Lightweight Materials for Transport: Developing a Vehicle Technology Roadmap for the Use of Lightweight Materials

MIT Roundtable: “The Future of Manufacturing Innovation - Advanced Technologies

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Why might lightweighting make strategic sense for the U.S. Auto Industry?
Why might lightweighting make strategic sense for the U.S. Auto Industry?

1. Automotive Lightweighting is Future Oriented.
   A. Global fuel demand and fuel prices seem likely to remain on an *upward trend despite severe volatility*. Heavy vehicles consume much fuel and produce much CO2.
   B. As the vehicle population is replaced, a *lightweight fleet will reduce total national fuel needs*. Positive political externalities may accompany positive economic externalities.
Why might lightweighting make strategic sense for the U.S. Auto Industry?

1. Automotive Lightweighting is Future Oriented.

2. Lightweighting is challenging technologically.
   A. Technologically, there is still much R&D to be done. 
      
      Followers will not be able to copy so quickly. Licensing royalties possible as a first-mover advantage.
   B. Vehicle lightweighting requires a redesign of the entire automotive supply chain with regards to materials, product design, and process design. 
      
      Established companies in other countries will not easily do this. Industry roadmapping suggests a path.
Why might lightweighting make strategic sense for the U.S. Auto Industry?

1. Automotive Lightweighting is Future Oriented.
2. Lightweighting is challenging technologically.
3. Lightweighting is challenging economically.

A. The world’s largest, established auto companies of Europe, North America, and Asia have so much sunk investment in heavy, conventional-steel vehicles that significant commitment will be required to lead the way to ultra-lightweight vehicles.

B. Alternate financing models may be required. Who pays the up-front investment costs so society can reap the later benefits?
Why might lightweighting make strategic sense for the U.S. Auto Industry?

1. Automotive Lightweighting is Future Oriented.
2. Lightweighting is difficult economically.
3. Lightweighting is challenging technologically.
4. Lightweight Vehicles will be exportable.

As fuel prices rise, demand for lightweight vehicles will also rise. If U.S. automobiles are the lightweight leaders, U.S. technology and products will be in high demand around the world.
How to (re-) build an automotive industry
Focused around a lightweighting strategy?

Let’s benchmark how another industry redesigned itself.
Collaborative Roadmapping in the Semiconductor Industry:

1. Initiation in mid-1980’s in the U.S. at the industry and government level:
   12 largest U.S. semiconductor firms,
   Department of Defense, Department of Justice

2. Coordinate the supply chain: 150 suppliers
   -- Leverage scale & scope of the whole industry

   -- Ambitious goals for technological achievement

4. “Field of Dreams” Business Model
   “If you build it, they will come.”
   (There was not a sophisticated business model at that time; now there is.)
Industry Roadmapping: What are the Lessons?

1. Engage the entire value chain
   A. All the major players -- OEM’s and Suppliers
   -- Achieve scale economies in R&D and Manufacturing
   B. Intellectual Value Chain -- Technologists and Scholars
   C. Government agencies and regulators

2. Build parallel, interlocking roadmaps
   A. Technology Roadmap
   B. Business and Industry Roadmap
   C. Regulatory Roadmap

3. Build consensus around a common vision and leadership
   A. In Semiconductors: Moore’s Law
   B. In Vehicle Lightweighting: Total mass and fuel economy
   C. Industry Leaders and Visionaries Must Lead

4. Build Collaborative Processes around Projects
   Create cross-company working groups
   -- to tackle technological challenges
   -- to build and test prototypes
   -- to continuously update the Roadmap
# Value Chain Roadmapping

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Key Points

1. Many possible choices, including timing
2. Manufacturing cost is generally higher
3. More complete cost picture may offset manufacturing cost premium
4. Lightweight alternatives offer synergies with advanced powertrain / electric vehicles
Many Lightweighting Strategies to Consider

Vehicles:
- High/Low Volume
- Compact Cars
- Midsize Cars
- SUVs …

Subsystems:
- Body
- Closures
- Chassis …

Materials:
- Steel
- Aluminum
- Magnesium
- Composites

Processes:
- Stamping
- Molding
- Casting …

Other:
- Paint
- Assembly …

Many possible approaches
Lightweight Vehicle Structures Generally Cost More to Manufacture

Values estimated based on a collection of MSL vehicle cost analyses and other sources

Mass Reduction

Additional Manufacturing Cost ($/kg)

Carbon Fiber
Magnesium
Al Unibody
Al Space Frame
SMC
GF
HS Steel

$16
$12
$8
$4
$0

0% 10% 20% 30% 40% 50% 60%
Lifetime Fuel Savings Generally Insufficient to Offset Manufacturing Costs

15,000 miles/year, 12 year vehicle life, 27.5 mpg base fuel economy, fuel savings using 10-5 rule, $2.50/gallon gasoline, baseline body mass = 250kg, vehicle mass = 1300kg, discount rate = 15%
Consideration of Secondary Weight Savings Improves the Case for Lightweighting

Based on secondary mass savings of 0.8kg for every 1kg primary mass saving.
Impact of Consumer Willingness to Pay and Gasoline Prices (a carbon tax would accentuate this effect)

Gasoline = $4.00/gallon
100% Willingness to Pay

Gasoline = $2.50/gallon
25% Willingness to Pay

Cost Difference (compared to baseline steel vehicle)
Alternative Powertrain Vehicles Offer Even Greater Opportunities for Lightweighting

Based on 2.5 miles/kWhr, electricity cost = $0.05/kWhr; linear relationship between vehicle mass, battery mass and battery cost

Body Cost – Battery Savings – Use Electricity

- $250

+$250

$0

$250

$500

$750

Primary Mass Reduction

0%

10%

20%

30%

40%

50%

60%

25% Willingness to Pay

USABC PHEV Target
Battery Cost = $3400

Battery Cost = $10,000

Battery Cost = $7,500

Battery Cost = $5,000

Carbon Fiber

Magnesium

Al Unibody

Glass Fiber

Al Space Frame

HS Steel

SMC

Alternative Powertrain Vehicles Offer Even Greater Opportunities for Lightweighting
Other Thoughts and Conclusions

• Mastering vehicle lightweighting technologies offers a path for growth in U.S. manufacturing and potential comparative advantage

• Technology improvements/manufacturing learning needed to ensure that lightweight approaches meet their cost targets

• Several lightweighting technologies look promising when viewed from a complete cost standpoint

• Advantages of lightweight vehicles greatly enhanced in vehicles with advanced (electric) powertrains
  - Most (if not all) technologies may be cost effective