DELPHI VII FORECAST AND ANALYSIS OF THE NORTH AMERICAN AUTOMOTIVE INDUSTRY

VOLUME 3: MATERIALS

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Foreword and Table of Contents

Foreword

Introduction

Delphi VII is a detailed analysis of forecasts by three separate panels of automotive industry executives, directors, managers and engineers who are expert in automotive technology, materials and marketing. These individuals were selected because they occupy positions of responsibility within the automotive industry and have strategic insight into important industry trends. In many cases they are in a position to influence these trends. This report, published in three volumes, is the seventh in a series of in-depth studies of long-range automotive trends, which began with Delphi I in 1979 and continued with Delphi II in 1981, Delphi III in 1984, Delphi IV in 1987, Delphi V in 1989 and Delphi VI in 1992.

The Office for the Study of Automotive Transportation (OSAT) collects the data, analyzes, interprets and presents the results. Since the forecasts are those of the panelists, Delphi VII is essentially the industry's own consensus forecast. These forecasts are not "crystal ball" predictions but, rather, well-informed estimates, perspectives and opinions. Such forecasts present an important basis for business decisions and provide valuable strategic planning information for those involved in all areas of the North American automotive industry: manufacturers; service, component and materials suppliers; government; labor; public utilities; and financial institutions. We believe these to be the most authoritative and dependable North American automotive forecasts available.

A key point to keep in mind is that the Delphi forecast presents a vision of the future. It obviously is not a precise statement of the future but rather what the industry thinks the future will likely be.

As an industry-wide survey, the project also allows individual companies to benchmark their vision and strategy against consensus industry opinions.

The Delphi method: general background

The study is based on the Delphi forecasting process. This process requires that experts consider the issues under investigation and make predictions about future developments. Developed by the Rand Corporation for the U.S. Air Force in the late 1960s, Delphi is a systematic, interactive method of forecasting based on independent inputs regarding future events.

The Delphi method is dependent upon the judgment of knowledgeable experts. This is a particular strength because, in addition to quantitative factors, predictions that require policy decision are influenced by personal preferences and expectations. Delphi forecasts reflect these personal factors. The respondents whose opinions are represented in this report are often in a position to influence events and, thus, make their forecasts come true. Even if subsequent events result in a change of direction of a particular forecast, this does not negate the utility of the Delphi. This report's primary objective is to present the direction of technological, materials and marketing developments within the industry, and to analyze potential strategic importance.

Process

The Delphi method utilizes repeated rounds of questioning, including feedback of earlier-round responses, to take advantage of group input while avoiding the biasing effects possible in face-to-face panel deliberations. Some of those biasing effects are discussed in this excerpt from a 1969 Rand memorandum:

> The traditional way of pooling individual opinions is by face-to-face decisions. Numerous studies by psychologists in the past two decades have demonstrated some serious difficulties with face-to-face interaction. Among the most serious are: (1) Influence, for example, by the person who talks the most. There is very little correlation between pressure of speech and knowledge. (2) Noise. By noise is not meant auditory level (although in some face-to-face situations this may be serious enough) but semantic noise. Much of the "communication" in a discussion group has to do with individual and group interest, not with problem solving. This kind of communication, although it may appear problem-oriented, is often irrelevant or biasing. (3) Group pressure for conformity. In experiments at Rand and elsewhere, it has turned out that, after face-to-face discussions, more often than not the group response is less accurate than a simple median of individual estimates without discussion (see N. C. Dalkey, The Delphi Opinion. Memo RM 5888 PR, p. 14, Rand Corp., 1969).

In the Delphi method, panelists respond anonymously, preventing the identification of a specific opinion with any individual or company. This anonymity also provides the comfort of confidentiality, allowing panelists to freely express their opinions. Among other advantages, this process enables respondents to revise a previous opinion after reviewing new information submitted by other panelists. All participants are encouraged to comment on their own forecasts and on the combined panel results. The information is then furnished to the panel participants in successive iterations. This procedure reduces the effects of personal agendas or biases and assists the panelists in remaining focused on the questions, issues and comments at hand.

Panel characteristics and composition

The very essence of a Delphi survey is the careful selection of expert respondents. The selection of such experts for this Delphi survey is made possible by the long-standing association between The University of Michigan faculty/staff and representatives of the automotive industry. Lists of prospective experts were assembled for Technology, Marketing and Materials panels. Members were selected on the basis of the position they occupy within the automotive industry and their knowledge of the topic being surveyed. They are deeply knowledgeable and broadly experienced in the subject matter.

The names of the panel members and their replies are known only to our office and are maintained in the strictest confidence. Replies are coded to ensure anonymity. The identity of panel members is not revealed. Upon publication of the final Delphi report, all questionnaires and lists of panelists are destroyed.

The characteristics of the 227 member panels are as follows: 10 percent of the Technology Panel were composed of CEOs, presidents, or vice presidents; 22 percent were directors; 23 percent were managers or supervisors; 42 percent were engineers (chief, assistant chief and staff); and 3 percent of the panel were made up of academic specialists and consulting technical-engineering specialists. The Marketing Panel was composed of 29 percent CEOs, presidents, or vice-presidents; 22 percent directors; 39 percent managers; 3 percent engineering specialists; and 7 percent academic and consulting marketing specialists. Among Materials panelists, 14 percent were CEOs, presidents and vice presidents; 12 percent were directors; 51 percent managers and supervisors; 16 percent engineering specialists; and 7 percent academic and consulting materials specialists. Approximately 34 percent of the Delphi VII panelists were employed by vehicle manufacturers; 56 percent by components and parts suppliers; and 10 percent were specialists, consultants and academics.

Presentation of Delphi forecasts and analyses

Data Tables. When a question calls for a response in the form of a number, responses are reported as the median value and the interquartile range (IQR). The median is a measure of central tendency that mathematically summarizes an array of judgmental opinions while discounting extremely high or low estimates; it is simply the middle response. The IQR is the range bounded at the low end by the 25th-percentile value, and at the high end by the 75th-percentile value. For example, in a question calling for a percentage forecast, the median answer might be 40 percent and the IQR 35-45 percent. This means that one-quarter of the respondents answered 35 percent or less, another one-quarter chose 45 percent or more, and the middle half of all responses ranged between 36 percent and 44 percent, with 40 percent as the middle response. That narrow interquartile range would indicate a fairly close consensus among the respondents.

In contrast, the percentage forecast for a different question might show a similar median forecast of 40 percent, but with an interquartile range of 20-70 percent, indicating less consensus and a considerable degree of uncertainty about the issue in question. Sub-group median estimates will not necessarily add to 100 percent, except in the case of a normal distribution.

Uncovering differences of opinion is one of the major strengths of the Delphi method. Unlike other survey methods, where differences of opinion among experts are often obscured by statistical averages, the Delphi highlights such differences through the presentation of the interquartile range.

Discussion. Narrative discussions are presented to highlight and explain a particular set of data.

Selected Edited Comments. Selected, edited comments from the Delphi panelists are shown following each data table in order to provide some insight into the deliberative process by which panelists arrived at their forecast.

In a Delphi survey, respondents are encouraged to contribute comments to explain their forecast and to perhaps persuade other respondents to change their positions. Many of these edited comments are included. These replies may provide important information which is not evident in the numerical data. An individual panelist may have unique knowledge that planners should carefully consider. However, readers should be careful not to overemphasize a particular comment. It is possible for a well-stated contrary opinion to mislead the reader into ignoring an important majority opinion which is accurately reflected in numerical data.

Manufacturer/Supplier Comparison. Delphi VII panelists include respondents from the North American automotive manufacturers; the major suppliers of components, parts, and materials for the industry; as well as consultants and academics. A concerted effort is made to obtain a relatively equal distribution of manufacturer and supplier panelists. Within the context of this survey, categorizations will refer simply to either Manufacturer (or for brevity in tables, OEMs—Original Equipment Manufacturers) and Suppliers.

For obvious competitive reasons, the automotive manufacturers seek to maintain a degree of secrecy regarding their design, engineering and marketing plans. While the relationship between the manufacturer and supplier is moving toward an increasingly closer degree of cooperation and integration, a considerable element of proprietary concern remains. Additionally, the very size and complexity of the automotive industry works against optimum information transfer. Therefore, where it is considered relevant to a better understanding of or perspective on the forecast, our analyses include a comparison of the forecast from manufacturer and supplier panelists in an attempt to illustrate where significant agreements or

differences exist between the opinions of these two groups.

Comparison of Panels. The three groups of Delphi panelists (Technology, Marketing and Materials) are asked questions that specifically focus on their respective area of expertise. However, a few questions are considered common to two or more panels. For example, the fuel-price question (see MAT-3) is considered so basic that it was submitted to all three panels.

At times, the panels will give differing responses to these questions. This may reflect the makeup of a particular panel and the panelists' subjective perception of the issue in question. Where differences do exist between the panels, serious consideration should be given to whether the difference reflects the composition and proprietary interest of that particular panel or whether there exists a substantial degree of uncertainty regarding the issue in question. We try to highlight both the differences and similarities.

Trend from Previous Delphi Surveys. A single Delphi survey is a snapshot which collects and presents the opinions and attitudes of a group of experts at a particular point in time. Some questions, in various forms, were asked in previous Delphi surveys, and thus provide trend data. The fact that forecasts for a particular question may exhibit considerable variation over the years does not diminish its relevance and importance to strategic planning, because it reflects the consensus of expert opinion at the time. These opinions and forecasts are predicated on the best information available at the time. However, market, economic and political factors do change. Trend data can reveal the stability or volatility of a particular market, material or technology issue. A careful analysis of trend data is an important consideration in strategic business planning decisions.

Strategic Considerations. Based on the replies to a particular question, other relevant Delphi VII forecasts, other research and studies, and OSAT's extensive interaction with the automotive industry, this report makes inferences and interpretations as to the core issues in questions and their potential impact on the industry. By no means are they exhaustive statements of critical issues. Rather, they are points that the reader might consider useful.

Materials Contents

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Executive Summary

EXECUTIVE SUMMARY

Just as quality is the ticket of entry into the vehicle market in the 1990s, cost and manufacturing competitiveness are the entry ticket for materials suppliers into the automotive industry. The *Delphi VII Forecast and Analysis of the North American Automotive Industry, Volume 3: Materials* reveals that cost competitiveness is still, more often than not, a critical success factor. However, over the next decade additional materials selection criteria, such as weight reduction and recycling, are expected to increase in importance.

The materials panel identifies several issues that offer significant challenges and opportunities for the industry (MAT-10). Material usage issues, especially those associated with the increased use of lightweight materials and cost concerns, are the areas the panel view as presenting the greatest barriers and the potential for the greatest rewards. Recyclability and manufacturing are also mentioned as critical issues. Material suppliers need to develop effective strategies to address an array of economic, performance, recyclability and manufacturing challenges.

Panelists rate the importance of several overall materials selection criteria (MAT-8) and judge material and processing costs most critical, with weight next in importance. Interestingly, the manufacturers rate the two factors almost equal, while suppliers, possibly feeling manufacturer cost reduction pressure, rate material and processing cost more important than weight.

The panel of industry experts suggests that growing governmental regulation and consumer demands will increase the importance of weight reduction and recyclability in the next decade. The past 10 years have seen exceptional activity in the development of lightweight automotive materials. Driven by the threat of increased regulatory pressure (i.e., increased Corporate Average Fuel Economy—CAFE), the application of these advanced materials is expected to increase in the mid-1990s. Although our current panelists do not believe that component weight is currently as important as cost, they expect weight to approach cost as a basis for material selection. Increased emphasis on weight reduction may prompt expanded use of materials and processes previously deemed too costly. Significant cost reduction opportunities (i.e., improved design methodology, more efficient processing, reduced inventory and enhanced productivity) are being developed which should limit the impact of materials cost changes on the retail price.

Although manufacturers have been incorporating lightweight materials to meet CAFE standards, much of the recent CAFE gain has been through powertrain advancement. Panelists suggest further fuel economy gains from the powertrain may be difficult and costly. Consequently, more stringent CAFE laws are expected to prompt significant mass reduction. There are three basic mechanisms for mass reduction: downsizing, lightweight materials and use of more efficient designs. Since consumers appear unwilling to forgo size, mass reduction will likely emphasize lightweight materials (MAT-13) and improved design.

The panel expects the weight of an average passenger car to decrease some 8 percent by 2003, assuming a 35 mpg CAFE standard (MAT-13). But some panelists, noting a recent trend toward increased weight of vehicles, expect the weight of an average passenger car to increase over the next 10 years.

During the coming decade, significant changes in the vehicle materials mix are forecast. Assuming a 35 mpg CAFE standard, the panel forecasts that the average passenger car in 2003 will use 9 percent less steel than in 1992 (MAT-15). They also forecast a 10 percent decrease for steel usage in light trucks over the same period. However, the panel foresees growth in the use of HSLA steel. To remain competitive, steel producers must continue to react quickly and incorporate advancements such as tailored blanks.

A 15 percent increase over the next decade is forecast in passenger car plastic usage (MAT-15). Polymers that are expected to experience increased use include polypropylene, polyethylene and nylon. Concurrently, polyvinyl chloride use is forecast to decrease (MAT-16). This forecast of overall increased plastics usage is especially interesting given the potential challenge that recycling raises.

Other lightweight materials are also expected to increase substantially. Aluminum and magnesium will likely see increased application. Aluminum will likely see gains in several strategic areas. It is expected to be used in 70 percent of cylinder heads and 40 percent of cylinder blocks by 2003 (MAT-22). Aluminum is also forecast to be used in 9 percent of space frames (MAT-30) and 89 percent of styled wheels (MAT-36) by 2003. Magnesium is forecast to see use in a wide variety of applications including various housings, instrument panel components and seat frames (MAT-17).

Increased use of lightweight materials, and the associated mass reduction, should lead to improved acceleration, driveability and fuel economy, which, in turn, should increase customer satisfaction (MAT-28). Powdered metals, metal matrix composites and other technologies expect to see increased application in engine components such as camshafts, crankshafts, connecting rods and pistons (MAT 20). In addition to overall vehicle weight reduction, improved performance will result.

A moderate increase in gasoline prices is forecast for the coming decade. Premium unleaded and regular unleaded gasolines are expected to increase to $1.85 and $1.68 per gallon, respectively, unadjusted for inflation, by 2003 (MAT-1). The moderate increase in prices suggests that, unless driven by legislation, gasoline powered internal combustion engines will continue to dominate the North American market over the next decade. However, the panel forecasts federal legislation mandating some degree of

alternative fuel capability as increasingly likely (MAT-3). It forecasts flexible fueled vehicles to account for 5 percent of North American passenger car production by 2003 (MAT-4). It also forecasts limited (2 percent or less each) penetration for electric, electric/gasoline hybrid, natural gas and propane powered vehicles by 2003.

The traditional Detroit/Washington relationship has been historically confrontational. Command and control regulations have typically been the Washington approach to shaping future vehicles. There are significant signs that this approach may be changing. The Clean Car Initiative is one of those signs and has significant implications for automotive materials. The initiative emphasizes the implementation of high-tech lightweight materials, such as composites and ceramics. Although the panel forecasts only modest increases in ceramics (MAT-15), the material, along with other high technology lightweight materials, must be watched closely. The increased cooperation between the industry and government agencies, such as the Department of Energy National Laboratories, may have a particularly important benefit in materials and processing advances.

Recycling is expected to play an increasingly important role in the selection of automotive materials (MAT-41 through 45). The panel comprehends the implications of the current recycling push. However, its enthusiasm seems to be tempered by the realities of developing a "green" car. The necessary technologies and materials for true life-cycle management, much like the development of lightweight materials, will take a major commitment of time and resources. Yet it is important to move aggressively to address this issue. Companies that are first to take a life-cycle approach to materials (recyclable, lightweight and cost-competitive) could gain an advantage.

Many panelists suggest that the recycling technology of currently nonrecycled materials must further develop before wide-scale implementation is viable. The industry, spurred on by the specter of Germany's take-back legislation and other regulations, is expected to rapidly incorporate design for recycling. Unless outside forces act directly on the automakers' decision processes, the North American producers may only gradually accept recycling as a primary selection criterion.

Body panels are expected to be an area of intense material competition (MAT-9). Panelists rate the relative advantages of aluminum, steel, thermoplastics and thermosets polymers for body panels over six important life-cycle stages. Steel is seen as the most advantageous material at the raw material and processing stages—the two stages panelists believe are most important. Steel also rates as the most advantageous material in two more of the six life-cycle stages. Aluminum is rated least advantageous in four of the six stages, although several manufacturers have recently made significant commitments to aluminum projects.

Importantly, manufacturers rate steel more positively than do suppliers. We suspect this is due to the manufacturers' comfort level with steel, and a sensitivity to cost and processing issues. However, the manufacturers' willingness to take risks could change rapidly if market or regulatory conditions shift as panelists suggest.

The greatest gain is forecast for aluminum—the material that was rated the least advantageous in four of six lif-cycle stages. This emphasizes that selection decision criteria are changing rapidly. The ability to be agile—in manufacturing, materials or customer demands—will be crucial for survival.

Panelists forecast continuing significant changes in materials technology. The competition should increase as essentially every vehicle component is embroiled in the battle. No material can be assumed the long-term winner for any application. Tougher fuel economy laws and recycling considerations should further heighten the challenges for manufacturers and suppliers alike.

MAT-1 Please estimate U.S. retail fuel prices, per gallon, for the following years. Please do not adjust for inflation.

Unleaded Gasoline	Est. 1992*	Median Response		Interquartile Range	
		1998	2003	1998	2003
Regular	$1.10	$1.35	$1.68	$1.25/1.55	$1.36/2.00
Premium	$1.29	1.55	1.85	1.45/1.75	1.60/2.20

***Source:** AAA December 1992 Survey.

Selected edited comments

Market-driven changes

- I believe that, due to refinements on engines, the demand for premium will not increase—rather, it may decrease.
- My estimate assumes no political disruption in the Middle East that affects supply/demand. It also assumes that further fuel efficiency improvements will keep oil consumption down.
- Supply and demand will drive up the price.
- The producers will keep the price marketable.
- Use of alternative fuels will keep prices of gas in check over the long run.
- We are living in a fool's paradise.

Discussion

The Materials panel forecasts a moderate increase in gasoline prices in the coming decade. The moderate increase in prices suggests that, unless a change is driven by legislation, the gasoline-powered internal combustion engine will continue to dominate the North American automotive market over the next decade.

Manufacturer/supplier comparison

The manufacturers panel consistently forecasts higher prices for both regular unleaded and premium fuels. For regular, the manufacturers' forecast is 10 cents per gallon higher than that of the suppliers in 1998 and 20 cents higher in 2003. The difference in the two groups' forecast for premium gasoline is 6 cents in 1998 and 20 cents in 2003. This difference may be due in part to the manufacturers maintaining a more active position in Washington (and thus perhaps having a clearer picture of potential legislative activity regarding gasoline taxes) and interact more with oil company representatives.

Comparison of forecasts: MKT-3 and MAT-1

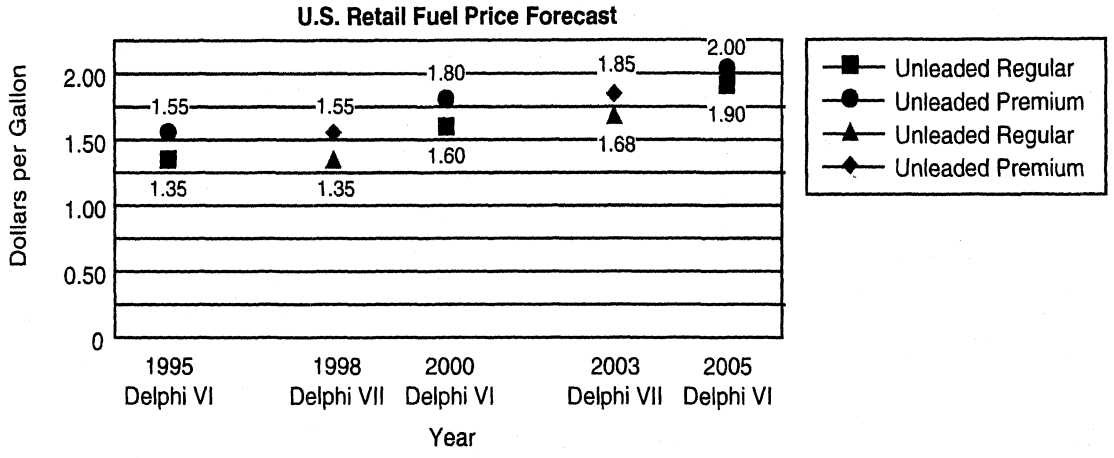
Results for the materials, technology and marketing surveys are summarized in the following table.

Unleaded Gasoline	Est. 1992*	Median Response					
		1998			2003		
		MAT	MKT	TECH	MAT	MKT	TECH
Unleaded regular	$1.10	$1.35	$1.45	$1.40	$1.68	$1.70	$1.75
Unleaded Premium	$1.29	1.55	1.60	1.70	1.85	1.90	2.00

*** Source:** AAA December 1992 Survey. This was provided to panelists as a baseline.

Trend from previous Delphi surveys

In previous Delphi studies, forecasts for future gasoline prices have often been far from reality. The Delphi process can best be described as what the panelists *expect* to happen. Sometimes this is vastly different from what *does* happen. In the early 1980s, our panel of industry experts expected gasoline prices to increase rapidly. However, the 1993 real price of gasoline has reached a 20-year low and is showing little pressure—except for increased taxes—to increase. Over the last several years, the availability of petroleum has stabilized, and political turmoil in the Middle East seems to be of less concern.



Strategic considerations

Although the supply of petroleum is not endless, the panelists appear to be in agreement that petroleum supplies will remain relatively stable. Gasoline prices should generally reflect this stability. This suggests that the industry does not foresee an impending shift from gasoline-powered internal combustion powerplants in the near future. Relatively low gasoline prices should lead to a continued high demand for gasoline-powered engines and a limited market for alternative fuel systems. The development of alternative energy sources and powerplants must be vigorously pursued both as a technological hedge against potential alternative legislation and as a means to potentially satisfy future customer demands. However, we agree with our panel that gasoline will remain the most cost-effective source energy for the automobile for at least the next decade.

The pressure to increase gasoline taxes will likely continue from two directions: federal budget deficit reduction and environmental protection. Interest in raising taxes on gasoline will continue to tempt those who are interested in decreasing the federal deficit. Although the 50-cent per gallon tax turmoil of the 1992 presidential campaign has quieted, the potential for significant deficit reduction efforts through tax increases remain possible.

Environmental concern is a very real and immediate threat to gasoline. Environmental factors such as global warming, smog and health concerns are potential difficulties. The worldwide demand for petroleum is expected to increase over the next decade as newly industrialized countries increase their consumption. This increased demand by developing countries will put further pressure on the environment and oil reserves. Corporate Average Fuel Economy (CAFE), the U.S. approach to automotive petroleum conservation, has come under increasing criticism from both environmentalists and those in the automotive industry. Many view CAFE as an ineffective means of regulating gasoline consumption. As frustration has increased, some have suggested eliminating CAFE requirements and replacing them with higher gasoline taxes. Proponents of this idea assert that it would lead to a more market-driven selection of high mileage vehicles. Yet any proposal for tax increases is met with great resistance.

