NHTSA's Mass/Size/Safety Workshop
Light-Duty Vehicle Technology Cost and Mass Analysis

Location: DOT Headquarters, Washington, DC
Date: May 13th, 2013
Presentation Time: 10:30am-11:00am
Primary Presenter: Greg Kolwich

kolwich@fev.com
Project Objectives
Vehicle Attributes and Analysis Assumptions
Project Methodology Overview
  Vehicle Analysis Overview
  BIW CAE Analysis
Project Costing Methodology
Mass-Reduction Results
  Summary of Mass-Reduction Results
  Examples of Mass-Reduction Component Alternatives
Cost Analysis Results
Conclusion and Recommendations
Q&A
Project Objectives

- Conduct a detailed CAE analysis of the Lotus proposed BIW mass-reduction changes to assess the impact on NVH performance (i.e., static and dynamic torsion and bending stiffness) and vehicle crash safety. In the case the proposed Lotus BIW changes resulted in performance degradation, propose alternative mass-reduction BIW alternative to support an overall vehicle mass-reduction of 20%.

- Review and expand on the initial Lotus mass-reduction ideas. Through additional research and engineering assessment, verify the feasibility of the mass-reduction ideas in terms of industry potential acceptance, product function degradation risk, product implementation timeframe, manufacturing risk, and the value of mass-reduction ideas in terms of the amount of mass reduction and the cost/kilogram of the mass savings.

- Develop detailed cost models to calculate the net incremental direct manufacturing cost (NIDMC) impact of the mass-reduced technology configuration over the baseline production stock Toyota Venza technology configuration. Both unit NIDMCs and incremental tooling cost calculations were required.
Toyota Venza Vehicle Attributes and Analysis Assumptions

- 2010 model year, Toyota Venza.
- Equipped with a 2.7 liter, I4 internal combustion engine and a 6-speed automatic transmission.
- The weight of production stock Toyota Venza vehicle, as measured, was 1711 kg (3772 lbs).
  - The target for the vehicle mass-reduction was 20% or 342 kg (754 lbs).
- The purchase price of the vehicle was $25,063. Based on the assumption of a 1.5 times retail price equivalent (RPE), the estimated direct manufacturing cost of the Venza vehicle was $16,709.
  - The upper boundary condition to the vehicle direct manufacturing costs increase was set at 10% or $1671.
- The 2011/2012 Toyota Venza annual production sales volume range is 60k-75k units/year.
  - For the overall project, an annual vehicle production volume of 200K units was assumed. In the case of the Toyota Venza, many of the components and assemblies (e.g. engine, transmission brake and other vehicle system components) are cross-platform shared well beyond the 200K units per year (i.e., 500K+ units per year).
  - For the cost portion of the analysis all components other than BIW were assumed to be manufactured at 450K units/year. The BIW and closures were assumed to be manufactured at 200K units per year.
Mass-Reduction and Cost Analysis Methodology

Step 1: Baseline Vehicle Fingerprint
Step 2: Mass-Reduction Ideas Generation
Step 3: Preliminary Mass-Reduction and Cost Estimates
Step 4: Mass-Reduction and Cost Optimization Process
Step 5: Detailed Mass-Reduction Feasibility and Cost Analysis

Task 1: Non BIW Analysis Roadmap
- Vehicle Teardown, Measurements, Baseline BOMs Development
- Review, Develop, Grade, and Rank Mass-Reduction Ideas
- Initial Idea Down-Selection
- Preliminary Mass Reduction and Cost Estimate
- Final Idea Down-Selection
- Sort, Combine Mass-Reduction Ideas into Optimized Vehicle Solution
- Final Detailed Mass-Reduction and Cost Analysis

Task 2: BIW Analysis Roadmap
- Vehicle Scanning Model Development and Validation
- Lotus BIW Mass-Reduction Model Runs
- Elimination of Unsuccessful Lotus Ideas
- BIW Lightweight CAE Design Optimization Process
- Detailed Cost Analysis
Step 1: Baseline Vehicle Finger Printing

Vehicle Attributes, Detailed CBOM, CAE Performance and Crash Model

Procurement
- Toyota Venza Vehicle
- Service Parts

Vehicle Measurements

Vehicle Level Scanning

Vehicle Teardown
- Photos, Weights Process
- Maps, Component Info

Procurement
- Toyota Venza Vehicle
- Service Parts

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- Toyota Venza Vehicle
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Vehicle Teardown
- Photos, Weights Process
- Maps, Component Info

BOM Initiation
- FEV/Munro
- EDAG

Scanning Process A
- BIW, Chassis and Closure Scanning

Scanning Process B
- Other Components for Crash Model (e.g. engine, transmission, fuel tank)

Performance Model Build-up
- Surrogate Production Venza

Run Performance Model
- Validate/Tune Performance Model
- NVH Test Data from Production Venza

Load Vehicle Mass Distribution

Load Powertrain Mass & Inertia Measurements

Run Crash Model
- Surrogate Production Venza
- Subjectively compare results to NHTSA

NHTSA Crash Model Review
- Work with NHTSA team to ensure model standards are in-line with NHTSA's expectations

Vehicle Categorization of Parts
- Update System BOMs to reflect system content
- Indented Manufacturing BOM
- Part Name, Quantity, Weight

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NHTSA Crash Model Review
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Step 2: Idea Generation & Initial Idea Validation

Mass-Reduction Idea Generation & Lotus BIW Low Development Validation

Develop Brainstorming List (Group)
- Add "potential" mass-reduction ideas to master brainstorming list for each system
- Ideas captured at assembly and/or component level.

