POWERTRAIN STRATEGIES
FOR THE 21ST CENTURY

FORECAST FOR THE NORTH AMERICAN AUTOMOTIVE INDUSTRY
FOR 2015 AND 2020

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UMTRI
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Acknowledgements
Our research team would like to acknowledge the efforts of our panel of experts who spent their time completing our survey. We would also like to thank our two corporate sponsors, Denso Corporation and the U. S. Environmental Protection Agency for their financial support. Finally, we would also like to thank our media sponsor, Ward’s Auto.com for their support in helping us connect with North American powertrain experts.

Foreword
The Powertrain Strategies for the 21st Century project is part of UMTRI-AAD’s Future Powertrain Program whose goal is to provide companies with intelligence about future directions in the powertrain strategies of manufacturers and suppliers, consumer views of alternative powertrains, and future directions in mobility and sustainability. The Powertrain Strategies for the 21st Century project an on-going, long term panel study that focuses on the future directions of powertrains. The insights are based on survey responses of global powertrain experts across Europe, North America, and Asia looking at the years 2015 and 2020 with a web-based survey of industry experts that aims to:

- Examine global powertrain strategies by surveying European, U.S., and Asian managers and engineers. Questions may include regional predictions of current and future powertrains by types of engines and transmissions; fuel-management systems; and any new technologies co-sponsors may suggest.
- Compare from a global perspective how regulatory regimes affect powertrains
- Benchmark current powertrain product development processes using financial, human resource, product development, and supply chain metrics.
- Explore how alternative powertrains, such as hybrids, advanced diesels, and fuel cells, will affect the powertrain product development process. Questions may include timing, cost tradeoffs, time to market, engineering and sourcing issues, and challenges for particular types of alternative powertrains.
- Develop a technology roadmap for powertrain and powertrain components over the next 15 years.

Process and Panel Characteristics
Using web-based survey tools and our industry databases we have gathered responses from slightly over 100 North American powertrain experts. As with all of our research projects, we guarantee respondents that their responses are treated confidentially, allowing them to express their opinions freely. We have grouped respondents into 3 groups: manufacturers (OEMs), suppliers, and other experts who represent government, academic, non-governmental organizations, and consultants.

Presentation of Results
The results of the survey are presented in the form of data tables and selected and edited comments of the experts.
Data Tables. Each question asked of the experts is presented, and their responses are reported as a weighted mean and as part of an interquartile range. For each overall question we asked the experts to rate how confident they were of their response on a five point scale, ranging from not confident at all to very confident. This rating is used in a univariate model using the weighted least squares method to weight each expert’s individual response, thus incorporating the experts own opinions of their confidence on their response into the group mean.

The interquartile range provides the reader a view of the range of unweighted responses to each individual question. A range that is relatively narrow can be considered one way of measuring consensus or uncertainty among experts about a particular issue. We report the first and fourth quartiles with the weighted mean representing a close estimate of the median response. By dividing all the responses into four equal groups, readers can determine not only the range of responses, but for questions related to company performance, the interquartile range represents best in class/worst in class comparisons.

Certain questions ask respondents to list other items such as fuels, powerplants, or energy storage devices that will play an important role in future powertrains. After the data table, we list these responses along with the percentage or rating the experts give to each of these items.

Selected and Edited Comments. One of the strengths of our survey method is the opportunity we give to our panelists to comment on the question or their response to a question. We encourage the panelists to contribute comments to explain their responses, and sometimes these comments provide insight into the logic behind particular responses.

If readers have any questions about the project or the survey, please contact Bruce M. Belzowski, Assistant Research Scientist, at 734-936-2704 or bbl@umich.edu.
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Sponsors not only receive the results that participants receive:

- Each sponsor will have access to the results from all questions in the survey.
- These results will be reported as industry means or medians and the sponsor will see their response next to the overall industry response.
- They will also see any comments participants added to explain their response in the "Selected Edited Comments" section.

They also receive:

- A comparison of their company's response to their response and the industry response (if desired)
- Inter-quartile / Best in Class, Worst in Class designations
- Manufacturer/Supplier/Government/Academic Comparisons (when applicable)
- Regional Comparisons between Europe, North American, and Asia
- UMTRI-AAD's analysis of results that provide strategic insight

Below are three sample questions showing the format of the participant report.

**Question 1 - SAMPLE**

Please estimate United States retail fuel prices, per gallon, for 2015 and 2020, including fuel tax. (Please use constant 2005 dollars without adjusting for inflation)

**2015:**

<table>
<thead>
<tr>
<th>Unleaded Gasoline</th>
<th>Median Response 2015</th>
<th>Interquartile / Best In Class, Worst In Class Range</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Industry</td>
<td>Your Response</td>
</tr>
<tr>
<td>Regular</td>
<td>$2.35</td>
<td></td>
</tr>
<tr>
<td>Premium</td>
<td>2.89</td>
<td></td>
</tr>
</tbody>
</table>

