UNIVERSITY OF MICHIGAN
TRANSPORTATION RESEARCH INSTITUTE

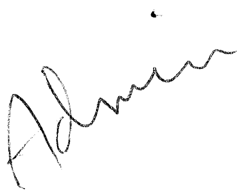
Forecast and Analysis of the North American Automotive Industry

For 2004 and 2009

Delphi X: Tenth in a Series

TECHNOLOGY
MATERIALS
MARKETING

Office for the Study of Automotive Transportation



Delphi X Forecast and Analysis
of the
North American Automotive Industry

VOLUME 2: MATERIALS

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Brett Smith was employed as a Senior Research Associate at OSAT for much of the Delphi X project. He completed the project as a Senior Industry Analyst for the Center for Automotive Research at the Environmental Research Institute of Michigan.

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FOREWORD

Delphi X 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, or marketing. For the first time in a Delphi report, the panelists also includes top automotive dealers. 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 tenth in a series of in-depth studies of long-range automotive trends. The study began as Delphi I in 1979 and continued with Delphi II in 1981, Delphi III in 1984, Delphi IV in 1987, Delphi V in 1989, Delphi VI in 1992, Delphi VII in 1994, Delphi VIII in 1996, and Delphi IX in 1998. With Delphi X, a new approach has been implemented to stagger the release of the three volumes. Each will now be released within a year (instead of two) of its start date, but not all on the same date.

The Office for the Study of Automotive Transportation (OSAT) collects the data and analyzes, interprets, and presents the results. Because the forecasts are those of the panelists, Delphi X 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 likely will be. In retrospective review, some areas (such as gas prices) have been predicted less accurately than others; yet the views of what the future will be influence decision makers of today.

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 developments in technology, materials, and marketing within the industry, and to analyze the 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 we do not mean 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's Office for the Study of Automotive Transportation 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. This ensures that respondents 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 Delphi report, all questionnaires and lists of panelists are destroyed.

The characteristics of the 59 Materials X panel members are as follows: 12 percent of the technology panel consisted of CEOs, presidents, or vice presidents; 31 percent were directors and executives, 55 percent were managers, supervisors, chief engineers, engineers, senior technicians, or specialists; and 1 percent of the panel was made up of consultants. Approximately 41 percent of the Delphi X panelists were employed by vehicle manufacturers; 58 percent by components and parts suppliers; and 1 percent were others (e.g., consultants and representatives of associations and publications).

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 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 an 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.

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.

Results summary. 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 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 that 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 X panelists include respondents from North American automotive manufacturers; 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 manufacturers (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.

Trend from previous Delphi surveys. A single Delphi survey is a snapshot that 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 their relevance and importance to strategic planning. The forecasts reflect the consensus of expert opinion based 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 X 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.

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EXECUTIVE SUMMARY

The North American automotive industry faces a decade of challenge and change. The *2000 Delphi X Forecast and Analysis of the North American Automotive Industry: Materials* publication identifies many of the challenges and opportunities facing industry participants. In doing so, the Materials volume presents an opportunity for companies to benchmark their vision of the future against that of an industry consensus.

The Materials volume is divided into six sections: strategic planning factors, strategic materials considerations, total vehicle, powertrain/drivetrain, body/chassis, and recycling. This summary highlights the key results from the 2000 Delphi X: Materials volume.

I. STRATEGIC PLANNING FACTORS

The panel forecasts the price of regular unleaded and premium gasoline to increase at an average rate of 6.3 percent annually and 5.8 percent during the next decade (MAT-1). The forecast indicates the panelists generally do not expect a significant disruption in the supply of oil in the coming decade. Panelists forecast reformulated gasoline to account for 50 percent of all gasoline sold by 2004, and 70 percent of all gasoline sold by 2009 (MAT-3).

The automotive industry enters the 21st century amid much talk of a new powertrain paradigm. The internal combustion engine, which has been the driving force for the first 100 years, may become obsolete in the coming decades. Panelists forecast diesels and electric-hybrid powertrains to see slightly increased application in the coming decade. Panelists indicate that propane, natural gas, and electric appear to offer little short-term potential application. Although each alternative power source has seen limited success in fleet applications, there appears to be little likelihood that it is viable in mass markets (MAT-5).

Both industry and society face many difficult challenges in the coming decade. The development of safer and cleaner vehicles is a top priority for both industry and government. Panelists forecast that regulations for alternate fuel/power sources, occupant restraint/interior safety, vehicle emission standards, fuel economy standards, and vehicle integrity/crashworthiness will be much more restrictive by 2009 (MAT-6).

II. STRATEGIC MATERIALS CONSIDERATIONS

Panelists forecast that federal legislation or regulation is extremely likely for the disposal of automotive fluids, the disposal of used tires, and the establishment of uniform identification/ coding standards for materials to facilitate recycling. Federal legislation/regulation for all listed areas is viewed as at least somewhat likely by 2009 (MAT-7).

Panelists forecast that the cost of raw materials and their processing (1.2) will be the most important material selection criteria in the coming decade. Weight, design/styling requirements, formability, safety considerations, warranty costs, and field experience will also be very important selection criteria in the coming decade (MAT-8).

III. TOTAL VEHICLE CONSIDERATIONS

Panelists forecast a reduction in vehicle weight of 3.5 percent in passenger cars and 3.0 percent for light trucks by 2004. They forecast a 10 percent weight reduction for both passenger cars and light trucks by 2009 (MAT-13).

The panel was asked to forecast passenger car and light truck material changes in the coming decade. For passenger cars, the panel was given one CAFE level for 2004 and two for 2009. For light trucks, the panel was given one CAFE for each year, 20.7 for 2004 and 24 for 2009 (MAT-14).

The two passenger car CAFE scenarios for 2009 present evidence that the panel expects mass reduction through material substitution. For the 30 mpg scenario, the panel forecasts low carbon steel and cast iron to decrease by 10 percent and 12.5 percent respectively. Aluminum and plastic are forecast to increase by 17.5 percent and 10 percent respectively. For a 35 mpg CAFE in 2009, low carbon steel and cast iron are forecast to decrease by 15 percent and 20 percent respectively, while aluminum and plastic are forecast to increase by 35 percent and 20 percent respectively. For light trucks in 2009, the panel forecasts a reduction of 15 percent and 20 percent for low carbon steel and cast iron respectively, and a increase of 25 percent for aluminum and 12.5 percent for plastics.

Panelists predict substantial growth for polypropylene (20 percent), TPO (17.5 percent), and polyester thermoset (12.5 percent) in the coming decade. Polyester thermoplastic and polyethylene are also forecast to increase by approximately 10 percent. According to the panel, ABS (-4 percent) and PVC (-10 percent) are expected to see decrease usage by 2009 (MAT-15).

IV. POWERTRAIN AND DRIVETRAIN

Panelists estimate that 95 percent of passenger car cylinder heads and 70 percent of cylinder blocks will be made from aluminum in 2009. The panelists forecast 85 percent of light truck cylinder heads and 35 percent of cylinder blocks will be cast from aluminum by 2009 (MAT-19). Panelists forecast that by 2009, 80 percent of aluminum engine blocks will be sleeved, 14 percent will be unsleeved and coated, and 5 percent will be unsleeved (MAT20).

The automotive industry continues to substitute lightweight materials for cast iron and steel in many engine applications. As components made from alternative materials approach manufacturing scale economies, these materials may more rapidly become the industry standard. Panelists forecast as moderately likely that steel will reach 20 percent application rate for camshafts by 2009 and that steel/powdered metal camshafts will reach 25 percent application rate by 2009 (MAT-23). Panelists forecast as moderately likely that steel will reach 55 percent application rate for crankshafts by 2009. According to panelists, performance and durability characteristics of steel crankshafts are drivers of the shift from cast iron to steel (MAT-24).

Panelists forecast increased application of ceramics in all listed components. Connecting rods (60 percent) and valve seat inserts (60 percent) are components where powdered metal is forecast to see the highest application. However, the wide interquartile ranges indicate a great amount of uncertainty or disagreement among panelists regarding the future application of powdered metals in these engine components (MAT-29).

The panel forecasts plastic to be the dominant fuel tank material by 2009. Stainless steel is also expected to see initial application. The panelists indicate that further development of plastic fuel tank layering materials and strategies, and sealing technologies, are necessary to meet increasingly stringent emission regulation (MAT-31).

V. BODY AND CHASSIS

Panelists forecast little change in frame construction for passenger cars and minivans in the coming decade. However, they forecast a significant increase in unibody frame construction for sport utilities. The sport utility market continues to undergo significant change. Many of the initial entries (MAT-34) were engineered from existing pick-up truck platforms. However, many new entries—specifically in the subcompact, midsize and luxury segments—are unibody designs. In fact, although many of these new vehicles are considered sport utility vehicles, they are often more similar to passenger cars than the traditional body-on-frame SUV. Steel is forecast to remain the dominant frame material for unibody construction in the coming decade. However, aluminum is forecast to see application as a frame material (15%) and space frame material (20%) by 2009 (MAT-35).

According to panelists, steel is expected to continue to be the dominant material for body panels. However, aluminum is predicted to see increased application for hoods (22.5 percent) and decklids (17.5 percent). Plastics are forecast to see increased application for fenders (15 percent) and doors (10 percent). The panel also forecasts increased usage of high strength steel for quarter panels (15 percent), hoods (15 percent), doors (20 percent), and decklids (10 percent) (MAT-36).

For light trucks, aluminum is expected to see significantly higher penetration rates for hoods (30 percent) and rear hatches (17.5 percent). Plastic is forecast to see significant growth in truckbed applications (20 percent). High strength steel is forecast to see increased usage for doors (17.5 percent), hoods (10 percent), and truckbed/liftgates (10 percent).

Panelists rate steel as advantageous over other listed materials in the raw material cost, component processing, and assembly stages of the vehicle life cycle. The panel rates thermoplastics and thermosets as slightly more advantageous than aluminum in the design stage (MAT-37).

The panel foresees little or no application of polycarbonate as an alternative window material by 2004. However, panelists do forecast limited penetration of polycarbonate for side and rear window applications by 2009. They also forecast increased application of special coatings and interlayers to reduce solar load and to provide defrosting capabilities in the coming decade (MAT-55).

Panelists forecast aluminum wheels to account for 88 percent of styled wheels for passenger cars, and 82.5 percent for light trucks in 2009. Steel is forecast to see slightly reduced application rates for both passenger car and light truck styled wheel applications in the coming decade. Hybrid (steel and plastic, 5 percent), magnesium (3.5 percent), and plastic (0.5 percent) are forecast to see limited application for passenger car styled wheels. The panel forecasts no usage of plastic styled wheels for light trucks (MAT-56).

The panelists forecast increased application in the coming decade of lead-free electrocoat, and increased powder and water-borne primer surfacer. They also forecast increased usage of water-borne topcoat/basecoat and powder-based clearcoat. The panel forecasts initial application of powder and water-borne clearcoat in the coming decade (MAT-57).

VI. RECYCLING ISSUES

Panelists expect the recyclability of thermosets and, to a lessor extent, thermoplastics to continue to present significant challenges to the industry. The panelists expect closed-loop recycling of thermosets to present an extremely severe challenge. Conversely, the panel does not expect the recycling issue facing ferrous and nonferrous metals to present significant challenges in the coming decade (MAT-61). Panelists expect manufacturers to take action restricting the number of plastics in the vehicle and pass on recycling requirements to suppliers (MAT-62).

Summary: The *2000 Delphi X Forecast and Analysis of the North American Automotive industry: Materials Volume* presents many challenges and opportunities for the industry. The materials panel has identified several factors that will likely drive the material selection process during the coming decade. Standing out among those factors is the challenge to continue to drive cost reduction throughout the vehicle. Yet it is also clear that the panel believes that the trend toward lighter-weight materials will continue in the coming decade.

I. STRATEGIC PLANNING FACTORS

MAT-1 Please estimate U.S. retail fuel prices per gallon for 2004 and 2009, including fuel tax. (Please use constant 1998 dollars without adjusting for inflation.)

UNLEADED GASOLINE	ESTIMATED	MEDIAN RESPONSE		INTERQUARTILE RANGE	
	1998*	2004	2009	2004	2009
REGULAR	$1.07	$1.45	$1.75	$1.30/1.57	$1.54/2.05
PREMIUM	1.26	1.65	2.00	1.50/1.84	1.75/2.43

*Source: U.S. Energy Information Administration, National Average, Jan. - Nov. 1998

SELECTED EDITED COMMENTS

Increase

- 2004 estimate reflects next oil crunch, which will narrow the gap between regular and premium. 2009 reflects response to 2004 prices (less growth in demand).
- After 2000, increasing global energy use will put pressure on supply and the price of crude will go up.
- Assume increased taxes and higher base energy cost.
- Gas tax will be imposed to reduce fuel consumption. Will be legislated instead of artificial manipulation proposed to significantly increase CAFE - especially for trucks.
- Prices could be higher in case of Middle East conflict or supply disruption.

No change or decrease

- I don't anticipate a dramatic change in fuel prices.
- As alternatives to gas become more prevalent and eventually mainstream, the demand for gas will decrease and, therefore, the cost will not continue to rise. Alternative sources of fuel are not estimated to be mainstream until after 2004.

RESULTS SUMMARY

The panel forecasts the price of regular unleaded and premium gasoline to increase annually at an average rate of 6.3 percent and 5.8 percent during the next decade.

MANUFACTURER/SUPPLIER COMPARISON

The manufacturer and supplier results are statistically different for two of the four forecasts. The manufacturers forecast higher per gallon prices of gasoline in 2009 for both regular ($2.30) and premium ($2.60) than did the suppliers ($1.75 and $1.97 respectively). Please note that whereas median values are reported in the original question, mean values are used to determine if there are statistical differences between the respondents, and are therefore presented in this comparison.

MANUFACTURER/SUPPLIER COMPARISONS OF UNLEADED GASOLINE PRICE PER GALLON	MANUFACTURER MEAN	SUPPLIER MEAN
REGULAR 2009	$2.30	$1.75
PREMIUM 2009	2.60	1.97

COMPARISON OF FORECAST: TECH-1

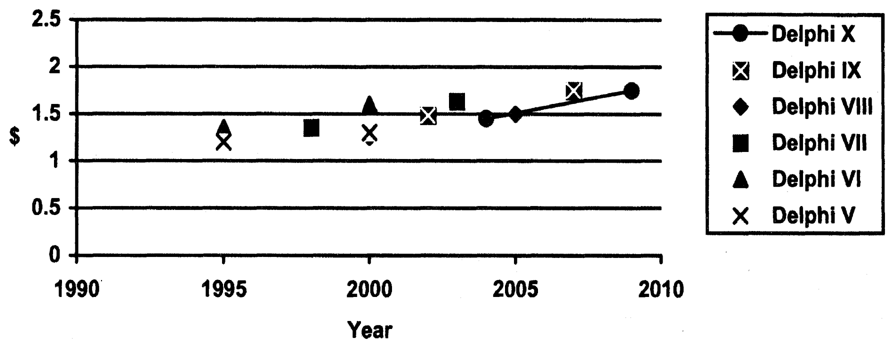
There are statistically significant differences in the mean responses between technology and materials panelists for the issues and years shown in the following tables. The Materials panel forecast for premium gasoline is higher than that of the Technology panel for both 2004 and 2009. This difference may be in part attributable to the fact that the materials survey was conducted at a later date than the Technology survey, and during a time of upward pressure on gasoline prices. It merits comment that even longer-term strategic views may be influenced by dramatic, shorter-term current developments.

FUEL PRICES, U.S. RETAIL PER GALLON 2004		
	TECHNOLOGY	MATERIALS
REGULAR GAS	$1.34	$1.54
PREMIUM GAS	$1.55	$1.77

FUEL PRICES, U.S. RETAIL PER GALLON 2009		
	TECHNOLOGY	MATERIALS
REGULAR GAS	$1.66	$1.99
PREMIUM GAS	$1.91	$2.26

TREND FROM PREVIOUS DELPHI SURVEYS

Regular Unleaded
(Responses given in constant Dollars from Date of Forecast)



STRATEGIC CONSIDERATIONS

The forecast indicates the panelists generally do not expect a significant disruption in the supply of oil in the coming decade. However, several factors have the potential to significantly affect the supply of, and demand for, gasoline. Certainly, current U.S. gasoline prices are vulnerable to another crisis in the Middle East or to the ability of OPEC nations to control the price of crude oil. Demand side shocks also could greatly affect gasoline prices. After several years of economic chaos, many Asian countries are returning to the economic growth rates of the early to mid 1990s. This growth will fuel increased demand for crude oil and in turn may significantly impact the price of gasoline in the United States. Conversely, any increase in alternatively fueled vehicles, including hybrid electric-gasoline, may reduce demand for gasoline in the coming decade.

Note that these forecasts are in constant dollars. Gasoline prices in constant dollars have remained stable—or even dropped during the 1990s. Therefore, the forecast indicates that the respondents do see some increase in the real price of gasoline at the pump.

One final comment is worth reiterating: the Delphi process can best be described as what panelists believe will happen, which is occasionally far from what does happen. Each forecast must be interpreted in the context of the current situation, which greatly influences the panelists' forecasts. Nowhere is this more apparent than in this question. The early Delphi forecasts were made in a period of severe gasoline shortages and rapidly increasing prices. In the context of the events of the early 1980s, the Delphi forecast of gasoline prices exceeding $4.00 by the early 1990s seemed very reasonable. The challenge is to review these results and analyze external factors to determine the validity of the panelists' forecasts. Helpful tools in the analysis of these results are the selected edited comments. These comments give insight into the factors that guide the respondents' forecasts and should be considered carefully to better frame the context of the forecast.

MAT-2 What percent of the change forecast in MAT-1 will be attributed to state and federal taxes?

PERCENT CHANGE ATTRIBUTED TO TAXES			
MEDIAN RESPONSE		INTERQUARTILE RANGE	
2004: 27.5	2009: 35	2004: 10/50	2009: 15/63.8

SELECTED EDITED COMMENTS

- Gas price balance is a function of OPEC pricing and market push.
- Gas is already heavily taxed in the U.S., so I don't expect higher taxes like in Canada and Europe.
- Highway maintenance needs will continue to increase.
- Hopefully, higher taxes will put a realistic value to gas so it will make sense to develop hybrid vehicles. We need a realistic worldwide value for gas.
- I think OPEC will be raising prices.
- A primary factor will be a CO2/global warming tax.

RESULTS SUMMARY

Panelists expect that 27.5 percent of the forecasted change in gasoline prices (MAT-1) for 2004 and 35 percent for 2009 will be attributable to increased taxes.

MANUFACTURER/SUPPLIER COMPARISON

There are no statistically significant differences in responses between manufacturers and suppliers.

TREND FROM PREVIOUS DELPHI SURVEYS

This question was first asked in the 1998 Delphi IX. The Delphi IX forecast for 2002 and 2007 tax content was 50 percent, which is substantially higher than the current panels' forecast.

REFORMULATED GASOLINE USAGE			
DELPHI FORECAST	SHORT-TERM YEAR/ LONG-TERM YEAR	SHORT-TERM FORECAST (PERCENT)	LONG-TERM FORECAST (PERCENT)
1998 DELPHI IX	2002/2007	50	50
2000 DELPHI X	2004/2009	27.5	35

STRATEGIC CONSIDERATIONS

The U.S. government has, since the mid-1970s, chosen to limit gasoline consumption via corporate average fuel economy regulation. Although there continues to be potential for increased gasoline taxes to reduce consumption, especially given the shift of consumers to light trucks from passenger cars, the panelists forecast a relatively small increase in gasoline taxes in the coming decade.

Gasoline taxes have often been presented by the automotive industry as a more effective alternative than CAFE for reducing gasoline consumption. Yet, the current U.S. political landscape makes any major gasoline tax increase highly unlikely. The panelists' forecast suggests they believe that U.S. gasoline prices will remain significantly lower than the rest of the world.

In light of the sharp increases in gasoline prices during the first and second quarters of 2000, it is apparent that politicians will continue to be hesitant to increase gasoline taxes. In fact, actions in the spring of 2000 instead show a propensity to repeal current gasoline taxes in times of rapidly increasing gasoline prices to gain support among constituents. Such actions, although politically wise, will not encourage reductions in gasoline consumption.

MAT-3 What percentage of 2004 and 2009 U.S. gasoline sales, in gallons, will be reformulated in accordance with 1990 Clean Air Act Requirements amendments?

REFORMULATED GASOLINE	MEDIAN RESPONSE		INTERQUARTILE RANGE	
1998*	2004	2009	2004	2009
33%	50%	70%	40/55%	50/80%

* Source: U.S. Energy Information Administration, 1998 National Average.

SELECTED EDITED COMMENTS

- Removal of sulfur will be the most important factor.

RESULTS SUMMARY

Panelists forecast reformulated gasoline to account for 50 percent of all gasoline sold by 2004, and 70 percent of all gasoline sold by 2009.

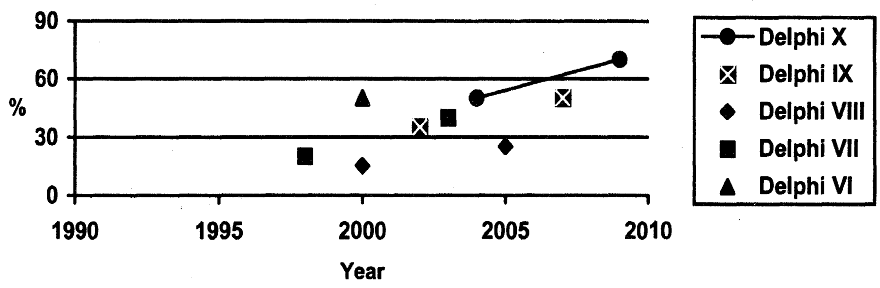
MANUFACTURER/SUPPLIER COMPARISON

There are no statistically significant differences in responses between manufacturers and suppliers.

TREND FROM PREVIOUS DELPHI SURVEYS

The Delphi VI forecast for 2000 was fifty percent, which appears to be slightly aggressive. Conversely, Delphi VII, Delphi VIII, and Delphi IX forecasts appear to be more conservative.

Reformulated Gasoline Prices



STRATEGIC CONSIDERATIONS

In accordance with the Clean Air Act of 1990, several cities, regions, and states within the U.S. that failed to meet required regulations are required to use reformulated gasoline. Since its implementation in 1995, the Environmental Protection Agency (EPA) estimates that reformulated fuel has cut emissions of pollutants 17 percent, compared to conventional gasoline. Phase II of the program became effective January 1, 2000. The second phase will require gasoline manufacturers to process and refine the components of Phase II reformulated gasoline to further reduce emissions.

The initial reformulated blend produced some consumer dissatisfaction. MTBE (methyl tertiary butyl ether), an additive used to add oxygen to reformulated gasoline, has been found in groundwater where reformulated gasoline is sold, causing further consumer dissatisfaction with the program. The EPA continues to work on a strategy to maintain the air quality gains of reformulated gasoline while reducing the use of MTBE.

In the coming decade, the number of non-attainment areas will likely increase and, concomitantly, reformulated gasoline as a percent of total gasoline sales will increase. It appears that the EPA will continue to pursue a clean air strategy that includes reformulated gasoline as an important element.

A critical issue for the auto industry is gasoline sulfur content. Significant reductions in sulfur seem to be required to attain future emissions standards.

MAT-4 What is the likelihood that federal legislation will mandate some degree of alternative fuel capability in retail vehicle sales, excluding fleets, by 2004 and 2009? Please include electric vehicles in your forecast.

SCALE →	1	3	5
	EXTREMELY LIKELY	SOMEWHAT LIKELY	NOT AT ALL LIKELY

LIKELIHOOD OF FEDERAL MANDATE	
2004 MEAN RESPONSE	2009 MEAN RESPONSE
3.5	2.5

SELECTED EDITED COMMENTS

- Electric-only powered vehicles do not make sense. Hybrids are a must!
- My forecast includes mainly electrically powered hybrids.
- Increased benefits in CAFE calculations should help drive the issue as well.
- Legislation by states is more likely.
- There are tremendous distribution infrastructure issues.

RESULTS SUMMARY

The panel believes it is somewhat unlikely that federal legislation regarding alternate fuels will be enacted by 2004, but that it is significantly more likely that such legislation will be enacted by 2009.

MANUFACTURER/SUPPLIER COMPARISON

There are no statistically significant differences in responses between manufacturers and suppliers.

TREND FROM PREVIOUS DELPHI SURVEYS

The 2000 Delphi X panel is in general agreement with previous Delphi panels.

STRATEGIC CONSIDERATIONS

Manufacturers are facing global pressure to reduce the amount of carbon dioxide and other harmful emissions. The 1997 United Nations Convention on the World Climate in Kyoto, Japan solidified the environmental concerns of many nations. There is pressure to increase fuel economy; in particular, to reduce CO_2 emissions. Alternatively fueled vehicles present a means of reducing emissions.

The requirement for so called zero-emissions vehicles by the California Air Resource Board may have served as a wake-up call for both industry and government. Although the laws—which were scheduled to be phased-in during the late nineties—have experienced delayed implementation, they served as a warning to vehicle manufactures that further legislation requiring alternative power sources is likely.

Concomitantly, the inability of all manufacturers to meet the ZEV requirements due to technical and economic challenges gave notice to government agencies that there are difficult barriers that must be overcome. Lessons learned from the California ZEV laws may be critical to future alternate powertrain development.

The recent proactive position of the manufacturers with regard to alternative power plants may forestall any possible legislation or regulation. This may be a case where the carrot of market leadership in a new technology may diminish the need for a legislative stick to encourage development. However, it is also very possible that if progress does not come soon, there will be increased pressure to use legislation or regulation to quicken the development of new technologies.

MAT-5 What percentage of North American-produced passenger cars and light trucks (including fleets) will use each of the following alternate energy sources in 2004 and 2009?

PASSENGER CARS	1998*	MEDIAN RESPONSE		INTERQUARTILE RANGE	
		2004	2009	2004	2009
FUELS					
ALCOHOL OR ALCOHOL/GASOLINE (>10 PERCENT ALCOHOL; INCLUDES FLEX FUEL OR VARIABLE FUEL)	<1%	1%	2.5%	1/3%	1/8.8%
DIESEL	0.2	1	2	0.2/1	0.4/5
ELECTRIC	0	0.1	1	0/1	0/1
HYBRID-ELECTRIC/COMBUSTION ENGINE	0	1	3	0.2/1	1/5
NATURAL GAS	0	0.1	0.2	0/1	0/2
PROPANE	0	0	0	0/1	0/1

LIGHT TRUCKS	1998*	MEDIAN RESPONSE		INTERQUARTILE RANGE	
		2004	2009	2004	2009
FUELS					
ALCOHOL OR ALCOHOL/GASOLINE (>10 PERCENT ALCOHOL; INCLUDES FLEX FUEL OR VARIABLE FUEL)	<1%	1%	2%	1/4%	1/10%
DIESEL	1.6	3	7	2/5	2.5/10
ELECTRIC	0	0	0	0/0.1	0/.8
HYBRID-ELECTRIC/COMBUSTION ENGINE	0	0	1	0/1	0/5
NATURAL GAS	0	0.2	1	0/1	0/2
PROPANE	0	0	0	0/0.5	0/1

*Source: Ward's Automotive Reports, Dec. 21, 1998 and Jan. 25, 1999; and OSAT estimates. Rates for 1998 are based on production in U.S., Canada, and Mexico for the U.S. market.

SELECTED EDITED COMMENTS

- A breakthrough in range is required for electric vehicles. The other alternatives will require breakthroughs in infrastructure.
- Electric-, natural gas- and propane-powered vehicles will be used mainly for fleets. I think low-sulfur grade diesel will be fully viable, and the influence of DaimlerChrysler will push towards diesel acceptance – even for passenger cars.

- It's going to be hard to beat gas/electric hybrids. Diesel may work, but the "smell" will keep people away.
- This is difficult to quantify. I see diesel going away in passenger cars and some electric cars in 2004. Hybrids will be coming on stronger by 2009. Natural gas and propane will not be as much of a factor because of fuel distribution problems/issues (i.e., the lack of infrastructure).

RESULTS SUMMARY

Panelists forecast most of the listed alternate energy sources to see slightly increased or minimal initial application in the coming decade.

MANUFACTURER/SUPPLIER COMPARISON

Manufacturers and suppliers are in general agreement, although manufacturers forecast higher penetration rates for diesel engines in passenger cars for 2004 and 2009 and in light trucks for 2009.

ALTERNATE FUELS MANUFACTURER/SUPPLIER DIFFERENCES IN FORECAST FOR DIESEL ENGINE APPLICATION RATES				
VEHICLE	2004	2004	2009	2009
	MANUFACTURER MEAN	SUPPLIER MEAN	MANUFACTURER MEAN	SUPPLIER MEAN
PASSENGER CARS	2.0	0.6	4.5	2.1
LIGHT TRUCKS	5.9	3.0	n/a	n/a

COMPARISON OF FORECAST:TECH-6

The Materials panel's forecast differs somewhat from the Technology's panel in their forecast for three alternative fuels. The Materials panel (7.9 percent) forecasts a higher 2009 rate of alcohol usage in light trucks than does the Technology panel (3.0 percent), but a lower penetration rate for propane fuel (0.6 vs. 1.5 percent) There is also a small difference in the forecasts for propane in passenger cars for 2004, as the Materials Panel again sees a lower penetration rate than does the technology Panel (0.3 vs. 0.6 percent)

ALTERNATIVE FUELS - 2004	TECH	MAT
CAR PROPANE	.6	.2

ALTERNATIVE FULES - 2009	TECH	MAT
TRUCK ALCOHOL	3.0	7.9
TRUCK PROPANE	1.5	.6

TREND FROM PREVIOUS DELPHI SURVEYS

The 2000 Delphi X panel is in general agreement with previous Delphi panels.

STRATEGIC CONSIDERATIONS

The automotive industry enters the 21st century amidst much talk of a new powertrain paradigm. The internal combustion engine, which has been the driving force for the first 100 years, may become obsolete within the coming decades. Yet, before any new paradigm in engine technology takes hold, there are many significant hurdles to overcome.

Panelists expect the internal combustion engine to continue as the dominant power source in the coming decade. Yet there is indication that other powertrains may become viable alternatives in the long term. Note that the panelists do not expect to see a significant increase in gasoline/electric hybrid vehicles by 2009. Every major vehicle manufacturer is expected to have saleable gasoline/electric hybrid vehicles within the next few years. However, these vehicles are not expected to be cost-effective (i.e. profitable) for several years. Yet there is increasing belief that they will offer significantly increased mileage and emissions reduction with minimal cost penalty over the longer term.

Most manufacturers have stated that they will produce fuel-cell powered vehicles within the next five years. Although significant advances have been made, it is highly unlikely that fuel cells will be a cost-effective power source during the coming decade. However, the gasoline/electric hybrid and the fuel cell are indicative of the significant changes that may take place in the coming decade, and therefore should be closely monitored.

Diesel engines present an interesting opportunity to significantly improve fuel economy. They are commonly used throughout much of the world, yet concerns over particulate matter and nitrogen oxide emissions may restrict their use in the United States. As one comment suggests, the globalization of the industry—via merger, acquisition, or organic growth—presents an opportunity for companies to offer diesel technology in the U.S. market. Panelists do not forecast major growth in diesel engines for cars. However, as companies develop cleaner diesel engines for overseas markets, the ability to offer increased mileage and decreased carbon dioxide emissions may lead to increased diesel engine application in the United States, particularly in light trucks.

Propane and natural gas fuels and electric vehicles are not likely to have a significant impact. These alternative power sources have seen limited success in fleet applications, but there is little likelihood they will expand their market position unless breakthroughs are made, e.g., lower pressure natural gas storage in a medium that could extend vehicle range or a new battery technology.

MAT-6 Please indicate your view of the trends in United States federal regulations and legislation over the short term (2000-2004) and long term (2005-2009). Also, please identify any likely additional areas of legislative and/or regulatory activity.

SCALE →	1	3	5
	MUCH MORE RESTRICTIVE	NO CHANGE	MUCH LESS RESTRICTIVE

LEGISLATION/REGULATORY ACTIVITY	SHORT-TERM 2000-2004	LONG-TERM 2005-2009
	MEAN RESPONSE	MEAN RESPONSE
ALTERNATE FUEL/POWER SOURCE		
PASSENGER CAR	2.7	1.9*
LIGHT TRUCK	2.8	2.0*
OCCUPANT RESTRAINT/INTERIOR SAFETY		
PASSENGER CAR	2.2	1.8*
LIGHT TRUCK	2.2	1.8*
PRODUCT LIABILITY		
PASSENGER CAR	2.6	2.5
LIGHT TRUCK	2.6	2.5
REGIONALIZATION OF NAT'L STANDARDS		
PASSENGER CAR	2.8	2.6*
LIGHT TRUCK	2.8	2.7
VEHICLE EMISSION STANDARDS		
PASSENGER CAR	2.2	1.7*
LIGHT TRUCK	2.1	1.7*
FUEL ECONOMY STANDARDS		
PASSENGER CAR	2.4	1.7*
LIGHT TRUCK	2.2	1.6*
VEHICLE INTEGRITY/CRASHWORTHINESS		
PASSENGER CAR	2.3	1.9*
LIGHT TRUCK	2.3	1.9*
ANTITHEFT EQUIPMENT		
PASSENGER CAR	2.8	2.6*
LIGHT TRUCK	2.8	2.6*

*Indicates statistically significant difference in short-term/long-term comparison.

