightfastness, for example, today do not present the same difficulties of say 10 to 15 years ago. However other challenges are always coming along. Stretch for instance which was quite a nice thing to have and usually a bonus in the early days has now become a prerequisite for many programmes where complex seat or door panel shapes are involved. This particular parameter has become a closely defined requirement with many Tier-1 suppliers, who are always experimenting with new and more adventurous seat and door panel shapes. Certain physical properties quite simply may be impossible to achieve in the chosen fabric technology so it has become necessary for the suppliers to become competent in all fabric-production techniques and also be able to transfer designs across technologies as and when required.

To the automotive engineer this seemed like a reasonable request, to the textile company with a 100-year tradition of specialization in one or at most two technologies it was certainly, in the early days, something of a revolutionary approach and many found great difficulty coping with the requirement.

The demands the various OEMs place on their fabric suppliers are in principle very similar. They require reviews of new products under development and regular design presentations, sometimes general, sometimes targeted. Car models are defined and designs short-listed and selected, colour and design modification work starts with fairly well-defined critical paths and timings. Technical considerations in terms of fabric performance to a standard test procedure have to be addressed and again modifications made to ensure laboratory approval. Increasingly the demands of the seat engineer are part of the fabric-development process to ensure that it can be trimmed efficiently.

Today's fabric designer has to cope with all these conflicting issues often in direct competition with competitors, maybe across several fabric technologies and on extremely short time scales for submissions following development meetings and they must never lose sight of the fact that styling aesthetic approval is key to obtaining the business. The designer is in effect the front-line sales force in most textile companies supplying the automotive manufacturer – unless the fabric, design and colour is developed and approved it cannot be sold!

It is possible to segment the process and adopt various approaches to meet the requirement:

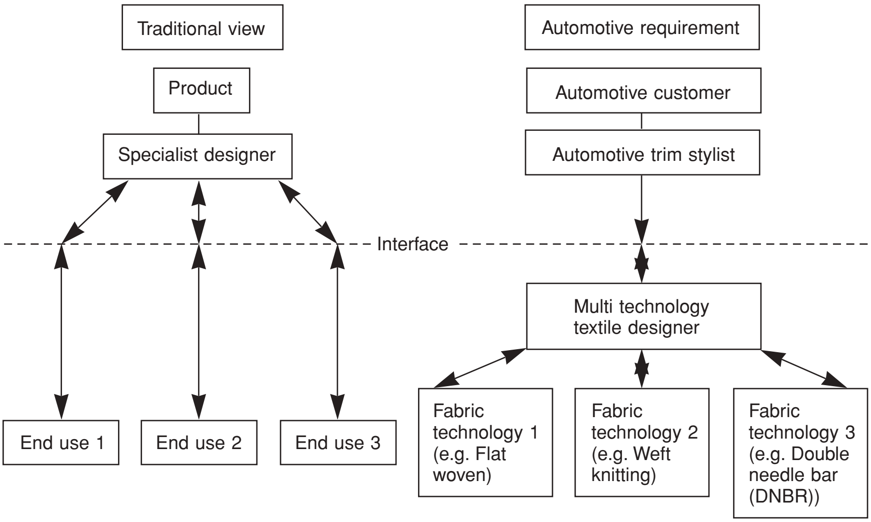
Creative work non-specific in terms of customer or technology.
CAD operations to convert creative work into hard copy.
Pilot fabric production to produce new concepts and ideas.
Train designers to specialize in one technology across all accounts – or train designers to specialize on one account across all technologies.
Involve technical specialists to handle the technical fabric development.
Establish a central design studio to 'pool' ideas and maximize creative potential – or consider locating design studios geographically close to customers to assist communication and support.
Involve designers in technical issues related to engineering requirements or free designers from technical issues to concentrate on the creation of new ideas.

How these issues are dealt with, will, over time, lead to an internal design culture which will be recognized by the customers.

