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DESIGN DRIVEN
The Development of New Materials in Automotive Interiors

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Abstract

Design is a critical component of the development of textile materials for automotive interiors. It contributes to the overall quality and cost of the vehicle interior. The appearance of the vehicle passenger cabin affects the perception and satisfaction of the occupants. This research analyzes how a fabric is developed through the supply chain from concept to product launch. The interrelationships between designers at each tier level are considered. The market factors are reviewed and the specific design issues important to fabric development in future transportation products are identified. This research reveals processes and considerations for new product development for academic and industrial consideration.

Key words: Design, automotive interiors, upholstery, development process

Introduction

With the automotive industries achieving their 100-year mark of continuous development, this research examines the current status of textiles in the North American automotive market, the development path for product adoption, and the challenges in designing transportation textiles in future global markets. Rapid prototyping, cost effectiveness and streamlining of supply systems will continue to be of high priority (Fung & Hardcastle, 2001). Results identified market factors influencing the need for not only innovative products, but also new creative strategies for design and development. The focus is primarily on interior fabrics: body cloth, headliner and door panel fabrics.

Current Automotive Market

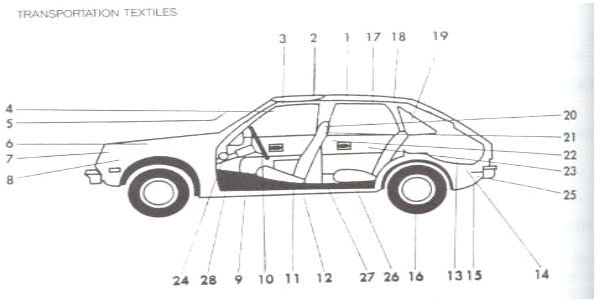
North American automotive sales have averaged about 17 million units annually for years 1999-2002. US Sales for 2003 are reported at 16.7 million units down about 1% in 2002 (Automotive News Data Center, 2004). With another three million plus for Canada and Mexico, sales are expected to exceed the 22 million mark by 2010. Although North America is forecasted to own a third of the world's market share in manufacturing of these vehicles (passenger cars and light trucks), more and more assembly plants are being located in emerging countries. (Ward's Automotive, 2002). Ward's Auto World projects that approximately 45% of the growth in global capacity will come from Asia (Stoddard, 2003).

- *Textile Applications*

Textiles are used extensively in automotive and have the potential to expand beyond the current applications (See Figure 1). These automotive textiles are predominantly polyester based, but polyamide, rayons and polypropylenes are used in carpet, airbags, tire cord, and other utility areas. Also alternative materials such as non woven polyesters are being evaluated as foam replacement for laminate composites in body cloth and interior panels. This type of product is believed to be advantageous as far as seat comfort and weight reduction plus it addresses environmental issues during production and end of vehicle recycling (Gunnarsson, 2002). Textile materials are also being brought into the interiors to reduce noise and enhance the acoustic properties of the interior environment (DesMarteau & Meadows, 2000).

Consumers are more familiar with the textiles they physically contact during the driving experience, specifically seat upholstery or body cloth, headliner and fabrics used throughout the interior compartment. Light weight headliner fabric may be required to meet stringent performance characteristics such as stretch and light fastness, but is more limited in its design complexity. As seat fabric or a variation of the original upholstery is used on door panels, the focus area for this research will be the design and development of body cloth or upholstery.

Figure 1.Transportation Textiles



1. Sunroof
2. Interior Roof
3. Salon Roof
4. Sun visor
5. Sun visor
6. Carburetor Filters
7. Battery separator
8. Belts & Hoses
9. Door Trim
10. Airbags
11. Seat belt anchorage covers
12. Seat Belt
13. Trunk Liners
14. Trunk floor covering
15. Muffler wraps
16. Tires
17. Inside Roof lining
18. Bodywork Parts
19. Molded seat covering
20. UPHOLSTERY
21. Insulation
22. Window frames
23. Decorative fabric
24. Filters
25. Molded fuel tanks
26. Coated backing
27. Carpeting
28. Carpet backing

Adanur, 1995. WELLINGTON SEARS HANDBOOK OF INDUSTRIAL TEXTILES, Technomic Publishing, p. 496.

- *Size of the Market for Interior Bodycloth*

  Leveled out at about 15.5 million vehicles produced yearly in North America using approximately 6 yards of textile (bodycloth) per interior seat set translates to a potential of 75 million linear yards annually. Multiply numerous brands by the different vehicle models times the average three trim levels offered (including vinyl and leather) and the potential for major fabric developments to differentiate interiors grows every year.

  Leather and vinyl has grown to an estimated 20% of the North American market, but both leather and vinyl normally have a textile scrim as part of the backing laminate. (Sako, 2003) Many automotive interior leather trim packages are a combination of leather, vinyl or man made suedes. Synthetic suedes such as Kuraray's Clarino ®, and Toray's Alcantara®and Ecsaine ® use polyester microfiber technology impregnated with polyurethane resins (Smith, 1999).