**2020:**

<table>
<thead>
<tr>
<th>Unleaded Gasoline</th>
<th>Median Response 2020</th>
<th>Interquartile / Best In Class, Worst In Class Range</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Industry</td>
<td>Your Response</td>
</tr>
<tr>
<td>Regular</td>
<td>$2.35</td>
<td></td>
</tr>
<tr>
<td>Premium</td>
<td>2.89</td>
<td></td>
</tr>
</tbody>
</table>
SELECTED EDITED COMMENTS - SAMPLE

Increase

- Current U.S. gasoline prices are out of step with the rest of the world and unrealistically low. The demand for cleaner gasoline will cause prices to rise.
- Fuel tax may increase even if crude oil price remains constant
- Increase when requirements for global reductions are implemented
- Most of the increase will be due to taxation
- Unless there is an unpredictable "political event," I would expect only very modest increases in the cost of fuel as the global consumption increases. Previous predictions of increasing energy costs have proven unfounded at least so far, excluding short-term perturbations.

Stay the Same

- I anticipate a stable condition
- Unless there is a major disruption (e.g. another Middle East war), a significant increase in U.S. fuel taxes, which is politically unlikely, fuel prices will remain virtually unchanged.

Other

- Gasoline prices have no relationship to actual value but are the result of taxation and price setting by the federal, state, and local governments. The actual price of gasoline is less than bottled water.
- Some small but significant efforts to match world averages in order to ease national "peer pressure".
- The drivers for fuel price are largely outside the real of the automotive industry.
- The price of fuel is so political that it is impossible to predict.
- These numbers could change dramatically if OPEC ever gets their act together, or if there is real trouble in the middle east. (2 responses)
- This is solely dependent on fuel availability and OPEC

RESULTS SUMMARY - SAMPLE

Delphi X panelists anticipate the prices of regular and premium gasoline to increase by approximately 40% in constant 2005 dollars by 2020. This increase will add about 3 percent per year above the inflation rate to the price of gasoline.

MANUFACTURER/SUPPLIER COMPARISON - SAMPLE

There are no statistically significant differences in the responses between manufacturers and suppliers with the exception of the estimate of the price of premium gasoline for 2015, as shown in the following table.
<table>
<thead>
<tr>
<th></th>
<th>Manufacturer Mean</th>
<th>Supplier Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Premium</td>
<td>1.62</td>
<td>1.50</td>
</tr>
</tbody>
</table>

Manufacturers forecast a higher price for premium gasoline in 2015 than suppliers. Please note that where median values are reported in the original question, mean values are used to determine whether there are statistical differences and are compared in this analysis.

**REGIONAL COMPARISONS - SAMPLE**

[This section will compare responses in Europe, Asia, and North America.]

**STRATEGIC CONSIDERATIONS - SAMPLE**

In spite of the decrease in fuel prices in the last few years, there have been significant price swings in the past year. The price of regular fuel was as little as $.80 per gallon in February of 1999 in some locations. The price of gasoline in the United States remains significantly below prices seen in most other parts of the world. This is forecast to continue through 2020.

Low fuel prices will continue to cause a challenge to automobile manufacturers in meeting CAFE standards. Consumers will continue to buy large passenger cars and light trucks, as the annual cost of fuel for these vehicles is affordable. This will also exacerbate efforts to reduce the emission of greenhouse gases (carbon dioxide) from vehicles.

Political or economic perturbations in oil-countries could drastically and rapidly impact the price of fuel. Panelists apparently do not foresee such events in the near future, although a number raise this specter in their comments. As one panelist commented, "the price of fuel is so political that it is impossible to predict." This makes long-range planning for automobile manufacturers very difficult.

Comments have been made in the past that fuel-price forecast should only be made by fuel suppliers, as they are in the best position to know. However it is important to note that the prices forecast in this survey are most likely the prices on which future product decisions are being made because in the forecast come from those within the automobile industry.

The future trends in fuel pricing are likely to be extremely volatile as the recent significant increases in gasoline and diesel fuel would attest. Clearly there are many factors outside the of the control of the governments and energy and auto companies that will define the future as we have seen with the recent supply cutbacks by OPEC. This suggests a future of uncertainty and the importance of preparing alternative strategies and increasing agility to be able to take advantage of this uncertainty.
Question 2 - SAMPLE

What percentage of North-American produced spark-ignited engines for passenger-cars will be either supercharged or turbocharged in 2015 and 2020?

2015:

<table>
<thead>
<tr>
<th>Spark-Ignited Engines</th>
<th>2005 (%)</th>
<th>Median Response 2015</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Industry Response</td>
</tr>
<tr>
<td>Supercharged</td>
<td></td>
<td>Response</td>
</tr>
<tr>
<td>Turbocharged</td>
<td></td>
<td>Company's Response</td>
</tr>
</tbody>
</table>

| Interquartile Range   |          |

2020:

<table>
<thead>
<tr>
<th>Spark-Ignited Engines</th>
<th>2005 (%)</th>
<th>Median Response 2020</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Industry Response</td>
</tr>
<tr>
<td>Supercharged</td>
<td></td>
<td>Response</td>
</tr>
<tr>
<td>Turbocharged</td>
<td></td>
<td>Company's Response</td>
</tr>
</tbody>
</table>

| Interquartile Range   |          |

SELECTED EDITED COMMENTS - SAMPLE

- Cost and CAFE are the issues
- Future emission standards may be more difficult to achieve with turbocharging (loss of heat energy for catalyst light off).
- Supercharging will remain a niche technology because of cost. Turbocharging will remain irrelevant because of emissions.
- This is highly dependent on fuel price or CAFE standards.