A fabric producer will become known as 'highly creative and design-led' or maybe 'technical and engineering-led'. It is a difficult task to be completely successful in both areas all the time even though this should remain a prime objective for automotive textile producers.

Most textile manufacturers with a history of production for non-automotive uses will be familiar with the notion of specialization in one fabric technology to supply various end-uses, requiring a specialist approach to the technology and a flexible approach to the end use customer.

To some extent the automotive industry turns this traditional idea on its head in that the producer has to adopt a specialist approach to the customer and a flexible approach to the fabric technology which may be required. The effect this situation has on the designer is best illustrated by Fig. 2.2. It is also important to recognize that different car companies place the emphasis in different areas, sometimes due to internal politics or maybe



2.2 Comparison of traditional textile and automotive textile design requirement.

cost constraints or even past problems or costly mistakes. These are further additional issues which have to be taken into account.

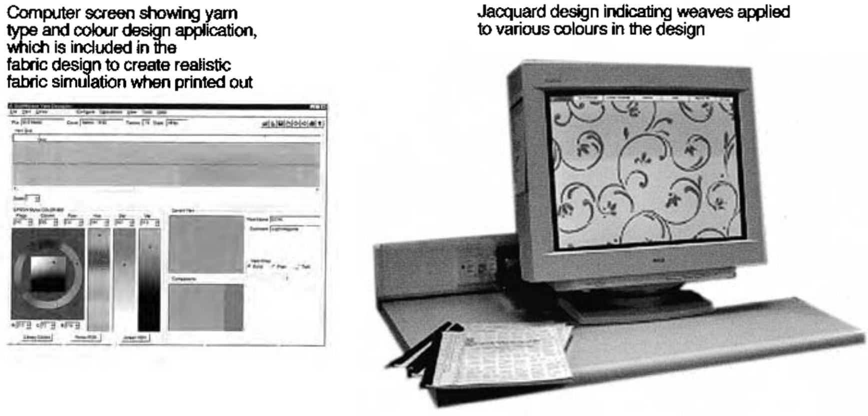
Any design manager or director has to juggle with all these options plus others and decide which permutation will work best for him and his company and of course for his customer. In order to do this it is important to have in place the necessary tools to do the job, these can broadly be divided into computer aided design (CAD) assistance and pilot-plant facilities to quickly make actual fabric samples.

2.1.3.1 Computer-aided design

In today's environment surface pattern design cannot really be undertaken without resorting to the specialized CAD packages which, in the case of woven fabrics, enable ideas to be quickly scanned into the computer and manipulated. They then have to be put into repeat and separated out into colours which represent weave effects. Weaves have to be applied to these colours before a woven simulation can be produced on a colour printer.

Weaving instruction and floppy disk or electronic instruction to program the loom selections are the final requirement prior to weaving the fabric.

The same process is applied to knitted fabrics, but in all cases it is necessary to have a starting point for the creation of the original idea and this can either be done manually or by the use of some non-specific creative CAD package or more probably by the combination of both.



2.3 CAD visualization of a jacquard-woven fabric at the design stage with yarn design simulation inset. (Yarn design reproduced by kind permission of SCOT Innovation and Development Ltd.)

This requirement for efficiency and speed has created a near total reliance on CAD particularly in automotive fabric design where designers are called upon to work on several fabric technologies at the same time and the search for suitable CAD packages should be done thoroughly and with care.

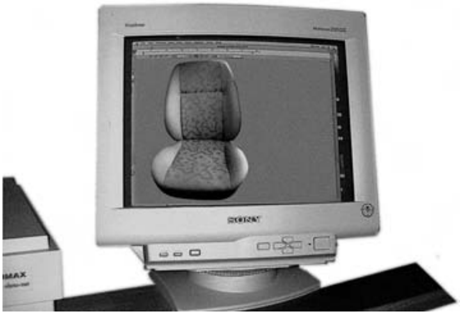
One company who devised and developed a CAD package from a designer's viewpoint starting from a basic knowledge of design is ScotWeave originating from the Scottish College of Textiles and now developed and marketed by ScotWeave Ltd., Galashiels, Scotland, and sold through Jeftex Ltd., Rochdale, Lancashire.