SELECTED EDITED COMMENTS

- Customer advocates will continue to push agendas, so our government will want to protect its taxpayers.
- I think there will be major efforts to set more global standards and they will become more restrictive in general.
- In the long term, a regulation on real-vehicle-use fuel economy may arrive.
- The size of cars and trucks will be much more restrictive.

RESULTS SUMMARY

Panelists forecast in the short term that most listed areas will see somewhat more restrictive legislation/regulation. Alternate fuel/power sources, occupant restraint/interior safety, vehicle emission standards, fuel economy standards, and vehicle integrity/crashworthiness are forecast to have much more restrictive regulation by 2009.

MANUFACTURER/SUPPLIER COMPARISON

There are no statistically significant differences in responses between manufacturers and suppliers, with the exception of the two responses noted below:

LEGISLATION/REGULATORY ACTIVITY SHORT-TERM: 2000-2004	MANUFACTURER MEAN	SUPPLIER MEAN
PASSENGER CAR		
REGIONALIZATION OF NATIONAL STANDARDS	2.6	3.0
LIGHT TRUCK		
FUEL ECONOMY STANDARDS	2.0	2.4

TREND FROM PREVIOUS DELPHI SURVEYS

This question has been asked in the same format since the 1994 Delphi VII. Over that period, the forecasts of the panelists have been similar. That is, in general, panelists for each for the Delphi surveys forecast somewhat more restrictive short-term ratings (2.8-2.3) and significantly more restrictive long-term ratings (2.0-1.6). Anti-theft legislation/regulation was not forecast to become increasingly restrictive by any of the Delphi panels.

STRATEGIC CONSIDERATIONS

The panels' forecast of substantially more restrictive legislation/regulation for several of the listed areas by 2009 is in many ways not surprising. Industry and society face many difficult challenges in the coming decade. The development of safer and cleaner vehicles is a top priority for both industry and government. Over the past decade, there has been much progress in the relationship between industry and the federal government. Congress and the executive branch have worked with industry in a more cooperative manner. However, industry and government are at a critical juncture regarding environmental legislation/regulation.

The automotive industry has been very proactive with regard to alternative powered vehicles. This approach has been an effective method for the automotive industry to gain the trust of the federal government. However, the likelihood of more restrictive legislation/regulation will increase if the industry's much publicized claims for new technology to redress these various concerns do not come to fruition.

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II. STRATEGIC MATERIALS CONSIDERATIONS

MAT-7 What is the likelihood that federal legislation and regulation will require the following actions for the recyclability of automotive materials? Please give your forecast for 2004 and 2009.

SCALE →	1	3	5
	EXTREMELY LIKELY	SOMEWHAT LIKELY	NOT AT ALL LIKELY

REQUIRED RECYCLING ACTIONS	2004	2009
	MEAN RESPONSE	MEAN RESPONSE
DISPOSAL OF AUTOMOTIVE FLUIDS (REGULATIONS FOR)	2.7	1.8*
ESTABLISHMENT OF UNIFORM IDENTIFICATION/CODING STANDARDS FOR MATERIALS TO FACILITATE SEPARATION	2.9	1.9*
DISPOSAL OF USED TIRES (REGULATIONS FOR)	2.6	1.9*
RECYCLABILITY OF PLASTICS (REGULATIONS FOR)	3.0	2.2*
BAN ON SOME CURRENT AUTOMOTIVE MATERIALS	3.3	2.3*
FINANCIAL PENALTIES/INCENTIVES BASED ON RECYCLED CONTENT	3.6	2.6*
MINIMUM RECYCLED CONTENT	3.4	2.6*
"TAKE BACK" REGULATIONS MAKING MANUFACTURERS RESPONSIBLE FOR FINAL PRODUCT DISPOSITION (REGULATIONS FOR)	3.8	2.8*

*Indicates statistically significant difference in 2004/2009 comparison.

SELECTED EDITED COMMENTS

- European countries are already requiring or scheduling to require these items, so it would not be surprising if North American governments follow suit.
- European regulation will drive recyclability issues. The U.S. will drive many of the same benefits through marketplace initiatives. Some form of "take back" is very likely in Europe, for example, but I think the U.S. will dodge that problem for the next decade because we'll get many of the same benefits in the U.S. without "take back." There are differences in the basic economies of the recycling infrastructure that will allow that to happen in the U.S.
- Some automotive suppliers are already planning for this. It will be a way to do business.
- The United States will follow Europe's and Japan's leads.

RESULTS SUMMARY

Panelists forecast federal legislation or regulation as extremely likely for the disposal of automotive fluids (1.8), the disposal of used tires (1.9), and the establishment of uniform identification/coding standards for materials to facilitate recycling (1.9). Federal legislation/regulation for each of the listed areas is viewed as at least somewhat likely by 2009.

MANUFACTURER/SUPPLIER COMPARISON

There are no statistically significant differences in responses between manufacturers and suppliers, with the exception of the activity noted below:

LEGISLATION/REGULATORY ACTIVITY SHORT-TERM 2000-2004	MANUFACTURER MEAN	SUPPLIER MEAN
BAN ON SOME CURRENT AUTOMOTIVE MATERIALS	3.0	3.7

COMPARISON OF FORECAST: TECH-13

The Materials panel forecasts the likelihood of some form of "take back" recycling regulation (3.4) as higher than does the Technology panel (2.8),

RECYCLING, REGULATORY AREAS OF INTEREST		
	TECHNOLOGY	MATERIALS
TAKE BACK REGULATIONS	3.4	2.8

TREND FROM PREVIOUS DELPHI SURVEYS

This question has been asked in the same format since the 1996 Delphi VIII. The three panels (Delphi VIII, Delphi IX, and Delphi X) rated each of the recycling activities as more likely to see federal legislation/regulation in their long-term, rather than short-term, forecasts. Although the three panels' responses are in general agreement, where there are differences, the Delphi VIII panel did forecast a more significant likelihood for three listed activities (e.g., establishing uniform identification/coding standards for materials to facilitate separation, and specific regulation for the disposal of used tires).

STRATEGIC CONSIDERATIONS

Note that each of the listed areas is forecast to see at least "somewhat likely" federal legislation/regulation in the coming decade. The recyclability of automobiles will increasingly become an integral part of every manufacturer's strategy. Although much of the current pressure is driven by European regulations, the global nature of the automotive industry will likely force companies to increase recyclability in their North American products before legislation is enacted in the United States.

The European community is moving toward regulation that will require manufacturers to be responsible for the disposal of their vehicles at the end of the vehicles' useful life. This "take back" law has forced companies that sell vehicles in Europe to investigate strategies for the dismantling of vehicles and the disposition of the materials. However, the panelists forecast the implementation of such " take back" laws in the United States as only somewhat likely in the coming decade. At least one manufacturer has become active, via ownership, in vehicle recycling in North America. As environmental concerns heighten, vehicle recycling will increasingly become an important element of business strategy for North American automotive participants. Companies will be challenged to develop recycling strategies that are effective and, hopefully, profitable.

The disposal of used tires is the most visible of the listed activities. We dispose of approximately 300 million tires annually. These tires, by design, are resistant to destruction and are comprised of many -materials. Therefore, it is not surprising that panelists see the possibility of federal action as extremely likely in the coming decade.

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.

SCALE →	1	3	5
	EXTREMELY IMPORTANT	SOMEWHAT IMPORTANT	NOT AT ALL IMPORTANT

ATTRIBUTE/CHARACTERISTIC	MEAN RESPONSE
MATERIALS AND PROCESSING COST	1.2
WEIGHT	1.8
CORROSION RESISTANCE	1.9
DESIGN/STYLING REQUIREMENTS	1.9
FORMABILITY	1.9
SAFETY CONSIDERATIONS	1.9
WARRANTY COST	2.0
FIELD EXPERIENCE	2.1
ENVIRONMENTAL ISSUES	2.7
PREFERENCE OF VEHICLE PURCHASER	2.7
DISPOSAL COST	2.9
RECYCLABILITY	3.0
EASE OF FINAL DISPOSITION	3.2

SELECTED EDITED COMMENTS

- Cost will continue to be the key driver for material selection.
- Importance of recyclability will be higher in Europe, but because vehicles will be moved from North America to Europe and there will be common designs, the recycling issue will be integrated into many North American designs, especially when it is cost effective through good design.
- Price stability, guarantee of price for the life of the project, and the willingness of suppliers to provide engineering services are all critical.
- Purchasing departments will continue to dominate the final decisions on material selection. OEM/supplier alliances will continue to grow in importance in determining material choices. Vehicle purchasers are not aware of the material used.
- The preferences of vehicle purchasers are taken very seriously by auto manufacturers. Customers don't know or care about material selection; they care only about the attributes and performance of the product.
- With so many important items, it will be impossible to build a car anyone can afford, without some trade-offs.

RESULTS SUMMARY

Panelists forecast that cost of materials and processing (1.2) will be the most important material selection criteria in the coming decade. Weight (1.8), design/styling requirements (1.9), formability (1.9), safety considerations (1.9), warranty costs (2.0), and field experience (2.1) will also be important selection criteria in the coming decade. The listed environmental factors are seen as somewhat important.

MANUFACTURER/SUPPLIER COMPARISON

There are no statistically significant differences in responses between manufacturers and suppliers, with one exception. Manufacturers (1.7) rate safety considerations as more important than do suppliers (2.1).

TREND FROM PREVIOUS DELPHI SURVEYS

This question has been asked in the same format since the 1996 Delphi VII. The Delphi VII panel responses ranged from 1.5 (cost) to 2.6 (ease of disposal). The Delphi VIII, Delphi IX, and Delphi X panels have forecasted an increased importance for cost of processing, relatively stable importance for performance criteria, and a lessening importance for environmental characteristics.

STRATEGIC CONSIDERATIONS

The 2000 Delphi X panel has made it clear that cost of materials and processing is the most important material selection decision criteria. Given several years of severe price competition, it is not surprising that cost reduction has been placed at the forefront of vehicle manufacturer purchasing strategy. In an environment of stable—even deflationary—prices, inexpensive gasoline, and a concomitant increase in demand for larger vehicles, participants in the North American automotive industry have been lead to an outcome that is markedly different from any other major market in the world.

Yet, two points are of importance. First, all of the listed attributes are forecast to be at least somewhat important. It is apparent the material selection process will continue to be very complex. Second, external factors may quickly change the balance of the current material selection equation. Although the Delphi X panelists do not view it as likely, any increases in gasoline prices and emissions or CAFE regulation would greatly change the ratings of several of these attributes.

MAT-9 The following is a partial list of manufacturing technologies and material properties/issues that may be drivers or barriers for the increased usage of aluminum in lightweight vehicles. Please rate how important the following factors will be in fostering or restricting the usage of aluminum, where 1=critically important, 3=somewhat important, and 5=not important. *Also, please use a (+) to indicate those factors which are drivers, and a (-) to indicate those which are barriers.*

SCALE →	1	3	5
	CRITICALLY IMPORTANT	SOMEWHAT IMPORTANT	NOT IMPORTANT

DRIVERS (+)	BARRIERS (-)	MANUFACTURING TECHNOLOGIES AND MATERIAL PROPERTIES/ISSUES	MEAN RESPONSE
MANUFACTURING ISSUES			
17	14	BODY DESIGN OPTIMIZATION	2.1
18	3	IMPROVED DIE LIFE	2.6
7	21	COMPATIBILITY TO CURRENT ASSEMBLY FACILITIES	1.7
11	7	ELECTROMAGNETIC FORMING	3.2
0	29	ENGINEERS UNFAMILIARITY WITH MATERIAL	2.2
19	6	HYDROFORMING	2.2
BONDING AND JOINING TECHNOLOGIES			
13	10	ADHESIVES	2.2
5	19	ARC WELDING	2.4
13	11	"INTELLIGENT" RESISTANT SPOT WELDING (I..E. COMPUTER CONTROLLED)	2.1
12	14	LASER WELDING (INCLUDING PROCESS CONTROL FOR LASER BEAM)	2.2
CASTING TECHNIQUES (COMPONENTS)			
17	2	METAL COMPRESSION FORMING	2.7
14	7	LOWER POROSITY	2.0
<11>	<4>	VACUUM CASTING	2.7
16	6	CONTINUOUS SLAB CASTING (SHEET)	2.6
PAINT ISSUES			
6	18	PRE-TREATMENT OF ALUMINUM	2.2
3	15	OVEN TEMPERATURE	2.6
12	10	TAILOR WELDED BLANKS	2.2

DRIVERS (+)	BARRIERS (-)	MANUFACTURING TECHNOLOGIES AND MATERIAL PROPERTIES/ISSUES (CONTINUED)	MEAN RESPONSE
MATERIAL PROPERTIES/ISSUES			
6	23	FORMABILITY ISSUES	1.7
3	17	SHEET FATIGUE	2.3
7	15	STAMPING SPRINGBACK	2.2
4	27	RAW MATERIAL COST	1.2

SELECTED EDITED COMMENTS

- Cost and formability are the biggest issues.
- Fatigue on aluminum will continue to "haunt" many applications. Raw material cost fluctuations scare big users off. The big aluminum companies can't protect a market.
- For aluminum, recyclability is the key factor that can ameliorate high initial cost. Engineers' unfamiliarity is a barrier to the adoption of new material.
- Hydroforming and tailor welded blanks will be drivers for aluminum as well as steel. Both of these processes are now technically viable and offer even more advantages for aluminum then they do for steel.
- More aluminum will be used in the future and the lowest cost applications will move fastest and into most applications. For example, aluminum casting is widely used because they give the biggest bang for the buck.
- Super plastic forming will be an emerging technology that will enhance expanded usage of aluminum.

RESULTS SUMMARY

The panelists rate all the listed manufacturing technologies and material properties/issues as at least somewhat important and most of them as critically important. Raw material cost (1.2) was viewed as the most critical barrier. Formability issues (1.7) and compatibility to current assembly facilities (1.7) were also rated as highly critical to the future use of aluminum.

MANUFACTURER/SUPPLIER COMPARISON

There are no statistically significant differences in responses between manufacturers and suppliers.

TREND FROM PREVIOUS DELPHI SURVEYS

This question has not been previously asked.

STRATEGIC CONSIDERATIONS

It is apparent that cost remains the critical barrier for aluminum in the automotive industry. A recurring theme throughout this survey is the importance of cost in the material selection process. According to the panelists, raw material cost is the most critical barrier to increased aluminum application. Interestingly, the metal's price volatility may be as much of a hurdle to automotive engineers as the relatively high price. In many instances, a vehicle manufacturer can justify the higher cost of aluminum given its many positive attributes, yet the fear of unstable prices for aluminum may still make it difficult for an engineer making the material selection to specify for aluminum. This concern for price volatility is at the root of the long-term purchasing agreements some industry participants have adopted, or are considering adopting.

Formability issues are also critical to increased application of aluminum. Tailor welded blanks and hydroforming appear to offer significant opportunities for advancing aluminum in the coming decade. As the industry gains experience with these techniques, increased application will likely follow. Electromagnetic forming, continuous slab casting and vacuum casting also offer opportunities, yet may be several years from volume application. The panelists identify the development of lower porosity aluminum alloys as a driver of increased aluminum usage.

Joining and bonding of aluminum also presents challenges for the automotive industry. The panel views intelligent spot welding and laser welding, along with the use of adhesives, as technologies that may prove to be critical. Note that nearly equal numbers of respondents indicated that adhesive joining, intelligent spot welding, and laser welding were barriers as did those who reported them to be drivers. This implies some disagreement as to the actual challenges facing aluminum use.

Panelists view compatibility with current assembly facilities as another critical barrier for aluminum. The automotive industry has, since its inception, been oriented to steel both in facility layout and engineering knowledge. Even today, with the large amount of effort that has gone into the development of aluminum and aluminum components for automotive applications, the panel sees the industry's high comfort level and plant investment in steel as critical barriers to aluminum.

Although the Aluminum Association has done an excellent job in recent years of making the benefits of aluminum known to vehicle-makers, they still have much work to do. The recent opening of the Auto Aluminum Alliance signals a more formal effort to work with automotive engineers and designers to implement optimized aluminum designs.

It is also important to develop appropriate data and design information to support the engineering process with aluminum. This is particularly important as the industry places greater reliance on analytical tools.

MAT-10 The following is a partial list of manufacturing technologies and material properties/issues that may be drivers or barriers for the increased usage of structural composites in lightweight vehicles. Please rate how important the following factors will be in fostering or restricting the usage of structural composites, where 1=critically important, 3=somewhat important, and 5 =not important. *Also, please use a (+) to indicate those factors which are drivers, and a (-) to indicate those which are barriers.*

SCALE →	1	3	5
	CRTICALLY IMPORTANT	SOMEWHAT IMPORTANT	NOT IMPORTANT

DRIVERS (+)	BARRIERS (-)	MANUFACTURING TECHNOLOGIES AND MATERIAL PROPERTIES/ISSUES	MEAN RESPONSE
MANUFACTURING ISSUES			
18	7	BODY DESIGN OPTIMIZATION	1.8
BONDING AND JOINING TECHNOLOGIES			
15	11	ADHESIVE BONDING	1.7
9	13	MECHANICAL FASTENING	2.2
<3>	<0>	COMPATIBILITY TO CURRENT ASSEMBLY FACILITIES	1.8
25	1	COMPONENT CONSOLIDATION	1.8
HIGH VOLUME PRODUCTION			
12	12	TOOLING COST	1.9
9	16	MOLDING PROCESSES	2.1
<4>	<3>	MATERIAL SELECTION	2.0
2	18	EFFECT OF PAINT OVEN TEMPERATURES	2.2
5	21	MANUFACTURING COST	1.2
16	4	NET SHAPE PREFORMS	2.4
6	18	PROCESS VARIABILITY	2.0
MATERIAL PROPERTIES/ISSUES			
11	14	ENERGY ABSORPTION/CRASH MANAGEMENT	1.9
0	25	ENGINEERS UNFAMILIARITY WITH MATERIAL	1.7
4	20	ENVIRONMENTAL DEGRADATION OF MATERIAL	2.4
6	15	FATIGUE RESISTANCE	2.3
3	18	FEA MODELING	2.1
2	17	FIELD USAGE ISSUES	2.2
0	23	LACK OF AVAILABLE INFORMATION DATABASE	2.2
0	23	LACK OF FIELD DATA	2.3
8	13	MATERIAL UNIFORMITY	2.6
6	21	RAW MATERIAL COST	1.6
3	24	RECYCLABILITY	2.2
1	23	REPAIRABILITY	2.0

SELECTED EDITED COMMENTS

- Because these are not "production" based solutions to many of the technologies/material property issues, many are critical. We need answers to all of the issues, not just some, if we are going to be successful.
- Breakthrough in low cost processing is the key to using composites.
- Composites need to "get their act together" on *measurable properties* important to FEA design programs.

RESULTS SUMMARY

The panelists rate most of the manufacturing technologies and material properties/issues as critically important. Manufacturing cost (1.2) was viewed as the most critical barrier. Raw material cost (1.6) was also rated as one of the most critical barriers. Component consolidation (1.8) and body design (1.8) are also important factors.

MANUFACTURER/SUPPLIER COMPARISON

There are no statistically significant differences in responses between manufacturers and suppliers, with the exception of the activity noted below:

MANUFACTURING TECHNOLOGIES AND MATERIAL PROPERTIES/ISSUES	MANUFACTURER MEAN	SUPPLIER MEAN
EFFECT OF PAINT OVEN TEMPERATURES	1.9	2.6
MANUFACTURING COST	1.1	1.4

TREND FROM PREVIOUS DELPHI SURVEYS

This question has not been previously asked.

STRATEGIC CONSIDERATIONS

The list of issues that present barriers to increased application of structural composites is, to say the least, daunting. The selected edited comment pertaining to the need to resolve all the technologies/issues is worth noting. The challenges presented by the implementation of structural composites are vast. Yet advancements in one or two—or even several—of the listed areas will not increase usage of structural composites. Instead, it will take major leaps in all listed areas to allow for significant increases in the application of structural composites.

There are many manufacturing technology/issue barriers to the implementation of composites for structural applications. The most critical, according to the panel, is manufacturing cost. The panel views body design optimization as a critical driver for structural composites. There is little doubt that composites offer profound opportunity for the complete redesign of the automotive body/chassis. The ability to consolidate components and develop a new paradigm in automotive body design is attractive. However, the automotive industry has been, and remains, deeply entrenched in the steel paradigm. Factories and products have been designed using steel from their inception. Any significant shift away from steel will require important breakthroughs.

Numerous material-related issues also prevent increased application. Panelists rate engineers' unfamiliarity with the material as a strong barrier to the use of composites in structural applications. The lack of finite element analysis and available design information are important barriers for future application. There are also concerns over field use (e.g.,. energy absorption/crash management, reparability, and recyclability).

The Delphi X panel has consistently rated cost as the single most critical material selection criterion. Therefore, the rating of manufacturing and raw material cost as the most critical barrier for the increased application of structural composites is not surprising. Structural composites offer great opportunity for part consolidation and weight reduction, but the many barriers make even limited usage unlikely in the near future.

MAT-11 The following is a partial list of manufacturing technologies and material properties/issues that may be drivers or barriers for the increased usage of magnesium in lightweight vehicles. Please rate how important the following factors will be in fostering or restricting the usage of magnesium, where 1=critically important, 3=somewhat important, and 5=not important. *Also, please use a (+) to indicate those factors which are drivers, and a (-) to indicate those which are barriers.*

SCALE →	1	3	5
	CRITICALLY IMPORTANT	SOMEWHAT IMPORTANT	NOT IMPORTANT

DRIVERS (+)	BARRIERS (-)	MANUFACTURING TECHNOLOGIES AND MATERIAL PROPERTIES/ISSUES	MEAN RESPONSE
2	28	MATERIAL COST	1.5
4	22	MANUFACTURING COST	1.9
4	18	MAGNESUIM PRODUCTION CAPACITY	2.2
15	10	PERFORMANCE CHARACTERISTICS OF MAGNESIUM	2.0
4	23	CORROSION RESISTANCE	2.1
CASTING TECHNIQUES (COMPONENTS)			
<13>	<1>	METAL COMPRESSION FORMING	2.5
13	3	IMPROVED DIE LIFE	2.5
12	7	LOWER POROSITY	2.3
<9>	<4>	VACUUM CASTING	2.6
11	5	METAL COMPRESSION FORMING	2.4
<11>	<4>	ALTERNATE FORMING PROCESSES	2.6

SELECTED EDITED COMMENTS

- Achieving lower porosity casting techniques is very important.
- All semi-solid molding processes are important drivers for small components in magnesium.
- Corrosion resistance is a perception and requires education.
- Disposal of magnesium chips is a huge cost, which engineers do not commonly recognize in the decision process.
- Magnesium is a great material for inside the vehicle. Very poor corrosion resistance in the weather.
- High pressure die casting is the standard production method for magnesium automotive components. Metal compression forming is very rare in magnesium today; minimal work is being done to automotive components. While not a main stream activity, I feel that extrusions have far more activity than metal compression formed parts.

- Regarding corrosion, my rating is due to working on chassis components, where galvanic corrosion of magnesium is a big issue. For components like cross-car beams, corrosion is a non-issue for magnesium.
- The safety aspect of magnesium will continue to bother people. Cars and fires go together, and everyone remembers how hot and fast magnesium burns.
- Thermal and corrosion characteristics are limiting factors in the application of magnesium. If creep and corrosion (and to lesser extent, wear) problems could be generally resolved, there would be many more applications of magnesium.

RESULTS SUMMARY

All of the listed manufacturing technologies and material properties/issues are rated as at least somewhat important. Material cost (1.5) and manufacturing cost (1.9) are rated as critical barriers.

MANUFACTURER/SUPPLIER COMPARISON

There are no statistically significant differences in responses between manufacturers and suppliers, with the exception of the forecast notedbelow:

MANUFACTURING TECHNOLOGIES AND MATERIAL PROPERTIES/ISSUES	MANUFACTURERS	SUPPLIERS
ALTERNATE FORMING PROCESS	2.8	2.4

TREND FROM PREVIOUS DELPHI SURVEYS

This question has not been previously asked.

STRATEGIC CONSIDERATIONS

Magnesium offers many positive attributes, yet faces many significant barriers. Although the current quantity of magnesium used in vehicles is very low (about 6.5 pounds per vehicle), magnesium is expected to see rapidly increased application in (MAT-16 and MAT interiors). However, the panelists indicate that there are still significant challenges that need to be addressed before magnesium experiences widespread application. Material and manufacturing costs are rated as the most critical barriers.

According to respondents, among the most important drivers for increased use of magnesium is the material's performance characteristics and corrosion resistance. Several of the listed casting techniques are also viewed as important drivers for increased magnesium use. While the industry is putting significant effort into the development of magnesium components and processes, panelists still see significant barriers to increased application.

The dichotomy presented by magnesium may best be illustrated by two of the selected comments. One makes reference to magnesium's outstanding attributes for interior applications, while the other highlights concerns over safety issues associated with magnesium. The material will continue to see significant developmental efforts and is worthy of close monitoring.

MAT-12 The following is a partial list of manufacturing technologies and material properties/issues that may be drivers or barriers for the increased usage of steel in lightweight vehicles. Please rate how important the following factors will be in fostering or restricting the usage of steel, where 1=critically important, 3=somewhat important, and 5=not important. *Also, please use a (+) to indicate those factors which are drivers, and a (-) to indicate those which are barriers.* Note: High strength steel is defined as incoming yield strength of 210 Mpa (30 kpsi) or greater.

SCALE →	1	3	5
	CRITICALLY IMPORTANT	SOMEWHAT IMPORTANT	NOT IMPORTANT

DRIVERS (+)	BARRIERS (-)	STEEL	MEAN RESPONSE
MANUFACTURING APPLICATIONS/ISSUES			
BONDING AND JOINING TECHNOLOGIES			
14	7	ADHESIVES	2.6
20	2	"INTELLIGENT" RESISTANT SPOT WELDING (I.E., COMPUTER CONTROLLED)	2.4
21	2	LASER WELDING	2.4
20	6	BODY DESIGN OPTIMIZATION	1.9
26	1	HYDROFORMING (HSS)	2.0
STEEL COMPOSITE SANDWICH STAMPINGS			
11	10	FORMABILITY	2.2
14	9	MECHANICAL FASTENING	2.4
13	9	WELDABILITY	2.0
21	1	TAILOR WELDED BLANKS	1.9
MATERIAL PROPERTIES/ISSUES			
7	21	FORMABILITY ISSUES (HSS)	2.1
13	7	SHEET STEEL FATIGUE (HSS)	2.5
3	22	STAMPING SPRINGBACK (HSS)	2.4
5	20	VARIABILITY OF THE MECHANICAL PROPERTIES OF HSS	2.3

SELECTED EDITED COMMENTS

- Steel has a lot of momentum so it will continue to be the low-cost material of choice. They will need to watch their durability on lightweight applications. HSS is not the same raw material.
- Steel will have applications over the next decade. The better and more efficiently we use steel, the more difficult it will be to apply the other materials. Cost-effective material applications are still the name of the game.

RESULTS SUMMARY

Panelists rated all listed manufacturing technology and material properties/issues as at least somewhat important. Respondents make little differentiation between the 13 manufacturing technology and material properties/issues. Body optimization and tailor welded blanks are rated as the most important (1.9) while the use of adhesives for body joining is rated as the least important (2.6). Panelists rated 10 of the 13 issues as drivers for the increased application of steel. The remaining three issues that were listed as barriers involve high strength steel.

MANUFACTURER/SUPPLIER COMPARISON

There are no statistically significant differences in responses between manufacturers and suppliers.

TREND FROM PREVIOUS DELPHI SURVEYS

This question has not been previously asked.

STRATEGIC CONSIDERATIONS

Almost since its beginning, the automotive industry been heavily committed to steel. Even today, the industry remains steel focused despite the significant effort to develop alternative materials for many automotive applications. The influences of experience, and past investment, lead the industry to favor steel.

The American Iron and Steel Institute, including the work done for the UltraLight Steel AutoBody (ULSAB) research program, is a benchmark for cooperation between industry and suppliers. Using body optimization as its goal, ULSAB developed an automotive body-in-white designed to be built within the current manufacturing paradigm at a weight that is reasonably competitive to lightweight alternative materials such as aluminum and composites.

The panelists see several of the technologies used for the ULSAB as important drivers for the increased application of steel. ULSAB makes extensive use of hydroforming and tailor welded blanks to achieve the required body-in-white weight reductions. They also extensively use high strength steels (incoming yield strength of 210-550 Mpa), and even ultra high strength steels (incoming yield strength of 551 Mpa or greater), for many applications. However, of all listed manufacturing technology and material properties/issues, HSS material properties are the only ones that panelists rate as barriers for increased application for steel.

Although steel maintains a strong position in the North American Automotive industry, it faces significant challenges. Much recent research and development effort has gone into the development of alternative lightweight materials. For example, work done by manufacturers for PNGV goals has focused on aluminum, composites, and even thermoplastics for many applications traditionally held by steel. These vehicles, while not yet cost effective, may signal an important change ahead.

III. TOTAL VEHICLE CONSIDERATIONS

MAT-13 What percentage change in total vehicle weight do you anticipate by 2004 and 2009? Please reference all percentage changes to current vehicles. *Please indicate plus or minus (e.g., +5%, -3%).*

VEHICLE TYPE	MEDIAN RESPONSE		INTERQUARTILE RANGE	
	2004	2009	2004	2009
PASSENGER CAR	-3.5%	-10%	-5.8/0%	-15/-4%
LIGHT TRUCK	-3.0	-10	-5.5/0.3	-10/-4

SELECTED EDITED COMMENTS

- 2004 light truck weight reflects upsizing of SUVs.
- Aluminum structures will start to have an impact after 2004. Until then, light-weighting by the adoption of aluminum closure panels will have a relatively small impact on total vehicle weight.
- Mass is a function of material selection, design, and vehicle size. Vehicle size and design will be key factors. Alternate materials will be used if they can be cost effectively applied.
- The primary drivers of percentage change will be due to shift in truck and car product mix.
- Trucks need to move a lot faster than they have on adopting composites and other light-weighting consolidations. They have not been the leaders, and they should be given their growth in the next several years.
- Weight reduction will be accomplished through the use of composites.

RESULTS SUMMARY

Panelists forecast a reduction in vehicle weight of 3.5 percent in passenger cars and 3.0 percent for light trucks by 2004. They forecast a 10 percent weight reduction for passenger cars and light trucks for 2009.

MANUFACTURER/SUPPLIER COMPARISON

The manufacturers and suppliers differ in their forecast for passenger car weight change for 2004 and 2009.

FORECAST YEAR	MANUFACTURER (MEAN)	SUPPLIER (MEAN)
2004	-6.4	-1.8
2009	-16.1	-5.6

COMPARISON OF FORECAST: TECH-27

The Materials panel forecast for total vehicle weight changes differ significantly from the Technology panel forecasts. The Material panel forecasts substantially greater weight reduction for both passenger cars and light trucks by 2009, and somewhat smaller, but significant, reductions for passenger cars in 2004.

TOTAL VEHICLE WEIGHT, PERCENT CHANGE		
	TECHNOLOGY	MATERIALS
PASSENGER CAR 2004	-1.1	-4.0
PASSENGER CAR 2009	-2.7	-10.4
LIGHT TRUCK 2009	-1.5	-8.7

TREND FROM PREVIOUS DELPHI SURVEYS

This question was first asked in the 1994 Delphi VII. Since then it is has included a forecast for both passenger cars and light trucks (Delphi VII and Delphi X), and for combined passenger cars and light trucks (Delphi VIII and Delphi IX). The results have been relatively similar for each forecast. However, the Delphi IX panelists forecasted slower weight reduction than did the other panels.