Supplier Issues

- *Industry Consolidation*

  The global automotive industry is dominated by about ten O.E.M.'s (original equipment manufacturers) and forecasted to shrink to fewer in the future. In North America, the "Big Three "(Ford, GM and DaimlerChrysler) are increasingly losing market share to Japanese companies like Toyota. In 2003, Toyota pushed Chrysler out of the top three for passenger car sales in the United States (Di-Natale, 2004). The Japanese transplants and now European O.E.M companies have located assembly plants in the southeastern United States such as Toyota in Tennessee, Nissan in Mississippi, BMW in South Carolina and Mercedes Benz in Alabama.

  The North American bodycloth suppliers have been reduced to four major U.S. players (Milliken, Collins & Aikman, Chatham Borgstena, Guilford) .The O.E.M.'s expect their global suppliers to supply any and all technologies specified at any assembly location whether in South America, Asia or Europe. An entire range of fabrics in construction, weights, widths, and colors must be available with the flexibility for rapid changes from one style to another if supply or performance issues should arise. This factor prompted various partnerships or acquisitions of companies in Asia and Europe during the past 20 years. Europe has about 15 or so smaller independent companies aligned with specific O.E.M.'s and servicing those accounts with customized products.

- *New Alignments and More Competitors in North American Market*

  As companies build assembly plants in the United States, they often bring an expectation that is based on their previous experiences with local native suppliers. An established relationship with a good supplier is a strong partnership. Factors that would influence the decision to change suppliers and risk a reduction in supply or service are improvements in costs, performance or innovation.

  As the alignments of United States suppliers with European and Japanese suppliers have recently seen a major adjustment with the dissolution of agreements, the O.E.M.'s are relying on existing relationships by encouraging Japanese or European suppliers to come into the North American market. Textile companies such as Seiren,(Southern Textile News, 2002), Kawashima, and

Suminoe have established locations in the Carolinas (SC DOC, 2002 & 2003) and are bringing their development methods to the domestic O.E.M.'s. Tom Lockwood of StorageTek found that Japanese organizations involved their suppliers earlier and interfaced throughout the development process (Lockwood, 2001).

As more and more lamination and trim plants moved south of the Mexican border after the signing of the North American Free Trade Agreement (NAFTA) agreement, Chrysler, Ford and GM expected suppliers to locally supply fabrics to meet the North American market standards. Also European or Asian textile manufacturers may ship yarns or greige goods into Mexico with minimum import tariffs and compete with North American fabrics for market share.

Market share In North America is commonly believed to be balanced with no single supplier dominating with more than a 25% market share for any sustained length of time. However, each supplier must maintain a constant flow of new styles and products on offer to the various vehicle developments to survive the lean times between openings. The window of opportunity to win business may be brief with long intervals between change outs.

- *Fracturing of the Market*

With 43 brands of light vehicles on sale in the U.S. in 2003 and 22 new vehicles introduced, the top ten brands held 67% of the market in 2002 (Stoddard, 2003).The 2004 North American International Auto Show in Detroit featured no less than 67 new model launches and world premieres (www.cardesignnews.com, 2004). GM alone premiered 28 new or updated products at the Detroit Auto Show (CBS NEWS, 2004. Each vehicle brand may incorporate the use of distinctive interiors to differentiate their products.

In addition to openings for production vehicles, more advanced products are developed for longer term development of vehicles. As these visions of future transportation are developed, an O.E.M. may invest in developing concept cars to be introduced at automotive shows around the world. These vehicles are a type of test market for new directions and textile products employed may not meet existing performance standards. These advanced developments create enthusiasm and acceptance in the market and may influence manufacturing's commitment to explore new processes that might be required.

Although the United States market has known periods of high volume long running interior trim styles, the low complexity of mass produced styles with extended product life cycles have become the exception.

The sharing of components across different vehicle platforms made economic sense for cost distribution (Korth, 2003). However, it is difficult for consumers to distinguish upgraded interiors if the same materials are employed in a base model.

- *Speed to Market*

New vehicle development has been forced by competitive moves from the Japanese transplants to reduce the traditional 48 months to a 29 month or shorter timeline. However, the reality is that textile suppliers are constantly developing new products for Color and Trim Designers on a weekly basis. The initial fabric concept development after the launching of a new vehicle opening may be as short as four weeks. Improvements to existing styles, color trials or advanced products for concept cars must be turned around in a matter

of weeks. Bringing a series of concepts, constructions and colorations to a customer can be not only a development challenge but also a logistical one within the supply chain (Spring, 2002). The sample development may depend on various priorities of the internal supply chain from fiber to finished fabric.

Once the fabric sample is visually approved by design then the certification process of the proposed fabrics begins to confirm quality and refine costs. Sample or "trim" yardage must be prepared and tested on the proposed seat designs. Feasibility studies and quality reviews must be completed before scaling up to production volumes. Feedback may be given to the component supplier at any point with requests for changes in the product. Reducing time to market without compromising quality is a competitive advantage at each point in the supply chain. Flexibility and responsiveness at each stage maximizes the opportunities for a total systems cost reduction.