MAT-2 What percentage of U.S. gasoline sales, in gallons, will be reformulated in accordance with 1990 Clean Air Act Requirements amendments in 1998 and 2003?

Reformulated Gasoline				
	Median Response		Interquartile Range	
Est. 1992*	1998	2003	1998	2003
0%	20%	40%	20/30%	40/50%

*** Source:** Oil company estimate.

Selected edited comment

- There are many areas of refinement on the vehicle (weight, efficiency, etc.) that are currently being addressed in place of gasoline reformulation.

Discussion

Reformulated gasoline is forecast to account for 40 percent of all gasoline sales by 2003. Even higher penetration rates for reformulated gasoline are possible, given the new administration's commitment to environmental issues.

Manufacturer/supplier comparison

The manufacturers and suppliers are in general agreement.

Trend from previous Delphi surveys

The 1994 Delphi VII panelists are less positive about the potential penetration for reformulated fuels than were the 1992 panelists. We find it interesting that the current panel's estimate is 10 percent lower than the forecast of the 1992 Delphi VI panel. This decrease could signal a shift in research efforts away from reformulated fuels and toward other areas of development such as engine and transmission improvements.

Strategic considerations

The use of reformulated gasoline is expected to increase significantly over the next decade, especially in those regions that do not meet the air quality standards mandated by the federal Clean Air Act. Like many other aspects of the motor vehicle fuel issue, legislation is driving the production and use of reformulated gasoline. Because the price of all gasolines in nonattainment regions will reflect the increased cost, the price of reformulated gasoline will not be differentiated by the customer. However, it will be interesting to see how reformulated gasolines are accepted where they are not required. In those regions, there will likely be a price premium on the cleaner gasoline. The consumer, even in this enlightened age of environmentalism, may not be willing to pay that premium.

MAT-3 **What is the likelihood of federal legislation mandating some degree of alternative fuel capability in the total fleet by 1998 and 2003? (include electric vehicles in your forecast). Where 1 = extremely likely, 3 = moderately likely, and 5 = not at all likely.**

Year	Mean Forecast
1998	3.3
2003	2.3

Selected edited comments

- Cost is the key to realizing alternative fuel capability.
- This administration is likely to redefine oxygenated fuels as alternative fuels, then legislate its use and claim victory.
- This should be driven by the metropolitan area. Cities that are most susceptible should define common requirements, e.g., Los Angeles, New York and Denver. Policies should not be at the national or federal level.

Discussion

The panel forecasts federal legislation mandating some degree of alternative fuel capability as increasingly likely for the coming decade. It is possible that any federal legislation will be influenced by state regulations currently being implemented.

Manufacturer/supplier comparison

The manufacturers and suppliers are in general agreement.

Trend from previous Delphi surveys

This question was asked differently in previous Delphi studies, so direct comparison is not possible. However, the 1992 Delphi VI and 1994 Delphi VII panelists seem to agree on the probable direction of the legislative trends. The 1992 panel was given the choice of "likely" or "not likely". Ninety-five percent of the panelists thought that some form of federal legislation would be mandated by 2000. The current panel forecasts that alternative fuel mandates are moderately likely by 1998, and more likely by 2003.

Strategic considerations

Over the next decade, market forces are not likely to be the impetus for a switch to alternative fuels. Economic and technological barriers and, in some cases, a lack of infrastructure will probably keep costs too high. Any significant increase in the use of such fuels will likely come as a result of local, state and federal regulation—some of which is already in place. Although the federal Clean Air Act addresses alternative fuels, the state of California is presently particularly aggressive in stimulating increased use of alternative fuels. Furthermore, several states are currently considering adoption of regulations based on California's model. Based on present actions, the future is highly uncertain.

It is interesting to note that there is already conflict developing between state and federal governments in this area. As the new California Air Resources Board (CARB) low emission vehicle program regulations are being implemented, the auto industry is aggressively attempting to address major elements of the regulation in a variety of ways. The basis of the industry's concern is its belief that the regulations are not the most cost-effective approach to meeting air quality concerns. Hopefully, balance can be achieved between government goals, economics and effectiveness.

MAT-4 What percentage of North American-produced passenger cars and light trucks will use an alternate energy source in MYs 1998 and 2003?

Alternate Energy Source	Median Response			Interquartile Range	
	Est. 1992*	1998	2003	1998	2003
Passenger Cars					
Alcohol or alcohol/gasoline	0.5%	2%	5%	1/3%	2/10%
Electric	0	.5	1	.05/1	.5/5
Electric/gasoline hybrid	0	.2	1	0/1	.7/3
Natural gas	0	1	2	.5/2.5	1/5
Propane	0	.5	1	0/1	.5/2
Light Trucks					
Alcohol or alcohol/gasoline	n/a	1%	3%	.1/3%	1/5%
Electric	n/a	0	.01	0/1	0/1.5
Electric/gasoline hybrid	n/a	0	.01	0/1	0/2
Natural gas	n/a	.5	2	0/3	.5/5
Propane	n/a	.5	1	0/1	0/2.5

***Source:** Various OSAT estimates.

Selected edited comments

- Alternate energy sources will vary by model type and ultimate usage (e.g., city delivery trucks)
- Large existing fleets of service vehicles currently utilize natural gas and liquid petroleum as fuels.
- This is political as much as technological. Why shouldn't personal use light trucks fall under passenger car regulations or achieve passenger car specifications? Engine and transmission combinations are very similar to cars. The auto industry could gather a lot of political favor by voluntarily forging ahead, and do something very positive.

Discussion

The Materials panel forecasts market penetration rates for flexible-fueled vehicles to be 5 percent for passenger cars and 3 percent for light trucks by 2003. The panel forecasts very limited application of electric, electric/gasoline hybrid, natural gas and propane technologies in vehicles by 2003.

Manufacturer/supplier comparison

The manufacturers and suppliers are in general agreement.

Comparison of forecast: MKT-39

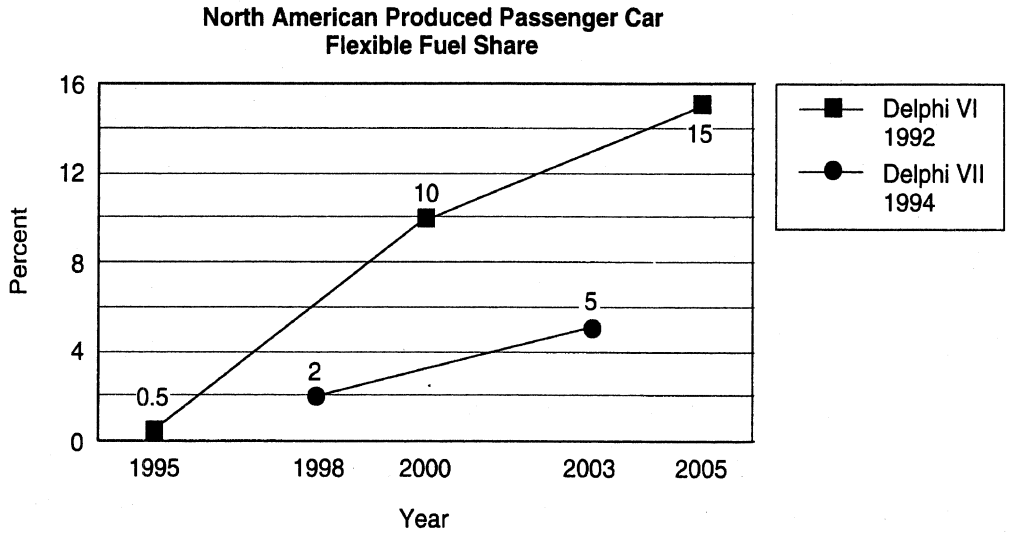
The Materials and Marketing panels are in general agreement. The table below compares the Materials panel results with the Marketing's passenger car forecast. While each of the represent limited production, the Marketing panel forecasts larger penetration rates for hybrids. The Materials panelists indicate greater shares for flexible or variable fuels, natural gas and propane vehicles.

Alternate Fuels	Est. 1992*	1998		2003	
		MAT	MKT	MAT	MKT
Flexible or variable fuel (Methanol/ethanol, gasoline blends)	**0.5%**	2.0%	1.0%	5.0%	3.0%
Electric vehicles	**0.0**	0.5	0.5	1.0	1.5
Electric/hybrid vehicles	**0.0**	0.2	1.0	1.0	1.5
Natural gas	**0.0**	1.0	0.5	2.0	1.0
Propane	**0.0**	0.5	0.1	1.0	0.5

***Source:** *AAMA World Motor Vehicle Data,* 1992. This was provided to panelists as a baseline.

Trend from previous Delphi surveys

In the 1992 Delphi VI study, this question was asked only about passenger cars, and the alternative fuels were limited to alcohol/gasoline, natural gas and propane. Panelists for the current study are much less positive about the implementation of flexible-fueled vehicles than were their predecessors. The two panels' forecasts are very similar on the penetration rate of natural gas and propane, although the current panelists again appear slightly more conservative than the earlier panel.



Strategic considerations

It is likely that the internal combustion gasoline engine will be the power source of choice for the next decade. It is also likely that legislation will force the industry to develop alternative fuel systems. Technological advancements of the past decade have led to a decrease of well over 90 percent in the emission of pollutants from new automobiles compared to pre-regulated vehicles. Alternative fuels may be a partial solution to environmental and energy concerns. It must be noted that, in some cases, these efforts (such as electronics), may transfer or change the nature of the problem.

The penetration rates forecast by the panel suggest only modest use of alternative fuels. Currently, vigorous development programs for each of the alternatives are underway. In most cases, initial implementation will be through commercial fleets, often supported by the alternate energy stakeholders. The success of these programs needs to be monitored closely. There are currently many potential alternative fuel technologies. However, there are pitfalls.

The future of alternative fuels will be based on a combination of policy and technological and economic factors. The stakes in this competition are high. Each fuel is supported by strong special interest groups. It is important that the winners not merely be those technologies with the strongest political or financial support, but rather those that provide the most cost-effective solution to a range of problems.

MAT-5 **Please indicate your view of the trend in U.S. federal regulatory and legislative standards over the short term (1994-1998) and long term (1999-2003), where 1 = much more restrictive, 3 = no change and 5 = much less restrictive. Also, list any likely new areas of legislative activity.**

Legislation/Regulatory Activity	Mean Forecast	
	Short term 1994-1998	Long term 1999-2003
Occupant restraint/interior safety		
Passenger car	2.0	1.5
Light truck	2.0	1.5
Vehicle emission standards		
Passenger car	2.0	1.6
Light truck	1.9	1.6
Fuel economy standards (CAFE)		
Passenger car	2.2	1.8
Light truck	2.1	1.8
Vehicle integrity/crash worthiness		
Passenger car	2.2	1.9
Light truck	2.1	1.7
Product liability		
Passenger car	2.7	2.2
Light truck	2.6	2.2
Antitheft		
Passenger car	2.7	2.3
Light truck	2.8	2.4

Short-term new area responses include:

Driver control (i.e., ABS): 2.0; traction, skid control: 3.0

Long-term new area responses include:

Electronic safety (radar, etc.): 1.0; traction, skid control: 2.0

Discussion

Each of the six legislative/regulatory activities listed are rated as at least somewhat more restrictive by the panel. The industry will likely continue to be faced with increasing guidance from the federal government in the next decade.

Manufacturer/supplier comparison

The manufacturers and suppliers are in general agreement.

Comparison of forecast: MKT-6 & TECH-15

Technology and marketing panelists are in agreement in all area with one exception. Marketing panelists rank long-term occupant restraint/interior safety for light trucks at 2.5, which is somewhat less likely than the 1.8 ranking by the technology panelists.

Trend from previous Delphi surveys

This question is substantially changed from previous Delphi studies.

Strategic considerations

Our panelists expect the federal government will continue to be very active in vehicle emissions, safety and fuel economy. The current Washington-Detroit relationship seems to be moving toward an era of cooperation, and away from the technology forced command and control relationship. This is good news, but the relationship is still in its early stages and has yet to demonstrate a tangible result. There is some suggestion that continuing this change in the relationship will be difficult to accomplish.

The panelists expect light truck regulations to increase substantially in the next decade. Historically, light trucks have not been subject to the same level of regulation as passenger cars. However, as consumer purchase patterns change—light trucks now account for over 40 percent of light vehicle sales—there is growing pressure to match light passenger car standards. Federal legislation of light truck safety standards has recently begun to approach the level of passenger cars. As safety and other federal requirements increase, this will have a modest impact on light truck design and cost.

Potential increases in CAFE are a concern for all manufacturers. Manufacturers that have come to rely heavily on light truck sales may be vulnerable to an increase in light truck CAFE. If this standard is increased significantly in the next decade, substantial redesign will be required and may have a negative impact on sales. This could lead to increased challenges for the North American domestic industry which has benefited greatly from the recent increased popularity of light trucks. Changes in CAFE, whether for light trucks or passenger cars, will create significant challenges and opportunities for suppliers.

MAT-6 **Do you expect federal or state level government regulatory activity to enforce the recyclability of automotive materials within the coming decade in the following areas, where 1 = extremely probable, 3 = somewhat probable, and 5 = not at all probable.**

Regulatory Issues	Mean Forecast
Specific regulation for the following:	
Disposal of automotive fluids	1.8
Disposal of used tires	2.0
Recyclability of plastics	2.0
Establishment of uniform identification/coding standards for materials to facilitate separation	2.3
Ban on some current automotive materials	2.4
Required minimum recycled content	2.7
Financial penalties/incentives based on recycled content	2.9
"Take back" regulations making manufacturers responsible for final product disposition	3.0

Selected edited comments

- A ban on some current automotive materials (e.g., lead) is likely.
- Most activity will be at the state level.
- "Take back" will be dependent on how Germany deals with this problem. It may not be the solution for the United States.

Discussion

The panel expects the federal government to take a more active role in regulating automotive recycling during the next decade. It views each of the listed regulatory issues as at least somewhat probable.

Manufacturer/supplier comparison

There is little substantial difference between the two panels. However, the manufacturers feel that financial penalties or incentives are more likely to be implemented (2.6) than do the suppliers (3.1).

Comparison of forecast: TECH-51

Materials and technology panelists are in agreement on this question.

Trend from previous Delphi surveys

The 1992 Delphi VI and 1994 Delphi VII panels are remarkably consistent in their forecasts. However, there are two areas where they disagree. The Delphi VII panelists see "take back" legislation—requiring manufacturers to be responsible for the final disposition of their product—as more likely than the previous panel. North American industry participants have been closely monitoring the legislative activities in Germany, and this has surely influenced their forecast. There is currently much disagreement as to the effectiveness of the German take back regulations. The current Delphi panel appears to feel that the potential for financial penalties or incentives are more likely. It is likely that the new administration's more active stance on environmental issues has influenced the panel's forecast.

Strategic considerations

Recycling is not likely to be market-driven over the next decade. Instead, it will probably be initiated by industry, and by federal and state regulation. A majority of consumers considers itself environmentally conscientious, yet we believe it will be some time before most vehicle buyers include environmental factors as an important vehicle purchase criteria. It is natural for consumers to declare themselves environmentalists, but paying for an environmental friendly vehicle is another matter. This does not suggest that companies should forego life cycle management strategies. They should move forward with sound business practices that support a trend to "green" thinking. Environmental factors may well become important purchase decision criteria in the future.

The North American automotive industry is at a critical juncture with regard to the recyclability of vehicles. The German government has legislated stringent recycling requirements, including a take back law that makes manufacturers responsible for the final disposition of their products. Many view the German laws as a precedent that should be matched in the United States. The German approach, however, may not be the best solution for North America. The existing infrastructure for motor vehicle dismantling and shredding in North America is very efficient. A take back law and the supporting disassembly facilities may not be the most economically or environmentally effective solution.

Varying international recycling regulations could cause trade friction. As the industry globalization continues, it is important for both manufacturers and suppliers to be keenly aware of trends in all international markets. This may be especially critical with recycling.

The challenge of environmental issues, specifically recycling, should be viewed by the industry as an opportunity. The establishment of the United States Council for Automotive Research (USCAR) Recycling Center is evidence that the domestic industry is pro-actively pursuing recycling issues. Recycling is an issue that can help create a positive tone for future relations between Washington and Detroit.

MAT-7 What do you believe that the U.S. Congress should do, or should not do, to assist the traditional, domestic automotive industry? Consider "automotive industry" to include both vehicle manufacturers and suppliers.

The U.S. Congress Should:	Percent of Responses	
	Yes	No
Pursue balanced trade more aggressively	78%	22%
Coordinate legislation, government agencies and other policy activities	76	24
Regulate based on technical considerations	54	46
Increase gasoline prices	51	49
Tighten regulation of foreign direct investment in the United States	32	68

Other responses include:

An increase in investment tax credit is needed.

Congress should pursue market strategies over mandates.

Congress should stay out of business interests other than safety and environment.

It should relax automotive emission standards at current levels and regulate other industry polluters such as coal-burning plants and chemical emissions.

Legislative incentives for maintaining a manufacturing base in the United States should be considered.

We should develop an industry secretary in Washington.

Selected edited comments

- Some government agency should coordinate legislation, government agencies and other policy activity, but I'm not sure that Congress is capable.
- Utopia would be to base policies on facts and reason.

Discussion

The panel strongly feels that Congress should more aggressively pursue balanced trade. However, it feels that Congress should not regulate direct foreign investment in the United States. Also, the panel strongly agrees that the federal government must do a better job of coordinating legislation, government agencies and other policy activities.

Manufacturer/supplier comparison

The manufacturers and suppliers are in agreement on each of the actions, with the exception of increasing gasoline prices. Some 56 percent of supplier panelists favor some form of gasoline price increases. Only 39 percent of the manufacturers panel agrees. We find it very interesting that the manufacturers panel is against an increased gasoline tax, especially given recent statements by the Big 3 CEOs in support of gasoline tax.

Comparison of forecast: TECH-17

There is some difference of opinion in this area between technology and materials panelists. The common questions are summarized below.

The U.S. Congress should:	Percent Yes Votes	
	MAT	TECH
Coordinate legislation, government agencies and other policy activities	76%	91%
Regulate based on technical considerations	54	72
Increase gasoline prices	51	67

The materials panelists view the involvement of Congress much less favorably than do technology panelists in the areas of coordination of legislation, increasing gasoline prices and regulating based on technical considerations. This difference may be a result of a more direct involvement in meeting standards by the technology panelists.

Trend from previous Delphi surveys

This question is substantially changed from previous Delphi studies.

Strategic considerations

The Detroit/Washington relationship has been historically confrontational. Command and control regulations have typically been the Washington approach to shaping future vehicles. There are significant and positive signs this may be changing. The current administration and the domestic manufacturers are demonstrating a desire to work more closely with one another on important economic, political and technical issues. Currently, foreign manufacturers—even those with production facilities in the United States—are excluded. This cooperation will certainly be a critical element in improving the competitiveness of the domestic industry.

Despite great progress in this newly established partnership, its continued growth will not be easy. For its part, the domestic industry must continue to develop a more credible and comprehensive public policy, and present its case in a straightforward manner. To be truly successful, the partners must develop mutual trust, and be willing to accept new ideas and paradigms. The not-invented-here syndrome must be set aside. Government/industry harmony should lead to technologically and economically viable public policy.

MAT-8 **The automotive manufacturers base their material decisions on many criteria, including a number of attributes and characteristics of competing materials. Please indicate your view of the importance of each of these attributes and characteristics in the material selection process over the next decade, where 1 = extremely important, 3 = somewhat important, and 5 = not at all important.**

Attribute	Mean Rating
Materials and processing cost	1.5
Weight	1.8
Warranty cost	1.8
Corrosion resistance	1.9
Design/styling requirements	2.0
Environmental issues	2.1
Perceived safety	2.2
Vehicle customer preference	2.2
Disposal cost	2.4
Recyclability	2.4
Formability	2.4
Ease of final disposition	2.6

Other responses include:
Avoidance of downsizing is important.
Field experience is extremely important.

Selected edited comment

- Weight can be extremely important or relatively unimportant based on CAFE and weight target per platform. If a platform is over the CAFE limit, weight can become the most important criterion for material decisions.

Discussion

Materials and processing cost is seen as the most important of the listed attributes. This is no surprise, given the industry's recent push to reduce costs. However, it is important to note that the panel views each of the 12 attributes as at least somewhat important.

Manufacturer/supplier comparison

The manufacturers and suppliers are in general agreement, but, the manufacturers view perceived safety as more important (1.8) than do the suppliers (2.3).

Trend from previous Delphi surveys

This question was not asked in any previous Delphi survey.

Strategic considerations

The already-complex automotive material selection process is likely to increase in complexity. Our panelists rate each of the 12 criteria at least somewhat important, and this list is not all-inclusive. As vehicle systems evolve to meet customer, government and business requirements, more criteria will certainly be introduced into the equation. The current criteria, and their relative importance in the decision process, are fairly well understood. The challenge will be the development of systematic decision-making strategies that can rapidly respond to market forces and, new regulations and new criteria. Manufacturers with a systems-based process for the selection of materials that is communicated effectively to their suppliers will have a clear advantage in the next decade.

MAT-9 **Please rate the relative advantages and disadvantages of each material for body panels over the specified stages of the vehicle life cycle, where 1 = an extreme advantage, 3 = neither advantage nor disadvantage and 5 = an extreme disadvantage.**

Material	Raw Material Cost	Design	Component Processing	Assembly	Field Use	Disposal
Aluminum	4.2	3.1	3.2	3.0	3.1	2.0
Thermoplastics	3.0	2.0	2.6	3.0	2.5	3.1
Thermosets	3.1	2.2	2.9	2.9	2.5	4.2
Steel	1.5	2.6	2.2	2.1	2.7	1.8

Selected edited comments

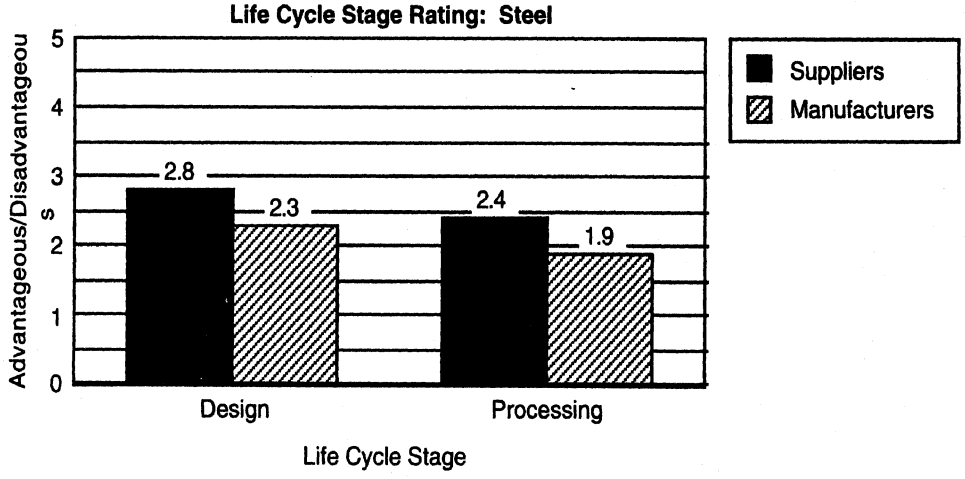
- Regarding exterior fascias and body panels, thermosets have an advantage for low-volume cars. Steel offers assembly advantages now because most plants are set up for steel stamping and processing.
- Thermoplastics have an advantage for high-volume cars. Thermosets could improve vehicle disposal based on advances in the use of regrind for non-critical, non-safety application.