DELPHI FORECAST	SHORT-TERM/LONG-TERM YEAR	PASSENGER CAR		LIGHT TRUCK		PC AND LT COMBINED	
		SHORT-TERM	LONG-TERM	SHORT-TERM	LONG-TERM	SHORT-TERM	LONG-TERM
1994 DELPHI VII	1998/2003	-3	-8	-5	-7	n/a	n/a
1996 DELPHI VIII	2000/2005	n/a	n/a	n/a	n/a	-5	-10
1998 DELPHI IX	2002/2007	n/a	n/a	n/a	n/a	-2	-5
2000 DELPHI X	2004/2009	-3.5	-10	-3	-10	n/a	n/a

STRATEGIC CONSIDERATIONS

The forecast of a 10 percent decrease in vehicle weight is noteworthy. Delphi Materials panelists have forecast a decrease in vehicle weight in each of the past four surveys, yet consumer demand has led to larger, heavier vehicles. Consumers, partially in response to CAFE forced changes in car design, have increasingly chosen to purchase full-size light trucks. As government regulation moves toward minimizing regulatory differences between passenger cars and light trucks, manufacturers will be severely challenged to increase light truck fuel economy and to reduce emissions while still delivering a vehicle that meets consumer demand.

Note that the percentage change in vehicle weight is a function of many factors. As asked, this question may be interpreted to be highly dependent on the sales mix of the fleet or the vehicle material mix or, more likely, some combination of those two factors.

Note that the differences in responses between manufacturers and suppliers for passenger car weight change. Throughout this survey, it is apparent that cost continues to be the driver for material selection. No group is more aware of this than the suppliers. Therefore it is not surprising that suppliers forecast a smaller decline in vehicle weight than do manufacturers. Conversely, the manufacturers' forecast may be influenced by the potential for increased government regulation due to perceived backlash regarding larger, less fuel-efficient passenger vehicles and the concomitant increase in the likelihood of stricter emissions. This may suggest that manufacturers may demand more aggressive weight reduction than suppliers are expecting. Manufacturers are also driving the future model mix, which can have a profound effect on average weight.

MAT-14 Please forecast the material content change for the typical North American-produced passenger car and light truck for 2004 and 2009, for each question in the indicated CAFE scenarios. Please estimate for only those with which you are familiar. *Please indicate plus or minus and reference all percent changes to the base year data (e.g., +5%, -3%).*

MATERIALS	PASSENGER CARS						
	EST. CURRENT WEIGHT* (20.7 MPG)	MEDIAN RESPONSE			INTERQUARTILE RANGE		
		2004 27.5 mpg	2009 30 mpg	2009 35 mpg	2004 27.5 mpg	2009 30 mpg	2009 35 mpg
STEEL							
LOW CARBON STEEL	1408.5 lbs.	-5	-10	-15	-8/-2	-15/-7	-25/-6
HSS STEEL	319	5	10	15	1/15	28/30	4/40
STAINLESS STEEL	49	1	.5	1	0/2	-0.8/2	0/3
OTHER STEELS	33.5	0	0	0	-0.5/0.3	-0.8/2.3	-1/2.5
TOTAL STEEL	1810	-3	-7.5	-10	-5/0	-10/-0.8	-15.8/-2
CAST IRON	359	-5	-12.5	-20	-10/-0.5	-22.3/-6.3	-30/-7.5
PLASTICS							
THERMOSETS	n/a	1	3	5	1/10	1.3/21.3	2.3/26.3
THERMOPLASTICS	n/a	3	5	8.5	2/5	4/13.5	4.5/18
TOTAL PLASTICS	359	5	10	20	3/9.8	6/20	5/25
ALUMINUM							
CASTINGS	n/a	6.5	13.5	19	2.5/15.3	9/27.5	13.8/37.5
FORGINGS	n/a	2	5	8	0/10	2.5/25	2.5/27.5
SHEETS	n/a	3	5	25	2/15	5/20	6/27.5
TOTAL ALUMINUM	219	10	17.5	35	3/23.8	8.5/53.8	18/79
RUBBER							
TIRES (INCLUDE SPARE)	n/a	0	-3	-5	-0.3/2.5	-10/1	-12.5/-1.5
ALL OTHER RUBBER	n/a	0	0	0	-1/0	-0.8/0	-1.3/0
TOTAL RUBBER	139.5	0	0	-2	-1/0	-4/0	-9/0
GLASS	95	0	-3	-2.5	-2/0	-5/0	-8/0
COPPER (INC. ELECTRICAL)	46	-1	-3	-5	-5/0	-10/0	-10/0
ZINC							
ZINC COATINGS	n/a	1	1	1	0/4.5	0/7.5	0/7.5
ZINC PARTS	13.5	0	0	0	-7.5/0.5	-10/0.5	-11.5/0.5
TOTAL ZINC	n/a	0	0	0	-1/1	-1/3	-1/3
POWDERED METALS	32.5	5	7	6.5	2/5	2/10	1/11.3
MAGNESIUM	6.5	20	40	85	5/50	7.3/94	10/200
CERAMICS	n/a	0	8	11.5	0/38.5	0.5/58.8	0.5/80

LIGHT TRUCKS					
MATERIALS	EST. CURRENT WEIGHT* (27.5 MPG)	MEDIAN RESPONSE		INTERQUARTILE RANGE	
		2004 20.7 mpg	2009 24 mpg	2004 20.7 mpg	2009 24 mpg
STEEL					
LOW CARBON STEEL	n/a	-5	-15	-10/-3	-20/-5
HSS STEEL	n/a	6	10	1/15	2.5/30
STAINLESS STEEL	n/a	0	1	0/2	0/4
OTHER STEELS	n/a	0	0	0/2	0/1.5
TOTAL STEEL	n/a	-3	-7.5	-6.5/-0.5	-10/-2
CAST IRON	n/a	-10	-20	-12.5/-3	-30/-10
PLASTICS					
THERMOSETS	n/a	5	20	1/17.5	3/28.8
THERMOPLASTICS	n/a	5	8	2/10	4.3/18.8
TOTAL PLASTICS	n/a	6	12.5	3/15	5/26.3
ALUMINUM					
CASTINGS	n/a	6	13	5/15	10/30
FORGINGS	n/a	5	8	1.5/12.5	2.5/25
SHEETS	n/a	5	20	2/10	6/20
TOTAL ALUMINUM	n/a	10	25	5/20	12.5/45
RUBBER					
TIRES (INCLUDE SPARE)	n/a	0	-1.5	0/5	-8.3/0
ALL OTHER RUBBER	n/a	0	0	-0.3/0	-1.5/0
TOTAL RUBBER	n/a	0	0	-1.3/0	-2.5/0
GLASS	n/a	0	-2	-2/0	-5.8/0
COPPER (INCL. ELECTRICAL)	n/a	0	-2	-3.5/0.5	-7.5/2
ZINC					
ZINC COATINGS	n/a	1	0.5	0/5.5	0/6.3
ZINC PARTS	n/a	0	0	-6.3/0.3	-7.5/0.3
TOTAL ZINC	n/a	0	0	-1/3	-0.8/2.3
POWDERED METALS	n/a	5	6.5	1/5	1/10
MAGNESIUM	n/a	15	27.5	3.5/43.8	7/125
CERAMICS	n/a	0	3	0/2	0/45

*Source: Ward's Automotive Yearbook 1998, except.
n/a–not available.

SELECTED EDITED COMMENTS

- The 1998 use of aluminum was nearer 241 lbs. than 219 lbs. Under aluminum should add extrusions as a product form. Our estimate of aluminum used in 1998 is: casting - 177 lbs., extrusions - 14lbs, sheet - 33 lbs., other - 18 lbs.

- Composites will displace structural parts, magnesium will displace zinc, copper will be reduced due to multiplexing, and polycarbonate will displace glass on rear and side DLO.
- Emission regulations and higher voltages will greatly increase use of ceramics.
- Magnesium figures above are an average for cars and trucks. In 1999, there is approximately twice as much magnesium in the average truck as in the average car.
- Rubber usage will decrease as mass goes down. Zinc usage will also decease.
- Weight alone will not account for these improvements. Changes in technology (such as DGI, CVT, diesel volumes, possibly hybrids, etc.) and/or fleet distributions will also be necessary to achieve the highest economies assessed in 2009 for cars and, to a lesser degree, trucks.

RESULTS SUMMARY

The panel was asked to forecast passenger car and light truck material changes in the coming decade.

For passenger cars, the panel was given one CAFE for 2004 and two for 2009. The short-term forecast with a given CAFE of 27.5 mpg shows continued movement toward lightweight materials. The panel forecasts low carbon steel and cast iron to decrease by 5 percent by 2004. Aluminum and plastic are expected to increase by 10 percent and 5 percent respectively.

The two passenger car CAFE scenarios for 2009 present further evidence that the panel expects mass reduction through material substitution. For the 30 mpg scenario, the panel forecasts low carbon steel and cast iron to decrease by 10 percent and 12.5 percent respectively. Aluminum and plastic are forecast to increase by 17.5 percent and 10 percent respectively. For a 35 mpg CAFE in 2009, low carbon steel and cast iron are forecast to decrease by 15 percent and 20 percent respectively, while aluminum and plastic are forecast to increase by 35 percent and 20 percent respectively

For light trucks, the panel was given a CAFE of 20.7 for 2004 and 24 for 2009. For 2004, the panel forecasts a weight reduction of 5 percent for low carbon steel and 10 percent for cast iron. Aluminum and plastic are forecast to increase by 10 and 6 percent respectively. For 2009, the panel forecasts a reduction of 15 percent and 20 percent for low carbon steel and cast iron respectively, and a increase of 25 percent for aluminum and 12.5 percent for plastics.

MANUFACTURER/SUPPLIER COMPARISON

The manufacturers and suppliers are in general agreement, with the exception of the differences shown below:

MATERIALS	MANUFACTURER MEAN	SUPPLIER MEAN
PASSENGER CARS MAGNESIUM 2009 30 MPG	76.00	19.67
TRUCKS MAGNESIUM 2009	93.33	14.83
TRUCKS LOW CARBON STEEL 2004	-8.31	-3.38

COMPARISON OF FORECAST: TECH-28

There are no statistically significant differences in the forecasts provided by the Technology and the Materials panelists for materials content change.

TREND FROM PREVIOUS DELPHI SURVEYS

This question was changed in the 1996 Delphi VIII, so comparison to surveys prior to Delphi VIII are not official.

For the passenger car 2009 CAFE of 35 mpg, the Delphi X panel forecasts a slightly higher percentage increase for total aluminum and ceramics than did the previous panels. The Delphi X panel forecasts slightly lower percentage increases for cast iron, thermoplastics, thermosets, and powdered metals than did previous panels.

For light trucks, the Delphi X panel forecast larger decreases in steel and cast iron, and a larger increase in thermoplastics and aluminum than the did the previous panels for the long-term forecast.

For both passenger cars and light trucks, the Delphi X panel forecasts lower growth rates for magnesium than did the previous panels.

STRATEGIC CONSIDERATIONS

The panel forecasts steady growth for the listed lightweight materials, for both passenger cars and light trucks for 2004. However, panelists indicate that the given "reach" CAFE requirements of 35 mpg for passenger cars and 24 mpg for light trucks, the application of lightweight materials would significantly increase in the coming decade.

The panelists indicate that in order to meet the increasingly tougher CAFE standards, a transition from traditional to lightweight automotive materials is necessary. However, to meet our stretch goal of 35 mpg, downsizing and management of the corporate fleet may also have to be considered. In addition, a CAFE of 35 mpg would likely require improved powertrain technology and design concepts.

Steel is expected to decrease by 1-2 percent per year in the coming decade. There are at least two drivers of this reduction: the direct substitution of lightweight materials for steel and a very proactive steel industry. In an effort to remain competitive, the steel industry, through the U.S. Auto/Steel Partnership, has become an industry standard for proactive development of cost-effective innovative designs.

Aluminum is expected to see continued growth in several automotive applications in the coming decade. Delphi X panelist forecast strong growth in aluminum castings, forgings, and sheet applications, as well as increased aluminum usage in heater cores, engine cylinder blocks and heads, unibody structures, and several chassis and brake applications.

The panel forecasts continuing increased application of plastics. Thermoplastics are expected to grow at a faster rate than thermosets. This is, in part, due to the difficulty of acceptable disposal for thermosets. Plastics offer substantial opportunity for weight reduction, but will increasingly face environmental constraints.

Clearly there are few materials that "own" a given automotive component. The competition between materials is expected to intensify.

MAT-15 Please consider the following list of plastic materials and forecast percentage change in plastic usage for 2004 and 2009. *Please indicate plus or minus (e.g., +5%, -3%).*

MATERIAL	MEDIAN RESPONSE		INTERQUARTILE RANGE	
	2004	2009	2004	2009
ABS	-3%	-4%	-5/3%	-13.8/3.5%
ABS/PC (PULSE)	2	4	0/5	0/10
ACETAL	.50	1	0/2	0/5
ACRYLIC	0	0	0/1.3	0/2
EPOXY	0	0	0/1.5	0/3
IONOMER	5	7.5	1.5/7.5	1.8/13.8
NYLON	2	5	.5/7	1/12.8
PC/PBT (XENOY)	1	4	0/4	-5/7
PHENOLIC	-1	0	-5/0	-10/1
POLYCARBONATE	2	4	0/4.5	0/8
POLYESTER ELASTOMER	5	7.5	2/5	3.5/11.3
POLYESTER THERMOPLASTIC	5	10	2/5	2.5/10
POLYESTER THERMOSET	3	12.5	0/11.3	1.5/20
POLYETHYLENE	5	10	2.5/10	5/13.8
POLYPROPYLENE	10	20	3/20	5/30
POLYUREA	0	0	-1.3/2.8	-3.3/6.3
PPO/NYLON	.5	1	-.5/5	-.8/10
PPO/STYRENE	0	0	-1.3/.5	-3.5/1
PVC	-5	-10	-20/-0.8	-35/-4.3
SMA	0	0	-3/0.5	-1.5/1.5
TPO	10	17.5	5/16.3	5/28.8
URETHANE	2	4	-2/5	-3.3/11
VINYL ESTER - TS	0	0	-.8/4	-3.5/7.3

SELECTED EDITED COMMENTS

- ABS/Pulse is way too costly at $2.77/lb. The automotive market will not accept it. Polypro is expected to reduce costs by 10-15% over the next 5-7 years, so they will hold their share.
- Body: If the olefins category includes SURLYN, these estimates reflect the increased usage. Chassis: Includes fuel tank usages.
- Composites with thermosets will be used for body panels. Polycarbonates will displace glass.
- HDPE - fuel tanks, HDPE foam - bumper, HDPE - ducts for interior air handling.
- Instrument panel: skin (cover) IP.
- Thermal stability of polyethylene is an issue.

- TPO applications in exterior trim and bumpers are growing. Problem: paint adhesion for TPO, also, if the bumper is deflected, paint on TPO cracks and comes back as a OEM defect. May lead to a more rigid fascia or different material with better paint adhesion. OEM does not want responsibility for replacement or repair. One class of thermoplastic materials not covered in this survey is ppo/styrene (~235f hdt) as used in blow molded spoilers. The spoiler application has grown steadily for the last 8 years and will grow for at least 5 more years.

RESULTS SUMMARY

Panelists predict substantial growth for polypropylene (20 percent), TPO (17.5 percent), and polyester thermoset (12.5 percent) in the coming decade. Polyester thermoplastic and polyethylene are also forecast to increase by approximately 10 percent. According to the panel, ABS (-4 percent) and PVC (-10 percent) are expected to see decreased usage by 2009.

MANUFACTURER AND SUPPLIER COMPARISON

There are no statistically significant differences in responses between manufacturers and suppliers.

TREND FROM PREVIOUS DELPHI SURVEYS

The 2000 panel is in general agreement with the forecast of previous Delphi panels.

STRATEGIC CONSIDERATIONS

The overall growth in plastics usage will essentially be in four resin families. These plastics offer the opportunity to reduce weight and increase design flexibility, while often reducing cost. The ability of materials engineers to chemically design a material with specific and unique characteristics has lead to a wide variety of compounds for a vast array of applications. Although these varied plastics offer nearly unlimited opportunity, they also can present environmental challenges regarding disposition of vehicles. Many industry participants, in an attempt to increase the recyclability of their vehicles, are developing strategies that markedly limit the number of different types of plastics in the vehicle. The ability to develop many elements of component systems from one family of plastics may represent an environmentally acceptable method of increasing the overall recyclability of vehicles.

Polypropylene usage is expected to increase—mostly due to its versatility for use in a number of interior trim applications as well as in instrument panel retainers. The addition of an ionomer resin to TPO greatly enhances scratch resistance, thus increasing the durability and concomitantly its likelihood for usage for bumper fascia.

MAT-16 What percentage of the following North American-produced automotive *components* will be made of magnesium? Please estimate for current vehicles, and for 2009. Leave blank any component with which you are not familiar.

COMPONENTS	MEDIAN RESPONSE		INTERQUARTILE RANGE	
	CURRENTLY	2009	CURRENTLY	2009
STEERING WHEEL	15%	40	3.5/40	10/40
ELECTRIC CAR TRANSAXLE	10	20	1/10	0/50
IP COMPONENTS	10	20	5/15	10/72.5
BRACKETS	5	7.5	1.5/8.8	4.3/18.8
STEERING WHEEL COMPONENTS	5	10	1.3/42.5	4.3/100
SUPPORT BRACES/BEAMS	3.5	10	0/16.3	2/20
TRANSMISSION COVER	2	10	0/10	0/15
SEAT FRAMES	1.5	10	1/4.5	5/30
BRAKE PEDAL	1	5	0/4.3	0.5/50
ENGINE COVERS	1	3.5	0/7.5	1/23.8
INTAKE MANIFOLD	1	1	0/11.3	0/30
OIL FILTER ADAPTER	1	1	0/5	0/10
TRANSMISSION CASES	1	10	0/10	1/17.5
WHEELS	1	2	0/2	0/10
DOOR HARDWARE	0.5	4.5	.5/4	0.8/20
OIL PAN	0.5	1	0/1	0.3/4.3
AIRBAG CANISTER	3	10%	2/10%	5/70%
DOOR FRAME	0	2	0/1	0/6.3
HOUSING	0	6	0/10	0/20
TRIM	0	0	0/7.5	0/0

SELECTED EDITED COMMENTS

- Because of corrosion concerns, I think magnesium will be used for interior parts only.
- I believe there will be other structural components such as B pillars, package shelves, or rear intrusion panels.
- Some likely parts for magnesium are not listed, namely, door inners and dash panel supports.

RESULTS SUMMARY

Panelists forecast magnesium usage for interior applications (such as instrument panel components, steering wheels, seat frames, and air bag canisters) to increase substantially in the coming decade. They also forecast several non-critical structural components (such as brackets, covers, cases, and housings) to experience significant increases in magnesium application rates in the coming decade. The wide interquartile ranges suggest a high level of uncertainty regarding the future use of magnesium and/or differing strategies between the manufacturers.

MANUFACTURER/SUPPLIER COMPARISON

There are no statistically significant differences in responses between manufacturers and suppliers, with the exception of the forecast for support braces as shown below:

MAGNESIUM SUPPORT BRACES	MANUFACTURERS	SUPPLIERS
CURRENTLY	2.3	17.5
2009	4.3	20.0

TREND FROM PREVIOUS DELPHI SURVEYS

This question has been asked in a similar format since the 1994 Delphi VII survey. The Delphi VII long-term forecasts (for 2003) are similar to the current estimates (i.e. the estimates for 1999) from the 2000 Delphi X. The 1996 Delphi VIII and 1998 Delphi long-term forecasts are generally much higher than the Delphi X forecasts.

STRATEGIC CONSIDERATIONS

Magnesium is considered an excellent lightweight material and will increasingly be utilized in many interior applications, while maintaining vehicle size. Increased usage of magnesium may be slowed somewhat by the uncertainty regarding magnesium production capacity and price fluctuations. Galvanic corrosion issues may also slow magnesium penetration rates for some applications. As with all light weight automotive materials, the industry is on the steep slope of the learning curve. Significant progress is being made across the board with both traditional and new materials.

MAT-17 Please indicate any significant new material applications/technologies that you think are likely to emerge within the next decade for each of the following vehicle systems.

SELECTED EDITED COMMENTS

Powertrain

Materials – increase usage of:

- Aluminum (5 responses)
- Magnesium (6 responses)
- Plastic (4 responses)
- Ceramics (4 responses)
- Powder metal (2 responses)
- Therma spray bores (3 responses)

Materials – less usage of:

- Cast iron

Materials – new technologies:

- Fuel cells
- Hybrid and combustion engines
- Hydroforming

Body

Exterior – increase usage of:

- Plastic/composite (22 responses)
- Aluminum (13 responses)
- Magnesium (5 responses)
- Molded in color (7 responses)
- In-mold film (2 responses)
- High strength steel (5 responses)
- Precoated steel (3 responses)

Exterior – less usage of:

- Steel
- Painting

Exterior – new technologies:

- Tailor blanks
- Hydroforming

Interior – increase usage of:

- Plastic/composite (8 responses)
- Magnesium (7 responses)
- Aluminum (2 responses)
- Molded in color (2 responses)

Interior – less usage of:

- Steel
- PVC

Interior – new technologies:

- Tailored blanks
- Hydroforming
- Thermoforming

Chassis

Brakes

Brakes – increase usage of:

- MMC/AMC (6 responses)
- Aluminum (5 responses)
- Composites (2 responses)

Brakes – less usage of:

- Cast iron

Wheels

Wheels – increase usage of:

- Composites (5 responses)
- Magnesium (3 responses)
- Aluminum (3 responses)
- HSS (2 responses)

Wheels – new technologies:

- Hybrid metal/plastic wheels

Suspension

Suspension – increase usage of:

- Aluminum (6 responses)
- Composites (4 responses)

Suspension – new technologies:

- Hydroforming
- Tubular torsion bars

Exhaust System

Exhaust system – increase usage of:

- Stainless steel (5 responses)
- Ceramics (2 responses)
- Titanium (2 responses)
- Thin wall cast iron

Exhaust system – less usage of:

- Cast iron

Exhaust system – new technologies:

- Catalytic systems

RESULTS SUMMARY

The panel lists several new material applications and technologies. However, many of the responses indicate an expectation for an evolution of automotive materials. Note that several responses indicate significant new potential material applications.

MANUFACTURER AND SUPPLIER COMPARISON

This comparison is not done for open-ended questions.

TREND FROM PREVIOUS DELPHI SURVEYS

This question was first asked in the 1994 Delphi VII. The Delphi X panel is in general agreement with previous panels.

STRATEGIC CONSIDERATIONS

Many of the applications and technologies are continuations or extensions of current developmental work. In the coming decade, the industry will likely see increased usage of aluminum, high strength steel, magnesium, and plastics. Competition among these materials will be great. The development of economically viable applications will increasingly rely on process and technological innovation. The responses represent a significant amount of effort on the part of the suppliers and manufacturers to develop cost-competitive applications for a wide range of materials.

Although the panel indicates that much of the effort in materials development will be evolutionary, there are numerous responses that indicate work is being done that, if successful, could lead to a new materials paradigm for the industry. Certainly, the development of the fuel cell and its implication for materials—both powertrain and the rest of the vehicle—would profoundly affect the automotive industry. It will be important to monitor developmental activity in all competing materials.

MAT-18 Please indicate any significant new developments that you think are likely to emerge within the next decade for each of the following fluids:

SELECTED EDITED COMMENTS

Brake fluid (new developments)

- Improved braking (stopping)
- Lower friction
- Increased usage of synthetics
- Brake by wire (no fluid)
- Environmentally friendly

Engine oils (new developments)

- Lower friction
- Increased usage of synthetics
- Longer life
- Better lubrication
- Environmentally friendly

Radiator fluid (new developments)

- Longer life fluid (100K or life)
- Increased usage of propylene glycol
- Improved temperature resistance/stability
- Environmentally friendly

Rear axle fluid (new developments)

- Lower friction
- Longer life
- Increased usage of synthetics
- Environmentally friendly

Power steering fluid (new developments)

- Longer life
- Commonization (with transmission fluid)
- Electric steering system (no fluid)
- Increased usage of synthetics
- Environmentally friendly

Transmission fluid (new developments)

- Longer life
- Increased usage of synthetics
- Environmentally friendly

RESULTS SUMMARY

The panelists forecast longer life and extended fluid change intervals for all listed fluids. They also expect to see increased usage of synthetic fluids and more environmentally acceptable fluids.

MANUFACTURER AND SUPPLIER COMPARISON

This comparison is not done for open-ended questions.

TREND FROM PREVIOUS DELPHI SURVEYS

This question was first asked in the 1996 Delphi VIII. The Delphi X panel is in general agreement with previous panels.

STRATEGIC CONSIDERATIONS

In the coming decade, improvements in formulations and additives are expected to extend the life and improve the performance of all listed automotive fluids. Panelists indicate that there is the opportunity to develop fluids that will be capable of lasting for the life of the vehicle. The use of synthetic fluids may increase slowly as consumers become more aware of the benefit/cost advantages that synthetic fluids may present.

IV. POWERTRAIN AND DRIVETRAIN

MAT-19 What percentage of North American-produced passenger car and light truck engines will utilize cast iron or aluminum cylinder heads and blocks in 2004 and 2009?

PASSENGER CARS					
MATERIAL	1998*	MEDIAN RESPONSE		INTERQUARTILE RANGE	
		2004	2009	2004	2009
BLOCKS					
ALUMINUM	32.0%	48%	70%	40/50%	50/72.5%
CAST IRON	68.0	51	32.5	50/60	26.3/50
TOTAL	100%	100%	100%	100%	100%
HEADS					
ALUMINUM	88.2%	90%	95%	90/99.5%	95/100%
CAST IRON	11.8	10	5	.3/10	0/5
TOTAL	100%	100%	100%	100%	100%

LIGHT TRUCKS					
MATERIAL	1998 *	MEDIAN RESPONSE		INTERQUARTILE RANGE	
		2004	2009	2004	2009
BLOCKS					
ALUMINUM	2.3%	10%	35%	5/20%	17.5/45%
CAST IRON	97.7	87.5	65	80/93.8	52.5/80
TOTAL	100%	100%	100%	100%	100%
HEADS					
ALUMINUM	51.2%	67.5%	85%	60/75%	71.3/98.8%
CAST IRON	48.8	30	15	25/40	0/25
TOTAL	100%	100%	100%	100%	100%

*Source: Ward's Automotive Reports, Dec. 21, 1998 and Jan. 25, 1999; Automotive Industries Engine Insert, Mar. 1998.

SELECTED EDITED COMMENTS

- Aluminum hardening techniques will help the material see increased engine component penetration. Weight reduction efforts will kill cast iron, even if it's cheap!
- In Delphi IX, the median response for aluminum blocks in 2002 was 25%. The actual for 1998 is 32%. Panelists may underestimate the continuing rate of change for cars and trucks.
- Magnesium engine blocks are a possibility as well.

RESULTS SUMMARY

Panelists estimate that 95 percent of passenger car cylinder heads and 70 percent of cylinder blocks will be made from aluminum in 2009. The panelists also forecast that 85 percent of light truck cylinder heads and 35 percent of cylinder blocks will be cast from aluminum by 2009.

MANUFACTURER/SUPPLIER COMPARISON

The manufacturers and suppliers are in general agreement, with the exception of the forecast for light truck cylinder blocks for 2004 and 2009 as shown below:

LIGHT TRUCK CYLINDER BLOCKS	MANUFACTURERS	SUPPLIERS
2004		
ALUMINUM	21	12
CAST IRON	79	88
2009		
ALUMINUM	43	27
CAST IRON	55	72

COMPARISON OF FORECAST: TECH-47

The Material panel forecasts slightly lower use of cast iron heads in 2004 passenger cars than does the Technology panel. However, the forecasts of the two panels differ more substantially for 2009 passenger car blocks and 2009 light truck heads applications. As the table below reveals, in both cases the Materials panel forecast calls for more rapid replacement of cast iron by aluminum.

ENGINE HEAD AND ENGINE-BLOCK MATERIALS	TECHNOLOGY	MATERIALS
	PERCENT CHANGE	PERCENT CHANGE
CAST IRON HEADS PASSENGER CAR 2004	8.3	6.5
ALUMINUM BLOCKS PASSENGER CAR 2009	56.5	65.8
CAST IRON BLOCKS PASSENGER CAR 2009	44.3	33.7
ALUMINUM HEADS LIGHT TRUCK 2009	76.2	83.4
CAST IRON HEADS LIGHT TRUCK 2009	24.4	15.7

TREND FROM PREVIOUS DELPHI SURVEYS

The 2000 Delphi X forecast is consistent with previous forecasts.

COMPARISON WITH TECHNOLOGY FORECAST

The forecast of the Materials panel differs somewhat from that of the 2000 Delphi Technology panel. The Materials panel forecasts greater penetration of aluminum cylinder blocks for passenger cars and greater penetration of aluminum cylinder blocks and heads for light trucks in the coming decade than does the Technology panel, as shown below:

PASSENGER CARS	2004 FORECAST		2009 FORECAST	
	TECHNOLOGY	MATERIALS	TECHNOLOGY	MATERIALS
CYLINDER BLOCKS				
ALUMINUM	40	48	50	70
CAST IRON	60	51	50	32

LIGHT TRUCKS	2004 FORECAST		2009 FORECAST	
	TECHNOLOGY	MATERIALS	TECHNOLOGY	MATERIALS
CYLINDER BLOCKS				
ALUMINUM	n/a	n/a	20	35
CAST IRON	n/a	n/a	80	65
CYLINDER HEADS				
ALUMINUM	60	68	75	85
CAST IRON	40	30	25	15

STRATEGIC CONSIDERATIONS

The use of aluminum for engine cylinder heads and blocks offers a significant weight reduction opportunity with an acceptable cost penalty. Because of the weight reduction, panelists forecast a continued shift to aluminum heads and, to a lesser extent, a shift to aluminum blocks. All new passenger car engine programs will likely include blocks and heads cast from aluminum.

The substitution of aluminum for cast iron in engine blocks, especially in the case of a major vehicle redesign, supports substantial further weight reduction throughout the vehicle. The use of a lighter weight engine block can cascade into numerous other parts of the vehicle. For example, if a new vehicle uses an engine with an aluminum cylinder block rather than a cast iron cylinder block, it is likely that many other components can be made lighter. These may include the engine cradle, front suspension, brakes, tire, and possibly integral frame sections. As these additional components are made lighter, the fuel economy of the vehicle will increase, thus possibly allowing for a smaller fuel tank, which further reduces weight. This cascade effect illustrates the value of approaching the vehicle as a complete system.

The manufacturing technologies for casting aluminum blocks and heads are well established. The automotive industry has developed a comfort level with aluminum heads. However, the industry has proceeded much more cautiously with regard to aluminum cylinder blocks—especially for light truck applications. Noise suppression, durability, and cost remain concerns for aluminum blocks. Cast iron sleeves are currently used in all North American produced engines to control noise and increase durability (Mat-20 and Mat-21).

MAT-20 What percentage of the aluminum blocks forecast in MAT-19 will be sleeved, unsleeved and coated, and unsleeved in 2009?

ALUMINUM BLOCK ENGINES	EST. 1998*	MEDIAN RESPONSE	INTERQUARTILE RANGE
		2009	2009
SLEEVED	100%	80%	50/90%
UNSLEEVED AND COATED	0	14	5/27.5
UNSLEEVED ALUMINUM 390 TYPE ALLOY	0	5	2/22.5
TOTAL	100%	100%	100%

*Source: OSAT estimates.

SELECTED EDITED COMMENTS

- Coating will be sleeved application only if high reliability is established.

RESULTS SUMMARY

Panelists forecast that by 2009, 80 percent of aluminum engine blocks will be sleeved, 14 percent will be unsleeved and coated, and 5 percent will be unsleeved.

MANUFACTURER/SUPPLIER COMPARISON

There are no statistically significant differences in responses between manufacturers and suppliers.

TREND FROM PREVIOUS DELPHI SURVEYS

This question was first asked in this form for the 1994 Delphi VII. A review of previous Delphi forecasts indicates that panelists have forecast initial application of sleeveless technology (both unsleeved and coated, and unsleeved), in each ten-year forecast. This appears to be a situation where the technical ability to make sleeveless aluminum blocks is present, but market factors and corporate culture continue to delay application. The Delphi X panel forecasts use of unsleeved, at 5 percent aluminum 390 type alloy. This is the first time a Materials panel has forecast significant penetration of unsleeved aluminum blocks.

STRATEGIC CONSIDERATIONS

Sleeved inserts are expected to be the dominant design for aluminum cylinder blocks in the coming decade. Failure of the engine block presents significant warranty cost and substantial consumer dissatisfaction. Therefore, it appears that North American manufacturers will continue to view sleeveless designs with great caution. Currently, there are several offshore manufacturers—mostly performance and luxury brands—that use sleeveless technology. If the processes used by these manufacturers become more cost effective, the move to sleeveless designs could accelerate.

MAT-21 What percentage of the sleeved aluminum blocks forecast in MAT-20 will use the following sleeve materials in 2009?

SLEEVE MATERIAL	EST. 1998*	MEDIAN RESPONSE	INTERQUARTILE RANGE
		2009	2009
ALUMINUM 390 ALLOY	0%	10%	1/40%
CAST IRON	100	70	50/90
CERAMIC	0	0	0/8
MATERIAL MATRIX COMPOSITES	0	10	2/15
THERMAL SPRAY	0	15	3/25
TOTAL	100%	100%	100%

*Source: OSAT estimates.