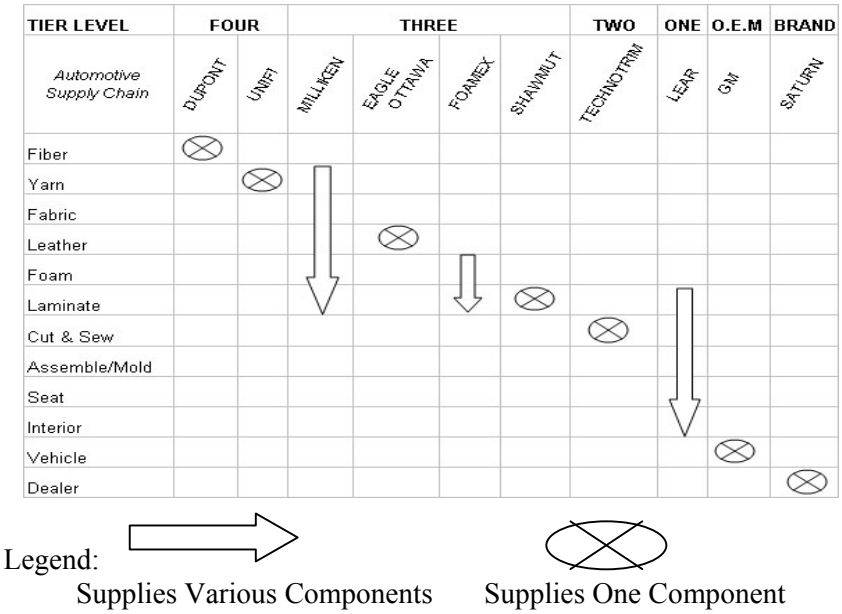
- *Lead times*

  Suppliers are expected to deliver consistent quality, innovative products, "just in time delivery" and to contribute to improved methods of purchasing and supply chain management. However with shorter runs and more complex fabrics, flexibility of manufacturing is key to shortening lead times on production.

North American Automotive Bodycloth Supply Chain

Textile suppliers to the transportation industry are not considered direct suppliers to the O.E.M. (original equipment manufacturers) as the goods may be delivered to a laminator, a cut and sew operation, or a seat manufacturer who is a Tier One or direct supplier (See Figure 2). However, the textile supplier must design and develop new products with the direct collaboration of the O.E.M.'s design, engineering and purchasing decision makers. A supplier with more than one core competency may wish to expand beyond one segment of the supply chain with the goal of controlling costs and gaining profits (See Figure 2).

Figure 2. Supply Chain Example



Source: Powell, N. (2003) Mass customization in transportation textiles through shaped three dimensional knitting, Intedec Conference Proceedings, Session 2.

- *Cost Reductions*

  The emphasis on cost reductions continues to be the leading focus at every O.E.M. De-contenting or the practice of eliminating features to create a lean base product for entry level affordable transportation was a founding characteristic as early in transportation development as the mass production of the Ford Model T (Brinkley, 2003). Today's competitive nature of the business continues the emphasis on cost controls, enforced cost reduction goals, and customer auditing of suppliers.

  Not willing to compromise quality, O.E.M.'s expect higher and higher levels of performance standards and customer service in order to continuously improve the resulting products. "Suppliers make up 70% of OEM costs, and Tier One suppliers passed the cuts down the chain." (Zachary, 2003) p. 34. The pressures to reduce costs fall on the suppliers at the same time as the demand for new and better products. Seat systems typically represent approximately 30 to 40% of the cost of the total automotive interior (Ward's, 2003). In times of economic downturn, manufacturers challenge their suppliers to be innovative in finding ways to reduce costs without sacrificing quality.

- *Quality*

  The end user's expectation is a vehicle of quality in performance and styling, readily available at a competitive price. Consumers demand an interior that maintains its appearance over the lifetime of its use or to contribute to the resale value of a previously owned vehicle. The fabric must be durable and resist fading, tearing or soiling. The fabric must also contribute to the overall comfort and safety of the passengers and driver. Upgrading of the interior can enhance the buyer's perception of the vehicle.

With today's extended financing of the purchase of a vehicle over several years, it's important for customer satisfaction that the interior fabrics maintain their appearance. The median age of automobiles in operation in the United States in 2000 was 8.3 years. With the increased popularity of light trucks and SUV's the expectation of longer use will demand rugged fabrics (Ward's, 2001).

- *QS 9000 Automotive Quality*

  North American suppliers must be certified according to the industry quality standard: QS 9000/14001 and the forthcoming TS 16949. Quality control procedures are documented according to the different elements of the QS standard and companies must maintain a regular schedule of internal audits in order to comply with the continuous improvement and re-certification by external auditors.

  Total quality management techniques (TQM) are employed such as FMEA (Failure Modes and Effects Analysis) and Statistical Process Control (SPC) (Bandyopadhyay & Sprague, 2003).

  Design Control guidelines and documentation of all procedures insures the "technical and organizational interfaces between different groups" such as manufacturing, sales and marketing, and development which have input into the design process. The output of this activity will be verified, validated and reviewed against customer requirements. Any design changes to the product whether in "form, fit, function, performance and durability" shall be evaluated according to procedures (IOS, 1996) Quality systems requirements, p. 16 -19.