ScotWeave provides flat-woven and woven velvet program for dobby and jacquard designs which allow for yarn-count characteristics and profiles to be stored ready for applying to specific designs. They also enable the universally recognized CIE (Commission Internationale l'Eclairage) colour definitions to be applied for accurate colour rendering and for the final fabric to be reproduced, by the application of contour grids, as a virtual three-dimensional (3D) simulation applied to the object whether it be a car seat or room setting.

Figure 2.3 shows the screen simulation of a flat-woven jacquard fabric where each individual thread interlacing can be checked manually or automatically and inset can be seen the yarn design application which is usually done prior to creating the fabric so that a realistic simulation of the cloth can be created when the image is printed out.

Figure 2.4 illustrates a 3D fabric simulation *in situ* on the model.

The universal acceptance of CAD in the designing of fabrics, both woven and knitted, has led to an enormous shortening of lead times from idea to



2.4 Simulation of car seat with woven fabric mapped on to surface to resemble 3-D model.

realization which is now accepted as the norm and no one can really operate successfully in the market without a significant investment in CAD.

The importance of having pilot plant available for quickly producing aesthetic and technical samples on short lead times during the development process cannot be overemphasized, and to have this easily accessible to the designers is a great advantage. Obviously the more fabric technologies involved, the more complex and expensive this process becomes. It is, however, difficult to efficiently service the customer base and establish a reputation for innovation and creative work without it.

The overall objective is to retain maximum creativity while at the same time meeting all the other technical and commercial pressures which are inevitably applied in the development of new products.

2.1.4 Design education

It is apparent from the above descriptions that designing textile trim fabrics for automotive use, although exciting and eventually rewarding, is complex and multifaceted and the importance of a good grounding in all aspects of design during the degree courses cannot be overemphasized. Some universities place a lot of emphasis on close contacts with industry to produce what employers want, others take a different view and prefer to give more freedom of expression leaving the realities until later when the graduates start work. Both approaches have advantages and disadvantages but irrespective of the curriculum it is in the long-term interest of the automotive textile producer to create close contacts with colleges and universities to sponsor special projects for students, take students on secondment, be prepared to give talks and lectures on the special requirements of the automotive market. These activities ensure that the the education process produces graduates who have at least a basic knowledge of what is required and do not have such a traumatic time adjusting to the strict requirements of the business.

In the UK it is possible, with the excellent range of quality courses and large number of students studying design, to find graduates who are capable of fulfilling the role described and, although other countries have different systems, it is significant that many automotive companies have taken advantage of the UK university courses to staff design studios in Europe and further afield.

2.1.5 Design development

The requirements of the OEM trim stylist is only one of the issues which the textile designer has to meet. For any fabric to progress to successful mastering against a model programme it must also meet the technical needs of the Tier-1 suppliers – i.e. the manufacturers of the seat and door panels. They must also pass through the laboratory testing procedures laid down by the OEM and be accepted aesthetically not only by the stylists but also by marketing and any other critical areas which the OEM might decide need to have design appeal. Price also is of prime consideration. Many of these issues will probably be referred to in the original design brief but often change as the fabrics progress through the design process.

It is not surprising, therefore, that additional expertise over and above that provided by the fabric designer is inevitably required – this assistance requires input from the technical and commercial departments within the company and it is an important part of the designer's job to see that the original design concept or vision is not sacrificed by the pressures of complying with all the other conflicting requirements.

Two major decorative uses for textile products are 'apparel' and 'furnishings', each of these areas has a long history of textile production – long enough in fact to have attained a definite design 'history' of their own with design styles moving through traditional, modern, geometric, avantgarde etc. etc. as fashion trends dictate. Included in this process are the favoured yarn and fabric technologies which provide the product with the latest in preferred aesthetics – crisp or soft hand – bright or dull lustre – firm or stretchy etc. etc.