SELECTED EDITED COMMENTS

No comments.

RESULTS SUMMARY

Panelists forecast that 70 percent of sleeves for aluminum blocks will be made from cast iron by 2009. Aluminum 390 alloy (10 percent), metal matrix composites (10 percent), and thermal spray (15 percent) are expected to see initial applications by 2009. Importantly, the wide interquartile ranges suggest that there is significant uncertainty or divergent views regarding the future of alternative materials for cylinder sleeves.

MANUFACTURER/SUPPLIER COMPARISON

There are no statistically significant differences in responses between manufacturers and suppliers.

TREND FROM PREVIOUS DELPHI SURVEYS

This question was first asked in the 1996 Delphi VIII. The 2000 Delphi X panels forecasts much higher penetration rates for aluminum, metal matrix composites, and thermal spray than did either of the previous panels.

STRATEGIC CONSIDERATIONS

Cast iron is forecast to be the predominant material for cylinder block sleeves. However, the panelists forecast some initial application of aluminum 390 alloy and metal matrix composites. Thermal spraying is also expected to see limited application. The wide interquartile ranges for each material is important. The cast iron sleeve has proven to be an effective cylinder block sleeve material. Yet uncertainty regarding CAFE and emissions standards lead manufacturers to explore weight reduction alternatives. The ability to eliminate—or drastically reduce—the weight of sleeves is of significant interest for manufacturers. Yet, concerns with cost, manufacturability, and durability issues will slow any progress in cylinder sleeve material substitution.

MAT-22 What percentage of the following North American-produced internal engine components will be made of the listed materials? Please estimate for current vehicles and for 2004 and 2009. Please total materials for each component to 100%. Leave blank any component with which you are not familiar.

COMPONENT MATERIAL						
ENGINE INTERNAL	MEDIAN RESPONSE			INTERQUARTILE RANGE		
	CURRENT EST.	2004	2009	CURRENT EST.	2004	2009
PISTON						
ALUMINUM	99%	98.5%	97%	99/100%	91.5/100%	86.3/100%
HYBRID (E.G., PLASTIC SKIRT/CERAMIC CROWN)	0	1	5	0/2	0/7.5	0/20
METAL MATRIX COMPOSITES	0	2	5	0/1	0/5	.8/9.8
TOTAL	100%	100%	100%	100%	100%	100%
VALVES						
ALUMINUM MATRIX COMPOSITE	0%	0%	0%	0/6%	0/5%	0/7.5%
STEEL	99	97	96.5	99/100	94.3/100	75.8/98.8
TITANIUM	1	1	2	0/4	0/5	2/20
TOTAL	100%	100%	100%	100%	100%	100%

COMPONENT MATERIAL						
ENGINE EXTERNAL	MEDIAN RESPONSE			INTERQUARTILE RANGE		
	CURRENT EST.	2004	2009	CURRENT EST.	2004	2009
AIR CLEANER HOUSING						
ALUMINUM	5%	5%	3%	0/17.5%	0/30%	0/35%
PLASTIC	80	83	95	100/90	30/99	80/99
STEEL	20	10	.5	7.5/45	3.5/30	0/16.3
TOTAL	100%	100%	100%	100%	100%	100%
EXHAUST MANIFOLD						
CAST IRON	90%	85%	75%	90/95%	70/90%	55/82.5%
STAINLESS STEEL	10	15	25	5/10	10/30	17.5/40
TOTAL	100%	100%	100%	100%	100%	100%

COMPONENT MATERIAL (CONTINUED)						
ENGINE EXTERNAL	MEDIAN RESPONSE			INTERQUARTILE RANGE		
	CURRENT EST.	2004	2009	CURRENT EST.	2004	2009
OIL PAN						
PLASTIC	0%	5%	15%	0/2%	2/10%	5/20%
STEEL	93	80	60	77.5/99	67.5/92.5	32.5/77.5
TOTAL	100%	100%	100%	100%	100%	100%
ROCKER ARM COVER						
ALUMINUM	25%	20%	25%	10/40%	5/40%	6.3/38.8%
MAGNESIUM	5	10	12.5	5/9.5	5/20	2.8/23.8
PLASTIC	5	10	20	2.8/13.8	7.5/22.5	12/40
STEEL	65	50	30	25/84	15/74	0/58
TOTAL	100%	100%	100%	100%	100%	100%

SELECTED EDITED COMMENTS
No comments.

RESULTS SUMMARY

Panelists forecast little material change for the listed internal engine components. They do however, forecast increased usage of stainless steel for exhaust manifolds and plastic oil pans. The panel also forecast a decrease in steel rocker arm covers, while plastic and magnesium are forecast to increase in rocker arm covers. Note that several of the listed components have wide interquartile ranges.

MANUFACTURER AND SUPPLIER COMPARISON

There are no statistically significant differences in responses between manufacturers and suppliers.

TREND FROM PREVIOUS DELPHI SURVEYS

The 2000 Delphi panel is in general agreement with previous Delphi panels.

STRATEGIC CONSIDERATIONS

The automotive industry continues to substitute lightweight materials for cast iron and steel in many engine applications. As components made from alternative materials approach manufacturing scale economies, these materials may become more rapidly the industry standard.

The panelists forecast little change in piston and valve materials in the coming decade. However, the interquartile ranges for both components include forecasts that have substantially higher levels of the alternative materials than do the medians. Also, more exotic materials are expected to make some inroads that could accelerate as the industry gains experience and performance requirements are increased.

Plastics are forecast to increase application rates for the listed external engine components. Plastics are lightweight and allow engineering the content of the material to best fit the needs of the specific application. The forecast for rocker arm covers offers an interesting insight into the battle for material supremacy. Although it is apparent that steel use will decrease for the component, the panel forecast indicates that aluminum, magnesium, and plastic are all strong candidates to replace steel.

MAT-23 Round 1 results indicate a shift from cast iron to steel or composite (e.g., a steel/powdered metal (PM) combination) in engine **camshafts**.

A. How likely is it that steel will reach 20 percent application rate, or steel/PM composite will reach a 25 percent application rate for camshafts by 2009? Note: Round 1 results indicate that steel/PM currently has a less than 10 percent penetration rate.

SCALE →	1	3	5
	LITTLE OR NO LIKELIHOOD	MODERATE LIKELIHOOD	SIGNIFICANT LIKELIHOOD

	MEAN RESPONSE
LIKELIHOOD OF REACHING 20 PERCENT APPLICATION RATE BY 2009	
STEEL CAMSHAFTS	3.1
LIKELIHOOD OF REACHING 25 PERCENT APPLICATION RATE BY 2009	
STEEL/PM COMPOSITE CAMSHAFTS	2.7

B. Please rate the relative advantages and disadvantages of steel or steel/PM composite for use in camshafts with regard to the following material selection criteria. (*Please use the following rating scale and respond with a number 1 through 5 in each appropriate box.)*

SCALE →	1	3	5
	A SUBSTANTIAL DISADVANTAGE	NEITHER AN ADVANTAGE NOR A DISADVANTAGE	A SUBSTANTIAL ADVANTAGE

MATERIAL SELECTION/PERFORMANCE CRITERIA FOR ALTERNATE MATERIAL RELATIVE TO CAST IRON CAMSHAFTS	ALTERNATIVE CAMSHAFT MATERIALS	
	STEEL CAMSHAFT	STEEL/PM COMPOSITE CAMSHAFT
	MEAN RESPONSE	MEAN RESPONSE
A. PERFORMANCE CHARACTERISTICS	3.7	3.5
B. COST	2.8	3.2
C. COST OF PROCESSING/MANUFACTURING	2.8	3.4
D. DURABILITY	3.8	3.2
E. FORMABILITY	2.8	3.7
F. MACHINEABILITY	3.0	3.1
G. PRODUCTION CAPACITY	3.3	2.9
H. LACK OF COMPONENT PROCESSING CAPACITY	2.6	2.7
I. RECYCLABILITY	3.3	3.3
J. WEIGHT	3.2	4.1

SELECTED EDITED COMMENTS

- CARB LEV II standards must be met.

RESULTS SUMMARY

Panelists forecast as moderately likely that steel will reach a 20 percent application rate for camshafts by 2009. According to panelists, durability and performance characteristics of steel camshafts are advantageous. The panelists also rate as moderately likely that steel/powdered metal camshafts will reach a 25 percent application rate by 2009. The lower weight of steel/powdered metal camshafts is viewed as an advantage compared to competing materials.

MANUFACTURER AND SUPPLIER COMPARISON

The manufacturers and suppliers are in general agreement, with one exception. Manufacturers (4.0) rate lower weight as more advantageous than do the suppliers (2.7).

TREND FROM PREVIOUS DELPHI SURVEYS

This question has not been previously asked.

STRATEGIC CONSIDERATIONS

The panel indicates that steel and steel/powdered metal camshafts are likely to see increased application in the coming decade. Both materials offer several features that provide an advantage over cast iron. According to panelists, steel camshafts offer performance and durability advantages, while steel/powdered metal camshafts offer performance, formability, and weight advantages. Steel camshafts withstand greater hertz stresses than do cast iron, thereby giving better performance and increased durability. However, the cost of manufacturing (forging and machining) steel camshafts is viewed as a disadvantage vis-à-vis composite cams.

Respondents indicate that steel/powdered metal camshafts have advantages over steel in cost of manufacturing, formability, and weight. The composite camshaft is manufactured by welding individual cams on a hollow steel shaft, thus giving it potential for significant weight savings. The chemistry of composite camshafts can be formulated to specific engineering requirements. Note that the manufacturers rated weight as a more significant advantage for steel than did the suppliers—in fact, their rating is very close to that of the mean response for steel/powdered metal.

The steel/powdered metal composite camshaft can be cost competitive with cast iron. However, the precision required to attaching the cams to the shaft makes steel/PM camshafts more vulnerable to manufacturing quality and reliability concerns.

MAT-24 Round 1 results indicate a shift from cast iron to steel in engine **crankshafts**.

A. How likely is it that steel will reach a 55 percent application rate for crankshafts by 2009? Note: Round 1 results indicate that steel currently has an estimated 35 percent penetration rate.

SCALE →	1	3	5
	NOT LIKELY AT ALL	MODERATELY LIKELY	EXTREMELY LIKELY

LIKELIHOOD OF REACHING 55 PERCENT APPLICATION RATE BY 2009	MEAN RESPONSE
STEEL CRANKSHAFTS	2.8

B. Please rate the importance of each of the following material selection/performance criteria with regard to a potential shift from cast iron to steel in crankshafts.

SCALE →	1	2	3	4	5
	A SUBSTANTIAL BARRIER	A MODERATE BARRIER	NEITHER A BARRIER NOR A DRIVER	A MODERATE DRIVER	A SUBSTANTIAL DRIVER

MATERIALSELECTION/PERFORMANCE CRITERIA FOR STEEL CRANKSHAFTS RELATIVE TO CAST IRON	MEAN RESPONSE
A. PERFORMANCE CHARACTERISTICS OF STEEL CRANKSHAFTS	4.1
B. COST OF STEEL CRANKSHAFTS	1.7
C. COST OF PROCESSING/MANUFACTURING STEEL CRANKSHAFTS	2.3
D. DURABILITY OF STEEL CRANKSHAFTS	4.0
E. FORGEABILITY OF STEEL CRANKSHAFTS	2.9
F. MACHINEABILITY OF STEEL CRANKSHAFTS	2.8
G. PRODUCTION CAPACITY FOR STEEL CRANKSHAFTS	2.5
H. PRODUCTION CAPACITY FOR CAST IRON CRANKSHAFTS	2.9
I. LACK OF COMPONENT PROCESSING CAPACITY FOR STEEL CRANKSHAFTS	2.6
J. RECYCLABILITY OF STEEL CRANKSHAFTS	3.5
K. WEIGHT OF STEEL CRANKSHAFTS	3.5

SELECTED EDITED COMMENTS

No comments.

RESULTS SUMMARY

Panelists forecast as moderately likely that steel will reach a 55 percent application rate for crankshafts by 2009. According to panelists, performance and durability characteristics of steel crankshafts are drivers of the shift from cast iron to steel.

MANUFACTURER AND SUPPLIER COMPARISON

The manufacturers and suppliers are in general agreement, with the exception of these ratings:

STEEL CRANKSHAFTS RELATIVE TO CAST IRON	MANUFACTURERS (MEAN)	SUPPLIERS (MEAN)
MACHINEABILITY OF STEEL CRANKSHAFTS	2.2	3.3
PRODUCTION CAPACITY FOR CAST IRON CRANKSHAFTS	3.3	2.3
WEIGHT OF STEEL CRANKSHAFTS	3.0	3.8

TREND FROM PREVIOUS DELPHI SURVEYS

This question has not been previously asked.

STRATEGIC CONSIDERATIONS

According to panelists, the critical drivers for increased application of steel for crankshafts are performance and durability. Production capacity for steel crankshafts (2.5) is rated as a barrier, though the manufacturers rate it as a neither a barrier nor a driver (3.2). Manufacturers rate the machinability of steel crankshafts as a moderate barrier (2.2) while the suppliers rate it as a slight driver (3.3).

The rotating mass of a steel crankshaft is significantly lower than that of a nodular cast iron crankshaft. Therefore the steel crankshaft can be made smaller and lighter. The endurance or fatigue limit of steel is also more advantageous than that of cast iron, so steel crankshafts are inherently more durable. The disadvantage for steel crankshafts is cost. The lack of production capacity is viewed by the suppliers as a disadvantage, but the manufacturers rate it as neither an advantage nor a disadvantage. The conversion of casting capacity to forging is an expensive change. Such a change may be more easily implemented with new engine introductions where financial justification may be more easily made.

MAT-25 Round 1 results indicate a shift from steel to plastic in engine **fuel rails**.

A. How likely is it that plastic will reach a 55 percent application rate for fuel rails by 2009? Note: Round 1 results indicate that plastic currently has an estimated 20 percent penetration rate.

SCALE →	1	3	5
	NOT LIKELY AT ALL	MODERATELY LIKELY	EXTREMELY LIKELY

LIKELIHOOD OF REACHING 55 PERCENT APPLICATION RATE BY 2009	MEAN RESPONSE
PLASTIC FUEL RAILS	3.2

B. Please rate the importance of each of the following material selection/performance criteria with regard to a potential shift from steel to plastic in fuel rails.

SCALE →	1	2	3	4	5
	A SUBSTANTIAL BARRIER	A MODERATE BARRIER	NEITHER A BARRIER NOR A DRIVER	A MODERATE DRIVER	A SUBSTANTIAL DRIVER

MATERIAL SELECTION/ PERFORMANCE CRITERIA FOR PLASTIC FUEL RAILS RELATIVE TO STEEL	MEAN RESPONSE
A. PERFORMANCE CHARACTERISTICS OF PLASTIC FUEL RAILS	2.9
B. COST OF PLASTIC FUEL RAILS	4.0
C. COST OF PROCESSING/ MANUFACTURING PLASTIC FUEL RAILS	3.7
D. DURABILITY OF PLASTIC FUEL RAILS	2.9
E. MOLDABILITY OF PLASTIC FUEL RAILS	3.8
F. PRODUCTION CAPACITY OF PLASTIC FUEL RAILS	3.4
G. PRODUCTION CAPACITY OF STEEL FUEL RAILS	2.9
H. LACK OF COMPONENT PROCESSING CAPACITY FOR PLASTIC FUEL RAILS	3.2
I. RECYCLABILITY OF PLASTIC FUEL RAILS	2.6
J. WEIGHT OF PLASTIC FUEL RAILS	4.2

SELECTED EDITED COMMENTS

No comments.

RESULTS SUMMARY

Panelists forecast as moderately likely that plastic will reach a 55 percent application rate for fuel rails by 2009. According to panelists, cost, weight, moldability, and processing costs of fuel rails are drivers for the increased usage of plastic fuel rails.

MANUFACTURER AND SUPPLIER COMPARISON

There are no statistically significant differences in responses between manufacturers and suppliers.

TREND FROM PREVIOUS DELPHI SURVEYS

This question has not been previously asked.

STRATEGIC CONSIDERATIONS

Plastic has been used increasingly for fuel rails in recent years. Plastics present significant cost and weight savings vis-à-vis steel for fuel rail applications. The only one of the listed selection/performance criteria that is viewed as a potential barrier is the recyclability of plastic.

MAT-26 Round 1 results indicate a shift from cast iron to aluminum in engine **front covers.**

A. How likely is it that aluminum will reach a 95 percent application rate for front covers by 2009? Note: Round 1 results indicate that steel currently has an estimated 60 percent penetration rate.

SCALE →	1	3	5
	NOT LIKELY AT ALL	MODERATELY LIKELY	EXTREMELY LIKELY

LIKELIHOOD OF REACHING 95 PERCENT APPLICATION RATE BY 2009	MEAN RESPONSE
ALUMINUM FRONT COVERS	3.5

B. Please rate the importance of each of the following material selection performance criteria with regard to a potential shift from cast iron to aluminum in fuel rails.

SCALE →	1	2	3	4	5
	A SUBSTANTIAL BARRIER	A MODERATE BARRIER	NEITHER A BARRIER NOR A DRIVER	A MODERATE DRIVER	A SUBSTANTIAL DRIVER

MATERIAL SELECTION/PERFORMANCE CRITERIA FOR ALUMINUM FRONT COVERS RELATIVE TO CAST IRON	MEAN RESPONSE
A. PERFORMANCE CHARACTERISTICS OF ALUMINUM FRONT COVERS	3.5
B. COST OF ALUMINUM FRONT COVERS	2.8
C. COST OF PROCESSING/MANUFACTURING ALUMINUM FRONT COVERS	3.1
D. DURABILITY OF ALUMINUM FRONT COVERS	3.4
E. CASTABILITY OF ALUMINUM FRONT COVERS	3.6
F. MACHINEABILITY OF ALUMINUM FRONT COVERS	3.6
G. PRODUCTION CAPACITY FOR ALUMINUM FRONT COVERS	3.2
H. PRODUCTION CAPACITY FOR CAST IRON FRONT COVERS	3.4
I. LACK OF COMPONENT PROCESSING CAPACITY FOR ALUMINUM FRONT COVERS	2.9
J. RECYCLABILITY OF ALUMINUM FRONT COVERS	3.6
K. WEIGHT OF ALUMINUM FRONT COVERS	4.7

SELECTED EDITED COMMENTS

No comments.

RESULTS SUMMARY

Panelists forecast as moderately likely that aluminum will reach a 95 percent application rate for front covers by 2009.

MANUFACTURER AND SUPPLIER COMPARISON

Manufacturers (4.0) rate the likelihood of aluminum front covers reaching a 95 percent application rate by 2009 as much more likely than do the suppliers (3.1). The manufacturers (3.6) also rated the cost of process/manufacturing aluminum front covers as more of an advantage than did the suppliers (2.7).

TREND FROM PREVIOUS DELPHI SURVEYS

This question has not been previously asked.

STRATEGIC CONSIDERATIONS

The panel forecasts a near complete conversion to aluminum front covers in the coming decade. Although panelists rate performance, castability, machinability, and recyclability of aluminum covers as drivers, weight remains the driving force behind the change. Strongly driven by the opportunity for weight reduction without significant cost penalty, the conversion to front covers will likely continue unabated in the coming decade.

MAT-27 Round 1 results indicate a shift from aluminum to plastic in engine **intake manifolds**.

A. How likely is it that plastic will reach a 60 percent application rate for intake manifolds by 2009? Note: Round 1 results indicate that plastic currently has an estimated 10 percent penetration rate.

SCALE →	1	3	5
	NOT LIKELY AT ALL	MODERATELY LIKELY	EXTREMELY LIKELY

LIKELIHOOD OF REACHING 60 PERCENT APPLICATION RATE BY 2009	MEAN RESPONSE
PLASTIC INTAKE MANIFOLDS	3.4

B. Please rate the importance of each of the following material selection/performance criteria with regard to a potential shift from aluminum to plastics in intake manifolds.

SCALE →	1	2	3	4	5
	A SUBSTANTIAL BARRIER	A MODERATE BARRIER	NEITHER A BARRIER NOR A DRIVER	A MODERATE DRIVER	A SUBSTANTIAL DRIVER

MATERIAL SELECTION/ PERFORMANCE CRITERIA FOR PLASTIC INTAKE MANIFOLDS RELATIVE TO ALUMINUM	MEAN RESPONSE
A. PERFORMANCE CHARACTERISTICS OF PLASTIC INTAKE MANIFOLDS	3.2
B. COST OF PLASTIC INTAKE MANIFOLDS	3.9
C. COST OF PROCESSING/MANUFACTURING PLASTIC INTAKE MANIFOLDS	3.7
D. DURABILITY OF PLASTIC INTAKE MAINIFOLDS	3.0
E. MOLDABILITY OF PLASTIC INTAKE MANIFOLDS	3.6
F. PRODUCTION CAPACITY OF PLASTIC INTAKE MAINIFOLDS	3.0
G. PRODUCTION CAPACITY OF ALUMINUM INTAKE MANIFOLDS	2.9
H. LACK OF COMPONENT PROCESSING CAPACITY FOR PLASTIC INTAKE MANIFOLDS	3.0
I. RECYCLABILITY OF PLASTIC INTAKE MANIFOLDS	2.9
J. WEIGHT OF PLASTIC INTAKE MANIFOLDS	4.2

SELECTED EDITED COMMENTS

- Europe is leading the way in this material shift.
- Some potential design capabilities with plastic.
- The acoustic performance of plastic intake manifolds compared with aluminum presents the biggest barrier to the use.

RESULTS SUMMARY

Panelists forecast as somewhat more than moderately likely that plastic will reach a 60 percent application rate for intake manifolds by 2009. Weight and cost are rated as the most important drivers for the increased application of plastic intake manifolds.

MANUFACTURER AND SUPPLIER COMPARISON

There are no statistically significant differences in responses between manufacturers and suppliers.

TREND FROM PREVIOUS DELPHI SURVEYS

This question has not been previously asked.

STRATEGIC CONSIDERATIONS

The shift from aluminum to plastic intake manifolds is driven by weight reduction and part consolidation. Plastic intake manifolds also offer the potential for increased airflow due to the ability to create reduced air turbulence within the manifold via mold surface refinements. The design flexibility offered by plastic intake manifolds allows designers greater versatility in design. There appear to be few barriers that will prevent plastic from dominating the intake manifold market in the coming decade.

MAT-28 What percentage of spark-ignited engines in North American-produced **passenger cars** will use the following ceramic engine components in 2004 and 2009?

CERAMIC ENGINE COMPONENTS	MEDIAN RESPONSE		INTERQUARTILE RANGE	
	2004	2009	2004	2009
EXHAUST MANIFOLD/PORT LINER	5%	12.5%	1.5/7.5%	5/42.5%
PISTON UPPER RING LAND	3	10	0/8.8	1/20
PISTON CROWN	3	6	0/5	.8/28.8
PISTON RINGS, COATING	5	25	0/8.8	5/70
SEALS	3.5	20	0/17.5	1/80
TURBOCHARGER TURBINE/ROTOR (BASED ON % OF ENGINES EQUIPPED WITH TURBOCHARGERS)	3.5	15	2/25	5/75
VALVETRAIN COMPONENTS (INCLUDES VALVES, INSERTS, GUIDE SEATS, TAPPETS, CAM, ETC.)	3.5	10	.3/8.8	2/20
WRIST PINS	0	2	0/2	1/10

SELECTED EDITED COMMENTS

- Seals include water pump seal.

RESULTS SUMMARY

Panelists forecast limited application of ceramics for the listed components in the coming decade. Ceramic is forecast to see the highest application in piston ring coatings (25 percent) and engine seals (20 percent). However, the wide interquartile ranges indicate great uncertainty or disagreement among panelists regarding the future application of ceramics in these as well as in other listed engine components.

MANUFACTURER/SUPPLIER COMPARISON

There are no statistically significant differences in responses between manufacturers and suppliers.

TREND FROM PREVIOUS DELPHI SURVEYS

The application of ceramics for engine components in spark ignited engines has been asked in different forms throughout all of our ten Delphi surveys. Early Delphi panels were highly aggressive in their forecast of ceramic engine applications, while panelists in the early 1990s suggested decreased potential for such applications. However, the 2000 Delphi X panels indicate renewed potential for ceramics usage in several of the listed components.

STRATEGIC CONSIDERATIONS

The panel indicates an increased interest in the application of ceramics for the listed spark ignited engine applications. Ceramics have very attractive wear and high temperature characteristics, but manufacturability, cost, and durability remain severe barriers.

There appears to be minimal expectation for significant increases in ceramics application for the listed engine components. Yet, the wide interquartile ranges suggest great uncertainty or disagreement among panelists regarding the future application of ceramics in the listed engine components.

MAT-29 What percentage of the following North American-produced automotive **powertrain components** will be made from various forms of powdered metals? Please estimate for current vehicles and for 2004 and 2009. Leave blank any component with which you are not familiar.

POWDERED METAL POWERTRAIN COMPONENTS	MEDIAN RESPONSE			INTERQUARTILE RANGE		
	CURRENT EST.	2004	2009	CURRENT EST.	2004	2009
CONNECTING RODS	10%	42.5%	62.5%	7.5/65%	13.8/77.5%	20/85%
TRANSMISSION GEARS	10	20	30	5/20	10/25	15/40
VALVETRAIN COMPONENTS						
CAMSHAFT LOBES	7.5%	12.5%	20%	1.3/10%	10/26.3%	20/35%
ROCKER ARMS	0	10	20	0/5	4/13.8	8.8/27.5
TAPPETS/LIFTERS	5	17.5	20	0/10	5/30	5/50
VALVE GUIDES	10	25	40	3.3/62.5	8.8/75	11.3/80
VALVE SEAT INSERTS	35	50	60	2.5/75	7.5/85	12.5/92.5

SELECTED EDITED COMMENTS

No comments.

RESULTS SUMMARY

Panelists forecast increased application for powdered metals in all listed components. Powdered metal is forecast to see the highest application in connecting rods (60 percent) and valve seat inserts (60 percent). However, the wide interquartile ranges indicate great uncertainty or disagreement among panelists regarding the future application of powdered metals in these engine components.

MANUFACTURER/SUPPLIER COMPARISON

There are no statistically significant differences in responses between manufacturers and suppliers.

TREND FROM PREVIOUS DELPHI SURVEYS

The 2000 Delphi X panels forecast for powdered metal usage in connecting rods, transmission gears, rocker arms, and tappets/lifters is somewhat higher than previous forecasts. Conversely, the Delphi X forecast for valve seat inserts and camshafts lobes is somewhat lower than the Delphi IX forecast.

STRATEGIC CONSIDERATIONS

Although the wide interquartile ranges suggest uncertainty—or differing business plans--the median forecast for all listed components suggests increased usage of powdered metal for engine components. Powdered metal is expected to continue to gain acceptance for many automotive engine applications. The ability of engineers to design in properties for powdered metals by controlling the alloys and densities of various mixtures allows creating more application-specific materials and increases the likelihood that the material will gain favor.

MAT-30 What percentage of the following North American-produced components will be made of aluminum, copper, or plastic? Please estimate for current vehicles and for 2004 and 2009. Please total materials for each component to 100%. Leave blank any component with which you are not familiar.

PASSENGER CARS						
MATERIAL	MEDIAN RESPONSE			INTERQUARTILE RANGE		
	CURRENT EST.	2004	2009	CURRENT EST.	2004	2009
ENGINE OIL COOLER						
ALUMINUM	75%	85.5%	84.5%	50/100%	70/100%	32.5/98.8%
COPPER	10	3	0	0/35	0/26.3	0/7.8
PLASTIC	0	0	0	0/1	0/3	0/20
TOTAL	100%	100%	100%	100%	100%	100%
HEATER CORES						
ALUMINUM	85%	91.5%	94.5%	45/99%	57.5/100%	72.5/100%
COPPER	20	6	.5	2.8/57.5	0/42.5	0/12.5
PLASTIC	0	0	1	0	0/8.8	0/10
TOTAL	100%	100%	100%	100%	100%	100%
RADIATORS						
ALUMINUM	85%	90%	90%	60/97.8%	70/100%	79/100%
COPPER	20	5	1	6/35	0/20	0/10
PLASTIC	0	0	1	0/5.5	0/6.3	0/12.5
TOTAL	100%	100%	100%	100%	100%	100%
TRANSMISSION OIL COOLER						
ALUMINUM	78.5%	96%	90%	42.5/100%	60/100%	70/100%
COPPER	45	30	10	1.5/85	0/50	0/30
PLASTIC	0	0	0	0/.3	0/.8	0/20
TOTAL	100%	100%	100%	100%	100%	100%

LIGHT TRUCKS						
MATERIAL	MEDIAN RESPONSE			INTERQUARTILE RANGE		
	CURRENT EST.	2004	2009	CURRENT EST.	2004	2009
ENGINE OIL COOLER						
ALUMINUM	67.5%	75%	79%	27.5/99.3%	45/100%	20/97.5%
COPPER	10	3	0	0/35	0/26.3	0/7.8
PLASTIC	0	0	0	0/1	0/3	0/20
TOTAL	100%	100%	100%	100%	100%	100%
HEATER CORES						
ALUMINUM	90%	93%	99%	45/100%	50/100%	70/100%
COPPER	20	6	.5	2.8/65	0/50	0/15
PLASTIC	0	0	1	0	0/7.5	0/10
TOTAL	100%	100%	100%	100%	100%	100%
RADIATORS						
ALUMINUM	80%	90%	80%	45/97.8%	60/100%	79/100%
COPPER	20	5	3	6.5/65	0/42.5	0/25
PLASTIC	0	0	0	0/5.5	0/6.3	0/12.5
TOTAL	100%	100%	100%	100%	100%	100%
TRANSMISSION OIL COOLER						
ALUMINUM	60%	83%	84.5%	30/100%	55/100%	62.5/100%
COPPER	40	30	10	1.5/77.5	0/50	0/30
PLASTIC	0	0	0	0/.3	0/.8	0/12.5
TOTAL	100%	100%	100%	100%	100%	100%

SELECTED EDITED COMMENTS

- I assume aluminum will come up with corrosion protecting coatings for radiators and transmission acid generation. Heat transfer of plastics will hurt radiator and transmission applications.

RESULTS SUMMARY

The panelists forecast a continued shift from copper to aluminum in all of the listed heat exchange components for both passenger cars and light trucks. Panelists forecast that approximately 80 to 90 percent of each of the listed components will be made from aluminum by 2009. The forecast for transmission oil coolers shows the most significant increase in aluminum usage.

MANUFACTURER/SUPPLIER COMPARISON

There are no statistically significant differences in responses between manufacturers and suppliers, with the exception of the forecast for copper usage in the components shown below:.

PASSENGER CARS	MANUFACTURERS	SUPPLIERS
COPPER TRANSMISSION OIL COOLERS		
2004	70%	16%
2009	65	6
COPPER HEATER CORES		
2009	20	0.3

LIGHT TRUCKS	MANUFACTURERS	SUPPLIERS
COPPER TRANSMISSION OIL COOLERS		
2009	23	0.3
COPPER HEATER CORES		
2009	65	8

TREND FROM PREVIOUS DELPHI SURVEYS

This question has been asked in this form since the 1996 Delphi VIII. The 2000 Delphi X panels forecast is in general agreement with previous forecasts.

STRATEGIC CONSIDERATIONS

Panelists expect the trend to replace copper with aluminum in all of the listed components to continue through the forecast period. Although the copper industry continues to develop innovative manufacturing and design techniques, for example a new brazing concept currently under development, much of the recent manufacturing investment has been in aluminum processes. Such new investment will represent a significant barrier for future copper application.

Panelists do not forecast any use of plastics for the listed components. However, some significant work is being done with plastics in heat exchanger components. Although future application of plastics appears to be less than certain, current developmental work should be monitored for advances that could lead to more rapid application.

MAT-31 What percentage of **gasoline-fueled** North American-produced vehicles will have fuel tanks made from steel, plastic, or other materials by 2009? Please estimate for current vehicles.