- *Performance Issues*

  Two of the most critical performance standards for automotive interior materials are UV and light degradation and abrasion. Polyester can meet these requirements and is the predominant fiber used in the transportation industry because of these high standards. Depending on the application area of the fabrics, standards may be elevated accordingly such as the use of fabrics in a window area such as the dashboard or package shelf. Ingress and egress of passengers across the seat surface may cause increased abrasion or wear on the leading edge of the seat.

  Meeting performance requirements is understood to be the first priority of an O.E.M. Every sample and every production shipment must maintain this standard if the relationship is to thrive. Performance standards are set by individual O.E.M's but are based on some 30 individual tests certified by British (BS), American (ASTM) and the Society of Automotive Engineers (SAE) and German (DIN) methods. Evaluation for characteristics such as flammability, abrasion, light fastness, seam strength and dimensional stability are only a few of the major ones (SAE, 1999).

- *Environmental Issues – QS 14000*

  In Europe by the year 2002 80% of the car must be recycled with not more than 15% going to the landfill. By 2015, the European standards will be 90% recycled and no more than 5% to landfills (Fung & Hardcastle, 2001).

  Because the laminate is composed of polyester fabric, polyurethane foam, and nylon scrim, it is difficult to dispose of or recycle. Attempts have been made in Europe particularly in Germany to replace foam with non-woven felt or spacer fabrics, but an appropriate substitute has not been adopted worldwide.

  Natural fibers such as flax, Kenaf, and wool are being researched in combination

with other man made fibers such as polypropylene (Smith, 1999). Komatsu Seiren is reported to be researching the practicality of dyeing polypropylene which would assist in recycling and reducing fabric weight (www.textileinfo.com, 2003). As weight reduction in any form of transport from planes to automobiles contributes to the fuel efficiencies of the engines, the use of lighter fibers such as polypropylene is considered a beneficial option in areas where performance standards such as abrasion can be met.

- *Sustainability: Green Cars*

  Sustainability has not become a marketing tool in today's price conscious environment. Although a few new "natural" (cellulosic) fibers such as polylactic acid polymer (PLA) (Gross, 2000) or Kenaf are being explored in composites, the customer has not seen this as added value to the product. Using materials that reduce weight which increases fuel efficiency is a desirable practice. If interiors using these materials increase occupant or cargo space in a vehicle, this may improve the functional appeal of the vehicle. This improved functionality combined with the social responsibility aspect may be a feature used as a competitive advantage.

  European legislation is advancing goals for manufacturing, vehicle use and end of life disposal ahead of the United States policies. Although the Toyota Prius has been selected as passenger car of the Year for 2004 for its midsize hybrid powered vehicle (Vasilash, 2003), it remains to be seen if United States drivers will readily accept the vehicles with combined electric-gasoline engines. Energy efficiency may seem contradictory in the North American flood of SUV's and light trucks. However, factors (such as governmental) outside the transportation industry may create new business conditions for manufacturers and consumers.

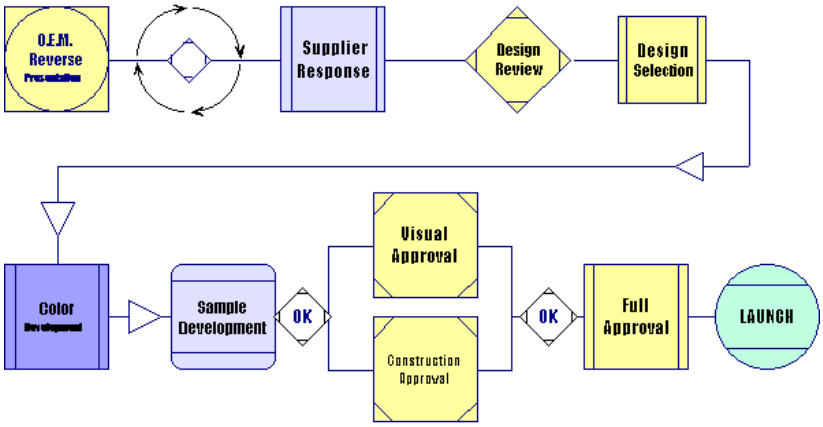
The Development Path for Product Adoption

- *Design Development and Selection*

  The O.E.M. Color and Trim design team initiates the process of designing a new interior image for a vehicle. The interaction of the vehicle user with the interior fabrics contributes to the overall satisfaction with the vehicle. This factor influences the color and trim designers' expectations of not only a high performing fabric, but also a distinctive colored and patterned fabric which attracts the targeted customer.

  "Reverse presentations" are given by the Color and Trim team to selected suppliers usually including certified seat, leather and fabric suppliers. This is the official 'kick off' of the new or freshening of an existing vehicle development. Communication of the brand image or new direction for the vehicle is enhanced with storyboards, inspirational images, market data, consumer socio-demographic profiles, color direction, and sometimes actual fabric swatches from other markets. A specific technology or construction may be specified at this time such as knitted pile or flat woven. The engineering and price parameters are established as critical parts of the total design brief. The seat design and manufacturer may or may not be disclosed at this point (See Figure 3).