Lotus LD Material Substitutions

Develop Lotus LD Performance Model
- Update Surrogate Production Venza Performance Model with Lotus HSS Material Substitutions producing a "Venza LD Performance Model"

Run "Venza LD Performance Model"

Compare "Venza LD Performance Model" results with Surrogate Production Venza Performance Model

Venza LD Performance Model results are equal to or greater than Production Venza Model

Initial Grading of Mass Reduction Ideas - 5 Factors
1. Manufacturing Readiness
2. Functionability/Performance Risk
3. Estimated % Mass-Reduction
4. Estimated % Change In Unit Cost
5. Estimated Tooling Cost Impact
Grade = \( F_1 \times F_2 \times F_3 \times F_4 \times F_5 \)
Lowest Number = Best Idea

Crash Model Build-up "Lotus LD Crash Model"

Load Vehicle Mass Distribution
- Update w. BIW weight Reduction

Load Powertrain Mass & Inertia Measurements
- Carry-Over from Baseline

Load Material Specifications
- Updated from Venza LD Performance Model

Run Crash Model
- Venza LD Crash Model
- Compare Results to Production Venza Crash Model

Venza LD Crash Model Validated
- Lotus recommendations have been verified in terms of performance and crash acceptability.
**Step 3: Preliminary Mass-Reduction & Cost Estimate Calculations**

**Initial Idea Filtering, Second Feasibility Assessment, Idea Grouping**

**Initial Idea Down-Selection**
- The initial list of potential mass-reduction ideas is reduced using the Idea grading system.
- Ideas with high values (>50) are typically excluded from any further analysis.

**Quantitative Mass-Reduction and Cost Impact Estimates**
- Ideas which pass the initial down-selection process are then further evaluated by estimating the absolute mass reduction and cost impact.
- Resultant \(\$/kg\) for each best initial ranked idea

**Idea Grouping**
- Five cost groups were established to group ideas based on their average cost/kilogram weight save:
  - **Level A**: \(\leq 0.00\$/kg\) (i.e., ideas that either save money or add zero cost)
  - **Level B**: \(>0.00\) to \(\leq 1.00\)
  - **Level C**: \(>1.00\) to \(\leq 2.50\)
  - **Level D**: \(>2.50\) to \(\leq 4.88\)
  - **Level X**: > \(4.88\)

- One additional category exists, which is independent of the cost per weight save ratio. This sixth category is referred to as the “Decontenting” category (Level Z) and is reserved for ideas which degrade a system’s function/performance by employing the mass reduction idea.

- Decontenting can occur at various functional levels: (1) comfort convenience components (e.g., cup holders, DVD player, storage concealer), (2) secondary support components (e.g., spare tire, jack), or (3) at a primary function level (e.g., downsized engine w/ less horsepower)
Step 4: Mass-Reduction and Cost Optimization Process

.strategy for Building Mass-Reduction Ideas Into Vehicle Solutions
Step 4: Mass-Reduction and Cost Optimization Process

Mass-Reduction Optimization at the Component/Assembly Level

Combining of Compatible and Complementary Mass-Reduction Ideas into Component Solutions
• For each component/assembly group ideas together creating feasible mass-reduction alternatives at different cost to weight ratio.
• Two methodologies employed: Low Cost Solution and Engineered Solution

Baseline Crash Model Evaluation
• Based on crash model analysis, subjectively assess ideas best suited for integration into Venza

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<tbody>
<tr>
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<td>≤ $0</td>
<td>Range &gt;$0.00 ≤ $1.00</td>
<td>Range &gt;$1.00 ≤ $2.50</td>
<td>Range &gt;$2.50 ≤ $4.88</td>
<td>&gt; $4.88</td>
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<tr>
<td>Subgroup X</td>
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</table>

| IDEA #1 | Reduce Rotor Thickness |
| IDEA #2 | Reduce Rotor Diameter |
| IDEA #3 | Vent/Slot Rotor |
| IDEA #4 | Cross-Drill Rotor |
| IDEA #5 | Drill Holes in Rotor Top Hat Surface |
| IDEA #6 | Rotor ID Scalping (Hat Perimeter) |
| IDEA #7 | Rotor OD Scalping |
| IDEA #8 | Change to Ceramic Rotor |
| IDEA #9 | 2 Pc Rotor Design (Iron & CF) |
| IDEA #10 | Change to Composite Rotor |