FUEL TANK MATERIAL	MEDIAN RESPONSE		INTERQUARTILE RANGE	
	CURRENT EST.	2009	CURRENT EST.	2009
STAINLESS STEEL	0	10	0/2	0/13.8
STEEL	50	15	30/50	10/28.8
PLASTIC	50	75	48.5/63.8	60/80

SELECTED EDITED COMMENTS

- We will see improved polyethylenes, increased use of multi-layered tanks, including nylon layers, and possibly the use of other materials, including some polypropylenes, nylons, etc.. I predict refinements of design techniques to take more advantage of plastics processing capabilities, and significant improvements for processing plastics.
- An effective barrier within the plastic (hdpe) material will be developed.
- I predict better co-extruded barrier materials and sealing or coating technologies for seams and connections.
- I foresee gas impermeable coatings or filled plastics.
- Plastic will continue to grow with gasoline-fueled vehicles. As alternative fuels and blends become more popular, the barrier and chemical resistance of the plastic fuel tanks may be a limiting factor in some cases and a benefit in others. Some fuel blends and additives tend to rust steel tanks. The design flexibility that plastic fuel tanks offer provides a significant advantage.
- Innovations must be made in the recyclability of plastics before they can become mainstream in this application.
- I predict multilayer construction of fuel tanks.
- New coating technology or co-extrusion blow molding techniques will prevent evaporation via plastics that are more impervious to gas.
- Plastic does not meet the need for evaporative emission requirements for ULEV. We need a leap of technology to meet future needs.
- Stainless steel will be used.
- The lack of barrier material (EVOH) at the punch-off line on the multi-layer plastic tanks is an issue with permeation. Plastic tank suppliers are working to resolve the issue.
- The selection of the components (layers, materials, thickness of layers) of multi-layer blow molded tanks will be adjusted to meet the future evaporation standards. Integral fuel filler tubes will additionally reduce the evaporative emission. Another alternative is to incorporate the use of surface treatments of the plastic (fluoridation, sulfonation, etc.) in addition to the multilayer composition.
- The tank is not the problem; it's the connection and delivery system.
- The wild card for plastic fuel tanks is disposal. Will an acceptable method of disposal for plastic tanks be found? I agree with earlier comment, "they can't be allowed to pile up at the dismantlers."

RESULTS SUMMARY

The panel forecasts plastic to be the dominant fuel tank material by 2009. Stainless steel is also expected to see initial application. The panelists indicate that further development of plastic fuel tank layering materials and strategies, and sealing technologies, are necessary to meet increasingly stringent emission regulations.

MANUFACTURER AND SUPPLIER COMPARISON

Manufacturers estimate a higher current penetration of plastic fuel tanks (60 percent) than do the suppliers (47 percent).

TREND FROM PREVIOUS DELPHI SURVEYS

The 2000 Delphi X panel is in general agreement with prior Delphi forecasts regarding the increased penetration of plastic fuel tanks. However, unlike prior panels, the current Delphi panel does forecast initial penetration of stainless steel fuel tanks.

STRATEGIC CONSIDERATIONS

The shift to plastic fuel tanks (polyethylene with an EVOH or fluorinated vapor barrier coating) is forecast to continue in the coming decade. The design flexibility and weight savings presented by plastics are significant. However, important issues must be resolved for continued growth in plastic fuel tanks, particularly the final disposition of plastic fuel tanks. Industry is proactively trying to reduce the amount of automotive shredder residue (ASR) that is landfilled. With the likelihood of stricter federal regulation regarding disposition of automotive plastics, final disposition may become a critical barrier.

The increased usage of plastic fuel tanks also may be hindered by future emissions regulation. The permeability of plastic fuel tanks must be improved. Panelists seem to disagree on the severity of the challenge; however, it is apparent that both better layering materials and better sealing designs for the "punch-off" line will be crucial to meeting future emission regulations.

MAT-32 Round 1 results indicate a shift from steel to powdered metal in transmission **gears**.

A. How likely is it that powdered metal will reach a 25 percent application rate for transmission gears by 2009? Note: Round 1 results indicate that powdered metal currently has a less than 10 percent penetration rate.

SCALE →	1	3	5
	NOT LIKELY AT ALL	MODERATELY LIKELY	EXTREMELY LIKELY

LIKELIHOOD OF REACHING 25 PERCENT APPLICATION RATE BY 2009	MEAN RESPONSE
POWDERED METAL TRANSMISSION GEARS	3.0

B. Please rate the importance of each of the following material selection/performance criteria with regard to a potential shift from steel to powdered metal in transmission gears.

SCALE →	1	2	3	4	5
	A SUBSTANTIAL BARRIER	A MODERATE BARRIER	NEITHER A BARRIER NOR A DRIVER	A MODERATE DRIVER	A SUBSTANTIAL DRIVER

MATERIAL SELECTION/PERFORMANCE CRITERIA FOR POWDERED METAL GEARS RELATIVE TO STEEL	MEAN RESPONSE
A. PERFORMANCE CHARACTERISTICS OF POWDERED METAL GEARS	2.4
B. COST OF POWDERED METAL GEARS	3.7
C. COST OF PROCESSING/MANUFACTURING POWDERED METAL GEARS	3.4
D. FORGEABILITY OF POWDERED METAL GEARS	3.1
E. COMPACTABILITY OF POWDERED METAL GEARS	2.5
F. DENSITY REQUIREMENTS OF POWDERED METAL GEARS	2.6
G. PRODUCTION CAPACITY OF POWDERED METAL GEARS	2.8
H. PRODUCTION CAPACITY OF STEEL GEARS	2.9
I. LACK OF COMPONENT PROCESSING CAPACITY FOR POWDERED METAL GEARS	2.9
J. WEIGHT OF POWDERED METAL GEARS	3.5

SELECTED EDITED COMMENTS

No comments.

RESULTS SUMMARY

Panelists forecast as moderately likely that powdered metal will reach a 25 percent application rate for transmission gears by 2009. The lower weight and lower costs of powdered metal transmission gears are rated as the most important drivers for the increased application in the coming decade. However, the performance characteristics of powdered metal are viewed as a moderate barrier.

MANUFACTURER AND SUPPLIER COMPARISON

There are no statistically significant differences in responses between manufacturers and suppliers.

TREND FROM PREVIOUS DELPHI SURVEYS

This question has not been previously asked.

STRATEGIC CONSIDERATIONS

Powdered metal transmission gears are formed and compacted in one processing operation. Therefore, these gears require little machining. Although this reduces some processing costs, it results in a gear with approximately 80 percent theoretical density that is lightweight and less costly. Due to their performance characteristics, powdered metal gears are used in lower stress applications.

MAT-33 Round 1 results indicate a shift from steel to aluminum in transmission **rotors**.

How likely is it that aluminum will reach a 50 percent application rate for transmission rotors by 2009? Note: Round 1 results indicate that aluminum currently has a less than 5 percent penetration rate.

SCALE →	1	3	5
	NOT LIKELY AT ALL	MODERATELY LIKELY	EXTREMELY LIKELY

LIKELIHOOD OF REACHING 50 PERCENT APPLICATION RATE BY 2009	MEAN RESPONSE
ALUMINUM TRANSMISSION ROTORS	2.7

B. Please rate the importance of each of the following material selection/performance criteria with regard to a potential shift from steel to aluminum in transmission rotors.

SCALE →	1	2	3	4	5
	A SUBSTANTIAL BARRIER	A MODERATE BARRIER	NEITHER A BARRIER NOR A DRIVER	A MODERATE DRIVER	A SUBSTANTIAL DRIVER

MATERIAL SELECTION/PERFORMANCE CRITERIA FOR ALUMINUM ROTORS RELATIVE TO STEEL	MEAN RESPONSE
A. PERFORMANCE CHARACTERISTICS OF ALUMINUM ROTORS	2.9
B. COST OF ALUMINUM ROTORS	2.5
C. COST OF PROCESSING/ MANUFACTURING ALUMINUM ROTORS	2.4
D. FORMABILITY OF ALUMINUM ROTORS	3.3
E. WELDABILITY OF ALUMINUM ROTORS	2.5
F. PRODUCTION CAPACITY OF ALUMINUM ROTORS	2.9
G. PRODUCTION CAPACITY OF STEEL ROTORS	3.1
H. LACK OF COMPONENT PROCESSING CAPACITY FOR ALUMINUM ROTORS	2.8
I. WEIGHT OF ALUMINUM ROTORS	4.2

SELECTED EDITED COMMENTS

No comments.

RESULTS SUMMARY

Panelists forecast as somewhat less than moderately likely that aluminum will reach a 50 percent application rate for transmission rotors by 2009. The opportunity to save weight by using aluminum rotors is offset by cost issues associated with the change.

MANUFACTURER AND SUPPLIER COMPARISON

There are no statistically significant differences in responses between manufacturers and suppliers.

TREND FROM PREVIOUS DELPHI SURVEYS

This question has not been previously asked.

STRATEGIC CONSIDERATIONS

As with many applications for aluminum, the opportunity for weight reduction is the significant driver for aluminum usage in transmission rotors, while cost is the most critical barrier.

V. BODY AND CHASSIS

MAT-34 What percentage of North American-produced vehicles will have each of the following frame constructions in 2004 and 2009?

FRAME CONSTRUCTION	MEDIAN RESPONSE			INTERQUARTILE RANGE	
	1998*	2004	2009	2004	2009
PASSENGER CARS					
INTEGRAL BODY/FRAME OR UNIBODY	92.1%	92.1%	92%	90.3/95%	83.3/95%
SEPARATE BODY/FRAME	4.8	3.5	2	2/5	.1/5
SPACE FRAME	3.1	4	5	3/5	3/10
TOTAL	100%	100%	100%	100%	100%
SPORT UTILITY VEHICLE					
INTEGRAL BODY/FRAME OR UNIBODY	24.5%	30%	40%	25/35%	30/50%
SEPARATE BODY/FRAME	75.5	70	50	64.5/75	45/65
SPACE FRAME	0.0	0	.5	0/1	0/5.3
TOTAL	100%	100%	100%	100%	100%
MINIVAN					
INTEGRAL BODY/FRAME OR UNIBODY	n/a**	88%	90%	77.5/97.5%	77.5/98.5%
SEPARATE BODY/FRAME	n/a**	15	10	6.5/31.5	0/16.5
SPACE FRAME	n/a**	0	2	0/4	0/10
TOTAL	100%	100%	100%	100%	100%

*Source: Ward's Automotive Reports, Jan. 18, 1999, and OSAT estimates.
**Baseline information not available.

SELECTED EDITED COMMENTS

- Space frame just has too much wasted design; not using the outer panels as stressed design loads is wasted effort.
- SUVs will evolve to become closer to cars in ride and performance as most SUV-users don't really utilize their truck-type attributes.

RESULTS SUMMARY

Panelists forecast little change in frame construction for passenger cars and minivans in the coming decade. However, they forecast a significant increase in unibody frame construction for sport utility vehicles.

MANUFACTURER/SUPPLIER COMPARISON

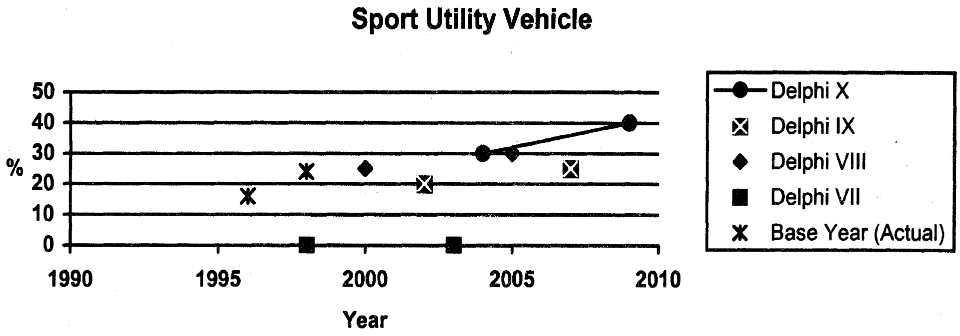
The manufacturers and suppliers are in general agreement with the exception of the forecast for minivan space frame construction. The manufacturers forecast no application of space frame construction for minivans, while the suppliers expect limited usage (6 percent).

COMPARISON OF FORECAST: TECH-31

There are no statistically significant differences in the forecasts provided by the Technology and the Materials panelists for frame construction projections.

TREND FROM PREVIOUS DELPHI SURVEYS

This question has been asked in this form since the 1994 Delphi VII. The 2000 Delphi X forecast is in general agreement with previous forecasts, with the exception of frame construction for sport utility vehicles, as shown in the graph:



STRATEGIC CONSIDERATIONS

In the coming decade, integral (or unibody) frame construction is forecast to be the dominant passenger car and minivan frame design for the North American automotive industry. However, panelists forecast a continued increase in unibody frame construction for sport utility vehicles over the next decade.

Unibody construction is an inherently effective and efficient weight saving design, vis-à-vis body on frame and space frame designs. Therefore, as manufacturers face increasing pressure to reduce weight, unibody construction will continue to be attractive for passenger cars and minivans.

Previous Delphi surveys have included a forecast for pick-up trucks. However, due to the lack of expectation for change from the current body on frame design, the 2000 Delphi X did not include a forecast for pick-up frame design.

The sport utility market continues to undergo significant change. Many of the initial entries were engineered from existing pick-up truck platforms. However, many new entries—specifically in the subcompact, midsize, and luxury segments—are unibody designs. In fact, although many of these new vehicles are considered sport utility vehicles, they are often more similar to passenger cars than the traditional body on frame SUV.

Although the 2000 Delphi panel forecast for space frame-designed passenger cars is slightly lower than that of the previous panel, the panel still forecasts some space frame applications by 2009. Currently, General Motors' Saturn division is the only high volume passenger car manufactured in North America using a space frame design. Saturn's future independence continues to be in doubt. Any further assimilation into the parent company could signal the end of high volume space frame construction in North America.

MAT-35 Please forecast the material mix of steel, aluminum, and plastic frame/structural members in both integral body/frame and space frame North American-produced passenger cars in 2009.

FRAME MATERIALS	MEDIAN RESPONSE		INTERQUARTILE RANGE
	EST. 1998*	2009	2009
INTEGRAL BODY/FRAME OR UNIBODY			
STEEL	100%	85%	80/90%
ALUMINUM	0	15	5/20
PLASTICS	0	2	0/5
TOTAL	100%	100%	100%
SPACE FRAME			
STEEL	100%	80%	67.3/91.3%
ALUMINUM	0	20	7.5/27.5
PLASTICS	0	0	0/5
TOTAL	100%	100%	100%

*Source: OSAT estimates.

SELECTED EDITED COMMENTS

- I'd like to think space frames will see increased application, but I don't believe they will.
- Magnesium B pillars are being investigated.
- The technical challenges to both unibody and space frame aluminum structures are now solved. Cost is the only issue that remains—not just material cost, but the cost of risk associated with new material. I believe those uncertainties will be solved by 2009, largely by appreciation of the value chain benefits of aluminum (mainly the recycle value capture).

RESULTS SUMMARY

Steel is forecast to remain the dominant frame material in the coming decade. However, aluminum is forecast to see application as a frame material (15%) and space frame material (20%) by 2009.

MANUFACTURER/SUPPLIER COMPARISON

There are no statistically significant differences in responses between manufacturers and suppliers.

TREND FROM PREVIOUS DELPHI SURVEYS

The 2000 Delphi X panel is in general agreement with previous forecasts.

STRATEGIC CONSIDERATIONS

Steel is forecast to remain the dominant frame/structural member material for unibody passenger cars in the coming decade. However, the panel forecasts significant application of aluminum unibody vehicles by 2009. Although steel suffers from a weight disadvantage vis-à-vis aluminum, it provides a significant cost advantage. Steel also benefits from having been the material of choice for nearly a century. The combination of cost advantage and a high comfort level places steel in a very strong position. However, that may be changing as the forecast role of aluminum may indicate a trend.

The aluminum industry has undergone many critical mergers in recent years, which may present an opportunity for the aluminum industry to develop more cohesive and stronger relationships with their automotive customers. Although the Aluminum Association has been actively making the benefits of aluminum known to vehicle-makers, they still have much work to do. The recent opening of the Auto Aluminum Alliance, based in Detroit, signals a more formal effort to work with automotive engineers and designers to implement aluminum-optimized designs. The new Detroit office gives the aluminum industry a viable response to the highly successful auto/steel partnership. The ability of aluminum industry participants to offer a "holistic" approach to an aluminum-intensive vehicle will likely be an integral part of future acceptance of aluminum as a viable unibody frame/structural member material.

Note that the panel forecasts initial—yet extremely limited—application of plastics as unibody frame/structural member material. The USCAR Automotive Composites Consortium continues to make significant strides on precompetitive issues pertaining to composite frames, yet many hurdles remain. The forecast by 2000 Delphi X panelists indicates that, although these issues may not be fully resolved, there will be continued developmental work.

MAT-36 What percentage of the following North American-produced passenger car and light truck **body components** will be made of the listed materials? Please estimate for current vehicles, and for 2009. Please total material for each component to 100%. Leave blank any component with which you are not familiar.

PASSENGER CAR BODY COMPONENTS				
MATERIAL	MEDIAN RESPONSE		INTERQUARTILE RANGE	
	CURRENT EST.	2009	CURRENT EST.	2009
DECKLID				
ALUMINUM	5%	17.5%	2/10%	5.8/25%
PLASTIC, THERMOPLASTIC	1	5	0/5	1/10
PLASTIC, THERMOSETS	4	5	1.3/5	1.5/12.5
HSS	1	10	0/18.8	0/40
STEEL	90	70	82.8/94.5	40/84
TOTAL	100%	100%	100%	100%
DOOR				
ALUMINUM	1%	10%	0/2%	4.5/16.3%
PLASTIC, THERMOPLASTIC	2	5	1.5/5	2.8/16.3
PLASTIC, THERMOSETS	2	5	1/5	1/10
HSS	10	20	0/15	0/30
STEEL	92	71	84/97	40/86
TOTAL	100%	100%	100%	100%
FENDER				
ALUMINUM	1	5	0/5	1.8/20
PLASTIC, THERMOPLASTIC	3.5	10	1/5	4.5/15
PLASTIC, THERMOSETS	3	5	.8/5	1/10
HSS	1	2	0/10	0/40
STEEL	89.5%	70%	81/96%	45/81.5%
TOTAL	100%	100%	100%	100%
HOOD				
ALUMINUM	8%	22.5%	5/10%	8.5/37.5%
PLASTIC, THERMOPLASTIC	0	2	0/2	0/10
PLASTIC, THERMOSETS	3	5	1/5	2/10
HSS	1	15	0/15	0/30
STEEL	87	63	79.8/94.3	40/80.8
TOTAL	100%	100%	100%	100%

PASSENGER CAR BODY COMPONENTS - CONTINUED				
MATERIAL	MEDIAN RESPONSE		INTERQUARTILE RANGE	
	CURRENT EST.	2009	CURRENT EST.	2009
QUARTER PANEL				
ALUMINUM	0%	6%	0/1%	1/22.5%
PLASTIC, THERMOPLASTIC	1	3	0/4.3	0/10
PLASTIC, THERMOSETS	1	3	0/2	0/7.5
HSS	1	15	0/10	0/40
STEEL	96	80	88.5/98.8	42.5/90.5
TOTAL	100%	100%	100%	100%
ROOF				
ALUMINUM	.5%	5%	0/1%	1/22.5%
PLASTIC, THERMOPLASTIC	0	2	0/.5	0/10
PLASTIC, THERMOSETS	1	1	0/1.5	0/5
HSS	0	6.5	0/7.5	0/40
STEEL	98.5	89	90/100	25/92
TOTAL	100%	100%	100%	100%

SELECTED EDITED COMMENTS

No comments.

Passenger car:

- Magnesium should be included for deck lids, doors, rear hatch, and cabriolet components.
- Steel dominates today. Hang-on parts will continue to diversify as time goes on. Aluminum will make the most inroads but steel will still have largest market share.

LIGHT TRUCK BODY COMPONENTS				
MATERIAL	MEDIAN RESPONSE		INTERQUARTILE RANGE	
	CURRENT EST.	2009	CURRENT EST.	2009
DOOR				
ALUMINUM	0%	12.5%	0/2.8%	.8/30%
PLASTIC, THERMOPLASTIC	0	5	0/1.5	0/12.5
PLASTIC, THERMOSETS	0	2	0/4	0/15
HSS	10	17.5	0/10	0/40
STEEL	94.5	75	90/100	25/90
TOTAL	100%	100%	100%	100%
FENDER				
ALUMINUM	0%	5%	0/2.8%	0/25%
PLASTIC, THERMOPLASTIC	0	5	0/1.5	0/10
PLASTIC, THERMOSETS	.5	3.5	0/5	0/17.5
HSS	10	10	0/20	0/30
STEEL	98	80	90/100	20/90
TOTAL	100%	100%	100%	100%
HOOD				
ALUMINUM	7%	30%	3/15%	6.5/45%
PLASTIC, THERMOPLASTIC	0	1	0/0	0/12.5
PLASTIC, THERMOSETS	0	0	0/5	0/10
HSS	4.5	10	0/18.3	0/28.8
STEEL	90	62.5	75/100	36.3/90
TOTAL	100%	100%	100%	100%
REAR HATCH				
ALUMINUM	0%	17.5%	0/4.5%	2.8/32.5%
PLASTIC, THERMOPLASTIC	0	5	0/1	0/22.5
PLASTIC, THERMOSETS	2.5	2.5	.3/5	0/17.5
HSS	5	5	0/10	0/30
STEEL	95	76.5	90/100	20/88.5
TOTAL	100%	100%	100%	100%
ROOF				
ALUMINUM	0%	6%	0/5%	.5/30%
PLASTIC, THERMOPLASTIC	0	1.5	0/0	0/12.3
PLASTIC, THERMOSETS	0	0	0/5	0/12.5
HSS	0	0	0/10	0/40
STEEL	100	80	90/100	25/98
TOTAL	100%	100%	100%	100%
TRUCKBED/LIFTGATE				
ALUMINUM	0%	1.5%	0/.3%	0/12.5%
PLASTIC, THERMOPLASTIC	0	10	0/2	0/30
PLASTIC, THERMOSETS	3	10	0/5	0/35
HSS	2	10	0/15	.8/23.8
STEEL	98	72.5	85/100	20/86.3
TOTAL	100%	100%	100%	100%

Light truck:

- I am assuming HSS includes bake hardenable grades.
- Light trucks will see less plastics than passenger car applications.
- Most Ford light trucks have for some time had aluminum hoods – the previous current estimates were too low.
- CAFE is driving weight reduction in trucks.
- Truckbeds will probably end up with plastics at over 50% penetration.

RESULTS SUMMARY

Panelists forecast steel to continue to be the dominant material for all listed exterior body panels. However, aluminum and high strength steel are expected to see increased application in each of the listed applications. The wide interquartile ranges suggest that there is uncertainty regarding the extent that these materials will be used.

For passenger cars, aluminum is expected to see significantly higher penetration rates for hoods (22.5 percent) and decklids (17.5 percent). Plastics are forecast to see increased application for fenders (15 percent) and doors (10 percent). The panel also forecasts increased usage of high strength steel for quarter panels (15 percent), hoods (15 percent), doors (20 percent), and decklids (10 percent)

For light trucks, aluminum is expected to see significantly higher penetration rates for hoods (30 percent) and rear hatches (17.5 percent). Plastic is forecast to see significant growth in truckbed applications (20 percent). High strength steel is forecast to see increased usage for doors (17.5percent), hoods (10 percent), and truckbed/liftgates (10 percent).

MANUFACTURER/SUPPLIER COMPARISON

The manufacturers and suppliers are in general agreement with the exception of the differences shown below:

PASSENGER CAR BODY COMPONENTS – 2009		
THERMOSETS	MANUFACTURERS	SUPPLIERS
DOOR	4.3	10.8
FENDER	4.1	19.4
HOOD	5.6	14.0
QUARTER PANEL	32.6	11.2

LIGHT TRUCKS – 2009		
	MANUFACTURERS	SUPPLIERS
REAR HATCH (THERMOPLASTICS)		
CURRENT ESTIMATE	0	2.2
HOOD (THERMOSETS)		
2009	0	11.0

TREND FROM PREVIOUS DELPHI SURVEYS

The Delphi X forecast continues the trend set in previous Delphi surveys. The long-term forecast for all listed alternate materials is slightly higher than the long-term forecast of the 1998 Delphi IX panel and in line with previously forecasted growth rates.

STRATEGIC CONSIDERATIONS

Although the panel forecasts the continued dominance of steel for all listed exterior body components, it also foresees increased usage of aluminum, high strength steel, and plastics. For several decades, the automotive industry has investigated the potential application of lighter weight materials for body panels, yet steel remains dominant. There appear to be indications that this dominance will lessen in the coming decade. The increasing likelihood that alternative powered vehicles will become a viable alternative in the coming decade, combined with the lessons learned from the work done with lightweight materials, is indicative of the growing viability of aluminum, high strength steel, and plastics for exterior body panels.

Aluminum has experienced growth in horizontal panels, specifically in hood applications. Several high volume vehicle programs have committed to aluminum hoods. And, although at least one of those programs has returned to steel, there is potential for higher-than-forecast hood and other horizontal applications, and possibly also for vertical panels. Several low-volume vehicle programs currently use aluminum fenders. It is possible that the knowledge gained in these programs will lead to significantly increased application of aluminum for vertical panels.

Reinforced thermoplastics continue to see limited application for vertical body panels. Although thermoplastics, perceived as more recyclable than thermosets, are viewed as somewhat more environmentally friendly than thermosets, panelists forecast relatively similar penetration levels for the two materials.

High strength steel, due in part to the automotive industry's increased comfort level with tailor welded blanks, is forecast to see growth in the coming decade. The ability of engineers to tailor body panels by placing steel with the appropriate attributes in critical sections of a stamping will be a key enabler for high strength steels.

MAT-37 Please rate the relative advantages and disadvantages of each material for body panels over the specified stages of the vehicle life cycle.

SCALE →	1	3	5
	AN EXTREME ADVANTAGE	NEITHER AN ADVANTAGE NOR DISADVANTAGE	AN EXTREME DISADVANTAGE

MATERIAL FOR BODY PANELS	MEAN RESPONSE					
	RAW MATERIAL COST	DESIGN	COMPONENT PROCESSING	ASSEMBLY	FIELD USE	VEHICLE DISPOSAL
ALUMINUM	4.2	3.4	3.3	3.3	2.8	2.1
THERMOPLASTICS	3.3	2.0	2.9	3.2	2.9	3.2
THERMOSETS	3.3	2.1	3.4	3.3	2.7	4.4
STEEL	1.2	2.4	1.8	1.8	2.5	1.7

SELECTED EDITED COMMENTS

- Raw material costs per pound are not really the issue. It is cost per pound of weight saved that matters, including allowances for secondary weight savings and full recycle value for plant and post-consumer scrap.
- Thermoplastics have a significant design and processing advantage due to their extreme drawing ratio capabilities, and when made into a paintless film layered design (i.e. high weatherability ASA over ABS or ASA+PC) and back injection molded with a thermoset material, virtually any design could be manufactured. Improved recyclability is necessary.

RESULTS SUMMARY

Panelists rate steel as having an advantage over the other listed materials in the raw material cost, component processing, and assembly stages of the vehicle life cycle. The panel rates thermoplastics and thermosets as slightly more advantageous than aluminum in the design stage.

MANUFACTURER/SUPPLIER COMPARISON

There are no statistically significant differences in responses between manufacturers and suppliers, with the exception of those shown below:

STAGE OF VEHICLE LIFE CYCLE	MANUFACTURERS	SUPPLIERS
DESIGN STAGE		
STEEL	1.9	2.8
COMPONENT PROCESSING STAGE		
ALUMINUM	3.6	3.0
STEEL	1.6	2.2
VEHICLE DISPOSAL STAGE		
STEEL	1.4	2.1

TREND FROM PREVIOUS DELPHI SURVEYS

This question has been asked in this form since the 1994 Delphi VII. The 2000 Delphi X panel is in general agreement with previous forecasts.

STRATEGIC CONSIDERATIONS

Although aluminum, thermoplastics, and thermosets are forecast to see increased application rates for body panels, this question illustrates the challenge these materials face with regard to supplanting steel. Steel is rated as substantially advantageous in three of the six categories. However, this question assumes current CAFE standards. If CAFE—or the price of gasoline—were to increase, it is possible that these ratings would also change.

It is interesting that where manufacturers and suppliers differ in their responses, manufacturers rate steel more positively than do suppliers. This may be viewed as further evidence that manufacturers have a comfort level with steel that will be difficult—but in no way impossible—to overcome.

The customer is not concerned with which material is utilized for body panels. Most customers want value and performance at a competitive price. In most cases, steel currently appears to meet the customer's needs best, yet there will continue to be increased efforts to develop cost-competitive plastic and aluminum body panel applications

Raw material cost:

The cost of steel is rated as a significant advantage. In an industry where cost reduction is critical, the cost of steel alone presents a difficult barrier for increased application of the more costly alternatives. The high and often volatile price of aluminum is viewed as a significant disadvantage at the raw material stage. The cost of thermosets and thermoplastics is rated as neither an advantage nor a disadvantage.

Design:

The panel rates thermosets and thermoplastics as significantly more advantageous in the design stage than aluminum. Plastics offer automotive designers significant freedom and versatility that is difficult to match with the metals. Steel is viewed as design competitive, not because of the versatility of the material, but more likely the nearly century of experience the industry has had with the material.

Component processing and body assembly:

The panel rates steel as having a significant advantage in the manufacturing and assembly stages. As has been mentionedpreviously, the automotive industry has a built a long—and successful—history with steel. Yet, that comfort level will increasingly be challenged. Several companies have introduced composite truck beds that offer durability, part consolidation, and design flexibility, while several others have had several years of experience with aluminum body panel applications. As the lessons learned are incorporated into the organizations, it is likely that engineers will gain confidence in these materials and in turn increasingly incorporate them into future programs.

Field use:

The four materials are viewed as relatively equal for field use. Steel suffers from corrosion and higher weight than the other materials, yet it meets current customer requirements and is extremely reliable for crash predictability. Plastics present significant weight and durability advantages, yet may suffer due to a lack of predictability during a crash. Aluminum also offers weight savings over steel, yet suffers in galvanic corrosion issues.

Vehicle disposal:

According to the panel, thermosets are at a significant disadvantage at the vehicle disposal stage. Thermoplastics—although not as disadvantaged as thermosets—also present problems for disposal. Aluminum and steel, with economically viable recycling infrastructures, are viewed as advantageous in this stage.

MAT-38 Has the issue of corrosion been satisfactorily resolved for each of the following systems?

SCALE →	1	3	5
	YES, IT HAS BEEN RESOLVED	IT IS PARTIALLY RESOLVED	NO, IT HAS NOT BEEN RESOLVED

SYSTEM	MEAN RESPONSE
COSMETIC CORROSION	
BODY	2.0
CHASSIS	2.4
POWERTRAIN	2.1
PERFORATION CORROSION	
BODY	1.9
CHASSIS	1.9
POWERTRAIN	1.4

SELECTED EDITED COMMENTS

- Corrosion is mostly under control but there is always room for improvement. Corrosion is not the reason other materials will replace steel.
- I don't see any further improvement in perforation protection. The issue is will there be a retreat if suppliers of materials can lighten up protective coatings, or if improved paints will allow a return of some parts to CR steel.
- Just when we thought we were there regarding perforation in the chassis, we have two new targets: do it without hexavalent chromium by 2003 and do it for 15 years by 2004.
- No one wants to pay $25K for a vehicle that dings in one month and starts to scale rust in one year without repair. YOU GOTTA DO BETTER.
- We need to maintain current levels with more environmentally friendly materials.
- With the introduction of composite body panels, corrosion would be eliminated.

RESULTS SUMMARY

Panelists indicate that perforation corrosion, and to a slightly lesser extent cosmetic corrosion, has been satisfactorily addressed.

MANUFACTURER/SUPPLIER COMPARISON

There are no statistically significant differences in responses between manufacturers and suppliers, with the exception of those differences shown below. Manufacturers indicate that body corrosion has been more satisfactorily resolved than do suppliers.

	MANUFACTURERS	SUPPLIERS
COSMETIC CORROSION (BODY)	1.7	2.4
PERFORATION CORROSION (BODY)	1.6	2.4

TREND FROM PREVIOUS DELPHI SURVEYS

The 2000 Delphi X panel tends to rate the issue of cosmetic and perforation corrosion as slightly more satisfactorily resolved than did previous panels.

STRATEGIC CONSIDERATIONS

Although the panelists indicate that corrosion has been satisfactorily addressed, several comments highlight the fact that there is still room for improvement in cosmetic corrosion. As the average age of vehicles continues to rise, the challenge of providing longer-term protection against cosmetic corrosion will increase.

Effective corrosion protection involves a system approach. Vehicle design, material selection, and process design and monitoring are critical to the effectiveness of the corrosion protection. The technology and materials are available to improve corrosion protection, yet many are not implemented due to cost concerns. If any of these elements is not thoroughly executed, the vehicle is more susceptibile to corrosion.

MAT-39 Please estimate the number of years before panel perforation will develop in a severely corrosive environment such as Detroit or Pittsburgh for North American-produced passenger cars and light trucks produced in 1999, 2004, and 2009.

YEARS TO PANEL PERFORATION					
MEDIAN RESPONSE			INTERQUARTILE RANGE		
1999	2004	2009	1999	2004	2009
10	10	11.5	7/10	10/12	10/15

SELECTED EDITED COMMENTS

- For 2009 at 20%: Increased aluminum and plastics.
- Perforation by corrosion will become less of an issue as aluminum closure panels are introduced.
- Potentially, by 2009 composite body panels would be mainstream and corrosion would not occur.
- There is certainly a concern about dings, chips, and surface rust on weld spots through e-coat and zinc phosphate coatings.
- There will be continuous improvements in corrosion resistance.
- This is not an issue.