By contrast, decorative automotive textiles have only just started to attain an 'applied design' character of their own. In the early days (and we are only talking about 20–25 years ago) the industry 'borrowed' design styles from first the apparel and then the home-furnishing sectors and tried to translate these into structures which could be approved for automotive trim. This translation process caused much of the original aesthetic attractions to be lost due to toning down of the colours, amendment of structures such as the shortening of floats to improve abrasion in the woven structures, and also to approve fibres and yarns – mainly textured polyester for the bulk market – being unable to support the demands of the designer in terms of handle, lustre etc.

During the past 20 years or so the situation has improved considerably with improvements in the technology of yarn and fabric production. In terms of surface pattern the automotive industry has started to gain an identity of its own with the various styling departments today having fairly clear ideas as to what designs are suitable for sports-level, base-level, luxury-level etc., in most cases these ideas are defined within a company and are likely to differ considerably between companies. In this way, of course, badge identities are promoted although a fairly common theme across most car companies would be for design and colours to become more restrained or understated as they progress up the model ranges. Now that more fabric-producing technologies are available to the stylists and fabric designers it is possible to visualize designs and concepts on various substrates requiring yet another selection process to be included into the development programmes.

It is the responsibility of the designers from both the fabric supplier and the OEM between them to consider proposals which cover all the options of fabric technology, structure, design, colour etc. before narrowing down the choices as the design process proceeds.

2.1.6 Interior styling issues and cultural preferences

There are issues, some technical, some cultural, some perceived, which can have a definite influence on the choices of design and fabric technology for any given model programme. Although briefly referred to earlier it may be interesting to consider these in slightly more detail.

The manager or director charged with the responsibility of creating an interior for a new model has many issues to consider, of which the type design and colour of the trim fabric is but one, albeit an important one. Some of these are technical – it is necessary to work within the achievable while constantly striving to push out the barriers, and some are aesthetic – the interior as a whole has to work and items have to be seen to complement each other. There will probably be an overall concept or idea of what the car and the interior of the car should convey to the end user. This concept or target can usually be summed up in a few words or phrases such as; 'extravagant', 'simple elegance', 'Innovative', 'Sporty' used to transmit an overall idea. Another equally important concept is the target market: '20 to 30-year-old single women' or '50 to 60-year-old retired couples' or 'family-orientated purchasers'.

Then there is the geographic location of the major sales area. The same concept could mean a very different thing in terms of trim material to a purchaser in Tokyo compared with a purchaser in Trinidad or even Tunbridge Wells. Apart from any differences in design and colour the actual material conveys different images in different places. This is noticeable, particularly with regard to the attitude towards printed materials which are now becoming increasingly available. In Europe, generally print except in terms of printed silk, is not usually regarded as an up-market product but in Japan this is not the case and very expensive substrates are printed. In America, fabric trim in general is perceived much further downmarket than leather although velvet takes a larger share of the market in the US than Europe where it is regarded as a relatively cheap option although a *wool*-blend velvet is regarded here almost on the same level as leather. It is necessary therefore for the textile designer to have a close association with the interior trim stylist in assessing all these ideas before serious work commences on the product.

Textile products generally have the advantage that once the substrate is approved the changing of the design and the colour is a relatively simple task for the producer but unfortunately the mastering systems of most automotive companies slow even this process down to turn what should be a simple decision into a fairly big issue. Textiles in general are in competition mainly with leather when it comes to modern trim materials and when it comes to surface decoration, there is little option but to specify a textile product. Although printed leather is available it tends to detract rather than add to the aesthetic and perceived 'quality image' of the product.

This means that the choice of which textile technology to specify is becoming an increasing problem and for the textile supplier it is becoming ever more necessary to have a detailed technical knowledge and capability in all the available technologies so that all the available options can be tried and tested as and when required.