Figure 3. Design Selection Flow Chart



Source: Powell, N. (2003)

Usually, the bodycloth supplier will learn whether the seat cover is to be cut and sewn or molded which would require adjustments to fabric performance characteristics. Any specifications on lamination or additional requirements should be revealed as early as possible (Sirvio, 2003).

One of the important factors noted is that the design decision responsibility currently resides primarily with the O.E.M. designer, not the Tier One or seat designer. Fabric selection by the seat supplier has recently been delegated to certain vehicle programs but is not a general practice.

A strict timeline is set and the format of response, as in type of samples and the style of presentation, is structured. Suppliers vary in their quantity and quality of response depending on the available resources and priority of the project.

A long standing positive relationship with a fabric supplier on certain vehicles builds confidence in reducing risk associated with an unproven supplier. The onus is upon the new supplier to come up with an innovative look, advanced performance or outstanding design service to instigate a change of supplier. Conversely, if there is a change of O.E.M. design staff, vehicle direction, or positioning in the market, a fresh perspective may be a competitive challenge to all existing and new suppliers.

- *Color Development*

  A shorter time frame usually permits one or two sample rounds, where as a longer time frame may encourage multiple submissions of samples by the suppliers. Initial fabric samples may be requested in the customer's specified color code. This color code is usually provided via a fabric, vinyl or leather standard. According to Borgsteena representatives, the majority of fabrics in North American production vehicles are developed in a neutral gray, black or beige colorway (Knitting Technology, 2003). Exterior paint colors are often used as accents on the neutral interior shades. A homogenous color scheme has often been used to create a feeling of spaciousness in an interior and to make the interior more versatile with different exterior colors. However, it is desirable to show the designs in an additional lighter or darker colorway to reveal any changes in the design intent.

- *Virtual Samples*

  Computer Aided Design has been an effective tool in creating a range of

designs and color ways more efficiently on paper before the first fiber is dyed. CAD simulations may represent some types of fabrics better than others, such as flat wovens or prints. Pile fabric simulations have limitations in representing the depth and three dimensionality of velours, knitted or woven. Digital prints on an existing basecloth can be a significant time saving sampling process over the traditional rotary screen print process (Boehme, Haerri, Johnson, & McGarrie, 1998).

- *Design Service*

  Individual reviews with the design decision makers can eliminate experimental looks that are outside the specific target vehicle design brief. This will allow alternative solutions to be created and contribute to the final success rate. This process also creates a confidence in the supplier designer in listening to the voice of the customer, but moreover increases the confidence on the O.E.M. designers' part in the supplier's ability to create appropriate products.

  The O.E.M. may have multiple design studios in the market place, near the corporate research centers, or near the assembly plant. Each design center expects development support from suppliers. Responsibility for specific vehicle may be assigned to one location or all locations may be making design proposals to the O.E.M. management. For example, companies such as Volkswagen work with North American suppliers through their advanced studio in California and their production design studio in Puebla, Mexico. However, decisions may be finalized by corporate design team in Wolfsburg, Germany. New product proposals designed and developed for the North American market maintain brand image but target the American customer's preferences.

  Lockwood suggests in his research that with advances in communication technology global teams of designers, engineers and marketers are able to collaborate more efficiently to provide innovative products which appeal to local preferences (Lockwood, 2001).

  Best practices reflect a strategy of bringing a total design service to the O.E.M. including market research on related products and leading styling directions. O.E.M. designers seek information on new trends in fashion, home furnishings, and other consumer products. The popular SEMA show (Special Equipment Manufacturer's Association) held annually in Las Vegas can be influential in suggesting adoptions of new trends from customized vehicles. After market and accessories was a 5.3 billion US$ trim segment in 2001(AAIA Fact Book, 2003). Related market trade exhibitions such as those for outdoor activities or extreme sports may also reveal the lifestyle directions of consumers.

Key Design Issues

In developing fabrics for automotive there are key design elements that must be considered. Performance is the foundation for every component for the transportation industry. Material characteristics which affect trimability of the seat and the overall acceptance of the product are key elements of the design brief.
These factors are the guiding parameters for the design and construction of the fabrics. The following factors are prevalent in a design brief:

- **Performance**
  - Yarn
  - Trimability
  - Pattern
  - Color

- Luster
- Hand
- Cost
- Differentiation

- *Performance*

As stated earlier, each O.E.M. establishes and evaluates their performance standards. Reliability and extending product life in the field is critical in maintaining confidence in the brand and the suppliers. As new expectations develop from the field, the competition, or the technologies, components makers must respond with an improved product.

- *Yarn Development*

Two factors set the parameters for development in automotive textiles. First, the preponderance of polyester fiber limits the variety within the design characteristics. Texturized polyester dominates bodycloth because of its performance characteristics in the interior environment which sees tremendous changes in temperature, exposure to UV light and long periods of wear (Artunc, 2001). Polyester also has been the cost effective choice.

Second, fabric developments are highly dependent on the nature of the fiber or yarn component. Without a change of basic fiber and resulting yarn characteristics, it is difficult to create new looks or performance features.