RESULTS SUMMARY

Panelists indicate that the length of body panel perforation will be 10 years by 2004 and 11.5 years by 2009.

MANUFACTURER/SUPPLIER COMPARISON

There are no statistically significant differences in responses between manufacturers and suppliers.

TREND FROM PREVIOUS DELPHI SURVEYS

The 2000 Delphi X panelists' forecast of 11.5 years to panel perforation for 2009 is higher than previous Delphi panel forecasts.

STRATEGIC CONSIDERATIONS

Presently, vehicles are manufactured to meet the 6-year, no panel perforation corrosion warranty. Panelists predict that by 2004 body panels will last 10 years without perforation due to corrosion and that in 2009 they will last 11.5 years. Although the knowledge exists today to deliver vehicles with greater corrosion protection, there is little incentive to do so given the current six year/60,000 mile warranty industry standard.

The forecast of an 11-year, no panel perforation may have its most significant effect on the used car market. The average age of the passenger car fleet is now over eight years. However, the average new car purchaser owns the car for considerably fewer than eight years. For many new vehicle buyers, and individuals who lease vehicles, corrosion protection is a consideration because it may affect used car prices.

MAT-40 What percentage of the following North American-produced **passenger car and light truck bumper components** will be made of the listed materials? Please estimate for current vehicles and for 2009. Please total materials for each component to 100%. Leave blank any component with which you are not familiar. Also, please comment on the drivers and barriers for the material substitution trend for each of the listed components.

BUMPER COMPONENTS				
FASCIA/BUMPER	MEDIAN RESPONSE		INTERQUARTILE RANGE	
	CURRENT EST.	2009	CURRENT EST.	2009
PASSENGER CAR				
ALUMINUM	0	0	0/0	0/0
PLASTIC, THERMOPLASTIC	85	95	85/85	90/95
PLASTIC, THERMOSETS	15	5	15/15	5/10
LIGHT TRUCK				
ALUMINUM	2	2	0/3	1/10
PLASTIC, THERMOPLASTIC	20	40	20/25	30/60
PLASTIC, THERMOSETS	5	5	3/8	0/5
STEEL	70	40	65/75	25/60

BUMPER COMPONENTS				
SUPPORT	MEDIAN RESPONSE		INTERQUARTILE RANGE	
	CURRENT EST.	2009	CURRENT EST.	2009
PASSENGER CAR				
ALUMINUM	10	20	10/10	10/30
PLASTIC, THERMOPLASTIC	10	15	5/13	6.3/23.8
PLASTIC, THERMOSETS	5	5	4.3/7.3	0/10
HSS	12	23.5	0/50	5.5/43.8
STEEL	40	15	6.3/67.5	0/39
LIGHT TRUCK				
ALUMINUM	0	10	0/2	0/12
MAGNESIUM	0	0	0/0	0/0
PLASTIC, THERMOPLASTIC	0	0	0/0	0/5
PLASTIC, THERMOSETS	0	0	0/2	0/5
HSS	19	30	14/30	15/60
STEEL	71	40	58/85	20/60

BUMPER COMPONENTS				
ENERGY ABSORPTION	MEDIAN RESPONSE		INTERQUARTILE RANGE	
	CURRENT EST.	2009	CURRENT EST.	2009
PASSENGER CAR				
ALUMINUM	0	0	0/2.5	0/5
PLASTIC, THERMOPLASTIC	40	30	22.5/55	25.5/67.5
PLASTIC, THERMOSETS	10	10	5/22	0.5/31.5
STEEL	40	20	10/50	10/38.3
LIGHT TRUCK				
ALUMINUM	0	0.5	0/0	0/5
PLASTIC, THERMOPLASTIC	15	17.5	5/20	6.3/27.5
PLASTIC, THERMOSETS	11.3	10	5/20	0/20
STEEL	70	55	60/80	40/70

SELECTED EDITED COMMENTS

No comments.

Passenger car:

- Plastics will win the war with energy-absorbing material development.

Light truck:

- Absorbing more high-speed impact energy with bumper systems.
- Magnesium should be included for bumper support beams.

RESULTS SUMMARY

Panelists forecast thermoplastic to reach a 95 percent penetration rate for passenger car fascia/bumper applications in the coming decade. Panelists forecast a reduction in steel bumper supports, and increased usage of aluminum, HSS, and thermoplastic for supports. They also forecast decreased use of steel for bumper energy absorption. The interquartile ranges for bumper supports and energy absorption are extremely wide, suggesting differing strategies or uncertainty by panelists.

MANUFACTURER AND SUPPLIER COMPARISON

There are no statistically significant differences in responses between manufacturers and suppliers, with the exception of those shown below:

PASSENGER CAR BUMPER COMPONENTS	MANUFACTURER MEAN	SUPPLIER MEAN
SUPPORT: HSS – CURRENT EST.	40.9	10.9
SUPPORT: STEEL – CURRENT EST.	26.8	50.7
SUPPORT: HSS – 2009	42.2	14.1

TREND FROM PREVIOUS DELPHI SURVEYS

This question has not been previously asked.

STRATEGIC CONSIDERATIONS

The panelists' forecast makes it clear that thermoplastic fascia/bumpers will remain the standard for passenger cars in the coming decade. Current styling trends dictate thermoplastic bumpers. Any change in these trends may lead to a material switch for bumpers. However, the light weight and low cost associated with thermoplastic bumper/fascias will be difficult to beat. The panels also forecast an increase in thermoplastic use for light truck bumper/fascias. As light truck design—especially for unibody sport utility vehicles and minivans—increasingly merges with passenger car design, the use of passenger car-like thermoplastic bumpers will become more commonplace in light truck design. However, several panelists indicate that the need to maintain a truck-like image will assure that some truck designs maintain the traditional steel bumper.

The panel forecasts decreased usage of steel for bumper supports and energy absorption. However, according to the panels responses, the future material usage for these applications is somewhat uncertain. For passenger cars, supports, aluminum, thermoplastics, and HSS are forecast to see increased application. The results for energy absorption are less clear. Steel will continue to be used in light trucks with traditional steel bumpers, and thermoplastics are likely to see some increased usage. Polypropylene bead type foam is currently used as the energy absorption material for many passenger car-designed bumper/fascias. Urethane, a thermoset, is not expected to see significant use in the coming decade.

The differences between manufacturers and suppliers indicate a great deal of uncertainty regarding the future of the listed components. As noted earlier, design issues are critical in bumper component material selection. Therefore, it is important to closely monitor vehicle design trends to gain more insight into future bumper component material selection.

MAT-41 Round 1 results indicate a shift from steel to aluminum, plastic (composite), or magnesium in **seat frames**.

A. How likely is it that aluminum, plastic (composite), and/or magnesium will reach a 15 percent application rate for seat frames by 2009? Note: Round 1 results indicate that each of the listed materials currently has a less than 5 percent penetration rate.

SCALE →	1	3	5
	NOT LIKELY AT ALL	MODERATELY LIKELY	EXTREMELY LIKELY

LIKELIHOOD OF REACHING 15 PERCENT APPLICATION RATE BY 2009	MEAN RESPONSE
ALUMINUM SEAT FRAMES	3.4
PLASTIC COMPOSITES SEAT FRAMES	3.1
MAGNESIUM SEAT FRAMES	3.2

B. Please rate the relative advantages and disadvantages of aluminum, plastic (composite), or magnesium for use in seat frames with regard to the following material selection criteria. *(Please use the following rating scale and respond with a number 1 through 5 in each appropriate box.)*

SCALE →	1	3	5
	A SUBSTANTIAL DISADVANTAGE	NEITHER AN ADVANTAGE NOR A DISADVANTAGE	A SUBSTANTIAL ADVANTAGE

MATERIAL SELECTION/PERFORMANCE CRITERIA FOR ALTERNATE MATERIALS RELATIVE TO STEEL SEAT FRAMES	MEAN RESPONSE		
	ALUMINUM	PLASTIC (COMPOSITE)	MAGNESIUM
A. PERFORMANCE CHARACTERISTICS	3.1	3.0	3.7
B. COST	1.9	2.6	1.5
C. COST OF PROCESSING/MANUFACTURING	2.4	2.9	2.4
D. DURABILITY	3.1	3.1	3.5
E. PRODUCTION CAPACITY	3.1	2.8	2.6
F. LACK OF COMPONENT PROCESSING CAPACITY	2.7	2.6	2.6
G. RECYCLABILITY	4.1	1.9	3.8
H. WEIGHT	4.2	4.0	4.5

SELECTED EDITED COMMENTS

No comments.

RESULTS SUMMARY

Panelists forecast as moderately likely that aluminum, plastic (composite), and magnesium will reach a 15 percent application rate for seat frames by 2009. The driver for each of the three materials is weight savings. For all materials, cost is rated as the most severe disadvantage.

MANUFACTURER AND SUPPLIER COMPARISON

There are no statistically significant differences in responses between manufacturers and suppliers, with the exception of the items shown below:

ALTERNATE MATERIALS RELATIVE TO STEEL SEAT FRAMES	MANUFACTURER MEAN	SUPPLIER MEAN
PLASTIC (COMPOSITE): COST OF PROCESSING/MANUFACTURING	2.3	3.4
MAGNESIUM: RECYCLABILITY	4.2	3.5
MAGNESIUM: WEIGHT	4.8	4.2

TREND FROM PREVIOUS DELPHI SURVEYS

This question has not been previously asked.

STRATEGIC CONSIDERATIONS

The competition in seat frame materials is intense, and will likely become even more intense in the coming decade. All three of the listed materials, driven by weight reduction opportunities, appear to be viable candidates for increased application. Yet, the fact each of the three materials is listed as only somewhat likely to reach 15 percent application rates indicates that barriers—foremost among them cost—appear to remain significant and that competition among these three is fierce and close.

Note that each material had several respondents indicate it was extremely likely that the material would reach 15 percent application rate by 2009. Conversely, only one respondent indicated that aluminum and composites were not at all likely to reach a 15 percent application rate by 2009, while no respondents indicated that it was not at all likely for magnesium.

Aluminum:

Aluminum remains a candidate for increased application. However, its light weight and recyclability may be offset by the higher cost.

Composites:

Significant challenges remain to the to application of structural composite seat frames. The seat frame is considered a critical safety component, and, therefore, is subject to considerable validation testing for reliability. Although there is ample evidence that structural composites can meet and exceed safety requirements, the conservative nature of the industry may represent an important barrier, as will recyclability.

Magnesium:

Panelists rate magnesium as having an advantage over the other materials in three areas: weight, performance characteristics, and durability. Magnesium has an excellent strength to weight ratio and great damping properties, making it an outstanding candidate for seat frames. However, cost remains a barrier.

MAT-42 Round 1 results indicate a shift from PVC to TPO or urethane in **instrument panel skins**.

A. How likely is it that TPO will reach a 55 percent application rate, and/or urethane will reach a 30 percent application rate for instrument panel skins by 2009? Note: Round 1 results indicate that both materials currently have less than a 5 percent penetration rate.

SCALE →	1	3	5
	NOT LIKELY AT ALL	MODERATELY LIKELY	EXTREMELY LIKELY

	MEAN RESPONSE
LIKELIHOOD OF REACHING 55 PERCENT APPLICATION RATE BY 2009	
TPO INSTRUMENT PANEL SKINS	4.0
LIKELIHOOD OF REACHING 30 PERCENT APPLICATION RATE BY 2009	
URETHANE INSTRUMENT PANEL SKINS	3.4

B. Please rate the relative advantages and disadvantages of TPO and urethane for use in instrument panel skins with regard to the following material selection criteria. *(Please use the following rating scale and respond with a number 1 through 5 in each appropriate box.)*

SCALE →	1	3	5
	A SUBSTANTIAL DISADVANTAGE	NEITHER AN ADVANTAGE NOR A DISADVANTAGE	A SUBSTANTIAL ADVANTAGE

MATERIAL SELECTION/PERFORMANCE CRITERIA FOR ALTERNATE MATERIALS RELATIVE TO PVC INSTRUMENT PANEL SKINS	ALTERNATIVE INSTRUMENT PANEL SKIN MATERIALS	
	MEAN RESPONSE	
	TPO	URETHANE
A. PERFORMANCE CHARACTERISTICS	3.6	3.9
B. COST	3.2	2.4
C. COST OF PROCESSING/MANUFACTURING	2.9	2.7
D. DURABILITY	3.9	4.2
E. PRODUCTION CAPACITY	3.4	3.0
F. LACK OF COMPONENT PROCESSING CAPACITY	2.9	2.9
G. RECYCLABILITY	4.0	2.8
H. WEIGHT	3.4	3.3
I. ENVIRONMENTAL IMPACT	4.1	3.1

SELECTED EDITED COMMENTS

- Both TPO and urethane have shown they are superior to PVC and are already making inroads into the skin applications inside the automobile. The evaluation should pick up speed in the next few years.
- Performance/durability are driving the change.
- Total systems cost with design flexibility of TPO and TPU should reduce systems cost. The industry will learn more as TPO and TPU become more common. The more they learn, the more they will be able to reduce costs.

RESULTS SUMMARY

Panelists forecast a strong likelihood of growth in TPO for instrument panel applications in the coming decade. The environmental impact of TPO is rated as a strong advantage. The panelists also forecast as moderately likely that urethane would reach a 30 percent application rate for instrument panels by 2009. Panelists indicate that TPO's cost, recyclability, and environmental impact are superior to urethane.

MANUFACTURER AND SUPPLIER COMPARISON

There are no statistically significant differences in responses between manufacturers and suppliers.

TREND FROM PREVIOUS DELPHI SURVEYS

This question has not been previously asked.

STRATEGIC CONSIDERATIONS

Utilizing TPO for instrument panel skins is driven by the desire to eliminate PVC from the recycling stream, the improved long-term durability of TPO relative to PVC, and the deeper texture—or feel—TPO provides. Even given the cost advantages of PVC, the panel expects TPO to quickly increase application rates in the coming decade.

The panel also expects urethane to be used for instrument panel skins in the coming decade. However, according to the panel, TPO has advantages over urethane in environmental impact, recyclability, and cost.

Polypropylene is also expected to see some use in instrument panel skins in the coming decade, but round 1 results indicated that the panel did not expect significant application rates in the coming decade. However, polypropylene has gained some favor in Europe and development should be monitored closely.

MAT-43 Round 1 results indicate a shift from steel to aluminum, plastic composites, magnesium, or high strength steel in **instrument panel cross beams**.

A. How likely is it that aluminum and/or plastic composites will reach a 25 percent application rate and that magnesium and/or high strength steel will reach a 35 percent application rate for instrument cross beams by 2009? Note: Round 1 results indicate that each of the listed materials currently has a less than 10 percent penetration rate.

SCALE →	1 NOT LIKELY AT ALL	3 MODERATELY LIKELY	5 EXTREMELY LIKELY

	MEAN RESPONSE
LIKELIHOOD OF REACHING 25 PERCENT APPLICATION RATE BY 2009	
ALUMINUM INSTRUMENT PANEL CROSS BEAMS	2.7
PLASTIC COMPOSITE INSTRUMENT PANEL CROSS BEAMS	3.1
LIKELIHOOD OF REACHING 35 PERCENT APPLICATION RATE BY 2009	
MAGNESIUM INSTRUMENT PANEL CROSS BEAMS	3.4
HIGH STRENGTH STEEL (HSS) INSTRUMENT PANEL CROSS BEAMS	3.1

B. Please rate the relative advantages and disadvantages of aluminum, plastic composites, magnesium or high strength steel for use in instrument panel cross beams with regard to the following material selection criteria. *(Please use the following rating scale and respond with a number 1 through 5 in each appropriate box.)*

SCALE →	1 A SUBSTANTIAL DISADVANTAGE	3 NEITHER AN ADVANTAGE NOR A DISADVANTAGE	5 A SUBSTANTIAL ADVANTAGE

MATERIAL SELECTION/PERFORMANCE CRITERIA FOR ALTERNATIVE MATERIALS RELATIVE TO STEEL INSTRUMENT PANEL CROSS BEAMS	ALTERNATIVE INSTRUMENT PANEL CROSS BEAM MATERIALS			
	MEAN RESPONSE			
	ALUMINUM	HSS	PLASTIC (COMPOSITES)	MAGNESIUM
A. PERFORMANCE CHARACTERISTICS	3.1	3.9	3.3	3.8
B. COST	2.6	3.6	3.0	2.1
C. COST OF PROCESSING/MANUFACTURING	3.0	3.5	3.1	2.7
D. DURABILITY	3.0	3.9	3.2	3.2
E. PRODUCTION CAPACITY	3.3	3.6	3.2	2.4
F. LACK OF COMPONENT PROCESSING CAPACITY	3.1	3.4	3.0	2.6
G. RECYCLABILITY	3.9	4.0	2.2	3.5
H. WEIGHT	4.1	2.5	3.7	4.0

SELECTED EDITED COMMENTS

No comments.

RESULTS SUMMARY

The panelists find it moderately likely that each of the listed components will reach the given application rates in the coming decade. According to the panel, aluminum, plastic composites, and magnesium offer opportunity to reduce weight, while HSS offers durability advantages over the other materials.

MANUFACTURER AND SUPPLIER COMPARISON

The manufacturers and suppliers generally agree, with two exceptions. The manufacturers (3.9) find it more likely that magnesium instrument panels will reach a 35 percent application rate than do the suppliers (2.8). This difference may in part be explained by the differences between the manufacturers' and suppliers' responses to the relative advantage of magnesium performance characteristics and recyclability. In both instances, the manufacturers rated magnesium as more advantageous than did the suppliers.

MATERIAL SELECTION CRITERIA FOR MAGNESIUM	MANUFACTURERS (MEAN)	SUPPLIERS (MEAN)
PERFORMANCE CHARACTERISTICS	4.2	3.2
RECYCLABILITY	3.8	3.0

Manufacturers and suppliers also disagree on the relative cost advantages of plastic composites. The manufacturers rate the cost of plastic composites as much more of a disadvantage than do the suppliers.

MATERIAL SELECTION CRITERIA FOR PLASTIC COMPOSITES	MANUFACTURERS (MEAN)	SUPPLIERS (MEAN)
COST	2.3	3.8
COST OF MANUFACTURING AND PROCESSING	2.6	3.7

TREND FROM PREVIOUS DELPHI SURVEYS

This question has not been previously asked.

STRATEGIC CONSIDERATIONS

Panelists indicate that although HSS is viewed as having a weight disadvantage vis-à-vis the other materials, it also has several advantages that make it an excellent candidate for instrument panel cross beams. It offers strong performance characteristics, cost, durability, production capacity, and recyclability. Aluminum, plastic composites, and magnesium present opportunity for weight reduction, yet barriers remain. With the exception of weight and recyclability, panelists rate most of the identifying key attributes for aluminum as neither an advantage nor a disadvantage. Therefore, there appears to be little driving force behind material substitution or very equivalent materials – except HSS is top on all but weight. Cost will likely continue to be a severe barrier for magnesium.

MAT-44 What percentage of the following North American-produced automotive **instrument panel components and air bag doors** will be made of the listed materials? Please estimate for current vehicles and for 2009. Please total material for each component to 100%. Leave blank any component with which you are not familiar. Also, please comment on the drivers and barriers for the material substitution trend for each of the listed components where asked.

COMPONENT MATERIAL	MEDIAN RESPONSE		INTERQUARTILE RANGE	
	CURRENT EST.	2009	CURRENT EST.	2009
INSTRUMENT PANEL RETAINER				
ABS	10	5	10/17	0/20
POLYCARBONATE (PC)	10	3	5/11.3	0/15
PC/ABS ALLOY	30	40	21.5/34.8	26/50
POLYPROPYLENE	5.5	15	5/20.3	5/29
SMA	14	15	10/21.3	10/25
AIR BAG DOORS				
POLYESTER	35	22.5	30/35	15/35
PVC	10	5	9.9/10.8	0/6.3
TPO	40	50	36.5/40	34.5/66.3
URETHANE	10.8	10	10/15	0/16.3

SELECTED EDITED COMMENTS

No comments.

RESULTS SUMMARY

Panelists forecast slightly increased application of PC/ABS alloy and polypropylene for Instrument panel retainers in the coming decade. ABS and PC are forecast to decrease in application.

TPO is expected to increase in application for airbag doors in the coming decade. PVC and polyester are forecast to see decreased application in the coming decade.

MANUFACTURER AND SUPPLIER COMPARISON

There are no statistically significant difference in responses between manufacturers and suppliers.

TREND FROM PREVIOUS DELPHI SURVEYS

This question has not been previously asked.

STRATEGIC CONSIDERATIONS

The panel forecasts only a slight change in materials for instrument panel retainers and airbag doors in the coming decade. Although the panel forecasts increased application in PC/ABS alloy blends in the coming decade, the forecast for rather limited application of more polypropylene is interesting. Polypropylene offers the opportunity to reduce cost (especially given the ability to use molded-in color), is lighter, and may be more recyclable. In fact, given recent activity, we find the panelists' rather low forecast for polypropylene usage for instrument applications to be noteworthy.

Several materials currently being used for airbag doors, and TPO is expected to experience increased application in the coming decade. TPO offers necessary performance characteristics and as an increasing percent of instrument panel skins are made from TPO, the ability to use similar materials may increase the potential for application of TPO airbag doors. The future usage of PVC will likely depend on environmental concerns. Because of its attractive cost, the material will likely remain a viable alternative for some companies. However, European initiatives to ban PVC from the disposal stream make its application on future "globally" engineered products unlikely.

MAT-45 Round 1 results indicate a shift from ABS and ABS/PC to polypropylene in **interior panels and door trim panels**.

A. How likely is it that polypropylene will reach an 85 percent application rate for interior and door trim panels by 2009? Note: Round 1 results indicate that polypropylene currently has a 45 percent penetration rate.

SCALE →	1	3	5
	NOT LIKELY AT ALL	MODERATELY LIKELY	EXTREMELY LIKELY

LIKELIHOOD OF REACHING 85 PERCENT APPLICATION RATE BY 2009	MEAN RESPONSE
POLYPROPYLENE	3.9

B. Please rate the importance of each of the following material selection/performance criteria with regard to a potential shift from ABS and ABS/PC to polypropylene in interior and door trim panels.

SCALE →	1	2	3	4	5
	A SUBSTANTIAL BARRIER	A MODERATE BARRIER	NEITHER A BARRIER NOR A DRIVER	A MODERATE DRIVER	A SUBSTANTIAL DRIVER

MATERIAL SELECTION/PERFORMANCE CRITERIA FOR POLYPROYLENE RELATIVE TO ABS AND ABS/PC IN TRIM PANELS	MEAN RESPONSE
A. PERFORMANCE CHARACTERISTICS OF POLYPROPYLENE TRIM PANELS	2.8
B. COST OF POLYPROPYLENE TRIM PANELS	4.4
C. COST OF PROCESSING/MANUFACTURING POLYPROPYLENE TRIM PANELS	3.9
D. DURABILITY OF POLYPROPYLENE TRIM PANELS	2.9
E. MOLDABILITY OF POLYPROPYLENE TRIM PANELS	3.8
F. MOLDED-IN COLOR OF POLYPROPYLENE TRIM PANELS	3.7
G. PAINTABILITY OF ABS AND ABS/PC TRIM PANELS	3.1
H. PRODUCTION CAPACITY OF POLYPROPYLENE TRIM PANELS	3.3
I. PRODUCTION CAPACITY OF ABS, ABS/PC TRIM PANELS	3.2
J. LACK OF COMPONENT PROCESSING CAPACITY FOR POLYPROPYLENE TRIM PANELS	3.1
K. RECYCLABILITY OF POLYPROPYLENE TRIM PANELS	3.9
L. WEIGHT OF POLYPROPYLENE TRIM PANELS	3.7

SELECTED EDITED COMMENTS

No comments.

RESULTS SUMMARY

Panelists forecast that polypropylene would likely reach an 85 percent application rate for interior trim and door trim panels by 2009. The cost of polypropylene panels and manufacturing/processing, and recyclability, are rated as moderate drivers for the increase usage of polypropylene.

MANUFACTURER AND SUPPLIER COMPARISON

There are no statistically significant differences in responses between manufacturers and suppliers.

TREND FROM PREVIOUS DELPHI SURVEYS

This question has not been previously asked.

STRATEGIC CONSIDERATIONS

The use of polypropylene door and trim panels is a low-cost, lightweight alternative that allows for good moldability and molded-in color. The ability to use molded-in color technology makes polypropylene especially well suited for interior trim panels on low-end vehicles. However, due to adhesion difficulties, polypropylene does not perform well in covered applications such as with carpet or cloth. This may be a concern for some luxury vehicle applications. And, although polypropylene meets new head impact requirements for pillars, ABS may provide improved impact performance properties and designs.

MAT-46 What percentage of the following North American-produced automotive **interior components** will be made of the listed materials? Please estimate for current vehicles and for 2009. Please total material for each component to 100%. Leave blank any component with which you are not familiar.

COMPONENT MATERIAL	MEDIAN RESPONSE		INTERQUARTILE RANGE	
	CURRENT EST.	2009	CURRENT EST.	2009
HEADLINER				
FABRIC	25	40	15.5/30	21.3/63
FIBERGLASS	30	9.5	30/30	5/13.8
URETHANE	40	40	32.5/45	27.8/50
SEAT COVER				
KNITTED AND CUT	70%	70%	60/75%	55/75%
LEATHER	23	25	15/30	15/40
PVC	10	0	4.3/12.5	0/5
URETHANE	0	5	0/7	0/12
SEAT CUSHION				
HORSE HAIR	2%	.5%	.3/4.5%	0/7.8%
POLYESTER	5	7.5	0/10	5/18.8
URETHANE	94	82.5	83.8/100	66.3/98
WOVEN/SUSPENSION	1	7.5	0/1.5	2.8/10
CARPET FIBER				
NYLON	50	20	30/50	20/32.5
POLYESTER	35	30	30/40	20/35
POLYPROPYLENE	20	40	10/25	30/55

SELECTED EDITED COMMENTS

No comments.

RESULTS SUMMARY

Panelists forecast moderate changes in headliner and carpet fiber materials in the coming decade. Fabric is forecast to increase to a 40 percent application rate while fiberglass is expected to decline to below 10 percent in the coming decade. For carpet fiber, nylon is expected to decline, while polypropylene is expected to see increased application.

Panelists forecast little change in seat cushion or seat cover material in the coming decade.

MANUFACTURER AND SUPPLIER COMPARISON

There are no statistically significant differences in responses between manufacturers and suppliers.

TREND FROM PREVIOUS DELPHI SURVEYS

The 2000 Delphi panel is in general agreement with previous Delphi panels.

STRATEGIC CONSIDERATIONS

The shift to polypropylene carpet fiber is in large part due to the desire of automotive manufacturers to increase the overall recyclabilty of interior plastics. Yet while offering a cost and recycling advantage, polypropylene may not meet performance requirements for luxury vehicle applications.

The forecast reduction in fiberglass usage in headliners is due in part to environmental concerns. Fiberglass presents difficulty in recycling at the end of the product life cycle.

MAT-47 What percentage of the following North American-produced passenger car **chassis components** will be made of the listed materials? Please estimate for current vehicles and for 2009. Please total material for each component to 100%. Leave blank any component with which you are not familiar.

PASSENGER CARS – CHASSIS COMPONENTS				
CHASSIS COMPONENTS	MEDIAN RESPONSE		INTERQUARTILE RANGE	
	CURRENT EST.	2009	CURRENT EST.	2009
STEERING LINKAGE – IDLER ARM				
ALUMINUM	2%	2%	0/10%	0/20%
STEEL	98	96	75/100	70/100
TOTAL	100%	100%	100%	100%
STEERING LINKAGE – PITMAN ARM				
ALUMINUM	4%	4%	0/10%	0/20%
STEEL	96	92	75/100	70/100
TOTAL	100%	100%	100%	100%
STEERING LINKAGE – TIE ROD				
ALUMINUM	5%	12%	0/10%	0/15%
STEEL	100	100	90/100	75/100
TOTAL	100%	100%	100%	100%
WHEELS				
ALUMINUM	35%	47.5%	30/48.8%	41.3/53.8%
STEEL	50	37.5	32/65	20.8/51.3
TOTAL	100%	100%	100%	100%

LIGHT TRUCKS – CHASSIS COMPONENTS				
CHASSIS COMPONENTS	MEDIAN RESPONSE		INTERQUARTILE RANGE	
	CURRENT EST.	2009	CURRENT EST.	2009
STEERING LINKAGE – IDLER ARM				
ALUMINUM	5%	12.5%	0/10%	0/25%
STEEL	100	100	85/100	50/100
TOTAL	100%	100%	100%	100%
STEERING LINKAGE – PITMAN ARM				
STEEL	100%	97%	80/100%	20/100%
ALUMINUM	5	5	0/10	0/10
TOTAL	100%	100%	100%	100%
WHEELS				
STEEL	50%	30%	40/70%	21.3/61.3%
ALUMINUM	25	37.5	10/52.5	31.3/52.5
PLASTIC (COMPOSITE)	0	10	0/5	7.5/22.5
TOTAL	100%	100%	100%	100%

SELECTED EDITED COMMENTS

No comments.

RESULTS SUMMARY

Panelists forecast little material change in the coming decade for the listed steering linkage components. The panel does forecast a continued increase in aluminum for wheels.

MANUFACTURER AND SUPPLIER COMPARISON

There are no statistically significant differences in responses between manufacturers and suppliers.

TREND FROM PREVIOUS DELPHI SURVEYS

The 2000 Delphi panel is in general agreement with previous Delphi panels.

STRATEGIC CONSIDERATIONS

The listed steering linkage components must meet critical safety and performance criteria, so the industry will continue to rely on steel for these applications.

Wheels are forecast to continue the trend toward increased use of aluminum. Styling and weight offered by aluminum has proven to offset any possible cost disadvantage when compared to steel.

MAT-48 Round 1 results indicate a shift from steel to aluminum or high strength steel in **control arms** for passenger cars and light trucks.

A. How likely is it that aluminum will reach a 25 percent and/or high strength steel will reach a 45 percent application rate for control arms in light vehicles by 2009? Note: Round 1 results indicate that each of the listed materials currently has a less than 5 percent penetration rate.

SCALE →	1 NOT LIKELY AT ALL	3 MODERATELY LIKELY	5 EXTREMELY LIKELY

	MEAN RESPONSE
LIKELIHOOD OF REACHING 25 PERCENT APPLICATION RATE BY 2009	
ALUMINUM CONTROL ARMS	3.1
LIKELIHOOD OF REACHING 45 PERCENT APPLICATION RATE BY 2009	
HIGH STRENGTH STEEL CONTROL ARMS	3.8

B. Please rate the relative advantages and disadvantages of aluminum and high strength steel for use in control arms with regard to the following material selection criteria. *(Please use the following rating scale and respond with a number 1 through 5 in each appropriate box.)*

SCALE →	1 A SUBSTANTIAL DISADVANTAGE	3 NEITHER AN ADVANTAGE NOR A DISADVANTAGE	5 A SUBSTANTIAL ADVANTAGE

MATERIAL SELECTION/PERFORMANCE CRITERIA FOR ALTERNATIVE MATERIALS RELATIVE TO STEEL CONTROL ARMS	ALTERNATIVE CONTROL ARM MATERIALS	
	MEAN RESPONSE	
	ALUMINUM	HSS
A. PERFORMANCE CHARACTERISTICS	2.9	4.1
B. COST	2.0	3.1
C. COST OF PROCESSING/MANUFACTURING	2.6	3.1
D. DURABILITY	2.6	3.7
E. FORMABILITY OF HSS	N/A	2.3
F. CASTABILITY	4.0	N/A
G. PRODUCTION CAPACITY	3.1	3.3
H. LACK OF COMPONENT PROCESSING CAPACITY	3.0	3.2
I. RECYCLABILITY	3.7	3.8
J. WEIGHT	4.2	2.9

SELECTED EDITED COMMENTS

- Development costs and time will keep aluminum from coming on fast.

RESULTS SUMMARY

The panel forecasts as moderately likely that aluminum control arms will reach a 25 percent application rate by 2009. Castability and weight are rated as important advantages for aluminum. They also view it as likely that HSS control arms will reach a 45 percent application rate by 2009. The panel views its performance characteristics and durability as important advantages for HSS.

MANUFACTURER AND SUPPLIER COMPARISON

The manufacturers (3.7) find it more likely that aluminum control arms will reach a 25 percent application than do suppliers (2.7). Manufacturers and suppliers also differ on the cost of manufacturing/processing aluminum control arms. The suppliers (2.3) rate the cost of processing/manufacturing as a disadvantage, while the manufacturers (3.0) rate it as neither an advantage nor disadvantage.