The recent expansion in options for trim material has created one unfortunate problem with which all interior stylists have to contend and that is how to take advantage of what the industry has to offer without taking too much of a risk with the design and colour, to the point that the ultimate customer might actually choose one car against another simply because they do not like the design or colour of the trim material.

Various ways have been devised to deal with this: customer clinics, either national or international can provide a general sampling view as to the suitability of the interior for a particular model from a cross-section of the public. Campaign (i.e. special limited edition) models can be used to test the market although they tend to be used for pushing out the design barriers rather than trying to weed out unpopular designs. The advent of advanced CAD now enables car showrooms to show what different materials will look like and offer options at the point of sale. Unfortunately, apart from the logistical issues which are raised, and have to to be paid for somehow, there is still no guarantee that the customer will like their own choice when it is delivered any more than they may like their new carpet after it has been fitted. The apparel and home-furnishing sectors of the market have for many years used store trials to test new designs, furniture, clothes etc., and this really does put the concepts before 'real' people who spend (or don't spend) their own real money on real products. So far no real equivalent of this has been found for the OEM.

The challenge is to create a system which can test the market as it were 'in real time' before committing to huge investment in production. This is a significant problem for all involved in the industry, particularly those who spend their lives designing fabrics because it means that the ultimate product frequently does not reflect either the technological development nor the design and colouration skills which go into its production – in other words the textile product frequently could be considered to be designed to offend the fewest people rather than to excite the most. One of the major complaints raised by almost all textile designers is the gradual 'dumbing down' of the original idea in terms of both colour and aesthetic effect as it progresses through the automotive development process. The statement is often made that no matter what colour created the initial excitement and interest it will eventually end up as some shade of grey or blue by the time it gets into the vehicle!

However the progress made over the past 20 years or so indicates that the situation is changing and at last the industry may be taking on board the need to experiment and really make use of the design potential offered now by many of the available fabric-producing technologies.

2.1.7 The creative issue

One area which is still a problem for both a buyer and supplier is an understanding of what they are dealing with and what is required. This issue particularly affects those dealing with aesthetic and technical design and development in both the car company and the textile supplier. The automotive manufacturers do not have a detailed background knowledge of textile production and technology, similarly neither do the textile producers necessarily have a detailed knowledge of what is involved in the production of seat and door panels etc.

Joint project meetings are held to overcome this problem but cultural and language difficulties often cloud the issues and lead to misunderstandings which can be aggravated further by subtle differences in how test procedures are performed in different laboratories. Thousands of pounds are often spent on issues as simple as how to mount a sample in a holder prior to a test. That such events should not really happen in a highly developed technical industry does not alter the fact that they sometimes do!

The differing ways in which we see colour, and subjectively judge surface pattern are problems particularly relevant to the designer. These issues of 'understanding' can compound development time and costs enormously particularly when decisions have to be delegated. For this reason it is worth spending the time at the start of projects to clarify exactly what is required and what outcome is expected or visualized. It is, in fact, the objective of this book to try and add to the pool of knowledge on both sides of the equation which will help those involved appreciate the importance of defining more closely the issues, the technological constraints and the actions required to deal with them.

Many innovative ways have and continue to be tried of making subjective decisions more objective but efficient ways of transmitting design ideas elude most companies. The age old notion of: 'I'll know it's right when I see it' still dominates most discussions concerning conceptual thoughts about what is and what is not required for a particular project in terms of surface pattern, colour combinations and even differing fabric technologies. This is one of the main reasons why those involved in devising and applying quality systems find such difficulty in coming to terms with 'design'. Creative thought processes come in an infinite variety, totally unique to the imagination of the individuals involved. Attempts to organize these creative elements into boxes or along tight procedural lines will, if taken too far, always have the end result of 'dumbing down' the creativity of first individuals then whole departments. Ultimately this can affect the reputation of whole companies, who could finish up having to copy, albeit very efficiently and to high quality standards, other companies' creative ideas instead of producing their own – a situation which quickly hits bottom lines in terms of attainable sales prices. Under these conditions it is not hard to appreciate the difficulties involved in transmitting creativity between individuals, departments and companies. Frequently the more people involved in the decision-making process the more complex and protracted it becomes.