The introduction of microfibers in synthetic suedes using polyurethane resins has created challenges for dyeing and finishing processes to meet automotive performance standards (Smith, 2001). The product development investments for fiber and yarn companies to initiate innovative new products through the long development process to meet high automotive standards is a major deterrent to many despite the lucrative nature of volume or price rewards.

However, it becomes increasingly important that fabric designers understand and collaborate with fiber and yarn developers for the components of new products. High performance fibers like aramids, carbon and glass fibers are not new to vehicle design but their cost may outweigh their advantages for interior fabrics.

- *Trimability*

The drape and sewability of a fabric influences the appearance of the finished seat. If a composite fabric cannot be upholstered to the seat design without wrinkling or puckering, it will not be acceptable. Stretch is a major factor in trimability. Fabrics may require more than 8 to 10 percent stretch depending on the application. Although this may be more easily achieved or surpassed in a knit fabric, woven fabrics must be constructed to meet these requirements. The use of elaster yarns may add stretch but usually add cost also. A deep draw of door panels, headliners or in a complex seat design may call for variables in stretch and stability from the same fabric (Fung & Hardcastle, 2001).

- *Pattern*

North American consumers prefer more conservative fabric designs than European in preferences for large scale or figurative patterns. Special editions in European cars may have animals or novelty figures. North Americans manufacturers have traditionally chosen plain or small scale geometrics reminiscent of menswear or suiting patterns. The Japanese models have brought in larger scale more dynamic patterning but still using low contrast subtle colorations.

- *Color*

As mentioned earlier, the O.E.M designers supply color standards that every supplier must match within an acceptable range. Each textile, plastic, vinyl, leather, metal or other material in the interior must be color matched to this same standard. As each one of these components may appear differently under different light sources, they must meet a metameric match in order to reflect a coordinated consistent color interior (SAE, 1999). If one supplier is creating the headliner, another the visor, and another the carpet or seat cover, the textiles must appear as one consistent shade. Managing the development of color with a limited range of high performance dyestuffs across all types of textiles from piece dyed to package dyed to solution dyed is a complex and critical process. The introduction of space dyed yarns into automotive constructions in the 1990's further complicated the development and matching of new color combinations. Furthermore, space dyed yarns added costs from yarn waste, inventory complexity, and quality issues.

- *Luster*

Frosty flop effects of the seat fabrics used in the 1970's were due to the use of bright yarns and high pile. When piece dyed fabrics dominated the market, yarns of contrasting lusters could be used to create tonal patterns. Today's interior fabrics use duller lusters in velours, polyester suedes, and combination of semi-dull and almost metallic yarns in flat wovens. Unique accents of vinyl coated or elastomeric yarns or technical neoprene looks also vary the luster.

- *Hand*

The handle or sensory touch of the material covering a seat affects the perception of comfort and aesthetics. Designers frequently describe the way a fabric feels as friendly or welcoming. These descriptive terms may reflect qualities which are not standardized in the industry but are becoming more important as the market moves away from softer pile goods to flat fabrics. Objective measurement of these properties has been studied and systems such as the Kawabata Evaluation System (KES) are used in developing fabrics which meet consumer expectations (Barker, 2002).

- *Cost*

In the competitive market new innovations may demand a premium for a limited amount of time. Customers will quickly expect the same advantages at less price or more improvements within a short period of time. The competition may quickly follow a market leader with equal or better features at a lower price to maintain market share (Urban & Hauser, 1993).

The overall prices of automotive fabrics have continued to decline as the costs of raw materials, labor, energy and technology have grown. Increased performance standards may also contribute to cost increases. Many technologies are excluded from consideration for a vehicle only because they do not meet the price structures.

- *Differentiation of Products*

Customer perception of a product is influenced by every detail of the brand from advertising to the appearance of the headliner in the vehicle. Increasingly O.E.M. designers are challenging their suppliers to develop components that reinforce the brand

character of the vehicle. Moreover, these details must also differentiate their products from the competition. An understanding by supplier and O.E.M. designers of the current position of the product and any potential repositioning of the vehicle in the market is critical in developing the parts and the ultimate product.

- *Fabric Preferences in the Market*

Traditionally, US consumers have perceived plush velour as being a luxury interior for an American or Japanese vehicle. Following the European interest in flat woven multi colored patterned goods; the market shifted in the early 1990's to yarn dyed jacquard fabrics (Automotive Review, 1997). With an increase in leather usage and the influence of consumer products with high tech looks, non-pile fabrics grew in importance.

Textures such as chenille's and synthetic suedes from the home furnishings market influenced the transition in the market from velvets to flat wovens. Technical looks and enhanced performance from flat wovens with improved hand and stretch have become a desirable interior fabric.

Leather continues to dominate the luxury level models whether installed at the factory or at the dealer or aftermarket level. Leather may be the only readily available option in the American dealer's showroom for an upscale European vehicle.

Launch of New Products to Production

Once the designs and construction at the specified price point are selected, then the process of visually approving trim yardage for each color in the pattern is initiated. Yardage is produced for master standards to be distributed for controlling quality in manufacturing and as sales promotional aids. Fabric specimens and test results are submitted on each design for construction certification by the customer. Upon construction approval by O.E.M. Engineering and visual approval by Design, the product is characterized as "Fully Approved". The sales and delivery contract is then negotiated by suppliers' Sales and Marketing team with O.E.M. Purchasing for a long term program including "ramp up" to full production and plan for phase out or "build out" when the style reaches obsolescence.