Discussion

Steel is viewed as having a relative advantage over thermoset and thermoplastics in raw material cost, component processing, assembly and disposal. The panel also views steel as having a relative advantage over aluminum in raw material cost, component processing and assembly.

Manufacturer/supplier comparison

The manufacturer panel views steel more favorably than do the suppliers in design and processing. We suspect that this is due in part to the manufacturers' comfort level with steel. Decades of working with steel have led to a strong familiarity with the material. These results may also reflect the mix of the supplier panel. The supplier panel includes representatives from all materials categories, and thus potentially reflects the varied opinions and interests of the different materials producers. The two panels agree on the most advantageous material at each stage, suggesting that there is some concensus on the relative attributes of the materials in each stage.



Trend from previous Delphi surveys

This question was not asked in any previous Delphi survey.

Strategic considerations

As environmental factors increase in importance, manufacturers are becoming more concerned with the impact of a material throughout the vehicle's life. Design for the environment (DFE)—including design for disassembly (DFD), design for recycling (DFR), and life cycle assessment (LCA)—is gaining in acceptance throughout the industry. Although our question is limited to body panels, it raises many issues that are rapidly becoming important. Clearly, the panel views steel as the material of choice: it is favored in four of the six stages, including being perceived as the most advantageous material at the raw materials and processing cost stages. These are the two stages our panelists view as most important (see MAT-8). Yet

there is constant pressure to replace steel with lightweight materials. Obviously the industry must overcome the cost, manufacturability and disposal issues associated with lightweight materials.

Even with advances in lightweight materials, steel remains a viable choice for body panels. The steel and auto industries jointly have made significant strides in many critical technologies and design strategies that make steel more weight-efficient. Tailored blanking with the use of laser welding, for example, is rapidly becoming a realistic method to reduce weight while maintaining other attributes of steel.

It is helpful to contrast this question with the responses from MAT-15. In that question, the panelists forecast steel usage to decrease 9 percent by weight in the next decade. Aluminum sheet—the same material that was viewed as least advantageous in four of six life cycle stages—is forecast to increase in usage by 7 percent. This emphasizes the competitive nature and volatility of material selection decisions in the coming decade.

MAT-10 What materials issues will present the most significant challenges or opportunities to the North American automotive industry in the coming decade? Please consider all aspects of the business from concept design to manufacturing, use and disposal.

Issues	Percent of Responses
Material usage	33%
Cost	25
Recyclability	20
Manufacturing	11
Corrosion resistance	6
Environment/safety	5

Comments concerning:

Material usage

Aluminum will have limits in usage.

Lightweight materials will increase in usage.

Magnesium may replace aluminum in die cast applications.

Magnesium usage will be dependent upon stable price.

Mass reduction is a significant issue.

Reduction in the number of plastics used in a vehicle may be a trend.

Strength-to-weight ratio will be important.

Thermoplastics will see increased applications.

Cost

Cost is the number one driver.

Life cycle energy costs of material choices need to be evaluated.

Materials need to be cost effective.

Recycling and disposal costs will increasingly become important.

Recyclability

Design for disassembly/recycling is a major challenge.

Development of a recycling infrastructure is a big issue.

Selection of "green" materials over those perceived as non-green will increase in importance.

Use of materials that are directly recyclable into the same application will become increasingly critical.

Manufacturing

Flexibility, reliability, ease and formability of processes and materials will be critical.

Improvements in manufacturing of aluminum is an important issue.

The ability to convert manufacturing processes to handle new materials is an increasing challenge.

Corrosion resistance

We need to improve corrosion protection and resistance for engine, chassis and body applications.

Environment/safety

Balancing safety issues against environmental problems will grow in importance.

Environmental safety is a challenge.

Learning to handle hazardous materials better will become more critical.

Discussion

This question presents the increasing complexity of the automotive industry. The industry, already facing capital constraints, will face a wide array of challenges concerning lightweight materials in the coming decade.

To remain competitive, suppliers and manufacturers will likely need to become increasingly agile with their manufacturing processes. Companies that are able to quickly adapt their manufacturing systems and incorporate new technologies or materials will find themselves in a position of competitive advantage.

Manufacturer/supplier comparison

These comparisons are not made for open-ended questions.

Trend from previous Delphi surveys

This question was not asked in any previous Delphi survey .

Strategic considerations

The panel has identified several issues that offer significant challenges and opportunities for the industry. Cost, long a critical factor in materials selection, will continue to be a major concern for the automotive industry. As resources are further constrained, the pressure to be cost competitive will continue to drive material selection. The failure of a supplier to develop materials that are lightweight and environmentally sound, while maintaining cost competitiveness, could lead to a noncompetitive position.

Recyclability presents a vast unique array of challenges and opportunities, particularly with respect to plastics and resins. The resin industry must continue to develop products that are recyclable, yet meet the requirements of their customers. Perhaps even more daunting is the challenge of developing an economically viable recycling infrastructure. Resin suppliers, molders, component manufacturers, manufacturers and shredders must join with local and federal governments to determine actions that best meet the needs of the customer, industry and environment. Only through an organized effort to bring all stakeholders to the table can the future recycling infrastructure be effectively designed. The United States Council for Automotive Research (USCAR) Recycling Center is an early attempt to research the technology and issues of recycling.

Recyclability challenges are not limited to the plastics industry. Although ferrous metals are currently recycled, they are usually done so in a cascading manner. Nearly 100 percent of steel is recycled, yet only a small amount is reused in automobiles. Recent years have seen more recycled steel being incorporated into automotive structural components. However, it will probably be some time before recycled steel appears in any substantial quantities in components requiring grade-A surfaces.

Three lightweight materials warrant special mention. Plastics, aluminum and magnesium have been increasingly used to reduce vehicle weight. Each of these materials will likely continue to see increased application in the coming decade.

The automotive industry has stressed the importance of lightweight materials for several decades. The next decade may bring even more substantial gains. As aerospace industries look to new markets, they will likely focus on the automotive industry. The presence of these high-tech materials manufacturers may greatly increase competition within the automotive industry and may well lead to rapid advancements in materials applications. But it must be kept in mind that the economics of the two industries are different. By no means can one assume that aerospace materials will dominate automotive applications.

Manufacturers of high-tech materials face the challenge of processing them in a mass production system. The shift from limited production to full scale mass production may prove to be a critical barrier for many materials.

Current automotive industry participants will increasingly need to track information from an array of sources. The ability to locate and apply new materials technologies may become important in the next decade.

MAT-11 A number of automotive industry experts suggest that the issue of corrosion has been satisfactorily resolved. For the following systems, do you agree or disagree with that analysis, where 1 = strongly agree, 3 = neither agree nor disagree, and 5 = strongly disagree?

System	Mean Rating
Cosmetic Corrosion	
Body	2.6
Chassis	2.6
Powertrain	2.6
Perforation Corrosion	
Body	2.2
Chassis	2.3
Powertrain	2.3

If you disagree, please comment on the present status of the issues that remain to be resolved.

Cosmetic corrosion

- All you have to do is to look at 2- to 3-year-old cars (especially non-Toyota Japanese vehicles) on the road in the salt belt to see that the problem is still serious. As costs of cars and lengths of loans increase, the public will object more and more.
- Appearance corrosion is definitely not resolved. Just look at any vehicle in Michigan.
- Cars are still showing signs of rust in northern areas where road salts are used.
- Chassis and powertrain components still corrode relatively early. However, I am not sure how much protection is really necessary as it doesn't seem to affect functionality.
- Recent showings on Ford Taurus in the north where salt is used indicates continued weakness in current corrosion strategy.
- The cost benefit of cosmetic corrosion protection has not been resolved.
- The problem is much improved over last 10 years, but I still see too many new cars with corrosion which could be related to improper cleaning/preparation/painting.
- While body corrosion has been greatly reduced, we're far from "satisfactorily resolved." At today's vehicle costs and length of loan terms, vehicle bodies *must* be corrosion free for 10 years!

Perforation corrosion

- Performance failure due to corrosion is less of a problem.
- Significant improvement has occurred over the last five to eight years. However, room for additional improvement exists on body panels.

The issue has been addressed but not solved

- First, body durability has improved vastly over the last 20-30 years, but issues remain. Corrosion is first a design issue. Corrosion protection is a vehicle systems, processing and manufacturability issue and a cost issue. OEM corrosion warranties still have limitations for both cosmetic and perforation. Secondly, there is limited data to support the validity of any accelerated test that can adequately guarantee a 10-year body.
- Functional corrosion is largely under control (except where processing breaks down). Cosmetic corrosion is not and represents a customer concern, e.g., underhood, under vehicle.
- Road salt in use for snow and salt solutions for dust control still eat cars.
- The major problems have been addressed but there is still room for improvement.
- Utility vehicles and light trucks utilized in less than ideal driving locations (off road), expected to survive like cars, still require work underhood and underneath.

Other issues

- Chassis and even some powertrain components will be magnesium based in the near future. Although many of the impurity issues in magnesium alloys have been addressed, galvanic corrosion still is a problem and the fastener technology alternatives are often cost prohibitive.
- Conflicts between the need for improved cosmetics of underhood components and environmental concerns need to be addressed, i.e., chromate conversion coatings to provide long-term salt spray resistance still use hexavalent chrome, a hazardous material. Also, stainless steel does not need to be plated under normal conditions but performs poorly on lab salt/fog tests. Other corrosion resistant finishes such as electroless nickel also raise environmental issues.
- Corrosion protection is only as good as the applied coatings. Misapplication of coating or removal of coating in the field brings back the corrosion problem.
- Economically viable coating and processes have not been put in place.
- Except for plastic materials, steel is especially still vulnerable. Aluminum is vulnerable to a lesser extent, too, but limited to joining areas.
- I would "strongly agree" if what is known were used with greater discipline, but galvanizing and metal preparation are not yet as consistent as they could be.
- If this is to remain a major emphasis, then recyclability issues will have to gain in emphasis as cost becomes the driver.
- The lack of corrosion protection has given birth to the plastic body panel vehicles at a cost increase in tooling and piece cost.
- The technology is certainly available. The fact that it is not universally used is a business decision.

Discussion

Significant advance in corrosion resistance have been made in recent years. However, the panel still foresees the need to increase corrosion protection.

Manufacturer/supplier comparison

There is general agreement between the two panels, although the manufacturers (2.6, 3.1) may be less convinced than the suppliers (2.2, 2.5) that chassis corrosion, either perforation or cosmetic, has been resolved.

Trend from previous Delphi surveys

Although this question has been changed from previous Delphi forecasts, the comments of the current panel echo those of previous panels.

Strategic considerations

Corrosion protection is considered by customers to be a key factor in assessing the quality of an automobile. Great strides in corrosion protection have been made in recent years. Continued improvement could have a major effect on vehicle life expectancy. Purchasers of new cars currently keep their vehicles an average of 66 months, and the average age for passenger cars is at a post-World War II high. Although original purchasers may hold onto their vehicles longer as more buyers extend their car loans to 60 months, it is still likely to remain somewhat below the six-to-seven-year no-panel-perforation warranty offered by most manufacturers. The real beneficiary of better rust protection, may, in fact be the downstream owner.

Cosmetic corrosion still may be a concern for the initial purchaser, especially in areas where road salts are used extensively for snow and salt solutions are applied on dirt roads for dust control. Small dents and dings from road stones and parking lots are the most common root cause of cosmetic panel corrosion. These are difficult to prevent, and may require a more protective paint with a trade-off of extra cost and weight.

Chassis and some powertrain components suffer early cosmetic corrosion, but functional performance of these components is rarely affected.

The United States Council for Automotive Research (USCAR) Automotive Composites Consortium is currently researching the possibility of structural applications for composites. Successful application could greatly impact metals and change our view of corrosion since composites do not corrode.

Manufacturers and suppliers must improve their corrosion prevention systems. Corrosion protection can be viewed as a system including design, materials, coatings and manufacturing. Currently, manufacturers are proficient at each element. The challenge is to optimize the interaction between all elements, leading to the most cost effective systems.

MAT-12 Please estimate the number of years before panel penetration will develop in a severely corrosive environment, such as Detroit or Pittsburgh, for North American-produced passenger cars and light trucks produced in MYs 1993, 1998 and 2003.

Years to Panel Penetration	Median Response			Interquartile Range		
	1993 MY	1998 MY	2003 MY	1993 MY	1998 MY	2003 MY
	7 years	8 years	10 years	5/8 years	7/10 years	7/10 years

Selected edited comments

- 2003 MY - No panel penetration throughout life of vehicle.
- Detroit is about a 50 percent severely corrosive environment. If you're looking for 95 percent or 99 percent (Montreal or St. Johns), you get a new set of numbers.
- Domestic producers are all using similar materials for body components.
- This is model dependent. Corrosion resistance is nearly a linear function of the coating mass of substrate.
- What about dent and ding? Not measured by warranty and so no focus. Ask consumers how they like a quarter panel crater in their $25,000 car. They blame it on the guy next door -- should blame automaker.

Discussion

The panel forecasts the number of years before panel penetration to increase from seven currently to 10 by 2003.

Manufacturer/supplier comparison

The manufacturers are much more confident regarding short term efforts on panel penetration. They forecast that, by 1998, panels will be capable of lasting ten years before panel penetration occurs. Suppliers are less convinced. The suppliers forecast that it will be 2003 before protection is capable of lasting 10 years.

Trend from previous Delphi surveys

This question was not asked in any previous Delphi survey.

Strategic considerations

Manufacturers currently design and manufacture vehicles to meet a 10-year no-perforation goal. Because of this goal, vehicles generally meet the six- to seven-year no-perforation warranty offered by most manufacturers. Therefore until recently, there was little incentive to improve the current manufacturing standards.

However, one manufacturer has recently raised the stakes in corrosion protection. For the 1994 model year, Volkswagen has announced a ten-year warranty for panel perforation. This new standard must be closely watched. If the other industry participants are placed at a competitive disadvantage in the marketplace, they will certainly offer similar warranties, and will intensify corrosion protection efforts. Many suggest the technology is available to meet or exceed the current 10-year no-perforation goal, but cost concerns create a dilemma.

MAT-13 What percentage change in total vehicle weight for North American-produced passenger cars and light trucks do you anticipate by 1998 and 2003? Please indicate plus or minus.

Total Vehicle Weight	Median Response		Interquartile Range	
	1998	2003	1998	2003
Passenger cars	-3%	-8%	-5/3%	-11/9%
Light trucks	-5	-7	-6/3	-10/10

Selected edited comments

- Engine (powertrain) technology has been milked for all it has to give. Vehicles have got to become more weight efficient.
- I expect this to occur through increased use of lighter materials.
- In general, weight will go down to meet CAFE and emission regulations.
- The current focus is on cost more than weight. Weight reduction won't get serious until the mid-'90s.
- The increased use of aluminum alloys and magnesium alloys will contribute to weight reduction. Wear resistant truck bed material must be developed in order to significantly reduce weight on trucks.

Discussion

The panel forecasts the average weight of passenger cars and light trucks to decrease by 8 and 7 percent, respectively. However, the interquartile ranges for both types of vehicles include forecasts for increased weight. This increase, in part, reflects the recent trend in which the average weight of the North American passenger car has been increasing.

Manufacturer/supplier comparison

The forecast by manufacturers and suppliers are similar. The only difference is that manufacturers forecast weight reduction to be more aggressive in the long term for passenger cars.

Comparison of forecast: TECH-48

Materials and technology panelists are in general agreement on this question.

Trend from previous Delphi surveys

This question was not asked in any previous Delphi survey.

Strategic considerations

There are at least two notable points to be drawn from the responses to this question. The first may best be represented by the comment, "The current focus is on cost more then weight. Weight reduction won't get serious until the mid-'90s." Second, the panel forecasts a weight reduction in the short and long term, yet each of the interquartile ranges also includes forecasts of weight increases. We believe the broad range suggests interesting insights into the current state and future trend of the automotive industry.

Assuming tougher CAFE standards, there will be a continued pressure to increase the use of lightweight materials in the short term. Yet demand for these materials often are subordinate to cost constraints and capital investment constraints (if they require new manufacturing processes). We agree with the Delphi panel that cost will remain a driver. Weight reduction, spurred on by CAFE and emissions regulations, will continue to increase in importance. Companies that develop optimized, cost-effective material systems will be positioned for success.

Over the past few years, even with the increasing use of lightweight materials, the average weight of North American passenger cars has increased slightly. Several factors have contributed to this increase, including slight upsizing with model redesign, and increased application of safety and other features.

Improvements in powertrain efficiency in most cases have more than offset weight gains. However, in terms of fuel economy, it is likely (barring significant breakthrough) that powertrain efficiency improvement will slow. Mass reduction is viewed as the most important factor in meeting future CAFE standards (TECH-3). One form of mass reduction—downsizing—appears to be unpopular with consumers. There are means to achieve improved efficiency ranging from aerodynamics to accessory drive, but generally the lowest cost ideas have already been used. A true systems approach considering all factors is necessary if we are to achieve improved fuel economy at a minimum cost. The cost issue is particularly of concern today because of vehicle affordability.

MAT-14 The value of weight savings varies based on platform team objectives for EPA weight class and fleet CAFE performance. Considering these two objectives, what is the current dollar value per pound of weight saved? What will it be in calendar years 1998 and 2003? Please do not adjust for inflation.

Weight Reduction Objective	Median Response			Interquartile Range		
	Current Value	1998	2003	Current Value	1998	2003
Meet CAFE requirements	$1.00	$1.75	$2.50	$.80/1.00	$1.50/2.00	$2.00/3.00
Meet specific EPA weight class	1.00	2.00	3.00	1.00/1.25	1.50/2.50	2.00/4.00

Selected edited comments

- A category should be added to assess value in "reducing a weight class."
- Five pounds over a weight class is worth $10. Five pounds under is worth nothing.
- If a car is losing money and you bring in a cost savings, weight gain (less than 10 percent) isn't discussed.
- It depends on vehicle class.
- It greatly depends on individual vehicle circumstances. For example, an electric-powered vehicle might value weight savings at $20 per pound.
- It's hard to put a value on this. The Big Three give credit for weight saving. But that doesn't force a re-engineering of the design process. There are still Japanese business techniques that haven't been incorporated into basic approach to design. There are too many people, and too many committees. There's no apparent systems approach. I believe that there are breakthroughs coming that will drive basic structure weight down while maintaining size and integrity.
- Reactive weight reduction late in the program, instead of lightweight vehicle systems from Day One, is the current method of operation.
- The value per pound of weight savings to meet specific EPA weight class will vary according to how close the vehicle is to the weight class boundary.
- The weight class value depends on the conditions. One can only give a range.
- This is difficult to answer because of the various vehicles and systems in these vehicles.
- This will impact the light truck market, too, not just passenger cars.
- Weight is segment dependent. Luxury cars have higher profit and higher image, and will pay more dollars per pound to be able to increase content or to not have to restrict options.

Discussion

The selected edited comments reflect the difficulty in assessing the dollar value of a pound saved. However, we feel the responses present an interesting insight into the increasing value of weight savings. The two objectives, meet CAFE requirements and meet specific EPA weight class are closely related, and may have caused some confusion among panelists. However, the estimates for the two objectives are significantly different, and suggests that the decision process for the two objectives may involve some unique criteria.

Manufacturer/supplier comparison

The panels agree on the current value of a pound saved, though their short- and long-term forecasts differ. The suppliers put a higher premium ($3.00) over the next decade on the value of a pound saved than do the manufacturers ($2.50).

Comparison of forecast: TECH-49

In the technology survey, the panelists are not asked to differentiate between EPA weight class and CAFE requirements. However, the technology panelists were asked to forecast values for differing CAFE scenarios. The technology panelists place a significantly higher current value on a pound of weight savings compared to the materials panelists. Results on the technology survey are summarized below.

Value of a Pound of Weight Savings Technology Panel Forecast			
1993 27.5 mpg	1998 27.5 mpg	2003 30 mpg	2003 35 mpg
$2.00	$2.00	$3.00	$4.00

Trend from previous Delphi surveys

The one key difference between the 1994 Delphi VII panel and its most recent predecessor is the comparison of current value of a pound saved. The current panel estimates the 1993 value of a pound saved to be 50 percent lower than the 1992 Delphi VI estimate for 1991. This itself suggests that, even with the attention being given to the use of lightweight materials, the North American automotive industry is focused almost entirely on cost. Recent highly publicized activities involving manufacturer purchasing strategies highlight the emphasis placed on cost. Manufacturers, in a battle to remain cost competitive, have placed cost cutting ahead of all other issues.

Weight Reduction Objective	Current Value	1995	1998	2000	2003
1992 Delphi VI	$2.00	$2.50	—	$3.00	—
1994 Delphi VII (EPA Class)	1.00	—	2.00	—	3.00

Strategic considerations

The value of a pound saved, according to our panel, will increase over the next decade. Although there is not the same immediate emphasis on weight savings as found in the 1992 Delphi VI study, the 1994 Delphi VII panel does forecast a significant increase. This is important to lightweight materials that are currently viewed as excessively expensive. As CAFE and EPA standards increase, the industry will face increasingly pressure to incorporate lightweight materials in a variety of applications. We believe there will be significant opportunity for those who pursue the development of lightweight materials and their related manufacturing processes. We also suspect that cost pressures will continue to drive the industry for the foreseeable future because of consumer demands for high value affordable vehicles. Any attempt to incorporate lightweight materials will face tough cost concerns and must be sold on the basis of good systems analyses.