This situation makes it essential that the supplier or designer has access to facilities which can short-circuit the problem of showing options, modifications, changes of direction etc. Efficient CAD systems can and do help but often there is no substitute for showing actual fabric samples, particularly when the customer may have several people involved in the selection process, some of whom will inevitably have difficulties in translating computer simulations into thoughts about real fabrics. It is here that quick and efficient sampling or pilot production facilities prove invaluable in shortening development lead times and helping the understanding processes. Without such facilities the designer and the customer quickly become disillusioned and cease to be effective contributors to the whole process. Sales are inevitably lost and very soon the heavy cost of providing the facilities are dwarfed by the costs of not providing them.

2.1.8 The choice – what technologies are available and what can they offer?

The possibilities offered to the designer of the interior have been referred to earlier and a more detailed study of the various technologies is dealt with in Chapter 3, but it is probably appropriate to consider what they offer in terms of design potential both to the textile designer and to the automotive stylist.

2.1.8.1 Flat-woven structures

The main fact to bear in mind is that flat-woven cloths are, by their structure, rigid or semi-rigid and any substantial degree of stretch has to be a function of the yarn rather than the fabric. This is an important factor for the engineer and designer to appreciate and build in to any development programme. However, it is a highly adaptable technology when it comes to the choice of raw materials, and by using flock or chenille yarns can in fact create a form of pile structure.

Add to this the patterning potential of the jacquard loom and it becomes probably the most creative technology for interior trim materials from both the design and aesthetic aspects for both engineer and fabric designer.

2.1.8.2 Pile woven

This refers essentially to double plush and is a flat-woven ground structure with a vertical pile added. The ground structure is rarely seen so serves as base for the pile which supplies all the aesthetic and surface pattern. Fairly flexible in terms of yarns but rather more restrictive than true flat woven; the fact that all visible yarns are viewed on the cross-section rather than along the periphery means that the opportunities for showing yarn characteristics is much more limited. Jacquard velvet offers similar scope for surface pattern and colour variations. The comments regarding the introduction of stretch are basically similar to flat woven.

2.1.8.3 Warp knit tricot

This technology offers limited opportuntity for surface design and the exploitation of yarn characteristics due partly to the requirement to meet specification and partly due to the limitations imposed by the machines, so the designer has to concentrate on subtle variations in yarn lustres, filament cross-sections and mixtures which show up during the finishing or dyeing process. Patterning possibilities are dictated by the number of guide bars used but even in a four-bar machine (usually considered the maximum) the restricted sideways movement means that designs are limited to small repeat geometric styles.

Dyeing and finishing, particularly brushing and other surface-active processes, play an important part in the creation of new fabrics. Developments in this area have produced dense high pile structures known as 'full rip' cloths where a dense surface has been repeatedly raised and brushed to create a very effective pile. It is a highly specialized finishing technique which has found a significant market.

The input of the designer for these types of structures is more as a technician rather than creative artist.

Warp knit by its fabric geometry offers greater stretch than flat woven without the use of stretch yarns. The structure offers a good base for printing.

2.1.8.4 Warp-knit raschel

A highly versatile method of fabric production which has seen greatest application in automotive trim as a pile structure is known as double needle bar Raschel or DNBR, produced as a plain or semi plain pile structure for both seat inserts and bolster areas.

In this form it has greater limitations than woven velvet in the yarns it can use but has the advantage of being a more efficient and cheaper production route due mainly to operating speeds. Surface patterning is limited.

It has the advantage in the plain or semi-plain form of offering a good base for printing particularly via the newer ink-jet technology. In terms of development the designer has to look more at subtle yarn characteristics paying particular attention to the cross-sectional aspects of the yarn such as filament denier, profile and lustre variants etc.