TREND FROM PREVIOUS DELPHI SURVEYS

This question has not been previously asked.

STRATEGIC CONSIDERATIONS

HSS offers durability and performance over steel, but its formability does present challenges. The extruded bushing hole—due to the potential for "splitting"—is possibly the most difficult of these manufacturing challenges. It is also critical to closely control springback due to the potential for tensile residual stresses that can decrease fatigue life. Aluminum control arms offer increased weight savings, but at a cost disadvantage.

MAT-49 Round 1 results indicate a shift from steel to plastic composite in **front and rear springs** for passenger cars and light trucks.

A. How likely is it that plastic composite will reach a 20 percent application rate for front and rear springs in light vehicles by 2009? Note: Round 1 results indicate that composites currently have a less than 5 percent penetration rate.

SCALE →	1	3	5
	NOT LIKELY AT ALL	MODERATELY LIKELY	EXTREMELY LIKELY

LIKELIHOOD OF REACHING 20 PERCENT APPLICATION RATE BY 2009	MEAN RESPONSE
PLASTIC COMPOSITE	2.2

B. Please rate the importance of each of the following material selection/performance criteria with regard to a potential shift from steel to plastic (composite) in front and rear springs.

SCALE →	1	2	3	4	5
	A SUBSTANTIAL BARRIER	A MODERATE BARRIER	NEITHER A BARRIER NOR A DRIVER	A MODERATE DRIVER	A SUBSTANTIAL DRIVER

MATERIAL SELECTION/ PERFORMANCE CRITERIA FOR PLASTIC COMPOSITE RELATIVE TO STEEL IN FRONT AND REAR SPRINGS	MEAN RESPONSE
A. PERFORMANCE CHARACTERISTICS OF PLASTIC COMPOSITE SPRINGS	3.0
B. COST OF PLASTIC COMPOSITE SPRINGS	2.1
C. COST OF PROCESSING/ MANUFACTURING PLASTIC COMPOSITE SPRINGS	2.6
D. DURABILITY OF PLASTIC COMPOSITE SPRINGS	2.8
E. CASTABILITY OF PLASTIC COMPOSITE SPRINGS	3.1
F. PROCESSABILITY OF PLASTIC COMPOSITE SPRINGS	2.8
G. PRODUCTION CAPACITY OF PLASTIC COMPOSITE SPRINGS	2.4
H. PRODUCTION CAPACITY OF STEEL SPRINGS	3.1
I. LACK OF COMPONENT PROCESSING CAPACITY FOR PLASTIC COMPOSITE SPRINGS	2.7
J. RECYCLABILITY OF PLASTIC COMPOSITE SPRINGS	2.4
K. WEIGHT OF PLASTIC COMPOSITE SPRINGS	4.7

SELECTED EDITED COMMENTS

- We must look to a short shift in the direction of small car production, where plastics may increase in the next few years.

RESULTS SUMMARY

Panelists forecast as moderately unlikely that plastic composite front and rear springs will reach a 20 percent application by 2009. Although weight is seen as a strong advantage, the cost of composites springs, production capacity, and recyclability of composite springs are viewed as barriers.

MANUFACTURER AND SUPPLIER COMPARISON

The manufacturers rate the lack of production capacity of plastic composite springs as a significant barrier (1.5), while the suppliers rated it as neither a barrier nor a driver (3.2).

TREND FROM PREVIOUS DELPHI SURVEYS

This question has not been previously asked.

STRATEGIC CONSIDERATIONS

The panel lists two moderate barriers for composite springs, and it appears composite springs may not see widespread application in the coming decade. Cost and production capacity and recyclability issues will likely represent the materials' biggest hurdles to increased application. However, the outstanding corrosion resistance and superior fatigue properties will continue to offer an enticing package. Although there are many barriers, the potential benefits of composite springs suggests that it may be of value to monitor closely future composite spring manufacturing advances.

MAT-50 Round 1 results indicate a shift from steel to aluminum in **steering assembly knuckles** in passenger cars and light trucks.

A. How likely is it that aluminum will reach a 30 percent application rate for steering assembly knuckles in light vehicles by 2009? Note: Round 1 results indicate that aluminum currently has a less than 10 percent penetration rate.

SCALE →	1	3	5
	NOT LIKELY AT ALL	MODERATELY LIKELY	EXTREMELY LIKELY

LIKELIHOOD OF REACHING 30 PERCENT APPLICATION RATE BY 2009	MEAN RESPONSE
ALUMINUM	3.4

B. Please rate the importance of each of the following material selection/performance criteria with regard to a potential shift from steel to aluminum steering knuckles.

SCALE →	1	2	3	4	5
	A SUBSTANTIAL BARRIER	A MODERATE BARRIER	NEITHER A BARRIER NOR A DRIVER	A MODERATE DRIVER	A SUBSTANTIAL DRIVER

MATERIAL SELECTION/PERFORMANCE CRITERIA FOR ALUMINUM RELATIVE TO STEEL IN STEERING KNUCKLES	MEAN RESPONSE
A. PERFORMANCE CHARACTERISTICS OF ALUMINUM KNUCKLES	2.8
B. COST OF ALUMINUM KNUCKLES	1.9
C. COST OF PROCESSING/MANUFACTURING ALUMINUM KNUCKLES	2.6
D. FORGEABILITY OF ALUMINUM KNUCKLES	3.1
E. CASTABILITY OF ALUMINUM KNUCKLES	3.4
F. MACHINEABILITY OF ALUMINUM KNUCKLES	3.4
G. PROCESSABILITY OF ALUMINUM KNUCKLES	3.2
H. PRODUCTION CAPACITY OF ALUMINUM KNUCKLES	2.8
I. PRODUCTION CAPACITY OF STEEL KNUCKLES	3.6
J. LACK OF COMPONENT PROCESSING CAPACITY FOR ALUMINUM KNUCKLES	2.7
K. RECYCLABILITY OF ALUMINUM KNUCKLES	3.6
L. WEIGHT OF ALUMINUM KNUCKLES	4.8

SELECTED EDITED COMMENTS

- Another long road for aluminum to follow.
- Aluminum influences NVH, ride, and handling substantially.
- Most of the steering knuckles in my penny-pinching division's vehicles are cast aluminum. We have had good success with performance of the cast aluminum knuckles. I see no reason (other than capacity, and I just don't know what the capacity is) for the whole industry not to switch to aluminum for mass savings.

RESULTS SUMMARY

Panelists forecast as moderately likely that aluminum steering knuckles will reach a 30 percent application by 2009. According to the panelists, weight is a substantial driver in the use of aluminum for steering knuckles, and cost is the most important barrier

MANUFACTURER AND SUPPLIER COMPARISON

There are no statistically significant differences in responses between manufacturers and suppliers.

TREND FROM PREVIOUS DELPHI SURVEYS

This question has not been previously asked.

STRATEGIC CONSIDERATIONS

Like many suspension components, aluminum steering knuckles face important barriers to further implementation due to the cost of raw material and manufacturing. of. Although the weight savings offered by aluminum are a substantial driver, it appears that unless there is unexpected pressure to increase gasoline mileage in the coming decade, the use of aluminum will not significantly increase.

MAT-51 Round 1 results indicate a shift from steel to aluminum in **stabilizer bars** in passenger cars and light trucks.

A. How likely is it that aluminum will reach a 15 percent application rate for stabilizer bars in light vehicles by 2009? Note: Round 1 results indicate that aluminum currently has a less than 1 percent penetration rate.

SCALE →	1	3	5
	NOT LIKELY AT ALL	MODERATELY LIKELY	EXTREMELY LIKELY

LIKELIHOOD OF REACHING 15 PERCENT APPLICATION RATE BY 2009	MEAN RESPONSE
ALUMINUM	2.4

B. Please rate the importance of each of the following material selection/performance criteria with regard to a potential shift from steel to aluminum stabilizer bars.

SCALE →	1	2	3	4	5
	A SUBSTANTIAL BARRIER	A MODERATE BARRIER	NEITHER A BARRIER NOR A DRIVER	A MODERATE DRIVER	A SUBSTANTIAL DRIVER

MATERIAL SELECTION/PERFORMANCE CRITERIA FOR ALUMINUM RELATIVE TO STEEL IN STABILIZER BARS	MEAN RESPONSE
A. PERFORMANCE CHARACTERISTICS OF ALUMINUM STABILIZER BARS	2.1
B. COST OF ALUMINUM STABILIZER BARS	2.0
C. COST OF PROCESSING/MANUFACTURING ALUMINUM STABILIZER BARS	2.6
D. FORGEABILITY OF ALUMINUM STABILIZER BARS	3.2
E. CASTABILITY OF ALUMINUM STABILIZER BARS	3.1
F. MACHINEABILITY OF ALUMINUM STABILIZER BARS	3.3
G. PROCESSABILITY OF ALUMINUM STABILIZER BARS	2.9
H. PRODUCTION CAPACITY OF ALUMINUM STABILIZER BARS	2.9
I. PRODUCTION CAPACITY OF STEEL STABILIZER BARS	3.4
J. LACK OF COMPONENT PROCESSING CAPACITY FOR ALUMINUM STABILIZER BARS	2.9
K. RECYCLABILITY OF ALUMINUM STABILIZER BARS	3.4
L. WEIGHT OF ALUMINUM STABILIZER BARS	4.5

SELECTED EDITED COMMENTS

No comments.

RESULTS SUMMARY

Panelists forecast as less than moderately likely that aluminum stabilizer bars will reach a 15 percent application rate by 2009. According to the panelists, weight is a substantial driver in the use of aluminum for stabilizer bars, but cost and performance characteristics are critical barriers.

MANUFACTURER AND SUPPLIER COMPARISON

Manufacturers and suppliers are in general agreement, with one exception: suppliers rate the weight of aluminum stabilizer bars as more of an advantage (4.7) than do the manufacturers (4.1).

TREND FROM PREVIOUS DELPHI SURVEYS

This question has not been previously asked.

STRATEGIC CONSIDERATIONS

There appears to be little expectation for aluminum stabilizer bars to gain even moderate penetration in the coming decade. Unlike many other listed components, the panel indicates that the performance characteristics of aluminum are a barrier to its use for stabilizer bars. The lower modulus of elasticity in aluminum may affect fatigue and permanent set, and possibly influence performance.

MAT-52 Round 1 results indicate a shift from steel to aluminum or plastic (composite) in **driveshafts** for light trucks.

A. How likely is it that aluminum will reach a 20 percent application rate or plastic (composite) will reach a 5 percent application rate for driveshafts in light vehicles by 2009? Note: Round 1 results indicate that aluminum currently has a 10 percent penetration rate and plastic/composite has a less than 1 percent penetration rate.

SCALE →	1	3	5
	NOT LIKELY AT ALL	MODERATELY LIKELY	EXTREMELY LIKELY

	MEAN RESPONSE
LIKELIHOOD OF REACHING 20 PERCENT APPLICATION RATE BY 2009	
ALUMINUM DRIVESHAFTS	3.2
LIKELIHOOD OF REACHING 5 PERCENT APPLICATION RATE BY 2009	
PLASTIC/COMPOSITE DRIVESHAFTS	2.9

B. Please rate the relative advantages and disadvantages of aluminum and plastic (composite) for use in light truck driveshafts with regard to the following material selection criteria. *(Please use the following rating scale and respond with a number 1 through 5 in each appropriate box.)*

SCALE →	1	3	5
	A SUBSTANTIAL DISADVANTAGE	NEITHER AN ADVANTAGE NOR A DISADVANTAGE	A SUBSTANTIAL ADVANTAGE

MATERIAL SELECTION/PERFORMANCE CRITERIA FOR ALTERNATIVE MATERIALS RELATIVE TO STEEL DRIVESHAFTS	ALTERNATIVE CONTROL ARM MATERIALS	
	MEAN RESPONSE	
	ALUMINUM	PLASTIC COMPOSITE
A. PERFORMANCE CHARACTERISTICS	3.2	3.7
B. COST	2.6	2.1
C. COST OF PROCESSING/MANUFACTURING	3.1	2.2
D. DURABILITY	3.3	3.6
E. PROCESSABILITY	3.4	2.8
F. MOLDABILITY	n/a	2.9
G. PRODUCTION CAPACITY	3.4	2.5
H. LACK OF COMPONENT PROCESSING CAPACITY	3.2	2.7
I. RECYCLABILITY	3.9	2.2
J. WEIGHT	4.1	4.5
K. ENVIRONMENTAL IMPACT	3.6	2.6

SELECTED EDITED COMMENTS

- Both materials are in production today.
- The plastic composite will offer advantages. It can be tuned for better noise and vibration optimization, no corrosion, and quieter operations.

RESULTS SUMMARY

Panelists forecast as moderately likely that aluminum driveshafts will reach 15 percent application. Panelists rate weight as an advantage for aluminum, and cost as the most significant disadvantage. Panelists also forecast as moderately likely that composite driveshafts will reach a 5 percent application rate in light trucks by 2009. Weight and performance characteristics are viewed as advantages for composites, while processing cost, production capacity, recyclability, and environmental impact are disadvantages.

MANUFACTURER AND SUPPLIER COMPARISON

The manufacturers and suppliers are in general agreement, with the exception of the ratings below:

	MANUFACTURERS (MEAN)	SUPPLIERS (MEAN)
PROCESSABILITY OF ALUMINUM DRIVESHAFTS	2.7	3.7
MOLDABILITY OF COMPOSITE DRIVESHAFTS	2.0	3.3

TREND FROM PREVIOUS DELPHI SURVEYS

This question has not been previously asked.

STRATEGIC CONSIDERATIONS

Aluminum and composites offer significant opportunities for driveshaft weight reduction. Yet this weight reduction comes at a higher cost. For aluminum, cost appears to be the only disadvantage. All other selection/performance criteria are rated as at least equal to or an advantage over steel.

For composites, weight, durability, and performance characteristics are viewed as advantageous over steel. Composite driveshafts offer the potential for reduced noise/vibration/harshness and the elimination of corrosion concerns. However, these advantages do not appear significant enough to overcome the cost and other negative issues associated with composite driveshafts.

MAT-53 Round 1 results indicate a shift from cast iron to aluminum in light truck **rear axle assembly-differential carriers**.

How likely is it that aluminum will reach a 30 percent application rate for differential carriers in light vehicles by 2009? Note: Round 1 results indicate that aluminum currently has a 10 percent penetration rate.

SCALE →	1	3	5
	NOT LIKELY AT ALL	MODERATELY LIKELY	EXTREMELY LIKELY

LIKELIHOOD OF REACHING 30 PERCENT APPLICATION RATE BY 2009	MEAN RESPONSE
ALUMINUM	3.0

B. Please rate the importance of each of the following material selection/performance criteria with regard to a potential shift from cast iron to aluminum in differential carriers.

SCALE →	1	2	3	4	5
	A SUBSTANTIAL BARRIER	A MODERATE BARRIER	NEITHER A BARRIER NOR A DRIVER	A MODERATE DRIVER	A SUBSTANTIAL DRIVER

MATERIAL SELECTION/PERFORMANCE CRITERIA FOR ALUMINUM RELATIVE TO CAST IRON IN DIFFERENTIAL CARRIERS	MEAN RESPONSE
A. PERFORMANCE CHARACTERISTICS OF ALUMINUM DIFF. CARRIERS	3.3
B. COST OF ALUMINUM DIFF. CARRIERS	2.1
C. COST OF PROCESSING/MANUFACTURING ALUMINUM DIFF. CARRIERS	2.5
D. CASTABILITY OF ALUMINUM DIFF. CARRIERS	3.4
E. MACHINEABILITY OF ALUMINUM DIFF. CARRIERS	3.4
F. PROCESSABILITY OF ALUMINUM DIFF. CARRIERS	3.3
G. PRODUCTION CAPACITY OF ALUMINUM DIFF. CARRIERS	3.1
H. PRODUCTION CAPACITY OF CAST IRON DIFF. CARRIERS	3.6
I. LACK OF COMPONENT PROCESSING CAPACITY FOR ALUMINUM DIFF. CARRIERS	2.9
J. RECYCLABILITY OF ALUMINUM DIFF. CARRIERS	3.5
K. WEIGHT OF ALUMINUM DIFF. CARRIERS	4.5

SELECTED EDITED COMMENTS

- Durability is a big question.

RESULTS SUMMARY

Panelists forecast as moderately likely that aluminum will reach 30 percent application for differential carriers by 2009. Panelists rate weight as an advantage for aluminum, and cost as the most significant disadvantage.

MANUFACTURER AND SUPPLIER COMPARISON

Suppliers (3.7) rate the castability of aluminum differentials as a driver, while manufacturers (3.0) rate it as neither a barrier nor a driver.

TREND FROM PREVIOUS DELPHI SURVEYS

This question has not been previously asked.

STRATEGIC CONSIDERATIONS

The panel forecasts moderate application of aluminum differential carriers in the coming decade. As increased scrutiny is given to light trucks with regard to fuel economy and vehicle mass, manufacturers will continue to explore opportunities to significantly reduce weight. However, unless there are significant changes in CAFE, emissions, or safety regulations regarding light trucks and their interaction with smaller passenger vehicles, much of the gains for lightweight materials will come at a steady, if relatively slow, pace.

MAT-54 Round 1 results indicate an increase in aluminum used in light truck **rear axle assembly-torque tubes**.

A. How likely is it that aluminum will reach a 25 percent application rate for torque tubes in light trucks by 2009? Note: Round 1 results indicate that aluminum currently has a 5 percent penetration rate.

SCALE →	1	3	5
	NOT LIKELY AT ALL	MODERATELY LIKELY	EXTREMELY LIKELY

LIKELIHOOD OF REACHING 25 PERCENT APPLICATION RATE BY 2009	MEAN RESPONSE
ALUMINUM	2.9

B. Please rate the importance of each of the following material selection/performance criteria with regard to a potential shift from steel to aluminum in torque tubes.

SCALE →	1	2	3	4	5
	A SUBSTANTIAL BARRIER	A MODERATE BARRIER	NEITHER A BARRIER NOR A DRIVER	A MODERATE DRIVER	A SUBSTANTIAL DRIVER

MATERIAL SELECTION/PERFORMANCE CRITERIA FOR ALUMINUM RELATIVE TO STEEL IN TORQUE TUBES	MEAN RESPONSE
A. PERFORMANCE CHARACTERISTICS OF ALUMINUM TORQUE TUBES	3.0
B. COST OF ALUMINUM TORQUE TUBES	2.0
C. COST OF PROCESSING/MANUFACTURING ALUMINUM TORQUE TUBES	2.5
D. FORGEABILITY OF ALUMINUM TORQUE TUBES	3.2
E. CASTABILITY OF ALUMINUM TORQUE TUBES	3.4
F. MACHINEABILITY OF ALUMINUM TORQUE TUBES	3.2
G. PROCESSABILITY OF ALUMINUM TORQUE TUBES	3.2
H. PRODUCTION CAPACITY OF ALUMINUM TORQUE TUBES	3.0
I. PRODUCTION CAPACITY OF STEEL TORQUE TUBES	3.6
J. LACK OF COMPONENT PROCESSING CAPACITY FOR ALUMINUM TORQUE TUBES	3.0
K. RECYCLABILITY OF ALUMINUM TORQUE TUBES	3.6
L. WEIGHT OF ALUMINUM TORQUE TUBES	4.6

SELECTED EDITED COMMENTS

No comments.

MANUFACTURER/SUPPLIER COMPARISON

There are no statistically significant differences in responses between manufacturers and suppliers, with the exception of the items shown below:

ALUMINUM RELATIVE TO STEEL IN TORQUE TUBES	MANUFACTURER MEAN	SUPPLIER MEAN
PROCESSABILITY OF ALUMINUM TORQUE TUBES	2.8	3.4
PRODUCTION CAPACITY OF STEEL TORQUE TUBES	3.0	4.0

TREND FROM PREVIOUS DELPHI SURVEYS

This question has not been previously asked.

STRATEGIC CONSIDERATIONS

As with many axle components, weight is a key driver and cost remains the critical barrier to increased application of aluminum torque tubes. All other material selection/performance criteria are listed as neither a significant barrier nor driver. Therefore, unless there is a marked shift in gasoline prices, or a similar change in CAFE standards, the conversion to aluminum for suspension and chassis components will continue at a slow to moderate pace.

MAT-55 What percentage of North American-produced passenger cars and light trucks will use materials other than conventional glass for windshields, side windows, or rear windows in 2004 and 2009?

2004	MEDIAN RESPONSE			INTERQUARTILE RANGE		
ALTERNATIVE MATERIAL FOR GLASS	WINDSHIELD	SIDE WINDOW	REAR WINDOW	WINDSHIELD	SIDE WINDOW	REAR WINDOW
POLYCARBONATE	0%	1%	1%	0/0%	0/10%	0/10%
POLYCARBONATE-GLASS LAMINATES	0	2	0	0/0	0/5	0/2.8
SPECIAL COATINGS AND/OR INTERLAYERS TO						
REDUCE SOLAR LOAD	27.5%	20%	22.5%	6.3/65%	10/50%	6.3/48.8%
PROVIDE DEFROSTING CAPABILITY	7.5	0	5	.8/11.3	0/5	.5/95
PROVIDE ABRASION RESISTANCE FOR PLASTICS (E.G., DIAMOND FILM GLAZES)	0	3	.5	0/0	0/5	0/8.8

2009	MEDIAN RESPONSE			INTERQUARTILE RANGE		
ALTERNATIVE MATERIAL FOR GLASS	WINDSHIELD	SIDE WINDOW	REAR WINDOW	WINDSHIELD	SIDE WINDOW	REAR WINDOW
POLYCARBONATE	0%	15%	10%	0/0%	5/23.8%	1/20%
POLYCABONATE-GLASS LAMINATES	0	10	1	0/10	0/10	0/20
SPECIAL COATINGS AND/OR INTERLAYERS TO						
REDUCE SOLAR LOAD	50%	45%	50%	12.5/96.3%	11.3/82.5%	10/100%
PROVIDE DEFROSTING CAPABILITY	10	1	40	1.8/41.3	0/15	3/100
PROVIDE ABRASION RESISTANCE FOR PLASTICS (E.G., DIAMOND FILM GLAZES)	0	15	10	0/7.8	5/40	3/52.5

SELECTED EDITED COMMENTS

- Includes EBLs.
- Programs with polycarbonate are underway in the industry.

RESULTS SUMMARY

The panel forecasts little or no application of polycarbonate as an alternative window material by 2004. However, the panelists do forecast limited penetration of polycarbonate for side and rear window applications by 2009. In the coming decade, special coatings and interlayers that reduce solar load or provide defrosting capabilities are forecast to continue to see increased applications.

MANUFACTURER AND SUPPLIER COMPARISON

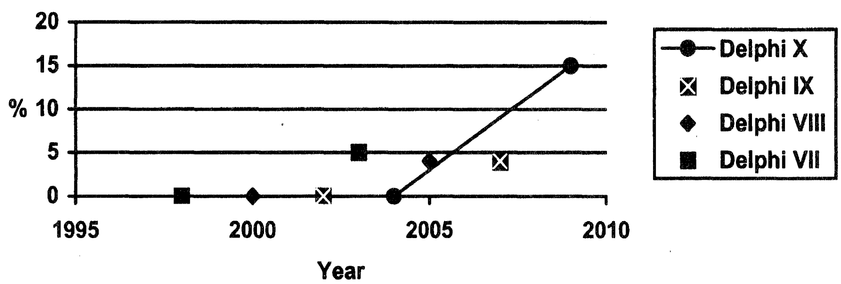
There are no statistically significant differences in responses between manufacturers and suppliers, with the exception of those differences shown below. The suppliers are more optimistic about the listed materials than are the manufacturers.

MATERIAL	MANUFACTURERS	SUPPLIERS
SPECIAL COATINGS AND/OR INTERLAYERS TO PROVIDE DEFROSTING CAPABILITIES		
WINDSHIELD (2004)	5.6	20.0
SIDE WINDOW (2004)	0.6	28.0
SPECIAL COATINGS AND/OR INTERLAYERS TO PROVIDE ABRASION RESISTANCE		
REAR WINDOW (2004)	0.6	
PLOYCARBONATE-GLASS LAMINATES		
REAR WINDOW (2004)	0.6	8.8
REAR WINDOW (2009)	2.5	18.3

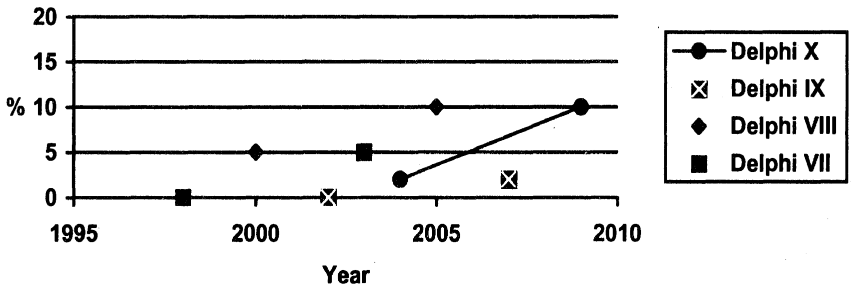
TREND FROM PREVIOUS DELPHI SURVEYS

Early Delphi panels (prior to the 1994 Delphi VII) were overly aggressive regarding the application of polycarbonates for automotive windows. Recent panels have been far less aggressive.

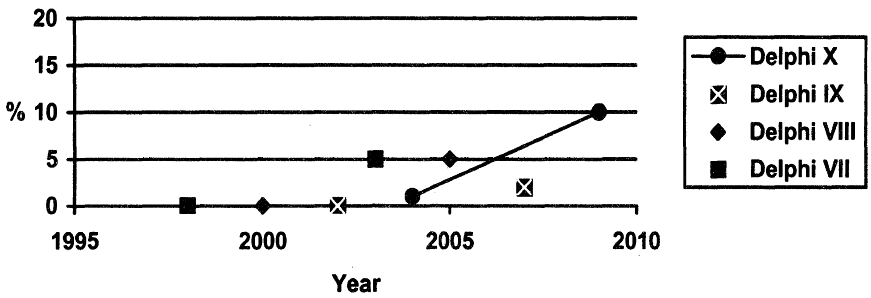
Side Window Polycarbonate



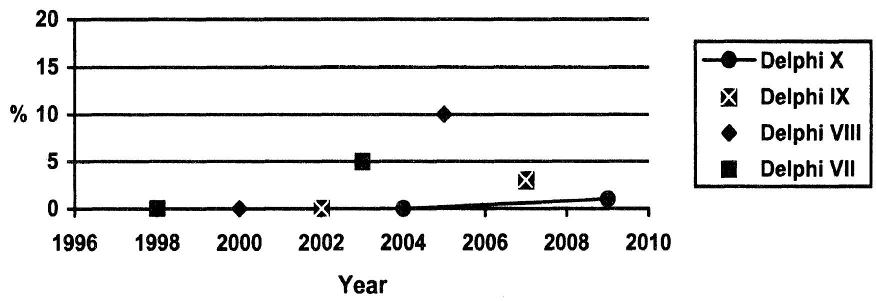
Side Window Polycarbonate-Glass Laminate



Rear Window Polycarbonate



Rear Window Polycarbonate-Glass Laminate



STRATEGIC CONSIDERATIONS

The panelists indicate that glass will continue to be the dominant material for window applications in the coming decade. They anticipate that polycarbonate will be used initially in side and rear window applications. However, the panel forecasts only limited application, likely where weight savings is critical. Polycarbonates offer the potential for weight savings, yet suffer from lower resistance to scratching, less sound dampening, and more damage at impact than glass laminate.

As greenhouse effects continue to grow, material engineers will be increasingly challenged to protect the occupants and vehicle from ultra-violet rays. It is not surprising that interlayers or special coatings to reduce solar load are forecast to see increased application in the coming decade.

MAT-56 Approximately 46 percent* of 1998 North American-produced passenger cars and 72.5 percent of light trucks had styled wheels. What percentage of styled wheels will be made from each of the following materials in 2004 and 2009?

STYLED WHEEL MATERIALS	EST. 1998*	MEDIAN REPONSE		INTERQUARTILE RANGE	
		2004	2009	2004	2009
PASSENGER CAR					
ALUMINUM	92.1%	93%	88%	82/95%	60/96%
HYBRID (STEEL AND PLASTIC)	0	0	5	0/10	0/22.5
MAGNESIUM	0	0	3.5	0/2	0/5
PLASTIC (COMPOSITE)	0	0	.5	0/10	0/11.3
STEEL	7.9%	6	5	1.5/10	1/9
TOTAL	100%	100%	100%	100%	100%
LIGHT TRUCK					
ALUMINUM	82.4%	85%	82.5%	80/90%	67.8/93%
HYBRID (STEEL AND PLASTIC)	0	2	5	0/5	0/15
MAGNESIUM	0	0	1.5	0/.5	0/5
PLASTIC (COMPOSITE)	0	0	0	0/10	0/10
STEEL	17.6	15	12	9.5/15.3	5/15
TOTAL	100%	100%	100%	100%	100%

*Source: Ward's Automotive Reports, Dec. 28, 1998 and Feb. 1, 1999.

SELECTED EDITED COMMENTS

No comments.

RESULTS SUMMARY

Panelists forecast aluminum wheels to account for 88 percent of styled wheels for passenger cars, and 82.5 percent of styled wheels for light trucks in 2009. Steel is forecast to see slightly reduced application rates for both passenger car and light truck styled wheel applications in the coming decade. Hybrid (steel and plastic, 5 percent), magnesium (3.5 percent), and plastic (0.5 percent) are forecast to see limited applications for passenger car styled wheels. The panel forecasts no usage of plastic styled wheels for light trucks.

MANUFACTURER AND SUPPLIER COMPARISON

There are no statistically significant differences in responses between manufacturers and suppliers.

TREND FROM PREVIOUS DELPHI SURVEYS

The 2000 Delphi X forecast for steel and aluminum wheels is similar to previous panels. However, the Delphi X panel forecast initial applications of hybrid (steel and plastic), magnesium, and plastic wheels by 2009.

STRATEGIC CONSIDERATIONS

The Materials panel expects aluminum to continue to be the dominant material for original equipment styled wheels in the coming decade. Aluminum wheels, while suffering from a cost disadvantage compared to styled steel wheels, meet current styling requirements. Aluminum wheels also present weight savings potential, while meeting durability and safety requirements.

The use of steel for original equipment styled wheels is forecast to decline slightly in the coming decade. Note that the panel forecasts initial application of plastic and magnesium and hybrid wheels. Although both materials present an opportunity for weight reduction, acceptance will be slow due to cost and safety concerns.

MAT-57 What percentage of North American passenger car and light truck manufacturing facilities will use the following **paint systems** in 2004 and 2009?

PAINT SYSTEMS	EST. 1999*	MEDIAN RESPONSE		INTERQUARTILE RANGE	
		2004	2009	2004	2009
UNDERCOAT/ELECTROCOAT					
CURRENT TECHNOLOGY	85%	60	40	20/80	0/75
LEAD-FREE	15	40	60	20/80	25/99.9
PRIMER SURFACER					
SOLVENT-BORNE	85%	65	35	50/71.3	5/51.3
POWDER	13	20	35	18.8/31.3	23.8/51.3
WATER-BORNE	2	10	30	3.8/23.8	3.8/52.5
TOPCOAT/BASECOAT					
SOLVENT-BORNE	65%	50	27.5	50/52.5	16/36.3
WATER-BORNE	33	50	72.5	43.8/40	56.3/82.5
CLEARCOAT					
CONVENTIONAL SOLVENT MELAMINE	38%	20	10	7.5/28	0/20
SOLVENT-BORNE ETCH RESISTANCE	62	70	70	57.5/85	55/80
POWDER	0	5	15	1/10	5/22.5
WATER-BORNE	0	0	5	0/6	0/15

*Source: automotive manufacturer estimate.

SELECTED EDITED COMMENTS

- Film: 2004: 2%; 2009: 5%.
- I assume powder slurry is included in powder.
- Not only the emergence of paintless film composite molding, but realistic through-colored thermoplastics and molded-in films for styling effects. will come along faster with the acceptance and rewards of not having costly paint systems and the elimination of emissions. With the acceptance of plastics for most of the aesthetics of decorative panels, the pressures from "bean counter" management will hurry this trend. The primer systems will become more important for the metal structural parts of the autos and will be easier to contain regards emissions. The increasing molded-in coverings (paint films, thermoplastic skins, and others) will also be more acceptable faster.
- Water-borne systems are increasing significantly. Low bake paint systems will be developed to support the use of thermoplastic body panels. New UV resistant thermoplastic materials are under development for application in body panels. The goal is a non-painted first surface. However, paint systems provide much better abrasion/scratch resistance compared to any current thermoplastic. To reinforce the comment on paint films from round 1, GE just introduced a new amorphous polymer - w4 - targeting the automotive exterior body market with high gloss, UV resistance, excellent chemical resistance (*Plastics News* – April 19]. The intent is to eliminate painting.
- With the emergence of paintless film composite molding in automotive body panels, many manufacturing facilities will discontinue their painting operations.