MAT-15 **Please forecast the material content change in percentage for the typical North American-produced passenger car and light truck for MYs 1998 and 2003, given the indicated CAFE scenarios. It is not necessary to enter a response for every material–just those you are familiar with. Please indicate plus or minus.**

Materials	Est. Current Weight*	Passenger Cars					
		Median Response			Interquartile Range		
		1998	1998	2003	1998	1998	2003
	27.5 mpg	27.5 mpg	30 mpg	35 mpg	27.5 mpg	30 mpg	35 mpg
STEEL							
Low carbon steel	1379 lbs.	-3%	-5%	-10%	-5/-2%	-10/-5%	-15/-7%
HSLA steel	247	2	4	5	0/10	2/10	3/15
Stainless steel	42	0	0	0	0/1	0/1	0/1
Other steels	42	0	1	1.5	0/5	0/5	0/7
TOTAL	1709	-1	-5	-9	-4/0	-10/-2	-20/4
CAST IRON	430	-5	-10	-15	-10/-2	-18/-4	-30/-5
ALUMINUM							
Cast	n/a	5	10	15	2/10	4/25	5/30
Forgings	n/a	3	3	5	1/5	1/10	3/10
Sheets	n/a	1	4	7	0/5	1/12	4/20
TOTAL	174	10	15	20	2/13	6/50	7/50
PLASTICS							
Thermosets	n/a	5	5	10	1/5	2/10	5/15
Thermoplastics	n/a	5	10	10	3/10	4/15	5/20
TOTAL	243	5	10	15	2/10	4/15	6/50
COPPER (including electrical)	45	0	0	0	-1/0	-5/0	-5/0
ZINC							
Zinc coatings	17	0	0	0	0/3	0/5	0/5
Zinc parts	20	0	-2	-5	-5/.7	-8/0	-20/0
TOTAL	37	0	-4	-4	-2/1.7	-5/2	-10/2
MAGNESIUM	7	5	8	15	3/20	5/30	10/70
GLASS	88	0	0	0	-1/5	-4/5	-5/5
CERAMICS	2	2	3	5	.5/10	1/20	3/50
POWDERED METALS	25	4	4	10	0/5	2/15	2/20
RUBBER							
Tires (include spare)	94	0	0	0	0/0	-2/0	-10/0
All other rubber	39	0	0	0	0/0	-4/0	-5/0

***Source:** *Ward's Automotive Yearbook,* 1992 and various OSAT estimates.
n/a–not available.

Materials	Light Trucks				
	Est. Current Weight	Median Response		Interquartile Range	
		1998	2003	1998	2003
	20.2 mpg	20.6 mpg	24 mpg	20.6 mpg	24 mpg
STEEL					
Low carbon steel	n/a	-2%	-7%	-5/0%	-10/-2%
HSLA steel	n/a	3	4	0/7	2/15
Stainless steel	n/a	0	0	0/1	0/2
Other steels	n/a	1	1	0/5	0/6
TOTAL	n/a	-5	-10	-5/0	-15/-2
CAST IRON	n/a	-3	-7	-10/0	-20/-3
ALUMINUM					
Cast	n/a	3	5	2/7	5/15
Forgings	n/a	2	3	0/3	1/5
Sheets	n/a	2	5	0/10	4/20
TOTAL	n/a	5	17	3/10	8/40
PLASTICS					
Thermosets	n/a	5	5	2/10	5/20
Thermoplastics	n/a	5	8	3/10	5/15
TOTAL	n/a	5	15	2/15	6/20
COPPER (including electrical)	n/a	0	0	-2/0	-5/0
ZINC					
Zinc coatings	n/a	.6	.6	0/5	0/5
Zinc parts	n/a	0	0	-5/.7	-10/.7
TOTAL	n/a	1.7	1.7	-5/2	-5/2
MAGNESIUM	n/a	3	10	0/10	3/40
GLASS	n/a	0	0	-1/0	-5/3
CERAMICS	n/a	1	4	0/5	3/30
POWDERED METALS	n/a	1	5	0/5	3/10
RUBBER					
Tires (include spare)	n/a	0	0	0/1	-5/1
All other rubber	n/a	0	0	-2/0	-5/1

n/a = not available

No comments

Discussion

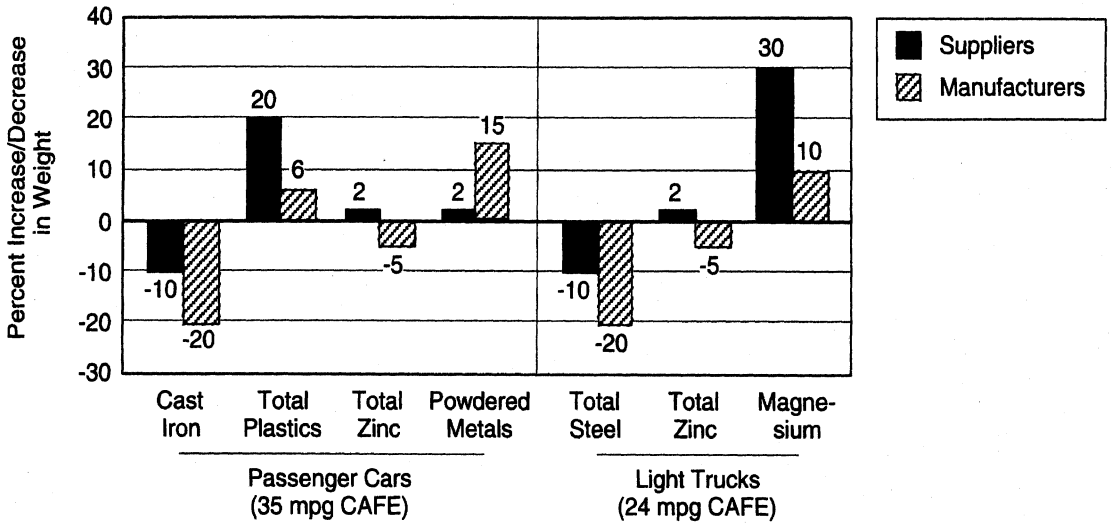
If CAFE standards are increased to 35 mpg for passenger cars during the coming decade, steel and cast iron content are expected to decrease 9-15 percent. At the same time, lightweight materials such as aluminum, magnesium and plastic may increase 15-20 percent. The trend is similar although less pronounced for light trucks. If CAFE requirements for trucks are increased to 24 mpg by 2003, steel and cast iron content are forecast to decrease 7-10 percent and the lightweight materials content may increase 10-17 percent.

Manufacturer/supplier comparison

The manufacturers and suppliers are in general agreement on the materials listed. Where they disagree, the manufacturers tend to be more likely to forecast smaller increases and larger decreases than do the suppliers. This may indicate a greater emphasis on weight reduction by the manufacturers.

The differences forecast for plastics usage in passenger cars reinforce a trend that has been apparent in many questions in the 1994 Delphi VII Materials survey. The supplier panel is more positive about the future of plastics application than is the manufacturer panel. Although this may be in part due to a larger representation of plastics interests on the supplier panel, we feel it also may represent the manufacturers' concern with recyclability issues associated with plastics.

Material Content Change for the Typical North American-Produced Passenger Car and Light Truck – 2003 Forecast



Trend from previous Delphi surveys

Panelists were asked to forecast the increase/decrease in weight as a percentage as opposed to pounds, as in previous Delphi studies. Because of this difference, direct comparisons are not possible.

Strategic considerations

The forecast indicates that in 2003, passenger cars will weigh approximately 5 percent less than in 1992, based on changes in the mass of individual material families. This mass reduction is reasonably significant with the assumed 35 mpg CAFE requirements. This indicates that weight reduction will play a modest role in achieving higher CAFE standards. Emphasis may also be placed on other factors such as powertrain efficiency, aerodynamics and model mix to achieve greater fuel economy.

The panel's responses to this question reinforces the fact that cost and customer demands will continue to influence material selection. Any shift to lightweight materials will likely be accompanied by higher costs depending, of course, on future developments. A substantial portion of the increased cost of the lightweight, high-tech materials will be passed through to the customer. Downsizing is an alternative method of decreasing mass. However consumers have been strongly opposed to this option.

In order to meet the increasing CAFE requirements, manufacturers may attempt to increase incentives for consumers to demand smaller vehicles. Generally, the expected move to lightweight materials including plastics, aluminum, powdered metals and magnesium is significant with commensurate reduction in steel and cast iron. While material substitution is certainly a factor, mass reduction is also available through improved design efficiency (i.e., more efficient steel structures) and consideration of higher strength variations of the same basic material.

These data strongly suggest that the fierce materials competition will continue through the foreseeable future and must be followed closely. A key point in the competition is that traditional materials are hardly stationary targets for their competitors.

MAT-16 Assuming the same market size, 10.8 million unit domestic production, as in the base year, 1992, please consider the following list of plastic materials, and forecast the percent change in plastic usage for model years 1998 and 2003. Please indicate plus or minus.

Material	1992* millions of pounds	Percent Change: Median Response 1998	Percent Change: Median Response 2003	Percent Change: Interquartile Range 1998	Percent Change: Interquartile Range 2003
Polyurethane	426 lbs.	2%	2%	-4/8	-5/8
Polypropylene	401	8	12	2/18	2/20
Polypropylene EPDM	118	3	3	0/6	0/10
ABS	254	0	0	-1/5	-3/5
PVC	226	0	-4	-10/1	-15/2
Polyethylene	200	5	8	0/9	2/15
Nylon	183	5	5	1/8	1/10
SMC (Polyester-thermoset & vinyl ester)	175	2	3	0/8	0/9
Polycarbonate	89	2	2	0/5	0/5
Polyester - thermoplastic	78	3	2	0/4	0/6
Alloy PPO-styrene	65	0	0	-1/3	-1/3
SMA	58	0	0	-5/1	-10/0
Acrylic	40	0	0	0/1	0/2
Alloy PC - PBT	40	0	0	0/2	0/3
Phenolic	36	0	0	-1/0	0/0
Acetal	21	0	0	0/1	0/1
Alloy ABS PC	19	1	2	0/5	0/2
Polyurea	17	0	-1	-10/0	-20/0
Other	67	1	1	0/5	0/8
Total	2,513				

* **Source:** Best Market Research estimates.

No comments

Discussion

The panel forecasts substantial growth for polypropylene and polyethylene. The ease which these materials are recycled will likely give them an advantage in the coming decade. It must be noted that the respondents were not specifically instructed to use 1992 as a base year so some may have compounded their estimates.

Manufacturer/supplier comparison

The manufacturers and suppliers are in general agreement.

Trend from previous Delphi surveys

This question was not asked in any previous Delphi survey.

Strategic considerations

The panel forecasts a modest increase in plastics usage during the coming decade. This projected growth is smaller than the actual growth of recent years and is at least partly due to recycling concerns associated with plastics. Polypropylene and polyethylene usage is forecast to increase substantially, while ABS and PVC usage is expected to decrease or, at best, remain constant. It is likely that polypropylene will be used to replace ABS in interior and bumper applications. Gains for polyethylene will likely come from the increased use of plastic fuel tanks.

The coming decade will be filled with challenges for the resin industry. Although plastics applications within the automotive industry may not have reached their peak, environmental pressures may force automotive designers to look elsewhere for lightweight materials. The era of rapid expansion for plastics applications may be ending at least in terms of the variety of plastics. Many manufacturers have developed intensive programs aimed at producing lightweight alternatives to plastics. The resin suppliers may face a future of intense competition on specific applications to reduce weight or cost, rather than on developing widespread new applications.

Recyclability of plastics will continue to be a concern for the next decade. The uncertainty surrounding future recycling regulations may cause designers to question the use of plastics, but one should not underestimate the ability of the plastics and automobile industries to resolve the recycling challenge.

Plastics have become such a basic material that there will be great difficulty in finding materials to satisfactorily replace plastics. In fact, even with the specter of recycling, there is significant activity in potential new applications for plastics. Although large scale implementation may be many years away, the next major step for plastics is likely to be widespread use in structural applications. There is a great deal of uncertainty about plastics in such applications.

MAT-17 What North American-produced passenger car and light truck components will utilize magnesium alloys in the next decade?

Components	Percent of responses
Housings	10%
IP components (structure carriers, retainers, etc.)	10
Brackets	9
Seat frames	9
Wheels	8
Covers (valve and transmission side)	8
Steering wheel	5
Steering wheel components	5
Support braces/beams	5
Transmission cases	5
Oil pan	2
Body	
Airbag canister, door frame, trim, door hardware	1% each
Engine/powertrain	
Oil filter adapter, intake manifold	1% each
Transmission	
Electric car transaxle	1%
Chassis	
Brakes, pedals	1% each

Discussion

The panel forecasts a varied applications for magnesium. Applications receiving several responses include housings, instrument panel components brackets and seat frames. The percentages do not represent penetration rates.

Manufacturer/supplier comparison

These comparisons are not made for open-ended questions.

Trend from previous Delphi surveys

This question was substantially changed for the current survey. However, comparison with responses of previous panels present significant insights. The 1994 Delphi VII panel has forecast several applications that its predecessors did not. Responses from the 1993 Delphi VI panel concentrated on engine applications, while the current forecast includes several applications in other vehicle systems.

Strategic considerations

Magnesium presents many enticing properties for automotive materials engineers, particularly its light weight. Increased CAFE regulations make lightweight, although higher-cost, materials such as magnesium a strong candidate for many applications.

The potential list of applications for magnesium is impressive. Although current applications are rather limited, each model year brings a substantial increase in the number of applications. Many of the applications mentioned, especially in the interior, are likely candidates for magnesium. But hurdles remain. Current high cost and availability concerns must be resolved before the industry can become comfortable with the material, or until CAFE or gas taxes shift cost-benefit the manufacturer's way. Also, early results from some magnesium engine applications have shown a potential for galvanic corrosion, a factor that increases uncertainty about the material from an engineering standpoint.

We believe lightweight, higher-cost materials such as magnesium will see substantial gains due to materials "hedging." As more high-cost, price-volatile materials become available, manufacturers may feel it necessary to reach a state of materials equilibrium. The manufacturers may, in an attempt to avoid relying on the price fluctuations of a specific material, be willing to make material substitutions based on an overall balance within a system or vehicle. Magnesium may be one of many materials that are used as a hedge against over-reliance on other materials.

MAT-18 Please indicate significant new material applications/technologies that are likely to emerge within the next decade for each of the following vehicle systems.

Vehicle System	Percent of responses
Engines	**22%**
Ceramic components	5%
MMC components	5
Aluminum block	
Without sleeves (base metal)	3
Alternatives to cast iron sleeves; ceramic; MMC	1% each
Aluminum valve lifters; nonferrous valve seals; nonferrous valves; polymer castings on pistons; titanium connecting rods; titanium valves	1% each
Transmission/Final Drive	**12%**
MMC	1
Drive shaft	3
Housing	1
Aluminum axle housing; aluminum differential cases; aluminum driveshafts; ceramic; Dextron III automatic transmission fluid; modified polyolefin to replace PVC and EPDM and some filled PP; thermoplastics seals and gaskets	1% each
Body–Exterior	**13%**
Complete composite bumper system	3%
Tailored welded blanks	2
Composite X car beams; direct paint TPO (no paint adhesion coating); extruded aluminum space frame; fast cure adhesives; hydroforming; new coating technologies to replace paint; new Corrosion resistant coatings; precoated (five-finish) body panels	1% each
Body–Interior	**10%**
Polyester foam replaces polyurethane foam	2%
Composite IP carriers; composite seat frame; instant stick adhesives; magnesium IP applications; magnesium substrates; MMC; new thermoplastic processing techniques (gas or co-injection); olefin plastic replaces PVC, urethane and ABS parts	1% each

Chassis	Percent of responses
Brakes	**11%**
MMC–aluminum	1%
Rotors	4
Drums	2
Calipers	2
Discs	1
Phenolic brake pads	1
Wheels	**13%**
Magnesium	7%
Plastic	3
High-strength steel	2
Adhesive bonded halves	1
Suspension	**14%**
Aluminum	5%
Control arms	2
Knuckles	2
Steering arms	1
Carbon fiber-reinforced plastic parts; plastic control arms; magnesium; semisolid aluminum forging process	1% each
Metal Matrix Composites (MMC)	**5%**
Exhaust	
Ceramics	2%
Aluminum; coated stainless steel; thermoset plastic	1% each

No comments

Discussion

The majority of the responses involve the application of lightweight materials. This suggests significant opportunity for suppliers, especially those that currently have expertise in lightweight materials or who can develop it quickly.

Manufacturer/supplier comparison

This analysis is not performed for open-ended questions.

Trend from previous Delphi surveys

Several changes in this question prevent direct comparison to previous Delphi forecasts. However, there are a number of general comparisons that can be mentioned.

The 1994 Delphi VII responses are coded to give a much more specific application response. This provides insight into the vast array of potential future applications for lightweight materials and new technologies. Aluminum and composites are forecast to make advances in all vehicle systems, while other lightweight materials will likely gain success in specific applications. Magnesium is not mentioned as frequently by the 1994 Delphi VII panel as by the 1992 Delphi VI Panel. The 1992 panelists forecast substantial increases in magnesium applications, while the 1994 panelists rarely mention the material. We believe this is largely due to the persistent concerns about the availability and price stability of magnesium.

Engine: As with previous Delphi studies, lightweight materials receive several comments from our panel. Metal matrix composites (MMC) and ceramics will likely be used in a wide variety of engine applications. Interestingly, the panelists do not mentioned magnesium in their responses even though there are several current magnesium engine applications. Magnesium is a material that may see increased usage and should not be overlooked. However, there are significant concerns regarding galvanic corrosion of magnesium in engine applications. While the 1992 Delphi VI panel was much more positive about magnesium uses in engine applications, the 1994 Delphi VII panel lists many potential applications for MMC.

Transmission/Final Drive: The current panelists agree with the 1992 Delphi VI panelists on the positive future of aluminum in transmission applications. Both panels forecast continued increased usage of aluminum in transmission applications. Most noticeable in comparison with previous panels is the increased application of MMC forecast by the 1994 Delphi VII panel.

Body—exterior: A significant advance in two areas of steel forming will likely increase the competition for body panels. Hydro-forming and tailored welded blanks are relatively new methods that make steel more competitive. These emerging technologies allow steel to compete better with other materials by reducing weight while maintaining the other attributes of steel.

Body—interior: Both panels present substantial changes in interior materials choices. The 1994 Delphi VII panel does forecast increased use of composites, a material type that was not mentioned by the previous panel.

Chassis: As in previous Delphi surveys, aluminum is forecast to increase significantly in chassis applications. Increasing application of MMC in suspension components is forecast by the 1994 Delphi VII panel.

Strategic considerations

The variety and breadth of the panel's response is significant. There is substantial materials and technology activity in all vehicle systems. The emphasis remains on cost-effective application of lightweight materials. Materials selection, already complicated, will continue to grow in complexity. As the drive to reduce weight increases, materials previously viewed as too expensive may become viable if system level value is present.

Manufacturers are increasingly relying on a systems-oriented approach in the development of vehicles. Whether it is the entire automobile or a subsystem of the vehicle, the materials engineer's goal is to optimize at the system level. Only materials fitting this objective will be viable candidates for future programs. To facilitate technology transfer, advances in one area must be communicated to everyone associated with the vehicle program. The only way a material will gain the confidence of engineers and designers is through increased knowledge and experience. Therefore, high-tech materials are slow to propagate into vehicle programs.

One of the greatest benefits from the increased cooperation between the industry and government agencies, such as the Department of Energy National Laboratories, may well be in materials. The industry could see increased focus on exotic materials with potential for significant gains in performance. It is becoming increasingly critical for companies to leverage all available resources. Research efforts involving the DOE National Laboratories, universities and other technical centers must be closely monitored. Today, it is prudent for both manufacturers and suppliers to maintain close connections with centers of material/processing expertise.

Developments must be watched closely. With the increased emphasis on new materials, the likelihood of technological and manufacturing breakthroughs is strong. Significant advances in materials technology and processing could drastically alter future vehicles. Companies that are best able to find, understand and apply these technologies will have a competitive advantage.

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MAT-19 What vehicle manufacturers recommended oil-change interval do you expect for the typical North American-produced passenger car and light truck in MYs 1993, 1998 and 2003?

Oil Change Interval (in miles)						
	Median Response			Interquartile Range		
Vehicle type	1993	1998	2003	1993	1998	2003
Passenger cars	6,000	7,500	7,500	3,000/7,500	4,000/8,000	5,000/10,000
Light trucks	4,000	5,000	7,000	3,000/6,000	3,000/7,000	5,000/8,000

Selected edited comment

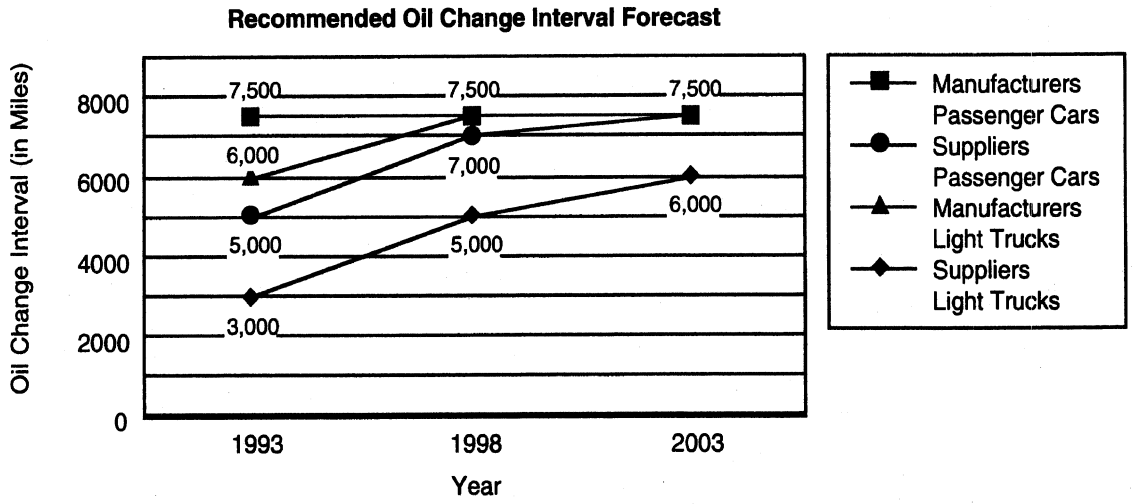
- The future will see the use of an oil life monitor based on coolant temperature, rpm, number of cold starts and type of driving sensed by computer. The expectation is to get the oil change intervals longer, i.e., 6,000 miles for an average customer.

Discussion

The forecast is for a substantial increase in the manufacturers recommended oil change interval for light trucks. However, the panel forecasts only a small increase for passenger cars.

Manufacturer/supplier comparison

The panels differ in five of the six comparisons. The only forecast they agree on is the interval for passenger cars in 2003.



Trend from previous Delphi surveys

There is no substantial change from the 1992 Delphi VI survey.

Strategic considerations

Panelists forecast only a slight increase in oil change intervals for passenger cars, but a 3,000-mile increase for light trucks by 2003. The wide interquartile ranges suggest there is significant uncertainty among the panelists. Part of the confusion may be attributed to the differing levels of manufacturers recommended intervals depending on the type of driving.

Advances made in synthetic oils will likely influence the oil change interval in the next decade. These substitutes may increase the interval substantially, and need to be watched closely.

One of the factors that could have a profound impact on oil life is the development of a sensor able to measure oil degradation. We could then see oil changes on the basis of need rather than schedule. Furthermore, continuing improvements are being made in oil formulations, including additives as well as engine design and precision, all of which could affect oil life. More of a systems approach is being used by the auto and energy industries which is certainly good news for consumers, but perhaps not for those benefiting from frequent oil changes.