2.1.8.5 Weft knit – flat bed

The versatility that this technology offers the designer, rivals, or even surpasses the weaving route. Yarns of widely different characteristics can be used and are viewed along the axis so their full effect is seen. Chenille, flock and fine boucle yarns are possible in order to create surface interest and the knitting of coloured yarns can, like colour weaving, create innumerable colour and design options particularly when combined with jacquard patterning. Air textured yarns can be developed both for weaving and flatbed allowing fabrics with very high abrasion resistance to be produced.

Three-dimensional effects are attainable and surface patterns which coincide with the panel shape are also possible [see Section 3.5].

By comparison with flat wovens the fabric geometry can create flexibility and stretch potential. Overall, for the designer, it offers great potential but as yet has not made any lasting impact on the automotive trim market.

2.1.8.6 *Weft knit – circular*

Circular knit fabrics can be produced as jacquard-designed structures offering wide surface pattern potential. This is a highly versatile medium and has had a big impact on the trim market particularly in Europe.

Single jersey jacquards are relatively cheap in comparison and offer good design possibilities which have been exploited in France and Italy. Yarn selection has to be carefully considered due to the critical nature of the knitting process and yarns of uneven surface profiles (i.e. boucles etc.) are not to be recommended.

The major development of recent years has been in the circular-knitted jacquard pile fabrics described in Section 3.4. They offer quite luxurious pile together with very versatile patterning possibilities capable of utilizing several yarn colours for the creation of multicoloured designs and a fabric which has inherent stretch. Despite the fact that the structure is under price pressure in competition with jacquard flat wovens it offers wide design possibilities for the designer, although again yarn selection is limited to fine counts with aesthetic differences being obtained by attention to fibre cross-section, variations in texturizing processes to create high/low surface effects and lustre variants.

2.1.8.7 *Print*

In Europe, printed fabrics have not enjoyed any great success unlike Japan and Korea where they have taken a large percentage of the market. The new non-contact ink-jet printing process could change this situation and designers should acquaint themselves with this technology (described in Section 4.3).

The potential is huge in that almost any substrate described earlier could be printed via this route thus allowing the fabric and the design to be considered as two entirely separate design operations. There is only one company world-wide, at the time of writing, that is producing automotive fabrics in volume via this route so it has to be considered as an evolving technology. However, since it is essentially a computer-based technology coming from the graphics industry rather than a traditional textile technology the rate of development will be rapid particularly if one of the major printer manufacturers such as Hewlett Packard decides to target the textile area. For a designer it has to be a case of 'watch this space'.

2.1.9 Realizing the ideas

Eventually after all the design and development work has been completed to the time scales agreed for the project, the success or otherwise of the way in which the original idea or concept for the completed interior has been interpreted will be assessed, first of all by the managers or designers involved in the individual products and finally by the director responsible for whole interior design element of the vehicle. This is the coming together of all the various elements which constitute the interior trim – it is of course a feature of the textile trim material that, along probably with seat and fascia design, it is the main element which the final customer will see when buying and examining a new purchase, and for this reason first impressions are extremely important. Once the customer has accepted the appearance of the trim fabric he or she will in all probability have difficulty in remembering much about it thereafter.

For this reason, it is important not to convey a negative impression with the textile designs but rather to complement not overpower the whole interior 'atmosphere' which has taken so long to create. This is a difficult and often delicate line for the fabric designer to tread because they have to create something which has a feeling of being unique but not too unique, adventurous but not too adventurous and if possible something which carries their own ideas and handwriting but which the automotive stylist can put forward as conveying their concept as well. There is always the constant danger, as mentioned before, of designs being 'dumbed down' to offend the fewest rather than excite the most. The importance of treading this line carefully and successfully cannot be overestimated for the textile producer. Some designers are extremely creative but have difficulty translating another designer's concepts into successful designs. Other designers are extremely good at translating ideas but have difficulty in imparting flair and creativity to this translation.