RESULTS SUMMARY

The panelists forecast increased application in the coming decade of lead-free electrocoat. The panelists also forecast increased powder and water-borne primer surfacer. They also forecast increased use of water-borne topcoat/basecoat and powder based clearcoat. The panel forecasts initial application of powder and water-borne clearcoat. The wide interquartile ranges suggest a great deal of uncertainty about the timetable for the application of the new paint technologies.

MANUFACTURER AND SUPPLIER COMPARISON

There are no statistically significant differences in responses between manufacturers and suppliers.

TREND FROM PREVIOUS DELPHI SURVEYS

The 2000 Delphi X panel is in general agreement with previous Delphi panels. Note that the interquartile ranges have been wide for all previous forecasts. The table shows the responses from the four Delphi forecasts in which this question was asked.

PAINT SYSTEM	SHORT-TERM				LONG-TERM			
	1998 DELPHI VII	2000 DELPHI VIII	2002 DELPHI IX	2004 DELPHI X	2003 DELPHI VII	2005 DELPHI VIII	2007 DELPHI IX	2009 DELPHI X
UNDERCOAT								
ELECTROCOAT								
CURRENT TECHNOLOGY	90%	90%	95%	60%	70%	50%	40%	40%
LEAD-FREE	10	10	8	40	30	50	70	60
PRIMER SURFACER								
NONE	40%	10%	10%	n/a	30%	5%	10%	n/a
SOLVENT-BORNE	40	60	75	65%	30	50	50	35%
POWDER	5	20	8	20	10	30	15	35
WATERBORNE	10	8	10	10	25	10	15	30
TOPCOAT								
BASECOAT/CLEARCOAT								
BASECOAT								
SOLVENT-BORNE	n/a	n/a	75%	50%	n/a	n/a	50%	27.5%
WATER-BORNE	20%	30%	25	50	40%	60%	50	72.5
CLEARCOAT								
CONVENTIONAL SOLVENT MELAMINE	60%	20%	25%	20%	25%	10%	15%	10%
SOLVENT-BORNE ETCH RESISTANCE	30	70	75	70	30	65	80	70
POWDER	0	0	0	5	8	5	5	15
WATER-BORNE	0	0	0	0	10	10	0	5

STRATEGIC CONSIDERATIONS

Airborne chemicals and volatile organic compounds continue to be significant byproducts of traditional automotive paint systems. Environmental regulation will force the industry to greatly reduce harmful emissions from stationary sources, and the paint systems will be a critical focal point of this reduction.

The removal of lead from the electrcoat process is an important step in the environmental challenge. The panel forecasts increased implementation of lead-free electrocoat systems, even given its higher cost. This change is due mainly to stricter government regulation.

The Low Emission Paint Consortium (LEPC) continues to research environmentally-sound paint systems and concentrates much of its effort on developing powdered paint systems. The work currently being done by this consortium should be closely monitored by all automotive industry participants.

The conversion of a paint shop is an expensive endeavor. Therefore, the comments regarding the development of paintless films for composites are worth special attention. There are currently several different approaches to eliminate the paint shop. The use of paintless films or molded-in color, while likely several years from application, presents interesting potential to eliminate a significant cost in vehicle manufacturing.

MAT-58 What are your expectations of **oven temperature** for 2009 for the following paint systems? Also, please comment on the drivers for any forecast change in oven temperatures.

OVEN TEMPERATURE				
PAINT SYSTEMS	MEDIAN RESPONSE		INTERQUARTILE RANGE	
	CURRENT EST.	2009	CURRENT EST.	2009
ELECTROCOAT	350	320	325/350	300/340
TOPCOAT	275	235	275/280	226.3/250

SELECTED EDITED COMMENTS

- Paint systems requiring lower oven temperatures will be developed to accommodate mid-range heat distortion temperature thermoplastics.

RESULTS SUMMARY

The panel forecasts that paint oven temperatures for electrocoat and topcoat will decrease by 30 degrees F and 40 degrees F, respectively, by 2009.

MANUFACTURER AND SUPPLIER COMPARISON

The manufacturers' estimate for current topcoat temperature (268 degrees F) is lower than the suppliers' estimate(282 degrees F).

TREND FROM PREVIOUS DELPHI SURVEYS

The 2000 Delphi Materials panel forecast a much larger reduction in electrocoat and topcoat oven temperatures in the coming decade than did the previous panels.

STRATEGIC CONSIDERATIONS

The panel forecasts a significant decrease in paint oven temperature in the coming decade. Such a decrease would reduce energy required to heat the ovens. There are several materials issues that are involved in determining the electrocoat and topcoat oven temperature. Plastics and adhesives, materials that are central to the oven temperature issue, are currently engineered to meet the demands of the topcoat ovens now in use. Any significant decrease in oven temperature would greatly affect the performance of these materials. If, as the panelists forecast, topcoat oven temperatures decrease in the coming decade, plastics may experience less shrinkage and warpage, which may allow for better fit.

MAT-59 Please indicate how materials should improve customer satisfaction over the next 10 years with vehicle body and chassis performance.

SELECTED EDITED COMMENTS

Body

Exterior – appearance and quality/reliability/durability (37)

- Improved paint performance (10 responses)
- Improved dent resistance (8 responses)
- Improved corrosion resistance (8 responses)
- More plastic materials (6 responses)
- Improved durability and damageability (5 responses)

Safety (8)

- Improved crash performance/energy absorption (5 responses)
- Higher requirements/longer life (2 responses)
- More plastics

Body

Interior - fit and finish, quality, reliability, durability (14)

- Improved aesthetic quality (4 responses)
- Improved durability (5 responses)
- Reduced squeaks and rattles (3 responses)
- Less shrinkage (2 responses)

Ergonomics (3)

- Better or soft feel (3 responses)

Safety (12)

- Improved crash performance/energy absorption (7 responses)
- Higher safety requirements (3 responses)
- More plastics (2 responses)

Chassis

Chassis – quality, reliability, durability (6)

- Improved durability (3 responses)
- Improved corrosion resistance (3 responses)

Chassis – noise, vibration, harshness (5)

- Improved damping (3 responses)
- Increased road isolation (2 responses)

Chassis – performance (9)

- Reduced mass/weight (5 responses)
- Improved corrosion resistance (2 responses)
- Improved stiffness (2 responses)

Chassis – safety (3)

- Higher requirements/longer life (3 responses)

RESULTS SUMMARY

Panelists list several material developments that will improve quality, reliability, and durability for increased consumer satisfaction with regard to the listed vehicle systems.

MANUFACTURER AND SUPPLIER COMPARISON

This comparison is not done for open-ended questions.

TREND FROM PREVIOUS DELPHI SURVEYS

This question was first asked in the 1994 Delphi VII. The Delphi X panel is in general agreement with previous panels.

STRATEGIC CONSIDERATIONS

The panelists suggest many potential material improvements—most evolutionary—will be used in an effort to improve customer satisfaction. Panelists' responses indicate that improvements in chip and mar protection will be critical to increased consumer satisfaction. Paint and clearcoat serve as the first line of defense for any successful corrosion protection strategy. The ability to better prevent damage to the paint will be a critical element to improved corrosion resistance. The conversion to water-borne paints—and the possible conversion to powdered paints—has lead to a new set of issues and challenges.

Dent and chip resistance can also be addressed by the increased use of alternate body panel materials. The panel views using HSS or composites for body panel applications susceptible to dent and chips as a possible method of reducing dent and chip damage, and therefore increasing customer satisfaction.

The changes listed by panelists to increase customer satisfaction for both interior and chassis components in the coming decade are more evolutionary than revolutionary. Several comments reference safety as a driver for many of the material advances.

VI. RECYCLING ISSUES

MAT-60 The recyclability of automotive materials and related environmental concerns may pose significant challenges to the entire industry in the coming 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?

SCALE →	1	3	5
	MOST IMPORTANT	SOMEWHAT IMPORTANT	LEAST IMPORTANT

POTENTIAL RECYCLING BARRIERS	MEAN RESPONSE						
	PLASTICS/POLYMERS			NON-FERROUS METALS			FERROUS METALS
	UNREINFORCED THERMOPLASTICS	REINFORCED THERMOPLASTICS	THERMOSETS	ALUMINUM	COPPER	ZINC	
ALLOY CONTENT/CONTAMINATION	3.1	2.3	3.1	2.7	3.2	3.4	3.8
AUTOMATED PROCESSING/ SEPARATION OF MATERIALS, E.G., DENSITY GRADIENT	2.6	2.2	2.4	3.2	3.3	3.3	4.3
DISMANTLING/DISASSEMBLY	2.4	2.2	2.3	3.0	2.9	3.0	3.8
EASE OF MATERIALS SEPARATION	2.0	1.6	1.7	3.0	3.2	3.1	4.1
ECONOMICS OF RECLAMATION/ RECYCLING PROCESS	1.9	1.7	1.7	3.1	2.9	2.9	3.4
ENERGY REQUIRED FOR RECOVERY	3.0	2.8	2.4	3.4	3.3	3.3	3.6
ENERGY REQUIRED TO PROCESS RAW MATERIAL	3.3	3.2	3.0	2.9	3.2	3.2	3.6
ENVIRONMENTALLY SAFE DISPOSAL	3.1	2.9	3.0	4.1	4.0	3.7	4.3
INDUSTRIAL ENVIRONMENT/ HEALTH ISSUES	3.5	3.2	3.1	4.0	3.8	3.4	4.2
LABELING/IDENTIFICATION	2.6	2.4	2.5	3.7	4.1	3.9	4.2
LACK OF DESIGN FOR DISASSEMBLY	2.7	2.5	2.6	3.4	3.5	3.6	4.0
LACK OF LABOR SKILLS FOR PARTS DISASSEMBLY	3.5	3.3	3.3	4.0	4.0	4.0	4.4
LANDFILL AVAILABILITY AND COST	2.8	2.7	2.6	4.0	4.0	3.9	4.3
LIMITED MARKETS/USES FOR RECOMMENDED PARTS AND MATERIALS	2.6	2.3	2.0	4.3	4.2	4.1	4.3
RECYCLING INFRASTRUCTURE/ LOGISTICS	2.0	1.9	1.6	3.8	4.3	4.2	4.5
SCRAP VALUE	2.1	2.0	1.8	3.3	3.4	3.5	3.5

SELECTED EDITED COMMENTS

- Plastics will be a problem for the industry. Thermosets have the toughest barriers to solve. Thermoplastics (resin/nonresin) have potential for solution but will require lots of work to get where we need to be.
- Thermosets are an obvious choice for structure but carry recycling issues with them.

RESULTS SUMMARY

Panelists indicate several severe barriers to plastics recycling in the coming decade: economics of the reclamation/recycling process, recycling infrastructure, scrap value, and ease of material separation. The panelists see no significant barriers to recycling ferrous and nonferrous metals.

MANUFACTURER AND SUPPLIER COMPARISON

There are no statistically significant differences in responses between manufacturers and suppliers.

TREND FROM PREVIOUS DELPHI SURVEYS

This question was first asked in the 1994 Delphi VII. Despite some change in responses in the Delphi VII, 1996 Delphi VIII, 1998 Delphi IX, and 2000 Delphi X surveys, the ratings are generally consistent. The severe barriers for plastics identified by the Delphi VII panel are rated as the most severe by the Delphi X panel. And, similar to previous panels, the Delphi X panel does not expect any significant barriers for ferrous or nonferrous metals.

STRATEGIC CONSIDERATIONS

Recycling of automobiles is an issue that has received considerable attention in recent years—especially in Europe where landfill availability is severely limited. Presently, about 75 percent of each vehicle is recycled by removing salvageable fluids, parts, and metals. The remaining 25 percent, comprised mostly of automotive shredder residue (ASR), is landfilled.

Guided in part by European regulations that make manufacturers responsible for the final disposition of vehicles, North American manufacturers have begun investigating methods for final disposition of vehicles. In an effort to better understand the issues—both technical and economical—regarding recycling, Ford Motor Company recently purchased an automotive recycling firm. Lessons learned from this business endeavor, and from similar programs, will be critical in developing an effective and efficient recycling strategy.

At a time when the automotive industry has become increasingly aware of the environmental impact associated with the final disposition of its product, plastics use in automobiles—an important element of automotive shredder residue—has greatly increased. Industry must proactively work to reduce the percent of the vehicle that goes to landfills as ASR, and a key element of that strategy is the increased recyclability of plastics. However, panelists indicate that there are many barriers to the successful reclamation of automotive plastics. Panelists rate 14 of the 16 listed barriers as at least somewhat important for reinforced thermoplastics, and 13 of the 16 as somewhat important for thermosets.

The use of plastic in automotive applications presents an interesting case study. Plastics offer weight reduction and reduction in energy use during the operational life of the vehicle. Yet the disposition of plastics at the end of the vehicle's operational life presents environmental concerns that may offset the benefits of the reduced energy consumption. As industry moves to develop more complex life cycle analysis tools, it may be better able to balance between often conflicting material selection criteria.

MAT-61 Please indicate your view of the degree of challenge each of the following methods presents to effective recycling/disposition.

SCALE →	1	3	5
	EXTREMELY SEVERE CHALLENGE	SOMEWHAT SEVERE	NOT AT ALL SEVERE

METHOD	MEAN RESPONSE
THERMOPLASTICS	
CLOSED-LOOP RECYCLING	2.5
HEAT RECOVERY	3.3
OPEN-LOOP RECOVERY	3.3
THERMOSETS	
CLOSED-LOOP RECYCLING	1.4
HEAT RECOVERY	2.5
OPEN-LOOP RECOVERY	2.3
FERROUS	
CLOSED-LOOP RECYCLING	4.1
OPEN-LOOP RECOVERY	4.6
NONFERROUS	
CLOSED-LOOP RECYCLING	3.4
OPEN-LOOP RECOVERY	4.1

Definitions: Closed-loop recycling: reusing material in the same automotive application. Open loop recycling: reusing material in other, usually less demanding, automotive or non-automotive applications.

SELECTED EDITED COMMENTS

- Metals are straight forward - the system works for ferrous as well as it has to. Aluminum will need work for closed recycling, but there will be plenty of users for aluminum scrap. Thermosets are a major challenge technically and from an economic point of view. Thermoplastics have technical challenges but economies will allow more options than the thermosets, so we'll get to solutions for open loop and save closed loop recycling.
- Open-loop recycling of aluminum is wasteful and unacceptable since closed-loop recycling is entirely feasible.

RESULTS SUMMARY

Panelists expect the recyclability of thermosets and, to a lessor extent, thermoplastics to continue to present significant challenges to the industry. The panelists expect closed-loop recycling of thermosets to present an extremely severe challenge. Conversely, the panel does not expect the recycling issue facing ferrous and nonferrous metals to present significant challenges in the coming decade.

MANUFACTURER AND SUPPLIER COMPARISON

There are no statistically significant differences in responses between manufacturers and suppliers.

TREND FROM PREVIOUS DELPHI SURVEYS

This question was first asked in the 1994 Delphi VII. The table shows the recycling methods where there has been some change in responses between the Delphi VII, the 1996 Delphi VIII, the 1998 Delphi IX, and the 2000 Delphi X surveys.

METHOD	DELPHI VII	DELPHI VIII	DELPHI IX	DELPHI X
THERMOPLASTICS: CLOSEDLOOP RECOVERY	2.4	2.4	2.0	2.5
THERMOPLASTICS: HEAT RECOVERY	3.3	3.3	3.8	3.3
THERMOSETS: CLOSED-LOOP RECOVERY	1.9	1.6	1.3	1.4
THERMOSETS: OPEN-LOOP RECOVERY	2.9	2.2	2.0	2.3
NONFERROUS: OPEN-LOOP RECOVERY	n/a	3.9	4.4	4.1

STRATEGIC CONSIDERATIONS

The final disposition of the automobile is increasingly becoming an issue for the industry. Although there is already an economically viable recycling infrastructure for steel and other ferrous metals, the final disposition of automotive plastic—both thermoset and thermoplastics— is expected to present a severe challenge. There are a few successful examples of reclaiming plastics from vehicles for reuse; however, most plastics used for automotive applications are landfilled in the form of ASRC automotive shredder residue. The degree of severity for recycling of plastics depends on the method, material, and secondary usage of the material. Thermosets continue to be viewed as difficult to recycle, both with a closed- or open-loop method. However, thermoplastics are viewed as a somewhat less severe challenge, yet they too present problems.

Many of the challenges preventing implementation of plastic recycling are not technical, but economics-based. Plastic recycling will not become viable until there is an economic or regulatory incentive to develop an infrastructure. Until that happens, many plastics will be viewed as unrecyclable. Note that one form of plastic disposition, heat recovery, is both technically and economically feasible. However, heat recovery suffers from the "not in my backyard" syndrome, which makes implementation politically difficult.

The panel does not view recycling of ferrous or nonferrous metals as a significant challenge. Currently there is an economically viable recycling infrastructure for metals. For several years, almost all of the ferrous metals used in automobiles have been reclaimed, though until recently much of that material was used in open-loop recycling (i.e. reuse for lower-value applications).

MAT-62 Relative to plastics usage in the next decade, how likely are North American light vehicle manufacturers to undertake each of the following actions?

SCALE →	1	3	5
	EXTREMELY LIKELY	SOMEWHAT LIKELY	NOT AT ALL LIKELY

ACTION	MEAN RESPONSE
PASS THROUGH RECYCLING REQUIREMENTS TO SUPPLIERS	2.2
RESTRICT THE AMOUNT OF PLASTICS IN THE VEHICLE	4.0
RESTRICT THE AMOUNT OF ECONOMICALLY UNRECYCLABLE PLASTICS IN THE VEHICLE	2.6
RESTRICT THE NUMBER OF TYPES OF PLASTICS IN THE VEHICLE	2.3
SUBSTITUTE LIGHTWEIGHT METALS FOR PLASTICS	3.1

SELECTED EDITED COMMENTS

- Landfill reduction techniques are needed to reduce volume and to see if plastics, etc. can be used as time release moisture absorbers in conjunction with farm crops.

RESULTS SUMMARY

Panelists expect manufacturers to take action restricting the number of plastics in the vehicle and to pass on recycling requirements to suppliers.

MANUFACTURER AND SUPPLIER COMPARISON

There are no statistically significant differences in responses between manufacturers and suppliers, with one exception. Manufacturers rate it much more likely that North American manufacturers will limit the number of types of plastics in an automobile (1.9) than do suppliers (2.6).

TREND FROM PREVIOUS DELPHI SURVEYS

The 2000 Delphi X panel is in general agreement with previous panels.

STRATEGIC CONSIDERATIONS

The final disposition of plastics continues to present a challenge for the industry. Increasingly, plastic is becoming a material of choice for many automotive applications, and Delphi X results indicate that it will remain a strong contender. Several potential actions may be implemented as the industry works diligently to resolve the disposition challenge. The panel thinks it is likely that there will be restrictions in the number of plastics in the vehicle and that manufacturers will pass on recycling requirements to suppliers. To its credit, the industry has been proactively developing disposition strategies. However, due to competitive pressures, these strategies are often subordinate to other material selection.

DEFINITIONS

BIG THREE. Refers to Ford, GM, and DaimlerChrysler.

CAFE. Corporate average fuel economy is based on all vehicles sold in the United States by a corporation. DaimlerChrysler will now have one CAFE value for cars and one for trucks.

EUROPEAN INDUSTRY. Includes functions and activities performed in Europe regardless of headquarter location or ownsership, e.g., Opel and Saab in Europe.

JAPANESE INDUSTRY. Includes functions and activities performed in Japan regardless of headquarter location or ownership, e.g., Mazda and Toyota in Japan.

LIGHT TRUCK. Includes sport utilities, vans, and pickup vehicles less than 6,000 lb. GVW.

NORTH AMERICAN INDUSTRY. Includes functions and activities performed in North America regardless of headquarter location or ownership, e.g., Honda design in California and BMW production in South Carolina.

PNGV. Partnership for a New Generation of Vehicles.

Notes:

"Year" refers to model year unless otherwise specified.

Installation rates for 1998 include production in the United States, Canada, and Mexico for the United States market.

"Current vehicles" refers to model year 1998 unless otherwise specified.

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KEY WORD INDEX

KEY WORDS	QUESTION NUMBER	
	TECHNOLOGY	MATERIALS
CAFE (Corporate average fuel economy)	1,2,3,4,27,28,29,30	2,8,13,14,37
CD Player	59	
Camshaft		23
Canadian	17	
California standards	48	
Capacitors	7	
Carburetors	44	
Carpet fiber		46
Cast iron	28,47	14,17,19,21,22,23,24,26,53
Casting		9,11,14
Catalyst	49a	
Composites, structural		10,41
Cellular phone		
Ceramics	28	14,17,28
Chassis	24,33,64	11,14,17,38,47,59
Chip-proof windshield	63	
Clean Air Act		3
Coatings		55
Coil-on-plug	46	
Collision warning system	37	
Combustion engine	8,41	5,17
Competition	14	
Components	18,29	9,11,16,22,28,29,30,36,40,44, 45,46,47,51,59
Compression ignition	8	
Computer-based tools	21,23	
Computer simulation	24	
Continuous variable transmission (CVT)	52	
Control arms		48
Coolant	63	
Copper	28	14,30
Corporate image	14	
Corrosion	63	8,11,37,38,39,49,52,59

KEY WORDS	QUESTION NUMBER	
	TECHNOLOGY	MATERIALS
Cost		1,2,8,13,14,15,21,23,24,25,26,27,28,29,30,31,32,33,34,40,41,42,43,45,48,49,50,51,52,54,55,56,57,58,59,60,61,62
Cost of technology	49b	
Crankshaft		24
Crash simulation	21	
Crashworthiness	12	6,59
Cross beams		43
Cruise control	37,59	
Cylinder blocks		17,19,20
Cylinder heads		14,19
Cylinder pressure ignition	46	
Cylinders	38,39,40,43,47	19
Cylinders, number of		
Cylinders, sleeved		20
Design issues		8,31,37,40
Design optimization		9,10,12
Designer	65	
Development cycles	19	
Development time	23	
Diesel	6,8	5
Direct cylinder injection	44	
Direct ignition engine	49a	
Disc brakes	34	
Disposal		7,8,14,37,44,60,61
Distributorless ignition	46	
Doors	29	36,44,45
Drive shafts		52
Drive-by-wire	49a,57,59	
Drivetrain	54	
Drivetrain configurations	9,54	
Drowsy-driver detection	58	
Dual overhead cam	41	
Durability	63	13,19,20,21,23,24,25,26,27,28,37,41,42,43,45,48,49,52,55,56,59

KEY WORDS	QUESTION NUMBER	
	TECHNOLOGY	MATERIALS
EPA	49b	
Electric	6,8	4,5
Electric drivetrain	9,11	
Electric motors	11,61,62	
Electric power plant	6	
Electric vehicle	7,11	4,5
Electrical	33,55,59,64	
Electrochromatic glass	59	
Electromagnetic		9
Electronic controls	4,33	
Electronic keyless entry	59	
Electronic systems	55,59	
Electronics technician	65	
Elimination of labor	26	
Emerging technologies	14,58,64	
Emission absorbers	49a	
Emissions		3,4,5,8,13,21,31,53,57
Energy		5,10,40,60
Energy storage	4	
Engine	9,38,39,40,41,42,43,44,45,46, 47,51,62,63	5,14,16,17,18,19,20,22,28,29, 30,24,34,59
Engine block	47	19,20
Engine controls	49a	
Engine efficiency	4	
Engine head	47	19
Engineering	15	13,16,39,60
Engineering duplication	26	
Engineers	65	
Environment	14	7,8,13,39,42
Epoxy		15,56
Ergonomics	14	59
Europe	3,16,19,20	
Evaporative controls	49a	
Exhaust manifold		17,28
Exhaust system	63	17,22
Exterior panels	29	

KEY WORDS	QUESTION NUMBER	
	TECHNOLOGY	MATERIALS
Fastening		10
Federal standards	48	
Fiber optic		14,17
Field experience		8,37
Fluid		18
Forgings		14
Formability		8,9,23,33
Forming		9
Four cylinder	43	
Frame construction	31	34,35,36,41,59
Front covers		26
Front fenders	29	
Fuel cells	6,9,49a	
Fuel economy	4,14,27	1,2,3,4,5,6,13,14,15,16,17,18, 35,36,37,61,62
Fuel injection	44	
Fuel price	1	1,2,13
Fuel rails	51	17,25
Fuel tank		31
Fuel taxes		1,2
Fuels	6,49a	
Fuels and fluids	64	5
GDI	44	
GPS	37	
Gas turbine	8	
Gasoline		1,2,3,4,5,8,17,35
Gasoline prices	1	1
Gasoline tank/fuel tank		31,37
Glass	28	14,17,37,55,56,59,60,54
Global warming		2
HID (high intensity) headlights	59	
HVAC control	57	
HSLA steel (HSS)		14,17,36,40,43,43,48
Handling	57	
Hardpoints	19	
Headliner		46

KEY WORDS	QUESTION NUMBER	
	TECHNOLOGY	MATERIALS
Heater cores		30
Hollow camshaft	42	
Hood	29	36
Human resources	65	
Hydrocarbon (HC) trap		
Hybrid		5,56
Hybrid electric combustion engine	6,8	5
Hybrid powertrains	4,10	5
Hybrid vehicle	7,11,49a	1,5
Hydroforming		9
Ignition system	46	
Ignition timing	49a	
Inline	41	
Inline (IL-6)	39	
Individual cylinder control	49a	
Information technology	58	
Infrastructure		1,7,37,60,61
Injection		5,59
Instrument panel		43,44
Intake manifold	51	15,16,17,27
Integral body/frame	31	
Interior components		46
Interior safety	12	6
Ionomer		15
Japan	3,16,19,20	
Job one	19	
Knock/adaptive control	46	
Korea	20	
Lean burn technology	48	
Legislation	12,13	4,5,6,7
Lift control		1,17
Lightweight materials		9,10,11,13,14,59
Load sensing	57	
Luxury vehicle	58,61	
MEMS	57	

KEY WORDS	QUESTION NUMBER	
	TECHNOLOGY	MATERIALS
MPX	56	
MacPherson struts	32	
Magnesium	28	11,14,16,17,19,37,38,41,43,56
Maintenance	63	1,18
Manual transmission	52	
Manufacturing		8,9,10,11,12,16,30,35,36,57,59
Market share		5,16
Material content	28	14
Materials		7,8,9,10,11,12,17,19,21,29,30, 31,55,59,60
Materials change		9,10,11,12,17,23,24,25,26,27, 31,32,33,41,42,43,45,48,49,50, 51,52,54
Math-based engineering	22	
Matrix composite		21
Message system	37	
Metal matrix composite (MMC)		14,17
Mexico	17	
Microelectromechanical systems	57	
Microprocessors	55	
Mini disc	59	
Modules	18,26	
Multiplexed power system	56	
Multipoint fuel injection	44	
Natural gas	6	1,5
Navigation system	37,58	
New technologies	64	4,17
North America	15,16,17,20	
NOx catalyst	48	5,17
Nylon		46
Occupant restraint		6
Offshore	18	
Oil pan	51	16,17,22
Outsourcing	18,26	
PC entertainment systems	59	
PC/PBT		15,44,45

KEY WORDS	QUESTION NUMBER	
	TECHNOLOGY	MATERIALS
PNGV (Partnership for a New Generation Vehicle)	5	6,13
PPO/nylon		15
PPO/styrene		15
Paint		9,10,37,45,56,57,58,59,61
Panels		44,45
Part sourcing	16,17	
Parts		7,15,17,19,35,37,38,39,59,60, 61
Pedals	37	
Performance	14	4,5,8,13,17,18,34,23,24,25,26, 27,38,39,58,59,62
Phenolic		15
Physical prototypes	24	
Piston		22,28
Piston skirts	51	
Plastic	29,51	15,17,22,31
Plastic/composite	28	14,25,27,30,31,35,36,40,41,43, 44,49,52,56,62
Platforms		34,40
Plastic fuel tanks		31
Polycarbonate		15,44,55
Polyester elastomer		15,44,46
Polyester thermoplastic		15
Polyester thermoset		15
Polyethylene		15
Polypropylene		15,41,42, 44,45,46
Polyurea		15
Port fuel injection	44	
Powdered metal	28,42	14,17,23,29,32
Power brakes	62	
Power cells	9	
Power plants	6	
Power steering pump	62	
Powertrain	5,24,64	38,29
Powertrain material applications		17,29

KEY WORDS	QUESTION NUMBER	
	TECHNOLOGY	MATERIALS
Prices		1,2,16
Product design	15	61
Product development	14,22,23	
Product liability	12	6,8
Product technology	20	
Production process		5,23,24,25,26,27,32,33,37,41, 42,43,45,48,49,50,51,52,54,55
Propane	6	5
Push rod	41	
PVC		15,16,42,44
Quality		3,7,8,20,21,56,59
Radiators		30
Rear axle		54,55
Rear deck	29	
Rear quarter panels	29	
Recyclability	13	7,8,15,23,24,25,26,27,36,37, 41,42,43,43,45,48,49,50,51,52, 54,55,56,60,61,62
Redesign		19
Reformulated gasoline		1,3
Regional industry	20	
Regionalization		6
Regionalization of regulation	12	
Regulations	12,13	3,4,6,7,8,13,57,59
Repair		1,2,17,37,39,59
Retail sales		4
Ride and handling	14,33	
Roller followers	42	
Roller lifters	42	
Roof	29	
Rubber	28	
SMA		44
Safety	12,14,35,64	6,7,8,13,35,36,55,56,59,62
Sales		3,4,8,13,38
Seals		28
Seat belts	37	

KEY WORDS	QUESTION NUMBER	
	TECHNOLOGY	MATERIALS
Security systems	58	
Seat frames		41
Semiconductors	55	
Sensors	49a,55	
Separate body/frame	31	
Service		8,38
Service technician	65	
Sheets		14
Simulation	24	
Single overhead camshaft	41	
Skilled trades	65	
Skills		15,60
Sleeve material		21
Software programmers	65	
South America	20	
Sourcing	16,17,26	
Space frame	31	34,35
Spark ignited engine	44,45,46,51	28
Spark ignition	8,46,51	
Spark plugs	46	
Springs	32	17,49
Stability control	34	
Stabilizer bars		51
Stainless steel		14,17,22,31
Standards		1,3,4,6,7,8,14,16, 37,56,58
Start-up catalyst		
Steel	28,29	12,14,15,16,17,21,22,23,24,25, 31,32,33,35,36,37,38,39,40,41, 43,48,49,50,51,52,56,57,58,59, 60,61
Steering	33	16,17,18,50
Stirling engine	8	
Structural composites		10
Styling	14	8,17,37,40,56
Subassemblies	16,17	
Subsystems	18	

KEY WORDS	QUESTION NUMBER	
	TECHNOLOGY	MATERIALS
Supercharged/supercharger	45	
Suppliers		7,8,14,16,17,35
Suspension	24,32,33	17,19
Systems engineering	25	
TPO		15,17,40,42,44,59,61,62
Taxes		1,2,8,13,15
Technology, bonding & joining		9,10,12
Technology leadership	20	17
Telecommunication	58	
Telematics	58	
Thermal spray		21
Thermoplastic		14,15,17,36,37,40,59,60,61
Thermoset		14,15,17,36,37,40,60,61
Throttle body	51	
Tier 1 supplier	18	
Tier 2 emissions	49	
Tire rolling resistance	4	
Tires	35	7,14,17
Tires/wheels	64	7,14
Titanium		17
Toll collection	37	
Tooling		37,59
Traffic information	58	
Transmission	4,52,53,63	29,30,32,33
Transverse		16,17,18,29,30,38
Turbine		28
Turbocharger, -ed	45	28
Twin A-arm	32	
Unibody	31	34,35
United States	17	
Urethane		15,42,44,46,56
V-6	43	
V-8	43	
Valve covers	51	
Valves	40,42	22,28
Valvetrain	41	28,29

KEY WORDS	QUESTION NUMBER	
	TECHNOLOGY	MATERIALS
Variable lift control	42	
Variable valve phasing	42	
Variable valve timing control	42	
Vehicle cost	14,22,26a,49c	
Vehicle downsizing	4	
Vehicle emission standards	12	6
Vehicle proximity	57	
Vehicle servicing		
Vehicle systems	37	
Vehicle weight	4,27,30,49a	
Vinyl ester -TS		15
Voice activated controls	59	
Voltage	11,60	
Warranty	63	8
Water pump	62	
Weight reduction/weight	4,49a	8,13,19,20,23,24,25,26,27,32, 33,36,41,42,43,45,48,49,50,51, 52,54,55,56,60
Welding		9
Western Europe	16	
Windows		55
Wheels		16,17,47,56,59
Wrist pins		28
Yaw control	34	
Zinc		14, 60
Zinc die casting	28	