If during any point in the production run of the adopted fabric style, issues in the processability of the fabric occur the supplier is responsible to correct the problem immediately. Just in time delivery is the standard mode of O.E.M. with all outsourced products coming together for assembly. Stopping a production line in Japan or Mexico because there is a quality issue with a fabric made in North America can be a very expensive issue and a deterrent to future business relationships.

- *Production Goods Customer*

The fabric supplier may be shipping to a lamination plant, a cut & sew plant or a seat assembler. The goods may be sold and delivered directly to other Tier suppliers, not the O.E.M. who has approved the development of the fabric. If the other suppliers responsible for building the interiors are not accustomed to using a certain type of fabric, there are opportunities for processability problems in trimming the seat. At each point along the development of the interior, a component builder can reject or require changes to the product if it does not meet their individual requirements to supply a quality product.

- *Seat Design*

As stated earlier, the fabric supplier may not know the final seat design during the development of the fabric. The fabric will be reviewed by the O.E.M. and the seat builder for appearance and performance on a prototype seat before final approval. If there are fabric or trim related issues, the fabric supplier will be required to make adjustments to the material. The adaptation of a fabric to meet the trim process while maintaining the original design intent requires the collaboration of the textile designer and the seat designer.

Seat designers must consider not only safety and comfort but also style in creating a vehicle seat (Steding, 2000). Vehicle development areas at the O.E.M.'s and the advanced design centers are a cross between artist's studios and engineering laboratories. As the original sketch or idea may be done by hand and transferred to computer software for three dimensional virtual modeling. Concept interiors are usually built full scale to evaluate new shapes and forms aligned with the exterior design. Concurrently, the interior may be outsourced to an interior component supplier. These Tier One suppliers may be developing new seat designs such as thinner profile seats with ergonomic features to meet the design brief of the O.E.M. These new shapes may require new trim materials and methods for building the seat set for assembly.

- Bodycloth or upholstery fabric is usually a trilaminate composed of the surface fabric, polyurethane foam and a scrim backing material. This composite contributes to a softer touch, reduces creases or "bagging" of the material in use and creates a more attractive appearance when deep sew lines are part of the seat design and construction. Also the scrim assists in controlling the stretch of knitted fabrics and acts as a "slide aid" during the sewing of the seat cover." (Fung, 1998) p. 14

Generally a cut and sewn fabric cover will be attached to a foam covered frame by another textile system of hook and latch strips or other bindings.

As seat systems typically represent approximately 30% to 40% of the cost of the total automotive interior according to Lear Corporation (Multexinvestor.com, 2003), opportunities for reducing costs through innovative processes and component advancements are of interest to the O.E.M. and the supplier.

General Motors developed a three dimensional knitting patented process with Courtaulds in the 1980's which Lear Corporation owns today (Powell, 2003). This process was in production from the late 80's until 2002 and was promoted as cost effective and versatile for customized designs (Leeke, 2003). It was reported to save 20 to 25% on the cost of a seat cover (Melliand International, 1998). As this technology created a heavier, thicker fabric it was possible to trim a seat without foam as part of the fabric composite. This whole cover technology has not been in production since 2002 by Lear nor made available to the industry (Tucci, 2003).

This fabric technology can be combined with different seat trim processes such as "foam in place" for improvements during seat assembly. The "foam in place" process replaces the process of a seat cover pulled over the seat cushion with a one step process where the liquid foam is poured into the sewn laminate seat cover. This method has proven more appropriate for smaller interior items such as headrests and armrests (Fung & Hardcastle, 2001).

- *Comfort*

Increasing the comfort of the occupants through better lumbar support without adding weight and cost is a challenge for the automotive designers (Steding, 2000). Textiles can contribute to the physical and psychological aspects of perceived comfort. One of the primary factors in occupant comfort is the transfer of heat and moisture (body perspiration) through the bodycloth, foam and other seat components. Phase change materials have been proven to improve comfort and also contribute to energy savings in bodycloth and headliner products (Pause, 2002). Research published in Autex Research Journal attributes moisture transport through thinner fabrics and better ventilation for increased comfort and resulting reduction in fatigue (Snycerski & Frontczak-Wasiak, 2002).

Future Market Factors

- *Consumer expectations*

Consumer behaviors and values is critical information for designers in making choices about the types of products the customer will prefer. Targeted consumer group's preferences are considered when developing vehicles' form and function and emotional appeal. Interior components have shown to be important to consumers, particularly seat features.

J.D. Power and Associates in their 2003 US Automotive Emerging Technologies Study ranked the new features interests by participating consumers. Anti whiplash seats and heated/cooled seats were ranked in the top seven by respondents. Flexibility in interior configuration was ranked number 15 pointing toward interest in cross functionality of vehicles (Power, 2003).