It can be seen therefore that if the textile producer takes either situation to the extreme it can result in failure to successfully complete the project. Carefully selecting designers to major on their strong points must be a priority for the textile trim manufacturer – reputations, good or bad, tend to last a long time in the automotive business. A flair for colouration is also an extremely large part of design development – designs can be transformed by clever use of colour and colour combinations within the textile fabric, and the modern use of coloured yarns prevalent, particularly in Europe, makes this aspect of the utmost importance.

Unfortunately the trend of automotive companies to frequently insist that the majority colour of trim fabric must match some interior trim shade most usually the vinyl or fascia colour which in turn is usually a rather unexciting variation on shades of black, grey or blue, mitigates against the intelligent use of colour in the fabric and it is often this situation which drives the use of either toning self colours or highlight colours on dark or predetermined backgrounds. It is not unknown for the exact non-metameric colour-matching of a vinyl shade onto a polyester yarn to take almost as long as the development of the design itself – not a situation which encourages creative textile design.

The situation is one, however, which the interior trim designer has to live and work with and it is a tribute to the design and colouration ingenuity which modern technology and clever designers have exploited that, despite the criticisms mentioned earlier, today's car interiors are infinitely more attractive in every way than even a decade ago. It is important however to emphasize that today's dyes, fibres, yarns, fabric technologies, finishing techniques and production techniques all offer an almost infinite range of possibilities in terms of creative design and colouration. Design in all its aspects does now and will, due to world overproduction of cars, continue to play an increasingly vital role in maintaining market share.

It would be wrong at this stage in the discussion about fabric design not to mention the important influence that the established fabric testing procedures operated by the OEMs have on the creativity of the designer. It is a fact of life that in most car companies the role and responsibility of the designer and that of the laboratory manager are separate and, it often appears, non-complementary. Most companies now employ textile designers in their trim design areas but few companies probably realize at a higher management level the dramatic effect the imposition of stringent test procedures has on their fabric-design options.

A textile supplier who may supply numerous OEMs will have to develop light flat wovens and heavy pile fabrics for company A, while exactly the reverse can be the case with company B. There cannot be many sound technical reasons for this when all manufacturers are selling predominantly into the same world market place, and the most likely explanation is historic. In today's design-led environment a very strong case can be made for thorough reviews of testing procedures to assess their real relevance in the light of many years of experience of using textile fabrics in cars. Relaxation or even minor changes to tests and assessment procedures can open up whole new fields of creativity and design possibilities for those responsible for the development of interior trim textiles.

2.1.10 Summary

The main requirements for any manufacturer who is contemplating moving into the automotive textile trim field can be summarized as follows.

Be prepared for high entry costs in terms of both money and time to market.
Invest in good quality designers and research the local market thoroughly.
Become involved in the design education process.
Be prepared to invest in several fabric-producing technologies and establish pilot plant production for design and development, if possible in each one.
CAD is essential and is often composed of two parts – a creative package to cover all technologies, these specialist creative design packages are available from most textile CAD suppliers – or the ubiquitous Adobe Photo shop package, which can be used very successfully as a more general creative tool.
In addition specialist targeted CAD packages related to the individual technology are also essential for the quick translation of creative ideas into design repeats and ultimately the fabric itself.
Research the availability of suitable raw materials and establish whether they can be supplied to the the high requirements of the automotive business.
Institute quality and auditing procedures to verify suppliers before investing large amounts of money in trials.
Become familiar with the physical test requirements and be prepared to invest in expensive fabric-testing equipment including lightfastness.
Establish test procedures alongside the development process and educate designers in the fabric requirements.

It is up to the managers, designers and technologists of both the OEMs and the textile suppliers to ensure that the possibilities offered by today's textile technology and the design flair of the fabric designers, which the UK universities lead the world in educating, are not wasted due to lack of imagination and forward thinking on the part of those responsible for creating, developing and specifying interior-design concepts.

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