MAT-20 **For the following North American-produced passenger car and light truck engine components, please indicate what percentage is likely to be made from the listed materials currently and by 1998 and 2003. Please total each component to 100%. Leave blank any materials with which you are not familiar.**

Component Material	Median Response			Interquartile Range		
	Current Est.	1998	2003	Current Est.	1998	2003
Air Cleaner Housing						
Aluminum	5%	10%	15%	5/10%	8/15%	10/20%
Steel	70	50	30	65/75	48/60	25/35
Plastic	20	35	50	15/30	25/40	50/60
Total	95%	95%	95%			
Camshaft						
Cast iron	80%	70%	60%	79/85%	70/75%	55/65%
Composites (e.g., steel/ powdered metal combination)	2	10	15	2/5	5/15	10/25
Steel	15	20	20	15	20	20
Total	97%	100%	95%			
Crankshaft						
Cast iron	90%	80%	80%	90/90%	80/88%	80/85%
Steel	10	20	20	10/10	12/20	15/20
Total	100%	100%	100%			
Connecting Rod						
Aluminum	0%	0%	0%	0/0%	0/2%	0/5%
Cast iron	20	20	20	15/45	15/35	10/35
Metal matrix composites (MMC)	0	0	5	0/0	0/5	0/8
Powdered metals	5	10	15	0/5	5/15	10/25
Steel	60	50	47	50/77	45/65	35/55
Total	85%	80%	87%			
Exhaust Manifold						
Cast iron	90%	80%	70%	90/90%	80/85%	70/80%
Stainless steel	10	20	25	10/10	15/20	20/30
Other	0	0	0	0/0	0/0	0/5
Total	100%	100%	95%			
Front Cover						
Aluminum	60%	60%	70%	30/90%	50/85%	60/80%
Cast iron	30	20	10	10/50	5/40	0/25
Plastic	0	5	15	0/5	5/10	10/20
Total	90%	85%	95%			

Component Material	Median Response			Interquartile Range		
	Current Est.	1998	2003	Current Est.	1998	2003
Intake Manifold						
Aluminum	60%	65%	50%	60/75%	55/75%	50/70%
Cast iron	30	20	10	20/30	10/25	5/15
Plastic	6	20	30	5/10	10/20	20/40
Total	96%	105%	90%			
Oil Pan						
Plastic	2%	5%	15%	1/5%	5/10%	10/25%
Steel	97	92	80	95/98	90/95	75/90
Total	99%	97%	95%			
Piston						
Aluminum cast	98%	90%	75%	92/100%	80/92%	70/80%
Aluminum reinforced	0.5	10	15	0/5	5/10	5/20
Hybrid (e.g., plastic skirt/ ceramic crown)	0	0	0	0/0	0/2	0/5
Magnesium	0	0	0	0/0	0/0	0/0
Metal Matrix Composite (MMC)	0	3	10	0/0	0/5	5/10
Total	99%	103%	100%			
Rocker Arm Cover						
Aluminum	15%	15%	20%	10/20%	15/20%	15/20%
Magnesium	2	5	5	0/5	3/7	5/10
Plastic	10	20	30	5/10	15/20	15/40
Steel	72	55	40	70/79	50/65	35/50
Total	99%	95%	95%			
Valves						
Steel	100%	98%	95%	100/100%	95/100%	90/98%
Other	0	2	5	0/0	0/5	0/10
Total	100%	100%	100%			

Selected edited comments

- Other underhood applications for plastics include fuel system components such as fuel rails and integrated air-fuel systems.
- Valve material in 2003 will be 10 percent aluminides and 2 percent ceramics.

Discussion

The panelists forecast increased use of lightweight materials for engine components, specifically plastics and aluminum, in the coming decade. During the same period, magnesium, powdered metal and metal matrix composites will be used in limited quantities.

Manufacturer/supplier comparison

The manufacturers and suppliers are substantially in agreement.

Comparison of forecast: TECH-85

Materials and technology panelists are in general agreement.

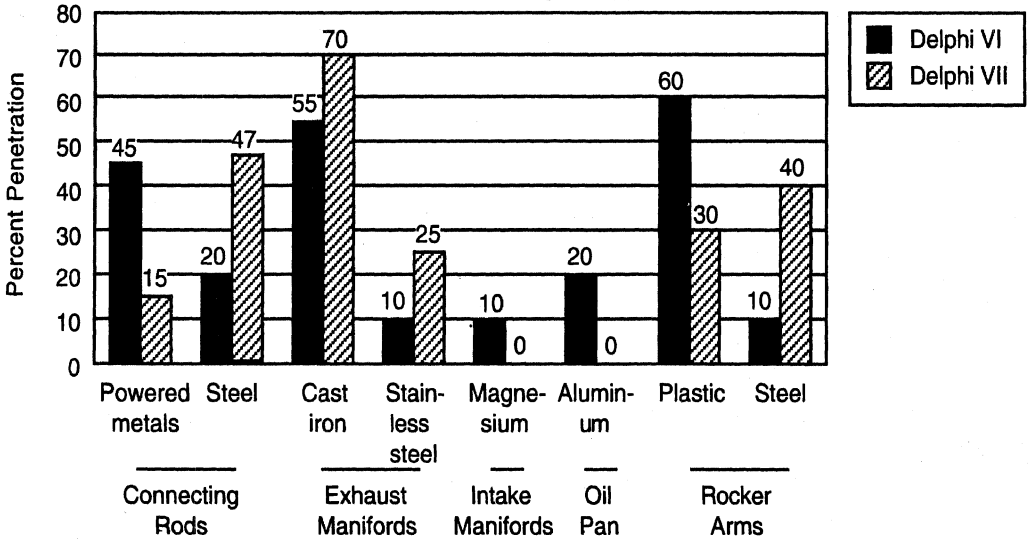
Trend from previous Delphi surveys

There are few differences between the 1994 Delphi VII panel and previous Delphi panels, although some are substantial. The current Delphi panel is more likely than previous panels to forecast lower

penetration rates for some lightweight, high-tech materials. This conservatism may be due to recent cost constraints within the industry. Also, the panel may be finding that the manufacturing and cost realities of these lightweight materials have made them less useful than they initially appeared.

The current panel differed somewhat from the 1992 Delphi VI panel on the material penetration rates for connecting rods, exhaust manifolds, intake manifolds, oil pans and rocker arms. Many of these differences represent decreases in penetration rates for lightweight materials.

Materials Penetration Rates for Engine Applications*



* Delphi VI study 1992; Forecast year 2000
Delphi VII study 1994; Forecast year 2003

Strategic considerations

The panelists forecast a continued trend toward lightweight materials in engine components over the next decade. In many applications, aluminum and plastic are the choice to reduce engine component weight. Of course, in some components, steel is increasing its penetration (e.g., camshafts, crankshafts and exhaust manifolds) which are lighter weight than traditional materials. Weight is a particular problem for internal moving components.

ALUMINUM: The use of aluminum is expected to increase steadily in selected applications. Where aluminum is currently used, the panel forecasts penetration rates of an additional 5-10 percent. The one exception is in pistons, where metal matrix materials (aluminum-based) are expected to increase while the traditional cast aluminum use is forecast to decrease.

PLASTICS: Plastics penetration rates are forecast to increase by an additional 13-30 percent for generally external components that currently use plastic. Substantial penetration is expected in air cleaners, rocker arm covers, oil pans and inlet manifolds. The panel forecasts plastic applications in front covers with a penetration level of 15 percent by 2003. Plastics offer many advantages, such as smooth complex surfaces for inlet manifolds, yet concerns over recyclability are important.

CAST IRON: A continued decline in usage over the next decade is forecast for cast iron. This material, a traditional engine component mainstay, will probably be increasingly noncompetitive because of weight and performance. Declines of 10-20 percent from current levels are forecast by 2003. Connecting rods present the only application where cast iron is not forecast to decrease in usage, and in that case, the forecast is for no change. Cast iron is inexpensive and easily recyclable, yet presents a substantial weight penalty, and this will likely continue to decline in usage rates.

STEEL: Steel, like cast iron, is forecast to steadily decrease in some engine component applications while expanding in others. The panel expects steel penetration rates to decrease by 5-40 percent in components that currently use the material. However, the panel does forecast increased penetration rates for steel in camshafts and crankshafts. These applications put a high premium on strength and strength-to-weight ratio.

STAINLESS STEEL: The panel forecasts stainless steel exhaust manifolds to increase from the current 10 percent penetration to 25 percent by 2003. Stainless steel exhaust manifolds provide significant weight reduction, but at a significant cost premium compared to cast iron. Stainless steel exhaust manifolds also may be noisier than cast iron manifolds.

The 1994 Delphi VII panel forecasts powdered metals, MMC and magnesium to experience some limited growth in engine component application in the coming decade. However, these materials are likely to see greater penetration rates if CAFE pressures increase. As with the broader vehicle material applications, the competition promises to be fierce. Engine component suppliers must follow these trends closely.

MAT-21a What percentage of spark-ignited engines in North American-produced passenger cars and light trucks will use these ceramic engine components in 1998 and 2003?

Ceramic Engine Components	Median Response		Interquartile Range	
	1998	2003	1998	2003
Exhaust manifold/port liner	2%	5%	1/2%	4/5%
Piston crown	5	10	2/5	4/10
Piston rings, coating	5	10	2/5	5/15
Seals	1	2	0/1	0/5
Valvetrain components (includes valves, inserts, guide seats, tappets, cam, etc.)	3	8	1/5	4/10

Discussion

Panelists forecast slow growth for ceramics in engine applications. Although anticipated usage is as high as 10 percent for some components, the total amount of ceramics will remain relatively small.

Manufacturer/supplier comparison

Manufacturer and supplier forecasts are similar. However, the suppliers' forecast for ceramic piston crown penetration is twice the level of the manufacturers' forecast. Both estimates are small (10 percent in 2003 for suppliers compared to 5 percent for manufacturers). But the difference may be especially important to suppliers that either have current technologies, or are investing in the development of such technologies.

Comparison of forecast: TECH-86

Forecasts for the materials and technology surveys are in agreement except for those compared in the following table.

Ceramic Engine Components	Median Response			
	1998		2003	
	MAT	TECH	MAT	TECH
Piston crown	5%	0%	10%	2%
Piston rings, coating	5	0	10	2
Seals	1	5	2	10

The materials panelists forecast lower use of ceramics on seals and lower use on piston crowns and piston rings than the technology panelists.

Trend from previous Delphi surveys

Previous Delphi panels have indicated a slow but steady increase in the penetration rate of ceramics. The forecast of the current survey continues this trend.

Strategic considerations

Ceramics are lightweight and exhibit some favorable mechanical properties (i.e., high temperature resistance, thermal insulation and wear resistance) that could be useful for internal engine applications. But cost, manufacturability and durability are concerns that limit penetration. Just a few years ago, there was widespread talk of ceramic-intensive engines. This vision has faded considerably, and efforts are now more directed at selected components. In some cases, ceramics can be a deterrent: In combustion chambers, its insulation properties can lead to greater knock problems. Therefore, systems management of heat, fuel and ignition to control knock is important. By no means are ceramics facing a predictable and certain future. Still, further developments could lead to breakthroughs that could have an important impact on high temperature and wear/friction related engine materials.

MAT-21b What percentage of turbocharged engines in North American-produced passenger cars and light trucks will utilize a ceramic turbine/rotor in 1998 and 2003?

Percent of turbocharged engines using a ceramic turbine/rotor			
Median Response		Interquartile Range	
1998	2003	1998	2003
5%	22%	5/8%	10/25%

No comments

Discussion

Panelists forecast relatively slow growth for ceramics in turbocharger turbine/rotor penetration to 22 percent by 2003.

Manufacturer/supplier comparison

The panelists agree on the short-term forecast. However, the forecasts for 2003 differ. Suppliers are more positive about future penetration rates for ceramic turbine/rotors. They forecast 25 percent penetration by 2003, compared to 15 percent by the manufacturers. This may be the same optimism displayed by suppliers in MAT-21a.

Trend from previous Delphi surveys

Previous Delphi panels have indicated a slow but steady increase in the penetration rate of ceramics turbine/rotors. The forecast of the current survey continues this trend.

Strategic considerations

With the increased penetration of multivalve engines, the outlook for turbochargers in North America has faded (see TECH-75 and MKT-40). However, the panel forecasts increased usage of ceramic turbine/rotors in the next decade and, in fact, ceramic materials are in production in some applications. Perhaps one of the most important aspects of ceramic "hot wheel" developments is the experience gained that could accelerate ceramic use in other applications.

MAT-22 What percentage of North American-produced passenger car and light truck engines in MYs 1998 and 2003 will utilize cast iron or aluminum cylinder heads and blocks?

Material	Passenger Cars				
	Median Response			Interquartile Range	
	Est. 1992*	1998	2003	1998	2003
Heads					
Cast iron	55%	45%	25%	35/50%	10/40%
Aluminum	45	55	70	47/60	60/90
Total	100%	95%	95%		
Blocks					
Cast iron	86%	75%	60%	70/80%	30/70%
Aluminum	14	25	40	20/30	30/50
Total	100%	100%	100%		

Material	Light Trucks				
	Median Response			Interquartile Range	
	Est. 1992*	1998	2003	1998	2003
Heads					
Cast iron	80%	70%	50%	60/75%	40/65%
Aluminum	20	30	45	25/40	30/60
Total	100%	100%	95%		
Blocks					
Cast iron	98%	90%	75%	80/95%	65/90%
Aluminum	2	10	20	5/20	10/35
Total	100%	100%	95%		

* **Source:** *Wards Automotive Reports*, December 1992.

No comments

Discussion

A significant increase in aluminum is forecast in both cylinder heads and blocks. Aluminum is expected to be used for 70 percent of cylinder heads and 40 percent of cylinder blocks on passenger cars by 2003. For trucks, aluminum will be used for 45 percent of cylinder heads and 20 percent of cylinder blocks by 2003.

Manufacturer/supplier comparison

The manufacturers and suppliers are in general agreement. However, the manufacturers forecast a higher penetration rate of aluminum cylinder blocks in passenger cars for 2003 (50 percent) than do the suppliers (35 percent).

Comparison of Forecasts: TECH-80

Responses of the Materials and Technology panels are in general agreement with the exception of the forecast for aluminum heads for 1998. In this case, the Materials and Technology panels forecast 55 percent and 65 percent respectively. This difference follows a general trend that Materials panelists forecast less rapid changes in materials compared to the Technology panelists, perhaps as a result of the closer association to materials for the Materials panelists.

Trend from previous Delphi surveys

This question was previously asked for combined light vehicles, whereas 1994 Delphi VII panelists were asked to differentiate between the passenger car and light truck segments. Therefore, a direct comparison is somewhat difficult. However, there are some interesting points to be drawn from comparing current responses with past studies. The short- and long-term forecasts for cylinder heads in each of the last four Delphi studies (1987 Delphi IV through 1994 Delphi VII) follow an interesting pattern.

Each of the four previous Delphi studies had similar short-term (i.e., five years or less) forecasts for the penetration rate for aluminum cylinder heads. The 1987 Delphi IV forecast for 1990, the 1989 Delphi V and 1992 Delphi VI forecasts for 1995, and the current forecast for 1998 all call for approximately 50 percent penetration for aluminum. The long-term forecasts follow a similar pattern, predicting 70 percent penetration for cylinder heads.

This may suggest that the current panel is reporting the results of limited resources. Recent years have seen an increasing emphasis on cost constraints. Therefore, the shift to aluminum—a more costly material—may be slowed by the increased need to control cost.

	Short term	Long term	Short term		Long term			
	1990	1995			1998	2000	2000	2003
Heads	Delphi IV (1987)	Delphi IV (1987)	Delphi V (1989)	Delphi VI (1992)	Delphi VII (1994)	Delphi V (1989)	Delphi VI (1992)	Delphi VII (1994)
Aluminum	50%	70%	55%	50%	55 %	70%	70%	70%

Strategic considerations

The current administration has increased the emphasis on CAFE, and this will likely prompt manufacturers to increasingly substitute aluminum for cast iron in cylinder heads and blocks. This represents a very attractive method for mass reduction, not just for the engine but also for the cradles, suspension, etc. However, there is a modest cost penalty for this substitution, both in the price of the material and the cost of redesign associated with aluminum.

The penetration rate for aluminum cylinder heads is forecast to be greater than aluminum blocks due to a number of factors, including cost and experience. However, the shift to aluminum cylinder blocks is generally more challenging, especially in terms of manufacturablity and noise suppression.

MAT-23 Of the aluminum blocks forecast in MAT-22, please forecast the percentage that will be unsleeved, unsleeved and coated, and sleeved.

Aluminum Block Engines	Median Response			Interquartile Range	
	Est. 1992*	1998	2003	1998	2003
Sleeved	100%	95%	85%	90/100%	70/95%
Unsleeved and coated	0	2	10	0/10	0/20
Unsleeved	0	0	0	0/0	0/5
Total	100%	97%	95%		

* **Source:** *Various OSAT estimates.*

Selected edited comments

- Sleeves may be MMC, not necessarily cast iron.

Discussion

Manufacturers remain very cautious about technologies that are currently available to replace cast iron sleeves in aluminum cylinder blocks.

Manufacturer/supplier comparison

Both panels forecast a slight penetration of unsleeved and coated technologies in the coming decade. The two panels have a somewhat differing opinion on the penetration of sleeved technology. The suppliers forecast higher penetration for sleeved cylinders in 2003 (90 percent) than do the manufacturers (70 percent).

Trend from previous Delphi surveys

This question was expanded to specify both unsleeved and coated, and unsleeved. However, limited comparison to previous Delphi studies is possible. The 1994 Delphi VII panel continues the trend of decreasing faith in unsleeved cylinder technology. The 1989 Delphi V panelists forecast 30 percent penetration for unsleeved cylinders by 2000, the 1992 Delphi VI panel forecast 20 percent for 2000 and the current panel forecasts 10 percent by 2003. The current panel may be facing the realities of cost, manufacturing and performance constraints on new materials that may, in fact, make the materials less attractive than they initially appear. The previous Materials panels seem more confident that advances would be made in unsleeved technology. The current panel is less convinced that it will happen soon.

Strategic considerations

In the coming decade, panelists believe that sleeved aluminum cylinder blocks will be the predominant choice. Based on current industry practice, we suspect cast iron will continue to be the dominant sleeve material. Unsleeved coated cylinders are forecast to achieve only limited acceptance. This technology involves coating an unsleeved cylinder wall with a material compatible with aluminum that meets quality, reliability and durability standards necessary for such a critical application. General Motors implemented sleeveless technology in the 1970s (Chevrolet Vega), but experienced significant problems and withdrew the technology from the market.

An application as critical to customer satisfaction as cylinder block performance may present higher hurdles for new materials. Any new technology must be essentially bulletproof.

Panelists view the unsleeved design as currently unrealistic for application in the next decade. Most manufacturers are still very unsure of the reliability of unsleeved cylinder blocks. They will likely remain so until there is significant proof that aluminum blocks can operate without sleeves. However, there is significant effort worldwide to remedy many of the concerns associated with unsleeved aluminum cylinders. These efforts bear close watching. In fact, some premium engines in the world are unsleeved.

MAT-24 Which powertrain components, for North American-produced passenger cars and light trucks will be made from various forms of powdered metals in MYs 1998 and 2003?

Powdered Metal Components	Median Response			Interquartile Range		
	Current Est.	1998	2003	Current Est.	1998	2003
Connecting rods	5%	15%	20%	5/10%	10/20%	10/30%
Valvetrain components:						
Camshaft lobes	2	10	15	0/5	5/10	10/20
Rocker arms	0	2	4	0/0	0/2	0/5
Tappets/lifters	0	0	0	0/0	0/1	0/3
Valve guides	15	25	40	10/20	20/35	30/50
Valve seat inserts	20	35	40	15/30	25/40	30/50
Transmission gears	10	15	24	10/15	15/20	15/25

Selected edited comment

- Cost constraints will cause a return to castings but with better property control.

Discussion

Panelists forecast a significant increase in powdered metal applications over the next decade. By 2003, the panel forecasts that 40 percent of valve guides, 40 percent of valve seat inserts, 24 percent of transmission gears and 20 percent of connecting rods will be made from powdered metal.

Manufacturer/supplier comparison

The suppliers' forecast for valve guides (35 percent) is higher than the manufacturers' forecast (15 percent). The two panels are in agreement for other applications. This is in sharp contrast to the 1992 Delphi VI panel. In that study, the suppliers' forecast for each component was substantially higher than the manufacturers'. The relative agreement shown by the current panels may suggest that the industry is better understanding the uses and limitations of powdered metal.

Comparison of forecast: TECH-81

Powdered metal cams and gears are addressed in the Technology survey. Forecast penetration is lower than that forecast in the Materials survey for camshaft lobes. Technology survey results are shown below.

Technology Survey Results Powdered Metal cam and gears penetration		
Current Est.	1998	2003
2%	3%	10%

Trend from previous Delphi surveys

The 1992 Delphi VI forecast is significantly higher for two components. The penetration of powdered metal connecting rods was forecast by the 1992 panel to be three times higher than the 1994 Delphi VII forecast. The current panel also forecasts substantially different levels for tappets/lifters. In 1992, the forecast for powdered metal tappets/lifters was 20 percent penetration by 2000. The current panel forecasts no powdered metal tappets/lifters by the year 2003. It is especially interesting to note that the interquartile ranges for the 1994 Delphi VII survey are much smaller than those in the 1992 Delphi VI study. This suggests that the 1994 panelists are much more comfortable with the forecast penetration of powdered metals than was the previous panel.

Component	1995	1998	2000	2003
	Delphi VI (1992)	Delphi VII (1994)	Delphi VI (1992)	Delphi VII (1994)
Connecting rods	30%	15%	60%	20%
Tappets/lifters	10	0	20	0

Strategic considerations

Automotive manufacturers are presently exhibiting widespread and growing enthusiasm for powdered metal technology. The panel reflects this trend. The use of powdered metals will likely expand beyond the listed applications. However, this will depend on the development of new and better powdered metals, which will lead to improved properties and new applications. Powdered metals certainly fit with the move to near net shape material technology. They require generally less follow on processing, and tailored properties generally yield better performance at lower weight.

Powdered metals will have to be watched closely. We expect significant advances in materials technology, and thus a wider range of components that can be manufactured using powdered metal.

MAT-25 Will the following components be made of copper or aluminum in MYs 1998 and 2003 (where 1 = all production of this component will be copper, 3 = 1/2 will be made of copper and 1/2 made of aluminum, and 5 = all production of this component will be aluminum).

Component	1998	2003
Passenger cars		
Engine oil cooler	3.4	3.9
Heater cores	4.0	4.3
Radiators	4.0	4.3
Transmission oil cooler	3.1	3.5
Light trucks		
Engine oil cooler	2.9	3.5
Heater cores	3.0	3.6
Radiators	2.9	3.6
Transmission oil cooler	3.0	3.5

No comments

Discussion

The panel forecasts aluminum to continue to increase penetration rates for the listed components.

Manufacturer/supplier comparison

The manufacturers and suppliers are in general agreement.

Trend from previous Delphi surveys

This question was changed and is not comparable to previous surveys.

Strategic considerations

The panel forecasts aluminum to increasingly replace copper in the listed applications. Recently, there have been advances in manufacturing and design, specifically for radiators, that may make copper a viable choice. However, it appears that many manufacturers have accepted aluminum, and considerable capacity has been converted to the manufacture of aluminum radiators, heater cores, oil coolers and transmission coolers. Unless copper technology can be adopted to the present aluminum manufacturing technology, there is only a small chance that copper will become a serious contender.

There is some disagreement regarding the material selection process for radiators. Aluminum is thought to have a cost and weight advantage over copper. But at least one industry leader is capable of producing copper radiators that are lower cost, and of equal cooling efficiency, compared to radiators made of aluminum.

MAT-26 What percentage of gasoline-fueled North American-produced passenger cars and light trucks will have gas tanks made from steel, plastic or other materials by MYs 1998 and 2003?

Gas Tank Material	Est. 1992*	Median Response		Interquartile Range	
		1998	2003	1998	2003
Steel	80%	70%	60%	60/75%	40/70%
Plastics	20	30	40	25/40	30/60
Total	100%	100%	100%		

***Source:** *Wards Automotive Reports*, August 1992

Selected edited comment

- As new programs come onboard, carryover fuel tanks that are made of plastic will be integrated in the design of the new vehicle to reduce the cost of tooling up for a new one. Those presently using steel will be replaced by plastic.

Discussion

Steel will continue to be a viable choice for light vehicle gasoline tanks. However the penetration rate of plastic gasoline tanks is forecast to double from the 20 percent of the 1992 estimate over the next decade. Because of their light weight, plastic gas tanks may be the material of choice as vehicles are redesigned.