RESULTS SUMMARY - SAMPLE

Panelists forecast that 3 percent of passenger-car engines will be supercharged in 2020. In the same time frame, only 1 percent of passenger-car engines are forecast to be turbocharged.

MANUFACTURER/SUPPLIER COMPARISON - SAMPLE

There are no statistically significant differences in the responses between manufacturers and suppliers with the exception of the items shown in the following table.

<table>
<thead>
<tr>
<th>Spark-Ignited Engines</th>
<th>Manufacturer Mean</th>
<th>Supplier Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supercharged 2009</td>
<td>8.4</td>
<td>3.7</td>
</tr>
<tr>
<td>Turbocharged 2009</td>
<td>3.4</td>
<td>1.6</td>
</tr>
</tbody>
</table>
Manufacturers forecast greater use of superchargers and turbochargers than do suppliers. Since vehicle manufacturers generally design their own engines, it is possible that future plans have not been adequately communicated to suppliers.

REGIONAL COMPARISONS - SAMPLE

[This section will compare responses in Europe, Asia, and North America.]

STRATEGIC CONSIDERATIONS - SAMPLE

As noted in panelist comments, increasingly more stringent emission standards will likely preclude the use of turbochargers. Cost, durability, and packaging are also concerns for turbochargers.

Superchargers do not take heat from exhaust gas, and therefore do not affect converter light-off time. Cost and packaging are issues, but do not exclude superchargers from upscale vehicles. Superchargers greatly increase low speed engine torque as well as high-speed horsepower. They therefore have an effect similar to increasing engine displacement dramatically. Superchargers may be used in the future as a fuel-economy enhancement by allowing the use of smaller engines to maintain vehicle acceleration performance.

The increased use of four-valve-per-cylinder engines has somewhat reduced the advantage of a supercharger. Significantly higher horsepower is available from these engines for a given displacement. Low-speed torque is generally not increased, however, with a four-valve-per-cylinder engine without a supercharger.

One general issue with either boost techniques is the trade-off in the cost of turbo of supercharging relative to a new engine program. Also, if you need power fast (design and development time) applying engine boost is faster than developing a new engine.
Please give your expectations in months for current and future development cycles from concept approval through Job One of a new spark-ignited engine and its associated transmission and driveline; a diesel engine, transmission, and driveline, a hybrid engine, transmission and driveline, and a fuel cell engine, transmission, and driveline.

### 2015:

<table>
<thead>
<tr>
<th>Future Development Cycles</th>
<th>Median Response</th>
<th>Interquartile / Best in Class, Worst in Class Range</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Industry Response (Mos.)</td>
<td>Your Response (Mos.)</td>
</tr>
<tr>
<td>Spark-Ignited Engine</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transmission</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Driveline</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diesel Engine</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transmission</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Driveline</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hybrid Engine</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transmission</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Driveline</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel Cell Engine</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transmission</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Driveline</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 2020:

<table>
<thead>
<tr>
<th>Future Development Cycles</th>
<th>Median Response</th>
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<tr>
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<tr>
<td>Driveline</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hybrid Engine</td>
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<td></td>
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<td></td>
<td></td>
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<tr>
<td>Driveline</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
SELECTED EDITED COMMENTS - SAMPLE

- "Fast" product capability may be constrained by economic-payback life cycle
- Time to market is the issue

RESULTS SUMMARY - SAMPLE

Panelists forecast that total-development-cycle time for high-volume vehicles will be reduced by 22 to 25 percent for manufacturers by 2015 maintaining current hardpoints and by 19 to 26 percent establishing new hardpoints.

Japanese manufacturers are forecast to retain their lead in cycle time over Ford, GM, and DaimlerChrysler and European-based manufacturers in this timeframe.

MANUFACTURER/SUPPLIER COMPARISON - SAMPLE

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

REGIONAL COMPARISONS - SAMPLE

[This section will compare responses in Europe, Asia, and North America.]

STRATEGIC CONSIDERATIONS - SAMPLE

Reducing development-cycle time allows a manufacturer to bring a product to market closer to the time that the requirements of the market are defined. The Japanese have a shorter cycle time than Ford, GM, and DaimlerChrysler and European-based manufacturers. They therefore have a competitive advantage in this regard. Panelists forecast that this advantage will decrease by 2015 however.

When the clock starts on measuring cycle timing is certainly an issue. Vehicle manufacturers have different requirements for starting the clock. In general, management approval of the clay model and business case, including financial, engineering, and manufacturing analysis and approval of the product content determines the start of the process. Certainly there are differences in detail in this area, even within the same company. The greatest significance in the result of this question may be the consensus that cycle time has been reduced by about 30 percent since 1992 and is forecast to be reduced another 20 percent by 2015.