- *Versatility*

As Ford has seen Taurus' best seller place taken away by Toyota Camry sedan (O'Dell, 2004), many Detroit O.E.M.'s have turned their development attention to passenger cars, but with crossover functionality. Vehicles which have flexible space to accommodate the multi functional aspects of drivers and their passenger and cargo are an alternative to light trucks. Multi purpose interiors which provide alternative arrangements of seating and interior space are being developed to create open environments for the various activities while traveling. Today's vehicles may accommodate working, playing and dining in the car.

In the current market consumers expect more choices of products and convenient ways to purchase them. Consumer preferences reflect the changes in demographics and lifestyles, as diverse as individual personalities. No longer can marketers forecast the majority's choice and build according to this generalization. (McKenna, 1988). One product will not suit all customers or even a large group of customers anymore. The products must be differentiated to appeal to the specific consumer desires. Suppliers must become more flexible with shorter runs involving more complexity. (Drucker, 1990).

- *Mass Customization*

The automotive assembly line is considered the hallmark of mass production (Brinkley, 2003). However, today's United States market expects individualized products to fit each consumer niche. Mass customization is a product development and manufacturing challenge. Approaches to this dichotomy of customized products within the efficiencies of volume production may demand greater flexibility in

manufacturing processes. The consumer may have a limited number of choices beyond the standard options. Some experts believe that the answer is to develop multiple vehicles and variations from a single platform or vehicle base (Korth, 2003). A new version of the modular approach with more component sharing will need to be distinguished from earlier homogenization of products.

Spring suggested that this modularity is critical in realizing the value of mass customization. Products should be "custom designed" in configuring modular units rather than "custom built" (Spring, 2002).

Manufacturers may have to change paradigms and accept smaller runs as the norm. Product development processes will need to be streamlined in order to respond to consumer choices. Ultimately, the interface with the consumer will need to be more direct and aligned with the physical or virtual dealership.

In the evolving digital age, more drivers are expecting to bring the interactive ease of the home and office into their transportation decisions and ownership experience. According to the Office for the Study of Transportation at the University of Michigan, 62% new car buyers use Internet in making purchasing decisions (Flynn, 2002).

- *Designing the Experience*

Consumers expect safe and reliable products. However they also prefer products that make their lives easier. As the driver population ages, the expectation is for more convenience in all aspects of their lifestyle. The experience of purchasing, owning and using your vehicle over time determines the consumers' satisfaction with the product. It is part of the designer's role to enhance that experience through comfort, color, style, and craftsmanship. Consumers express strong feelings about vehicle ownership and the psychographics involved in this relationship are considered important by vehicle designers.

- *Connecting Man and Machine to the World*

The vehicle as the tool of "connectivity" for drivers and passengers to their lives wherever they travel. "Telematics" is described as the "technology that delivers information and mobile services wirelessly into cars". This provides not only features that are considered added value to the vehicle but in effect, differentiates the brand (Pang, 2001) p. 24.

This technology is seen as a growth area for both the O.E.M. and the service provider. The many facets of communication, infotronics and entertainment during travel time are seen as a significant opportunity. The forecasts by various research studies vary on figures for hardware and services revenues in the next five years. However, in 2001 The Strategis Group forecasted 17 million cars and light trucks will be equipped with a telematics product by year end 2005 (Pang, 2001). This may be an optimistic prediction considering those 17 million vehicles will need to be in production before summer of 2004 to be in the market by that date.

O.E.M.'s and technology companies like Nokia, or Verizon and their suppliers are partnering to develop innovative new systems to provide information and entertainment in vehicles. As new materials are sought to facilitate this technology, textiles or fibrous composites are being considered. The key of this feature will be to provide connectivity

without distracting the driver, adding weight or complexity to use. The role smart or electro textiles may play in the telematics technology is the focus of continuing research and development.

In considering the future of transportation, these issues are reflected in the challenges to vehicle designers of the future. The Interior Motives design brief for its 2004 Student Design award includes such themes as enhancing the driving experience through well-designed interiors for comforting the occupants, technological connectivity, and individualizing the interior using new materials and processes (Interior Motives, 2004). The reinterpretation of these issues for future consumers and the creative resolutions of these design problems are certain to shape tomorrow's personal transport.

Summary

- The development of human transport is, at its core, the design of the interface between man and machine. Designers who can integrate the capabilities and advantages of textiles will be enhancing the future of product innovation for tomorrow's travelers. Color, pattern, texture, and interior craftsmanship will continue to be employed to upgrade the perception and experience of quality in a vehicle.

The cycle for new product development will become more demanding for value added products to efficiently supply the world markets. The O.E.M. concerns and consumer needs can be the opportunities for new innovations from the supply base. Product developers must respond to this demand with greater flexibility and speed. Cost reductions will remain a part of the design brief and in the overall corporate strategies of all suppliers.

If development decisions are made and controlled by any one point in the supply chain with limited interaction between seat designers and fabric suppliers, opportunities to shorten lead times, improve quality and improve products will be minimized. If these interactions are competitive rather than collaborative, new products and processes may take more time and cost in coming to the consumer. Global communication and collaboration between supplier, manufacturer, dealer and end consumer will allow for greater flexibility in providing new products and services to the market.

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