Manufacturer/supplier comparison

The manufacturers and suppliers are substantially in agreement.

Trend from previous Delphi surveys

This question was not previously asked.

Strategic considerations

Automotive manufacturers are confident in utilizing plastic material in fuel tanks, and, as shown in the data, expect to see an increase in penetration, particularly with the redesign of vehicles. Plastics offer several advantages over the traditional steel gas tanks, including weight reduction and ability to conform to irregular space. One problem that could inhibit use is vapor permeability which must be controlled to satisfy future emission standards. This may be a factor in the wide interquartile range. Different strategies on the part of various manufacturers can also be a factor.

MAT-27 What percent of alcohol- or flexible-fueled North American-produced passenger cars and light trucks will use the following fuel tank materials by MYs 1998 and 2003?

Alcohol- or Flexible-Fueled Gas Tank Materials	Median Response		Interquartile Range	
	1998	2003	1998	2003
Stainless steel	15%	20%	5/25%	10/25%
Coated, low carbon steels painted	50	30	40/60	20/40
Plastics	30	45	20/40	30/55

Selected edited comments

- Composite tanks will be used for compressed natural gas.
- I expect a limited number of flex-fueled vehicles using methan0ol.
- Permeation of plastics continues to be a problem unless fluorocarbon resin barrier films are used.
- The initial wave of optional-flexible-fueled vehicles will carry the traditional control vessel developed for the particular medium. Custom storage will not take place until 5-8 years later, when major emphasis is placed on styling.
- This assumes that methanol will be popular.

Discussion

In the coming decade, panelists forecast, stainless steel and plastics will become more favored as materials for flexible-fueled vehicle gas tanks. Coated, low carbon steels painted fuel tank materials will see some penetration.

Manufacturer/supplier comparison

The manufacturers and suppliers are substantially in agreement.

Comparison of forecast: TECH-47

Materials and Technology panelists are in general agreement on this question.

Trend from previous Delphi surveys

Although the question was asked slightly differently, the current forecast is similar in trend to previous Delphi studies.

Strategic considerations

There are several flexible fuel projects currently underway, but flexible fuels (alcohol based) remain somewhat of an uncertainty. Alcohol is corrosive to many materials, particularly most plastics, and will continue to present challenges in the development of fuel storage systems.

The comment, "the initial wave of optional flexible-fueled vehicles will carry the traditional control vessel developed for the particular medium," makes an interesting point. Early flexible fuel vehicles have used expensive stainless steel tanks, but, from a cost standpoint, this is not attractive. Clearly, if alcohol based fuels attain a reasonable level of popularity, the fuel tank material issue could become highly competitive considering the relative balance in the forecast.

MAT-28 Please indicate how materials development will improve customer satisfaction over the next 10 years in regard to these engine and transmission attributes.

Engine/Transmission Attributes	Percent of panelists
Acceleration	
Improved due to reduce mass (lightweight materials)	18%
Increased horsepower; friction reduction	1% each
Driveability	
Reduce mass (lightweight materials)	6%
Better, smoother braking through new materials	1
Fuel economy	
Reduce mass (lightweight materials)	20%
Friction reduction	2
Reformulated fuels	1
Noise/vibration/harshness	
Reduce mass (lightweight materials)	7%
Composite materials: valve covers; oil pan; intake manifold; and dual layered materials	1% each
Quality/reliability/durability	
Stable plastics; improve corrosion resistance	3% each
Better fit/finish; improve wear resistance	1% each

Discussion

The panel responses highlight the importance of material development as an indirect road for improving customer satisfaction through lightweight materials, friction reduction and better corrosion protection.

Manufacturer/supplier comparison

This comparison is not done for open-ended questions.

Trend from previous Delphi surveys

This question was not previously asked.

Strategic considerations

With regard to customer satisfaction, the panelists view gains in lightweight material technology as the most important developmental area. Increased use of lightweight materials and the associated reduction of mass will lead to improved acceleration, drivability and fuel economy, which, in turn, should increase customer satisfaction. This assumes no major compromises of safety, cost and other factors—a major challenge indeed.

Friction reduction related to both tire materials and powertrain components can play a significant role in increasing customer satisfaction. Friction reduction will increase acceleration and fuel economy. Advances in lubricating fluids also are crucial to increased friction reduction. Automotive manufacturers are relying heavily on lubricant and additive suppliers to develop new materials that will provide better antifriction and antiwear performance. Friction coatings are another area of concentration of the industry. However, there is still significant work to be done in this area.

Another critical factor in future customer satisfaction is corrosion resistance. Most vehicles meet the manufacturers' six- or seven-year no perforation warranty, but cosmetic corrosion is still a challenge. Efforts to improve corrosion resistance will likely be in two forms: the use of alternate corrosion resistant materials and coatings.

The panel has noted several areas where advances in materials should lead to significantly increased customer satisfaction. This list is not complete. Manufacturers and suppliers must work diligently to develop new materials and applications that go beyond merely meeting the customer's expectations, to delight and surprise the customer.

MAT-29 What percentage of North American-produced passenger cars and light trucks will use an integral frame or other design in MYs 1998 and 2003?

Passenger Cars Frame Construction	Median Response			Interquartile Range	
	Est. 1992*	1998	2003	1998	2003
Integral body/frame or unibody	92%	92%	88%	90/93%	83/94%
Separate body/frame	5	5	3	3/5	0/5
Space frame	3	4	8	2/5	3/12

Light Trucks Frame Construction	Median Response			Interquartile Range	
	Est. 1992*	1998	2003	1998	2003
Sport utility vehicle/pickup					
Integral body/frame or unibody	0%	0%	0%	0/5%	0/15%
Separate body/frame	100	100	100	90/100	80/100
Space frame	0	4	8	2/5	3/12
Full-sized van					
Integral body/frame or unibody	0%	0%	0%	0/5%	0/12%
Separate body/frame	100	97	90	80/100	80/100
Space frame	0	0	0	0/0	0/2
Minivan					
Integral body/frame or unibody	50%	55%	65%	50/70%	55/80%
Separate body/frame	38	30	20	25/38	10/30
Space frame	12	11	11	8/15	5/20

***Compiled from:** *Automotive News* Market Data Book.

Selected edited comment

- Full-size vans are *not* separate body/frame the same way a pickup or sport utility is. The front end has a frame, and the back end is basically constructed from reinforced panels.

Discussion

The panel forecasts little change in the penetration rates of frame designs for all types of vehicles. Constant pressure to reduce cost and weight will likely limit the growth of competing designs for unibody construction.

Manufacturer/supplier comparison

The manufacturers and suppliers are in substantial agreement. However the manufacturers forecast higher usage of unibody construction for minivans (80 percent) in 2003 than do the suppliers (60 percent).

Comparison of forecast: TECH-54

Materials and Technology panelists are in general agreement on this question.

Trend from previous Delphi surveys

The forecast by the current panel is substantially the same as the 1992 Delphi VI forecast.

Strategic considerations

Panelists forecast the continued dominance of the integral body/frame (unibody) system in the manufacture of passenger cars and minivans through 2003. Likewise, the panel forecasts that the separate body/frame design will remain dominant for sport utilities, pickup trucks, and full-size vans.

The forecast lack of change does not imply a lack of significant activity in frame design and construction. Several manufacturers are presently working on variations of the current frames using aluminum extrusions, and the USCAR Automotive Composites Consortium is developing processes that may make structural composites feasible. These programs have led to some interesting early results, and may soon have potential for application. Still, there is much to be learned about both aluminum and composites before commercialization. Body stiffness requirements, especially for unibody and space frames, will clearly increase in the next decade (See TECH-55).

Finally, the selected respondent comment is appropriate. There are many hybrid frame designs throughout the industry, and there will likely be many more in the future. Although the panel forecast calls for the design mix to remain relatively constant over the next decade, it will be important to remain informed on the variations that develop. These hybrid frame designs might prove to be the initial steps in subsequent significant changes in design and manufacturing.

MAT-30 Please forecast the material mix of steel, aluminum and plastic frame/structural members in both integral body/frame and space frame for North American-produced passenger cars in MYs 1998 and 2003.

Material Mix	Median Response			Interquartile Range	
	Est. 1992*	1998	2003	1998	2003
Integral Frame					
Steel	100%	99%	90%	95/100%	85/95%
Aluminum	0	0	5	0/5	1/13
Plastics	0	0	0	0/0	0/0
Total	100%	99%	95%	100%	100%
Space Frame					
Steel	100%	98%	88%	90/100%	70/95%
Aluminum	0	1	9	0/10	2/20
Plastics	0	0	0	0/1	0/5
Total	100%	99%	97%		

***Source:** Various OSAT estimates.

No comments

Discussion

In spite of the emphasis on lightweight materials for weight reduction, manufacturers will continue to rely on steel for frame construction applications. However, aluminum will likely become an increasingly viable material for frame applications within the next decade. Plastic is not forecast to see any significant application.

Manufacturer/supplier comparison

The manufacturers and suppliers are in agreement.

Trend from previous Delphi surveys

This question was not previously asked.

Strategic considerations

Over the next decade, steel is forecast to remain the material of choice for frame construction in the North American automotive industry. This suggests that steel continues to be the most cost-effective structural material available. There will, however, be important activity involving other materials. There may well be vehicles produced in North America with aluminum frames within the next several years, but the panel expects the total share of aluminum-framed vehicles to remain small through 2003. If CAFE rises substantially during the next decade, it is possible that significant redesign with aluminum may occur.

Essentially no role is expected for plastic materials in the next decade. This lack of interest is at least in part due to concerns about cost, manufacturability, reliability, recyclability and durability, as well as generally limited experience. As a first step to acceptance, the USCAR Automotive Composites Consortium is attempting to develop manufacturing methods that would increase the viability of composites in structural applications.

We agree with the panel that steel is the likely material of choice for frames over the next decade. However, it is critically important to understand the potential of alternative materials. The automotive industry is moving closer to the leading edge of materials science. As the DOE National Laboratories and defense contractors increasingly focus on the automotive industry, development of new materials and their processing will likely increase. Consequently, it will be essential for suppliers and manufacturers to become aware of new technologies and applications.

MAT-31 Consider the following list of automotive body components. Please indicate the percentage of each likely to be made from the listed materials in model years 1998 and 2003. It is not necessary to enter a response for every component; just those you are familiar with. Where you answer, please ensure that your estimates add up to 100%. Please use zeros where applicable.

(Please see data tables on pages 58 and 59)

Selected edited comments

- Bumper fascia will see the use of paint films grow rapidly, accounting for the nonreinforced thermoplastics materials. Plastics recycling will occur in fascia by 2003.
- For fascia, reinforced thermoset (reinforced reaction injection molding) will remain for complex shaped fascia. Otherwise, thermoplastics will make great inroads.
- If recyclability issues can be resolved, plastic will make greater overall inroads than aluminum, but both materials will be utilized more in 1998 and 2003.
- Some bake-hardenable steels will come into use.
- These estimates are dependent on what assumption you make for CAFE in 1998 and 2003.

Discussion

Steel is forecast to remain the most common material for vertical and horizontal panels, and for the floor pan in the next decade. Aluminum and plastic will likely see increased application, but the rate of increase for the two materials may be slowed.

Manufacturer/supplier comparison

The manufacturers and suppliers are substantially in agreement. There is, however, one exception: The suppliers and manufacturers disagree on the short-term and long-term penetration rates for bumper supports. The suppliers view steel as the material that will be predominant, while the manufacturer panel views several materials as potential candidates. It is important to note that the large interquartile ranges suggest a great deal of uncertainty among the panelists.

Trend from previous Delphi surveys

For the current survey, this question was expanded to include more specific definitions of the materials. However, comparison is still possible with previous surveys. The 1994 Delphi VII forecast is similar to the 1992 Delphi VI survey with one exception. The current Delphi panel is less convinced that plastics or aluminum will make substantial gains in horizontal panel applications. This lack of confidence likely is a result of the increasing emphasis on the recyclability of plastics and the uncertainty of cost regarding both materials. The curr0ent panel's forecast of aluminum usage in horizontal panels is interesting, given its current application as engine hoods in a few select vehicle programs.

Long-term Forecast for Horizontal Exterior Panels		
Material	**2000 Delphi VI (1992)**	**2003 Delphi VII (2003)**
Steel	70%	90%
Aluminum	5	0
Thermoplastics	5	0
Thermosets	20	0

Strategic considerations

Steel is forecast to remain the material of choice for body panels in the coming decade. This is in spite of substantial efforts to increase the use of other materials. Both the automotive and materials industries have worked diligently to develop alternatives to steel. New methods of manufacturing, such as tailored blanking, as well as increased use of HSLA steels, make steel a moving target for all competitors.

Several major vehicle programs have incorporated plastics in vertical panels with varying success. Saturn has become a success with its thermoplastic doors and fenders. However, another General Motors vehicle which makes extensive use of plastics body panels—the APV minivan—has been less well received. The industry has seen several examples of plastics in vertical applications but very limited use in horizontal panels. The Corvette is a notable example of a vehicle with a long-standing commitment to

polymer materials. Of course, economics are less of a factor on higher price vehicles such as the Corvette.

Early on, the majority of plastics applications involved reinforced thermosets, especially sheet molded compound (SMC). Recently there have been significant advances in the use of thermoplastics for body panel applications (e.g., Saturn). Thermoplastics are currently perceived as being more recyclable than thermosets, and thus may be viewed as more environmentally favorable for large applications. Generally, thermoplastics have not been as acceptable for horizontal panels.

While plastics have been available for body panel application for several years, aluminum has recently caught the attention of manufacturers. Several manufacturers currently have significant aluminum development programs and are gaining critical manufacturing data regarding aluminum. Over the years, there have been a number of programs that have incorporated aluminum body panels, particularly nonintegrated panels such as hoods and rear deck lids. Two foreign-produced vehicles extensively use, or plan to use, aluminum for body panels: The Honda NSX has all aluminum body panels, and Audi will soon introduce a vehicle with a mostly aluminum shell and structure.

Although it is likely that the industry will continue to rely on steel for body panels in the next decade, significant vehicle programs using plastic or aluminum panels are likely. Any significant increase in CAFE would raise the likelihood of greater penetration rates for plastic and aluminum than those currently forecast.\

Body Components	1998 Model Year									
	Vertical exterior panels*	Horizontal exterior panels**	Floor pan	Bumper fascia	Bumper support	Vertical exterior panels*	Horizontal exterior panels**	Floor pan	Bumper fascia	Bumper support
Passenger cars										
Steel	80%	80%	90%	0%	55%	75/85%	75/85%	90/95%	0/10%	30/80%
HSLA steel	5	5	5	0	20	2/10	0/10	0/10	0/1	10/25
Aluminum	1	3	0	0	10	0/2	3/7	0/2	0/0	0/10
Reinforced plastic										
Thermoplastic	1	0	0	5	0	0/3	0/1	0/0	0/20	0/5
Thermosets	7	8	0	15	5	3/10	2/10	0/1	0/35	0/10
Nonreinforced plastic										
Thermoplastic	0	0	0	50	0	0/0	0/0	0/0	15/70	0/0
Thermosets	0	0	0	0	0	0/0	0/0	0/0	0/10	0/0
Total	94%	96%	95%	70%	90%					
Light truck	Vertical exterior panels*	Horizontal exterior panels**	Floor pan	Bumper fascia	Bumper support	Vertical exterior panels*	Horizontal exterior panels**	Floor pan	Bumper fascia	Bumper support
Steel	90%	90%	95%	60%	80%	85/93%	80/95%	90/100%	20/75%	70/90%
HSLA steel	5	5	5	5	10	0/10	0/10	0/10	0/10	10/25
Aluminum	0	1	0	0	0	0/0	0/5	0/0	0/0	0/5
Reinforced plastic										
Thermoplastic	0	0	0	0	0	0/0	0/0	0/0	0/0	0/5
Thermosets	2	0	2	0	0	0/5	0/0	0/10	0/0	0/0
Nonreinforced plastic										
Thermoplastic	0	0	5	0	0	0/0	0/0	0/25	0/0	0/0
Thermosets	0	0	0	0	0	0/0	0/0	0/0	0/0	0/0
Total	97%	96%	107%	65%	90%					

* door, fender, quarter
** hood, deck lid, roof

2003 Model Year										
Body Components	Vertical exterior panels*	Horizontal exterior panels**	Floor pan	Bumper fascia	Bumper support	Vertical exterior panels*	Horizontal exterior panels**	Floor pan	Bumper fascia	Bumper support
Passenger cars										
Steel	65%	80%	0%	40%	10%	60/78%	80/90%	0/25%	10/70%	0/15%
HSLA steel	10	10	0	20	5	0/15	3/15	0/0	5/30	0/10
Aluminum	10	0	0	10	3	0/15	0/5	0/0	0/15	0/5
Reinforced plastic										
Thermoplastic	0	0	0	0	5	0/5	0/0	0/20	0/15	0/10
Thermosets	7	0	15	5	0	0/10	0/5	0/35	0/10	0/0
Nonreinforced plastic										
Thermoplastic	0	0	50	0	0	0/0	0/0	10/70	0/0	0/0
Thermosets	0	0	0	0	0	0/0	0/0	0/7	0/0	0/0
Total	92%	90%	65%	75%	23%					
Light truck	Vertical exterior panels*	Horizontal .exterior panels**	Floor pan	Bumper fascia	Bumper support	Vertical exterior panels*	Horizontal exterior panels**	Floor pan	Bumper fascia	Bumper support
Steel	80%	80%	90%	40%	60%	70/85%	65/80%	80/98%	0/55%	30/70%
HSLA steel	10	5	10	5	10	0/10	0/10	1/15	0/10	5/30
Aluminum	0	3	0	0	5	0/0	0/10	0/0	0/5	0/10
Reinforced plastic										
Thermoplastic	0	0	0	5	0	0/2	0/0	0/0	0/20	0/8
Thermosets	5	5	0	15	0	0/10	0/10	0/1	0/20	0/15
Nonreinforced plastic										
Thermoplastic	0	0	0	10	0	0/0	0/0	0/0	0/30	0/0
Thermosets	0	0	0	0	0	0/0	0/0	0/0	0/0	0/0
Total	95%	93%	100%	75%	75%					

* door, fender, quarter
** hood, deck lid, roof

MAT-32 **Consider the following list of automotive chassis components. Please indicate the percentage of each likely to be made from the listed materials in model years 1998 and 2003. Leave blank any materials with which you are not familiar. Where you answer, please ensure that your estimates add down to 100%. Please use zeros where applicable.**

Chassis components	1998				2003			
	Median Response		Interquartile Range		Median Response		Interquartile Range	
Passenger cars	Wheels	Suspension Control Arms	Wheels	Suspension Control Arms	Wheels	Suspension Control Arms	Wheels	Suspension Control Arms
Steel	40%	70%	30/45%	70/80%	25%	60%	20/35%	50/70%
HSLA steel	10	20	5/10	15/20	10	30	5/20	20/30
Aluminum	50	10	50/60	5/10	60	15	55/70	15/20
Total	100%	100%			95%	105%		
Light trucks								
Steel	70%	75%	60/70%	70/90%	60%	67%	50/60%	60/80%
HSLA steel	10	20	5/15	20/30	10	20	5/15	20/30
Aluminum	20	0	25/40	0/10	30	0	25/40	0/10
Total	100%	95%			100%	87%		

Selected edited comment

- Many suspension components are cast iron (e.g., steering knuckles and suspension control arms).

Discussion

In the coming decade, the panelists forecast, aluminum, steel and HSLA steel will see significant penetration levels in wheels and suspension control arms application in passenger cars and light trucks.

Manufacturer/supplier comparison

The manufacturers and suppliers are in general agreement.

Trend from previous Delphi surveys

This question was substantially changed from previous Delphi studies. Therefore, comparison is not possible.

Strategic considerations

Automotive manufacturers are concerned with potential future increases in CAFE. In order to meet any future increases in fuel economy standards, they will likely have to decrease vehicle weight. Using aluminum and HSLA steel in suspension control arms is a method of achieving weight reduction.

In the coming decade, steel will remain the predominant material for suspension control arms, but will likely show a slow decline in penetration rates as weight reduction designs are implemented. Increasingly, suspension control arms will be made from HSLA steel. HSLA steel presents an excellent cost/strength ratio and thus will be a viable alternative to heavier steels and more costly aluminum.

Penetration rates for aluminum suspension control arms in light trucks will continue to lag behind those of cars. However, as mentioned earlier in this report, light trucks may face substantially increased CAFE standards. If light truck CAFE does increase substantially, it could force materials engineers to significantly raise the amount of lightweight materials used, leading to penetration rates for aluminum and HSLA steel that more closely resemble the forecast for passenger cars.

Styled aluminum wheels have increased significantly in popularity recently, and their popularity is expected to continue to rise. Due to the higher costs associated with aluminum, however, steel will continue to maintain an important position in the styled wheel market.

MAT-33 What percentage of North American-produced passenger cars and light trucks will use materials other than conventional glass for either windshields, side windows or rear windows in 1998 and 2003?

1998 Alternative Material for Glass	Median Response			Interquartile Range		
	Windshield	Side Window	Rear Window	Windshield	Side Window	Rear Window
Polycarbonate	0%	0%	0%	0/0%	0/4%	0/5%
Polycarbonate-glass laminates	0	0	0	0/0	0/2	0/0
Special coatings and/or interlayers to:						
Reduce solar load	30	15	20	30/50	10/25	10/30
Provide defrosting capability	5	0	20	5/10	0/0	10/30
Provide abrasion resistance for plastics (e.g., diamond film glazes)	0	5	2	0/0	0/10	0/5
2003 Alternative Material for Glass	**Median Response**			**Interquartile Range**		
	Windshield	Side Window	Rear Window	Windshield	Side Window	Rear Window
Polycarbonate	0%	5%	5%	0/0%	0/15%	1/10%
Polycarbonate-glass laminates	1	5	5	0/5	2/10	1/10
Special coatings and/or interlayers to:						
Reduce solar load	60	25	50	50/80	20/50	25/60
Provide defrosting capability	15	0	30	10/25	0/10	20/90
Provide abrasion resistance for plastics (e.g., diamond film glazes)	0	10	5	0/2	4/20	2/20

Selected edited comments

- Look for new interlayers systems for improved safety also.
- Alternate material technology for polycarbonate is not yet as durable as the material it replaces. A move to this material is not planned at this time. In the glass material area, coatings and batch composition changes will be made to improve solar transmission characteristics.
- Polycarbonates used as a glass/plastic laminate has a probability of occurring only in response to a federally mandated anti-ejection system through the side windows.

Discussion

The panel forecasts that applications of polycarbonate and polycarbonate-glass laminates likely will see very limited usage for automotive windshield and side windows in the coming decade. However, the panel forecasts that the use of special coatings and/or interlayers to reduce solar loads will increase significantly by 2003.

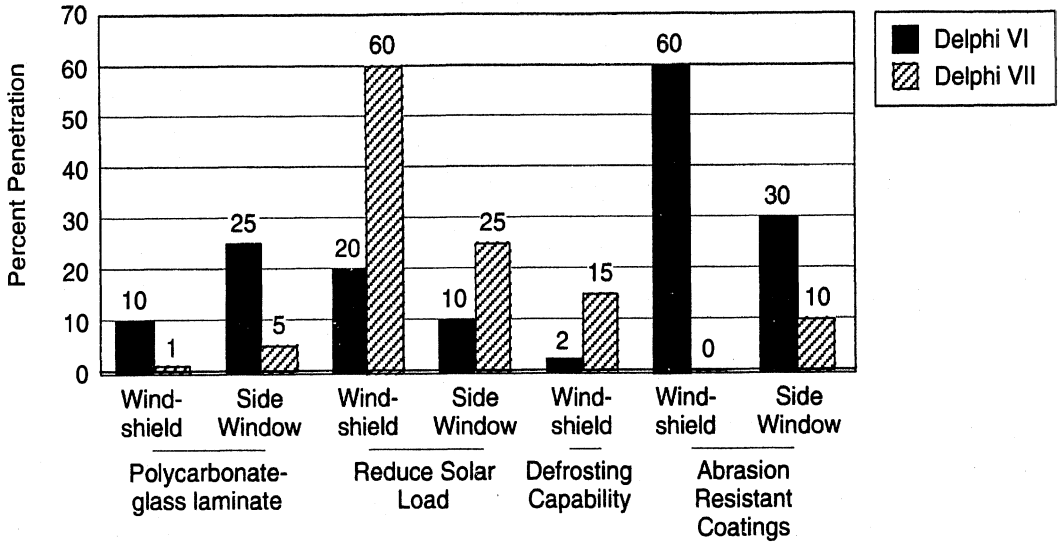
Manufacturer/supplier comparison

The manufacturers and suppliers are in general agreement. However, the suppliers forecast higher penetration rates for special coatings to reduce solar loads on side windows for 2003 (40 percent) than do the manufacturers (20 percent).

Trend from previous Delphi surveys

The 1994 Delphi VII panel is far less optimistic about the penetration rates for polycarbonate-glass laminate usage in side window applications than was the 1992 Delphi VI panel. The current panel also forecasts a lower usage rate for special coatings and/or interlayers to provide abrasion resistance. It does, however, forecast significantly higher penetration rates for special coatings and/or interlayers to reduce solar loads and add defrosting capabilities than did the 1992 Delphi VI panel.

Alternative Materials Penetration Rate for Automotive Glass*
2000 and 2003 Forecast



* Delphi VI study 1992; Forecast year 2000
Delphi VII study 1994; Forecast year 2003

Strategic considerations

The automotive industry continues to consider polycarbonate and polycarbonate-glass laminates in windshield and side window applications. Although polycarbonate offers a substantial weight savings over glass, the increased cost of polycarbonate and concerns with scratching remain a barrier. Of course, the weight advantages of nonglass substitutes remain important if economics and surface problems can be resolved, but the enthusiasm is considerably less than found in recent past Delphi forecasts. The volatility over time of these forecasts suggest trends should be followed closely.

Panelists forecast a significant increase in the use of special coatings and/or interlayers to reduce the solar load and provide defrosting capabilities. The trend toward cab-forward design (See TECH-42) and generally larger greenhouses for passenger cars and trucks has led to increased window areas, and therefore greater solar loading. The use of coatings and interlayers is necessary to compensate for the more severe environment associated with the larger greenhouse effect.

MAT-34 What percentage of the following brake components do you expect to be made from aluminum matrix composites (AMC) by 1998 and 2003?

AMC Application	Est. 1992*	Median Response		Interquartile Range	
		1998	2003	1998	2003
Drum	0%	3%	10%	0/10%	5/15%
Drum brake backing plates	0	1	5	0/10	2/15
Rotors	0	2	5	0/5	0/15
Brake caliper housings	0	10	15	1/30	5/50

No comments

Discussion

Due to the type of applications listed in this question, the total amount of AMC suggested by the forecast is relatively low. However, the forecast is for increased penetration of AMC into the listed components.

Manufacturer/supplier comparison

The manufacturers and suppliers are in general agreement. However, there may be some disagreement regarding the use of AMC in brake caliper housings by 2003. The suppliers' forecast of 30 percent usage for AMC brake caliper housings in 2003 is substantially higher than the manufacturers' forecast of 5 percent usage.

Trend from previous Delphi surveys

This question was not previously asked.

Strategic considerations

The panelists present an optimistic, but not overly enthusiastic, forecast for AMC in brake components. As with many high-tech materials, the industry faces many hurdles in increasing the use of AMC. Uncertainties surrounding cost, manufacturability and durability remain significant. Until these issues are satisfactorily resolved, materials engineers will likely not have complete confidence in the material, and thus be hesitant to use it in crucial safety-related applications such as brake components.

The wide interquartile range, especially for brake caliper housings, suggests that there is some uncertainty surrounding the future of AMC. It is noteworthy that the high end of the interquartile range for brake caliper housings is 50 percent, and that the suppliers are much more positive about the future of AMC for this particular component. This may be a case of several suppliers having knowledge of significant advances in AMC. Further, it may also suggest that AMC may be a viable alternative for brake components in the next decade and should be closely watched.

MAT-35 What percentage of friction lining materials used in brakes and clutches for North American-produced passenger cars and light trucks will be made from the following materials in MYs 1998 and 2003?

Friction Lining Materials	Est. 1992	Median Response		Interquartile Range	
		1998	2003	1998	2003
Brakes					
Carbon fiber	0%	0%	0%	0/0%	0/10%
Sintered metallic	0	0	0	0/3	0/5
Nonmetallic	0	0	5	0/5	0/10
Metallic/organic	100	90	80	85/100	50/96
Clutch					
Carbon fiber	0%	0%	10%	0/5%	0/27%
Sintered metallic	>2	3	4.6	2/5	2/10
Nonmetallic	0	0	0	0/0	0/5
Metallic/organic	<98	95	80	75/97	68/95

***Source:** Various OSAT estimates.

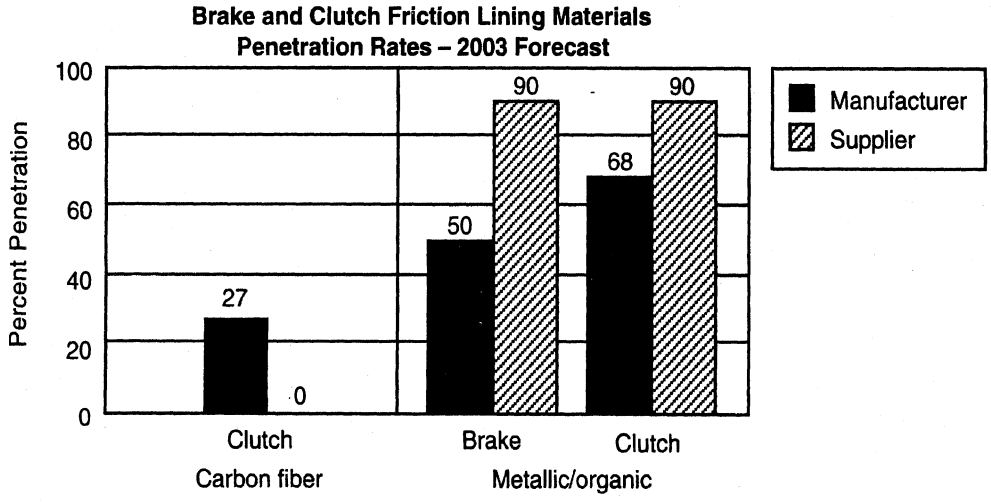
No comments

Discussion

Panelists forecast that metallic/organic materials will continue to be the dominant choice for brake and clutch linings. The panel forecasts no penetration for carbon fiber as a brake lining. However, the interquartile range suggest some panelists see potential for limited application.

Manufacturer/supplier comparison

The manufacturers and suppliers are in general agreement on the forecast for sintered metallic and nonmetallic brake linings. There are some differences in their 2003 forecasts for carbon fiber and metallic/organic lining materials.



Trend from previous Delphi surveys

This question was significantly changed from previous Delphi studies, yet the current study reinforces a trend from the 1992 Delphi VI survey. The 1992 and 1994 Delphi panels are far less enthusiastic about the potential for advanced brake and clutch friction materials than earlier panels were. Again, as we have noted, the realities of cost, manufacturing and performance of new materials may now make them less attractive than they appeared initially.

Strategic considerations

The attempt to find alternative materials for brake and clutch linings has increasingly been driven by environmental factors. However, it appears that the substitution of environmentally friendly materials for current materials will be a significant challenge for the industry. Brake component performance requirements are critical for safety concerns, and thus new materials must be extremely well proven before engineers are comfortable with them. However, the future of these materials could be significantly affected if environmental requirements change.

Carbon fiber presents a classic case of cost constraints limiting application. The materials has proven effective in Formula 1 racing, but is still too expensive to meet mass production cost constraints.

MAT-36 Approximately 45%* of MY 1992 North American-produced passenger cars and light trucks had styled wheels. What percentage of styled wheels will be made from each of the following materials in MYs 1998 and 2003?

Styled Wheel Materials	Est. 1991*	Median Response		Interquartile Range	
		1998	2003	1998	2003
Passenger car					
Aluminum	68%	90%	89%	75/90%	73/92%
Hybrid (steel and plastic)	0	0	0	0/0	0/0
Magnesium	0	0	1	0/3	0/8
Plastics	0	0	0	0/0	0/2
Steel	13%	10	5	9/11	5/10
Total	81%	100%	95%		
Light truck					
Aluminum	68%	70%	73%	68/75%	65/80%
Hybrid (steel and plastic)	0	0	0	0/0	0/3
Magnesium	0	0	0	0/1	0/5
Plastics	0	0	0	0/0	0/0
Steel	32	25	21	24/30	15/25
Total	100%	95%	94%		

* **Source:** *Wards Automotive Reports*, December 1992 and February 1993.

No comments

Discussion

Aluminum is forecast to continue dominating the styled wheel market. Neither plastic nor magnesium is expected to achieve substantial penetration.

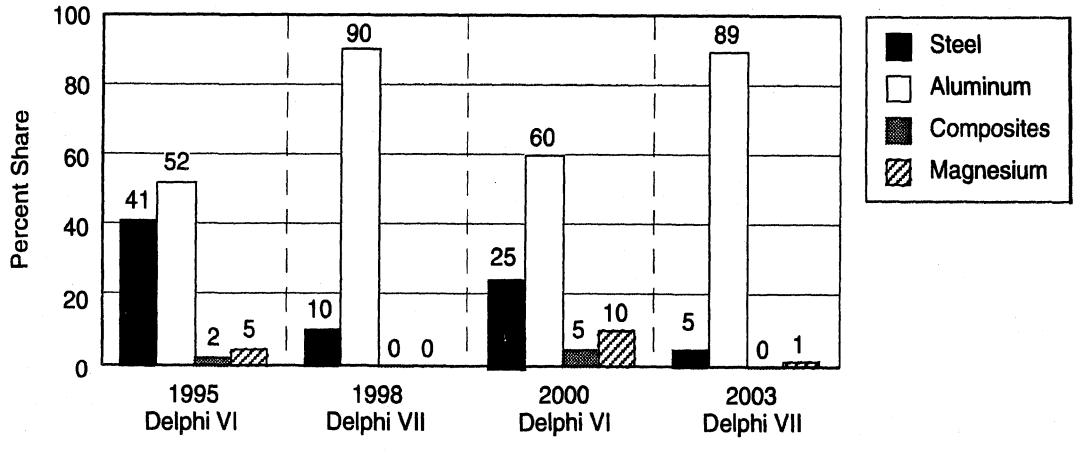
Manufacturer/supplier comparison

The manufacturers and suppliers are in general agreement.

Trend from previous Delphi surveysDelphi V

The 1994 Delphi VII panel differs from previous panels substantially. The current panel forecasts a very strong market position for aluminum, and little for the rest of the materials. The panel appears to have little confidence in plastics or magnesium compared to previous panels.

Materials for Styled Wheels – Forecast*



* Delphi VI study 1992; Delphi VII study 1994

Strategic considerations

Styled wheels, especially those made of aluminum, are increasingly popular. The panel expects aluminum to remain the overwhelmingly most common material for styled wheels. Aluminum offers important characteristics: It is lightweight, easily styled, meets safety requirements, is popular with consumers, and perhaps most important of all, has a history of successful application.

The 1994 Delphi VII panel forecasts magnesium and plastics to gain little or no significant entry into the styled wheel market. Each of these materials have positive attributes, yet they also have potential drawbacks that make them questionable.

It is likely that aluminum will continue to be the dominant material. Yet it is also likely that there will be significant activity regarding plastics, magnesium and steel styled wheels. This activity may well lead to major advances and changes in market penetration.

MAT-37 There is some reluctance to utilize adhesive bonding. Please rate, where 1 = extremely significant, 3 = moderately significant, and 5 = not at all significant, the significance of each barrier in slowing the adoption of adhesive bonding technology.

Adhesive Bonding Barriers	Mean Rating
Quality/durability/reliability	1.6
Manufacturing methodology	2.0
Design understanding	2.1
Environmental plant and recyclability	2.8
Cost	2.9

Selected edited comments

- Adhesive use suffers from an educational concern.
- Serviceability is an issue along with crashworthiness of a repaired vehicle—liability issue in second accident cases.
- Understanding of how and when to use (and not to use) adhesives is imperative.

Discussion

The panel considers quality/reliability/durability to be the most significant challenge for the adoption of adhesive bonding technology. It is important to note that the panel rated each of the listed barriers as at least somewhat significant.

Manufacturer/supplier comparison

The manufacturers and suppliers are substantially in agreement. However, the manufacturers may consider manufacturing as less of a barrier (2.3) than do the suppliers (1.8).

Trend from previous Delphi surveys

This question was not asked in previous Delphi surveys.

Strategic considerations

The implementation of adhesive bonding technologies faces many barriers. The Delphi panel considers the quality/reliability/durability issue to be the most challenging.

The panel also rates design understanding and manufacturing methodology as areas of significant concern for the industry. As with most new technologies, the implementation of adhesive bonding would require the industry to significantly change many of its current practices. The panel suggests that these barriers will be substantial.

The adhesive supplier face a broad range of issues. To be successful, they must work closely with capital tool suppliers, component suppliers and manufacturers to ensure an optimal system solution.

MAT-38 What percentage of North American-produced passenger cars and light trucks will utilize the following bonding/joining technologies in body assembly by the years 1998 and 2003? (No base estimates available).

Bonding/Joining Technologies	Median Response		Interquartile Range	
	1998	2003	1998	2003
Acrylics				
Body panels	0%	5%	0/5%	0/10%
Ornamentation	5	10	2/20	5/40
Glass	5	10	0/5	5/20
Body reinforcements	0	0	0/10	0/10
Hem flanges	2	5	0/10	0/20
Structural	0	0	0/5	0/15
Epoxies				
Body panels	15%	15%	5/25%	10/35%
Body reinforcements	10	15	5/15	10/30
Structural	10	20	0/20	10/35
Hem flanges	20	50	10/95	10/75
Foam tape				
Exterior trim	30%	50%	10/80%	10/90%
Interior trim	30	40	5/50	10/70
Urethanes				
Body panels	10%	20%	5/30%	10/35%
Hems	10	10	0/20	5/25
Stationary glass	90	90	31/98	50/95
Structural	5	20	0/40	3/40

Selected edited comment

- There is no data bank for life-cycle durability. Initial testing seems to demonstrate that *real* time is an important consideration in failure mode. Thus, when a body of knowledge is developed, transition could be rapid. Until then, it will be very slow.

Discussion

The forecast is for very limited penetration for acrylics as a body assembly joining material. However, the panel views as more likely the increased use of epoxies, foam tape and urethanes for body assembly joining in the next decade. The wide interquartile ranges suggest that there is significant uncertainty surrounding these materials and their viability as bonding/joining materials. Further, the large interquartile ranges highlight the presence of large barriers, and the potential for wide scale implementation of these materials, if the barriers are resolved.

Manufacturer/supplier comparison

The forecasts for the manufacturers and suppliers have wide interquartile ranges, and thus must be viewed with great caution. There are several areas where the two panels responses may be substantially different. The supplier panel forecast substantially lower penetration rates for exterior application of foam tape (20 percent in 1998; 30 percent in 2003) than the manufacturers (80 percent in 1998, 90 percent in 2003). The suppliers also forecast lower penetration rates for urethanes application rates on stationary windows (50 percent in 1998; 60 percent in 2003) than do the manufacturers (97 percent in 1998, 95 percent in 2003). For 2003, the manufacturer panel forecast substantially less usage of urethanes in structural applications (3 percent) than did the suppliers (30 percent).

Trend from previous Delphi surveys

This question was significantly different than in previous Delphi surveys, so no direct comparison is possible.

Strategic considerations

There are many concerns surrounding the use of the listed bonding/joining techniques. The industry has limited experience with the application of some of these methods, and therefore has limited data for analyzing their effectiveness. Cost, manufacturabilty, quality and durability of the bonding/joining techniques remain impediments to increased usage of these materials.

Another critical concern is the recyclability of vehicles assembled with these techniques. Disassembly of vehicles that have been joined with adhesives may prove difficult, thus preventing adhesives from gaining acceptance as a body joining material. Still, trends must be monitored closely since powerful technological forces are being directed at solutions and the incentives remain high to replace current fastening techniques. New automotive materials such as aluminum and plastics are, in many respects, dependent on new fastening technology.

MAT-39 What percentage of North American-produced passenger car and light truck manufacturing facilities will use the following paint systems in MYs 1998 and 2003?

Paint Systems	Est. 1992*	Median Response		Interquartile Range	
		1998	2003	1998	2003
Electrocoat					
Current technology	100%	90%	70%	90/95%	10/75%
Lead-free	0	10	30	5/10	25/75
Total	100%	100%	100%		
Primer surface					
None	49%	40%	30%	20/45%	20/40%
Solvent-borne	48	40	30	35/50	20/30
Powder	2	5	10	5/10	10/20
Waterborne	0	10	25	5/12	15/30
Total	99%	95%	95%		
Base coat					
Solvent-borne	81%	70%	50%	70/75%	35/53%
Monocoat/solvent-borne low solids	12	10	10	5/10	5/10
Waterborne	7	20	40	15/30	25/50
Total	100%	100%	100%		
Clear coat					
Conventional solvent melamine	85%	60%	25%	40/70%	5/50%
Solvent-borne etch resistance	15	30	30	20/60	25/55
Powder	0	0	8	0/5	5/10
Waterborne	0	3	10	0/6	5/15
Total	100%	93%	73%		

Other single responses include:

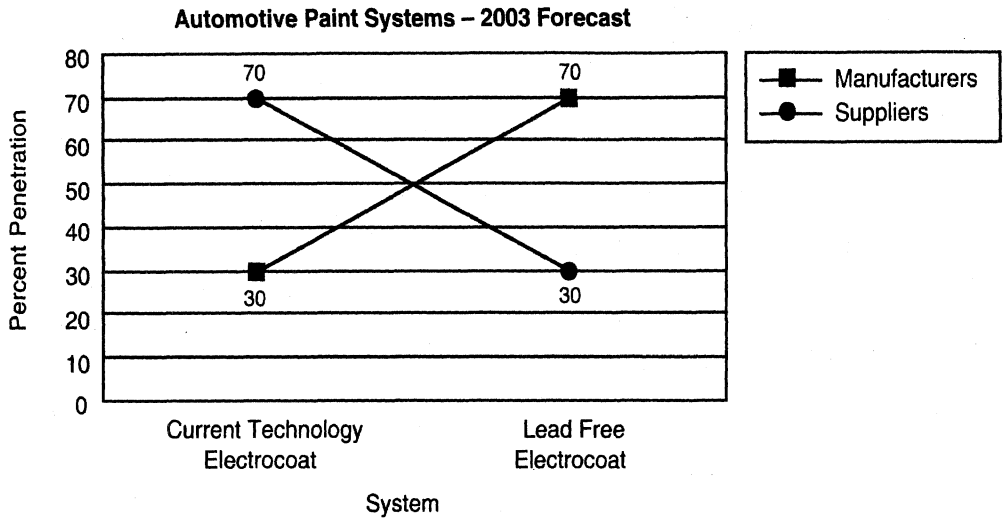
Base coat–Powder: 2003: 10%.

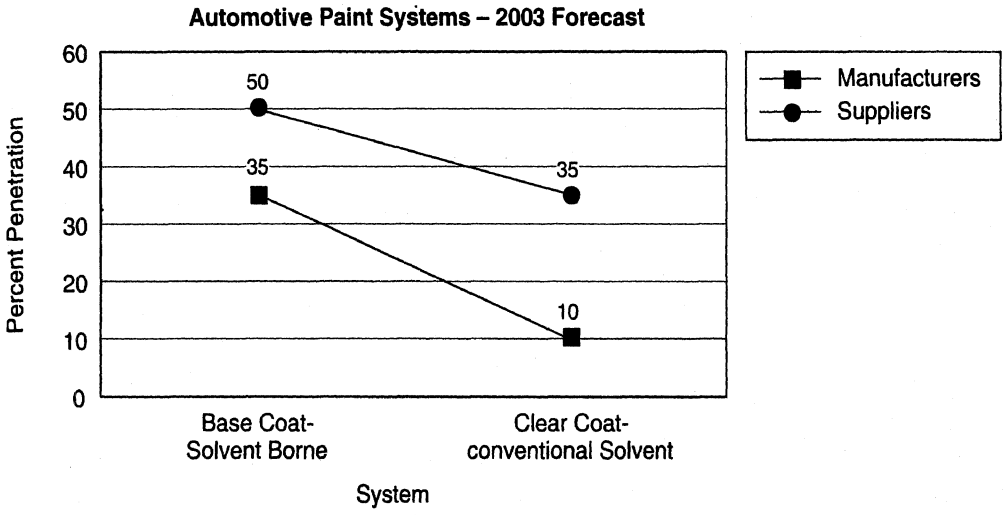
Discussion

Environmental regulations and changing customer demands are forcing significant changes in automotive paint systems technology. The challenge for the automotive industry is to continually increase customer satisfaction regarding paint finish and durability while implementing environmentally acceptable paint application systems within a capital constrained environment.

Manufacturer/supplier comparison

The manufacturers and suppliers generally agree. However, on those technologies where there may be a difference, the manufacturers forecast more broad scale implementation of new paint technologies than do the suppliers. This difference is likely due to the manufacturers being more aware of the current and potential environmental regulations that they face at their paint facilities. Manufacturers may also have a much clearer picture regarding capital expenditure plans and their schedule for converting facilities.





Trend from previous Delphi surveys

This question was changed significantly from previous Delphi studies and therefore comparison is not possible.

Strategic considerations

Airborne chemicals or volatile organic content (VOC) have been a significant byproduct of traditional automotive paint systems. The panel forecast reflects increased pressure to reduce VOC emissions and thus decrease environmental hazards associated with their use. The panel forecasts a significant decrease in the usage of solvent-borne application technology by 2003.

The removal of lead from the electrocoat process is another important environmental challenge for the industry. The panel forecasts continued implementation of a lead-free electrocoat system, in large part due to tightening government regulations.

The task for the manufacturers and their paint system suppliers is not only to overcome the technical hurdles of these more environmentally friendly paint systems, but to do so in a highly capital constrained business environment. The installation of a new paint system can cost hundreds of millions of dollars at each assembly facility and also result in considerable downtime.

Cost alone makes rapid implementation throughout a manufacturer's portfolio of plants difficult. In an attempt to manage these cost and production constraints, manufacturers have tried to install new paint systems during product changes. This strategy allows the company to combine both product change and paint system change downtime. Implementing new paint systems one plant at a time allows the manufacturer to spread the cost of converting all facilitates over several years. Due to the long product cycles of the automobile industry, ranging from four to 10 years, it may take full-line manufacturers at least a decade to convert all facilities.

Manufacturers are also striving to increase customer satisfaction with new paint system technology. Acid rain reduces the durability of motor vehicle clear coats. The development of etch resistant clear coat

technology is a response to customer dissatisfaction with the current level of protection. All in all, the changes in exterior coating technology are very significant and one of the most important product/manufacturing changes the industry must address.

MAT-40 Taking into consideration expected changes in body materials, paints and other coating technologies, and growing environmental and energy concerns, what is the lowest maximum oven curing temperature likely by the year 1998?

Lowest maximum oven curing temperature by 1998	
Median Response 250^0 F	Interquartile Range 220/300^0 F

No comments

Discussion

The panel forecast for lowest minimum oven temperature suggests little change from current standards.

Manufacturer/supplier comparison

There may be a substantial difference between the manufacturers forecast (200^0 F) and the suppliers forecast (275^0 F). For this question, it is likely that the manufacturers have better information regarding this critical temperature point and their response may be a better estimate of the future trend.

Trend from previous Delphi surveys

The 1994 Delphi VII panel has been substantially more conservative than previous panels, and its forecast for paint oven temperatures is no different. Its forecast (250^0 F) is higher than the 1992 Delphi VI forecast (225^0 F).

Strategic considerations

The technology is available to substantially lower the temperature of top coat ovens. However, benefits of the lower temperature ovens may not currently justify the increased costs.

There are several materials issues that are involved in decreasing the lowest minimum top coat oven temperatures. Plastics, materials that are central to the oven temperature issue, are currently engineered to meet the demands of top coat ovens now in use. However, any decrease in temperature would likely lead to less shrinkage and warpage, and possibly allow for better fit and finish. Adhesives and sealers also may need to be reformulated to reflect the lower top coat oven temperatures. This is not necessarily bad news for adhesives, however.

MAT-41 Please indicate how materials will influence the improvement of future customer satisfaction over the next 10 years for body and chassis.

Customer Satisfaction—Materials Issues	Percent of Responses
Body–Exterior	
Quality/Reliability/Durability	
Improved corrosion resistance	15%
Improved dent/ding resistance	6
Weight reduction	5
Improved environmental/etch resistance	5
Improved paint durability; Improved scratch resistance	2% each
Improved abrasion resistance; Improved chip resistance	
Recycling; Improved welds/joints; Improved durability of body panels with flexible SMC and thermoplastics; Improved aging characteristics; Improved solar control glazing systems; Improved fit	1% each
Appearance	
Distinction of image	6%
Improved paint appearance; Glass	2% each
Improved formability; Minimize tolerance for gap, fit, finish	1% each
Body–Interior	
Quality/Reliability/Durability	
Eliminate squeaks and rattles	4%
Reduce windshield fogging; NVH management	2% each
Recycling	1
Appearance	
Increase luxurious looks; Decrease cheap-looking plastics; Increase "soft feel" textures	1% each
Chassis	
Quality/Reliability/Durability	
Improved corrosion resistance	5%
Weight reduction	2
Recycling	1
Noise/Vibration/Harshness	
Increase use of damping materials	4%
Magnesium steering wheels; Magnesium wheels	1% each
Performance	
Weight reduction	6%
Tighter dimensional control	1

Discussion

Panelists note many areas in which materials could influence the improvement of customer satisfaction. The thr0ee areas most frequently mentioned are corrosion resistance, weight reduction and paint durability.

Manufacturer/supplier comparison

This comparison is not done for open-ended questions.

Trend from previous Delphi surveys

This question was not previously asked.

Strategic consideration

The panel has identified a number of materials issues that are currently customer "dissatisfiers." In many instances, technologies are available to significantly reduce or eliminate these problems. However, cost remains a major barrier to implementation. In many cases the higher cost does not appear to be

recoverable in the marketplace. Future implementation of such technologies bears close watching. The market is rapidly changing, and many "on the shelf" technologies may become required for future vehicle programs to meet customer or regulatory requirements.

Paint durability can have a profound effect on corrosion protection. Any improvements in corrosion resistance, specifically corrosion due to stone chipping and parking lot damage, will probably come from paint durability improvements.

Weight reduction also appears significant to increasing customer satisfaction. Decreased weight can improve performance and fuel economy and enhance ride characteristics in some situations. However, manufacturers continue to struggle with the cost-benefits associated with weight reduction. Currently, customers appear unwilling to forgo vehicle size to reduce weight. Therefore, weight reduction is preferred through use of lightweight materials and improved design techniques with conventional materials. Increased CAFE requirements, or higher gasoline taxes, could make the higher cost materials more competitive. Developments must be closely monitored.

Recycling Issues

MAT-42 The recyclability of automotive materials and related environmental concerns will be significant issues confronting the entire industry in the upcoming decade. With regard to recycling, what factors do you think are, or will become, recycling barriers to the utilization of materials within the listed categories? Where 1 = most important, 3 = somewhat important, and 5 = least important.

Potential Recycling Barriers	Plastics/Polymers			Nonferrous metals			Ferrous metals
	Unreinforced Thermoplastics	Reinforced Thermoplastics	Thermosets	Aluminum	Copper	Zinc	
Alloy content/ contamination	2.8	2.3	3.0	2.7	2.9	2.8	3.9
Automated processing/ separation of materials, e.g., density gradient	2.5	2.5	2.6	3.6	3.1	3.1	3.9
Dismantling/disassembly	2.1	2.2	2.3	3.0	3.1	3.0	3.7
Ease of materials separation	2.0	1.7	1.8	3.0	2.9	2.8	4.1
Economics of reclamation/recycling process	1.6	1.4	1.3	2.7	2.7	2.6	3.1
Energy required for recovery	3.1	2.7	2.6	3.2	3.0	3.0	3.4
Energy required to process raw material	3.4	3.4	3.3	2.7	3.2	3.3	3.3
Environmentally safe disposal	2.4	2.3	2.2	3.7	3.4	3.0	3.7
Industrial environment/ health issues	3.0	2.8	2.8	3.6	3.6	3.2	3.7
Labeling/identification	2.4	2.2	2.4	3.8	3.9	3.9	4.2
Lack of design for disassembly	2.5	2.3	2.2	3.1	3.3	3.4	3.6
Lack of labor skills for parts disassembly	3.3	3.3	3.3	4.0	4.0	3.9	3.8
Landfill availability and cost	2.2	2.1	2.1	3.5	2.8	3.4	3.7
Limited reapplication potential of recovered material	2.3	2.2	2.2	4.3	3.8	3.7	4.1
Recycling infrastructure/logistics	1.6	1.5	1.6	3.3	3.4	3.1	3.6
Scrap value	2.2	2.2	2.1	3.3	3.0	3.0	3.1

Selected edited comments

- Economics is the issue. Regulations will drive prices of raw materials, thus, mandatory responsibility will drive price of non-recyclables way up (thermosets) and the price of thermoplastics down (25 percent back into new raw materials).
- The infrastructure to reclaim and recycle aluminum from automobiles is already well established. For the most part, alloy mixture will not be a major problem. Some obvious disassembling methods will keep alloys segregated (e.g., wheels from engines and body panels from castings).

Discussion

The automotive industry faces many challenges in implementing recycling. Generally, the panel expects plastics to face more, and larger hurdles, than ferrous or nonferrous metals. Economics of reclamation/recycling and the recycling infrastructure for plastics are viewed as especially troublesome by the panel.

Manufacturer/supplier comparison

There is substantial disagreement about the importance of various barriers. The suppliers view barriers for nonferrous metals as more important than do the manufacturers. Conversely, the manufacturers are more concerned than are the suppliers regarding reinforced plastics and thermosets, and the labeling and energy required to process those materials. Both panels agree that the three most important barriers to successful recycling are ease of materials separation, economics of reclamation/recycling process and recycling infrastructure/logistics. Suppliers also view dismantling/disassembly, landfill availability and cost, and environmentally safe disposal as greater barriers than do the manufacturers across all values. Finally, the suppliers forecast the labeling/identification barrier as more important for copper and zinc, and less important for plastics than do the manufacturers.

	Manufacturers						
Potential Recycling Barriers	Plastics/Polymers			Nonferrous metals			Ferrous Metals
	Unreinforced Thermoplastics	Reinforced Thermoplastics	Thermosets	Aluminum	Copper	Zinc	
Dismantling/disassembly	1.9	—	2.1	2.8	2.6	2.5	—
Energy required to process raw material	—	3.6	3.5	—	—	—	—
Environmentally safe disposal	—	—	—	—	3.1	—	3.4
Industrial environment/ health issues	—	—	—	—	—	2.9	—
Labeling/identification	—	2.4	2.8	—	3.6	3.6	—
Landfill availability and cost	—	—	—	3.4	3.0	3.2	3.4
Recycling infrastructure/logistics	—	—	—	—	3.1	—	3.3
Scrap value	—	—	—	—	2.7	2.6	—

	Suppliers						
Potential Recycling Barriers	Plastics/Polymers			Nonferrous metals			Ferrous Metals
	Unreinforced Thermoplastics	Reinforced Thermoplastics	Thermosets	Aluminum	Copper	Zinc	
Dismantling/disassembly	2.5	—	2.1	2.8	2.6	2.5	—
Energy required to process raw material	—	3.0	2.9	—	—	—	—
Environmentally safe disposal	—	—	—	—	3.8	—	4.1
Industrial environment/ health issues	—	—	—	—	—	3.4	—
Labeling/identification	—	1.6	1.5	—	4.2	4.3	—
Landfill availability and cost	—	—	—	4.0	3.9	3.9	4.4
Recycling infrastructure/logistics	—	—	—	—	3.8	—	4.0
Scrap value	—	—	—	—	3.5	3.5	—

The lines of disagreement of the two groups further reinforce the differing views that recur throughout the current study. The manufacturers tend to view plastics less favorably than do the suppliers. This presents serious challenges—and opportunities—for the supplier community. Plastics suppliers should work diligently to inform manufacturers not only of the many advantages of plastics, but also the technologies and processes that will lead to environmentally friendly application. Companies that supply materials that compete with plastics must move quickly to take advantage of the uncertainty that the manufacturers may have with plastics. There is a great deal of activity within the resins supplier community, and it is likely that the near future will see dramatic increases in the availability of economically viable and recyclable plastics.

Trend from previous Delphi surveys.

This question was changed significantly from previous Delphi studies so comparison is not possible.

Strategic considerations

A number of recycling factors are currently, or will soon be, important factors in the utilization of most materials. The prevailing view is that plastics present the greatest challenge and opportunities for vehicle recycling. Panelists view the recycling infrastructure, economics of recycling, ease of separation, and identification as key barriers to successful recycling.

Recycling has become very topical in recent years. In response to this increased interest, efforts to increase the recyclability of materials and expand the recycling infrastructure have been given a greater deal of publicity. It is likely that some form of government policy will be needed to make recycling economically viable for some materials. Therefore it is important for industry to work proactively with government to develop a realistic and effective recycling infrastructure. Recycling, like many other industry challenges, should look beyond the traditional solutions and attempt to broaden the base of knowledge.

While recycling and life cycle issues are presently, and likely will continue to be, focused on plastics, metals are not immune from consideration. Still, a majority of metals in automobiles are efficiently reclaimed by the infrastructure already in place.

MAT-43 **Recycling/disposition involves a complex set of stages and issues. Please indicate your view of the degree of challenge each of these methods presents to effective recycling/disposition, where 1 = extremely severe challenge, 3 = somewhat severe, and 5 = not at all a challenge.**

Method	Mean Rating
Thermoplastics	
Closed loop recycling*	2.4
Heat recovery	3.3
Open loop recycling **	3.4
Thermosets	
Closed loop recycling*	1.9
Heat recovery	3.1
Open loop recycling **	2.9
Ferrous	
Closed loop recycling*	3.7
Heat recovery	3.1
Nonferrous	
Closed loop recycling*	3.3
Heat recovery	3.0

* Same application
** Less demanding applications—also referred to as cascade recycling.

Selected edited comments

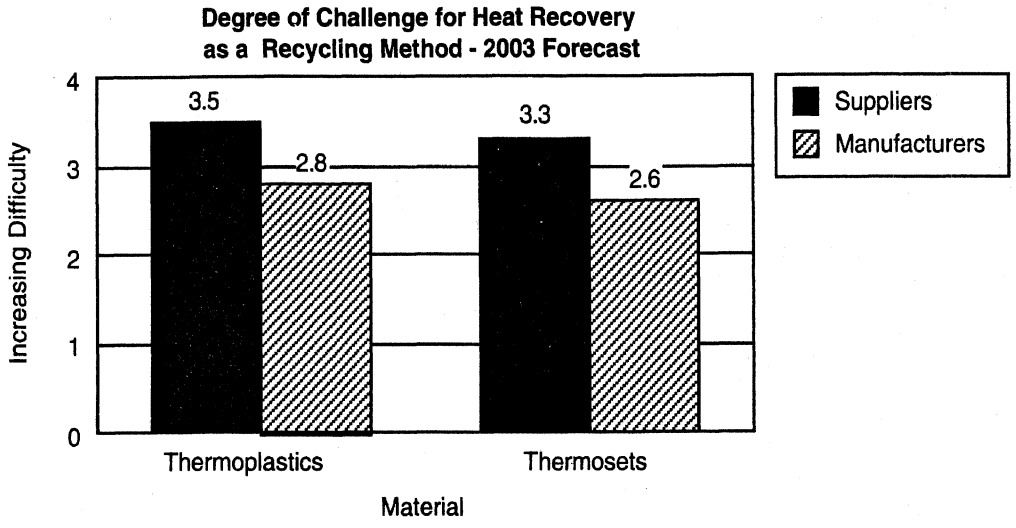
- Closed loop recycling of ferrous and nonferrous is being done now. Foundries are the best recyclers!
- Heat or energy recovery of plastics is a political challenge rather than a technical challenge.
- Open loop recycling has a cascading effect.
- Politics and landfill cost (environmental awareness) are big drivers. Germany and Austria have made huge strides in a very short time on all recycling. Automotive is quickly following.
- The degree of severity of the challenge depends on the material. Heat recovery applies to some plastics while closed loop is next to impossible for them. Heat recovery doesn't apply to metals while closed loop is a reality for many.
- There are air pollution concerns about heat recovery, and the process can adversely affect painted and adhesively bonded parts.
- What is break even of recycle cost plus market value vs. virgin production cost? Recycle value is a critical driver.

Discussion

The industry faces a challenge of developing secondary markets for many reclaimed materials. The response to this question shows that the panel views closed loop recycling as presenting a severe challenge for thermosets and thermoplastics. Open loop recycling and heat recovery, while still presenting many serious challenges, are seen as more viable than closed loop recycling.

Manufacturer/supplier comparison

Overall, the manufacturers view the list of recycling methods as more challenging than do the suppliers. The manufacturers view heat recovery for thermoplastics and thermosets as substantially more of a challenge than do the suppliers. As in other questions, the manufacturers tend to be more concerned than are the suppliers about to the viability of plastics recycling.



Trend from previous Delphi survey

This question has been significantly changed from previous Delphi surveys.

Strategic consideration

Panelists forecast closed loop recycling for thermosets and, to a lesser degree, thermoplastics to present severe recyling challenges in the next decade. This further confirms that plastics face at least a perceived barrier to recycling.

Heat recovery presents an environmental rather than technical problem. While significant advances have made heat recovery technology at least partially feasible, there are continuing air quality concerns. The technology clearly suffers from the "not in my backyard" syndrome.

It is interesting to note that the manufacturers view closed loop recovery for ferrous metals as more of a concern than do the suppliers. Even within the industry, many people believe steel reclaimed from discarded automobiles is recycled into new cars. In reality, there is a significant amount of reclaimed metals that can not be reused in equivalent applications. Until recently, almost no recycled steel was used in class A surfaces, but recent technological advances are changing that. The development of the thin slab caster process is potentially a major step toward closing the loop for class A finish surfaces. Thin slab processing and other similar technologies need to be watched closely since advances could have a significant impact on the steel industry.

MAT-44 Relative to plastics usage in the next decade, how likely are the auto manufacturers to undertake each of the following actions, where 1 = extremely likely, 3 = somewhat likely, and 5 = not at all likely?

Action	Mean Forecast
Pass through recycling requirements to suppliers	2.1
Restrict the amount of unrecyclable plastics in the vehicle	2.1
Restrict the number of types of plastics in the vehicle	2.4
Restrict the amount of plastics in the vehicle	3.6
Substitute lightweight metals for trim plastics	3.8
Substitute lightweight metals for structural plastics	4.3

Selected edited comments

- All plastics are recyclable; it's a matter of degree and the plastic recyclate value.
- Passing the cost of recycling to the supplier will drive up the cost of nonrecyclable materials and drive down the costs of recyclable materials (steel is there, as is aluminum, and thermoplastics are next). Modification of specification/expectation at the OEM are needed to drive change. Focus on performance, not composition.
- The current trend is to replace light metal with plastics.
- Unrecyclable plastic is an assumption. Currently I do not believe that OEMs are indicating that any plastic is unrecyclable.
- "Unrecyclable plastics" must be defined. Even a thermoset plastic such as RIM can be reused/recycled. It seems all plastics are recyclable whether they are reused as the same application, downgraded to other products, or energy recovered or reproduced into "oil form."

Discussion

The panel views the substitution of lightweight metals for plastics as unlikely. However, the panel also strongly believes that manufacturers will require suppliers to play an active role in the development of a plastics recycling strategy and will further restrict the types of plastic in the vehicle.

Manufacturer/supplier comparison

Manufacturers and suppliers are essentially in agreement.

Trend from previous Delphi surveys

This question is significantly changed from previous Delphi surveys.

Strategic consideration

The issue of plastics recycling appears to be growing in importance, and may well become a significant consumer purchase criteria in the future. Therefore, plastics that are easily recycled will be given priority in the material selection process. Price, quality, reliability, durability and safety will remain critical selection criteria.

The panel expects manufacturers to pass through recycling requirements to suppliers. There has been much discussion within the industry as to who will be held responsible for the development of a recycling infrastructure. Many suggest the manufacturers should take the lead since they are more visible. Others suggest that resin suppliers should take the lead because they have key technological knowledge and a business to defend. Whatever the outcome, it is likely that the resin supplier industry will need to be increasingly pro-active in developing more environmentally friendly materials including recycling technologies. To their credit, many resin suppliers are aggressively attacking the issue.

Our panelists also view restrictions on unrecyclable plastics as likely. The comment, "Currently, I do not believe that the OEMs are indicating that any plastic is unrecyclable" is an interesting one. From a technical point, the comment is correct. However, technical feasibility is far different from economic feasibility. Most plastics are in some form recyclable, yet the limited availability of secondary applications or the expense of reclamation often prevents economically viable recycling. Technologies and markets are changing rapidly, and what is now not viable, may quickly become so.

The panel does not expect lightweight metals to replace plastics in either trim or structural applications. The potential disadvantages associated with recycling do not currently outweigh attributes of plastics that made it the material of choice for many applications.

MAT-45 Please indicate your view of the probability and the usefulness of each of the following possible government recycling requirements/incentives over the next decade, where 1 = extremely probable or useful and 5 = not at all probable or useful.

Infrastructure	Usefulness	Probability
"Take back" regulations making manufacturer responsible for final product disposition	3.4	3.0
Disposition certificates, including final disposal	3.3	3.1
Location incentives for disassembly facilities	2.7	3.2
Tax credits for disassemblers	2.4	3.0

Technology	Usefulness	Probability
Use of federal laboratories for R&D	2.8	2.8
Technology transfer credits to ensure universal availability of recycling technology	2.7	3.2
R & D tax incentives	2.6	3.1

Financial	Usefulness	Probability
Consumer deposit on cars	3.6	3.9
Petroleum/natural gas tax increases	3.2	2.5
Incentives/credits based on recycled content	2.7	3.2

Selected edited comments

- Government directed regulation of recycling is less likely than a trickle down of environment regulation. Disposal issues will force change, and automakers are not prepared. The long development cycle creates reactive behavior.
- Tax credits subsidize dismantlers, but the real issue is developing markets for recycled materials.
- The "green movement" will pressure the auto makers to be more aware of recycling. However, auto makers are price/cost driven and are not overly environmentally concerned except when faced by law. The most economically viable material to recycle in the auto is, and will remain, aluminum. Steel is not difficult to recycle, but carries a weight penalty in the energy consumption of the auto during its useful life. Foreign nameplates have the potential to upstage North American autos due to the ethic of reuse and limited disposal in their home countries. The first lightweight, full size, crashworthy, recyclable auto will come from offshore sources, not North America. North America will then need to catch up again.

Discussion

The panel views each of the possible government recycling requirements or incentives as somewhat possible. Consumer deposits on cars is viewed as both the least useful, and the least probable. Tax credits for disassemblers is ranked as the most useful, while petroleum/natural gas taxes are viewed as the most probable.

Manufacturer/supplier comparison

The panels are in close agreement on all of the possible government recycling requirements/incentives except for use of federal labs for R&D and the issuance of disposition certificates. Manufacturers are substantially more confident that the national laboratories will be both useful and probable. The manufacturers also view the issuance of disposition certificates as more useful than the do the suppliers, but are no more convinced that such actions will be implemented.

It is important to note the difference between the two panels regarding national labs. The manufacturers have had significant contact with the national labs and are beginning to learn how to leverage them as a critical resource. Suppliers, with far less technical resources than manufacturers, have been slow to approach the national labs.

Trend from previous Delphi survey

This question was not asked in any previous Delphi survey.

Strategic consideration

As a panelist stated, "The 'green movement' will pressure the automakers to be more aware of recycling." Manufacturers and suppliers must jointly and aggressively address and resolve the recycling issues confronting the industry. This should be done in cooperation with government. However, because of the long product cycles and development times, implementation of a well-thought-out recycling strategy might not be acceptable to some. We are concerned that special interest groups may not have the patience to allow the automotive industry to implement recycling strategies in an orderly manner. Therefore it is essential that the industry work closely with government to develop a recycling strategy and implement it as promptly as possible while taking pains to communicate all aspects of the issue to the public.

There are three areas where the panel's view of usefulness and probability differ substantially. The panel views incentives, either for the location of disassembly facilities or for operation of such facilities, as far more useful than probable. The development of a recycling infrastructure is a major concern. Recycling—specifically the dismantling process—is not currently economical, and incentives to develop the infrastructure will be needed. Conversely, the comment "Tax credits subsidize dismantlers, but the real issue is developing markets for recycled materials" has considerable merit. For automotive recycling to be successful, there must be markets for reclaimed materials. Only with the development of secondary markets, closed or open loop, will recycling and true life cycle management be successful.

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Definitions

Light truck. Includes sport utilities, vans and pick-up vehicles.

M.Y. Model Year. When a year(s) is referenced in a given question, it always refers to model year(s) unless otherwise specified.

North American-produced passenger cars and light trucks. Refers to all vehicles produced in the United States and Canada.

Traditional Domestic or Big Three. Refers to all U.S.-headquartered (parent company) manufacturers or dealership networks regardless of production location (i.e., forecast for General Motors should include NUMMI-produced Prisms and imported Metros).

Quality/Reliability/Durability (QRD). Encompasses any customer dissatisfaction for which he/she would take their vehicle back to the dealership.

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