Cost Group: C

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<tr>
<th>Subgroup Cc</th>
<th>Range &gt;$1.00 ≤ $2.50</th>
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Cost Group: D

<table>
<thead>
<tr>
<th>Subgroup De</th>
<th>Range &gt;$2.50 ≤ $4.88</th>
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</table>

Rotor Option #1 is placed in the Low Cost Solution Assembly/Component Mass Reduction Matrix

Rotor Option #2 is placed in the Engineered Solution Assembly/Component Mass Reduction Matrix
### Step 4: Mass-Reduction and Cost Optimization Process

**Mass-Reduction Optimization at the Subsystem Level**

Combining of Compatible and Complementary Mass-Reduction Components into Subsystem Solutions

- Within each subsystem, evaluate all component and assembly combinations, at the defined cost/weight ratio levels

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<td>Range “$/kg” ≤ $0</td>
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<td>Subgroup Be</td>
<td>Subgroup Ce</td>
<td>Subgroup De</td>
<td>Subgroup Xe</td>
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<td>1. Mass-Reduced Rotors</td>
<td>Rotor Option #2</td>
<td>Dust Shield Option #2</td>
<td>Brake Caliper Option #2</td>
<td>Caliper Bracket Option #2</td>
<td>FRDSS Option #2</td>
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<td>2. Mass-Reduced Dust Shields</td>
<td>Rotor Option #3</td>
<td>Dust Shield Option #3</td>
<td>Brake Caliper Option #3</td>
<td>Caliper Bracket Option #3</td>
<td>FRDSS Option #4</td>
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<td>3. Mass-Reduced Brake Calipers</td>
<td>Rotor Option #4</td>
<td>Dust Shield Option #4</td>
<td>Brake Caliper Option #4</td>
<td>Caliper Bracket Option #4</td>
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</tr>
<tr>
<td>4. Mass-Reduced Pad Kits</td>
<td>Rotor Option #5</td>
<td>Dust Shield Option #5</td>
<td>Brake Caliper Option #5</td>
<td>Caliper Bracket Option #5</td>
<td>FRDSS Option #5</td>
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<tr>
<td>5. Mass-Reduced Caliper Brackets</td>
<td>Rotor Option #6</td>
<td>Dust Shield Option #6</td>
<td>Brake Caliper Option #6</td>
<td>Caliper Bracket Option #6</td>
<td>FRDSS Option #6</td>
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</tbody>
</table>

Same Process Repeated for Low Cost Solution Subsystems

- Built-up using Low Cost Solution Component Assembly Matrix

```
FRDSS Option #2
Rotor #2 + Dust Shield #3 + Brake Caliper #4 + Pad Kit #2
Caliper Brist #2 $0.93/kg
```

```
FRDSS Option #4
Rotor #3 + Dust Shield #4 + Brake Caliper #6 + Pad Kit #2
Caliper Brist #2 $4.40/kg
```
### Step 4: Mass-Reduction and Cost Optimization Process

**Mass-Reduction Optimization at the System Level**

- **Subsystems Included In System**
  1. Front Rotor/Drum and Shield Subsystem (FRDSS)
  2. Rear Rotor/Drum and Shield Subsystem (RRDSS)
  3. Parking Brake and Actuation Subsystem (PBAS)
  4. Brake Actuation Subsystem (BAS)
  5. Hydraulic Power Brake Subsystem (HPBS)
  6. Brake Controls Subsystem (BCS)

- **Combining of Compatible and Complementary Mass-Reduction Subsystems into System Solutions**
  - Within each system, evaluate all the subsystem combinations at the defined cost/weight ratio levels.

- **Mass-Reduced Subsystem Options => Mass-Reduced System Options**
  (Example: Brake System)

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<td>Range &quot;$/kg&quot; &gt; 0.00 - ≤ 1.00</td>
<td>Range &quot;$/kg&quot; &gt; 1.00 - ≤ 2.50</td>
<td>Range &quot;$/kg&quot; &gt; 2.50 - ≤ 4.88</td>
<td>Range &quot;$/kg&quot; &gt; 4.88</td>
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<td>FRDSS Option #1</td>
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<td></td>
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<td></td>
<td></td>
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<tr>
<td>RRDSS Option #1</td>
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<tr>
<td>BAS Option #1</td>
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<td>PBAS Option #2</td>
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<td>HPBS Option #1</td>
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<tr>
<td>FRDSS Option #3</td>
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<tr>
<td>RRDSS Option #2</td>
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<td>BAS Option #3</td>
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<tr>
<td>BAS Option #4</td>
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<tr>
<td>HPBS Option #4</td>
<td></td>
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</tbody>
</table>

- **Same Process Repeated for Low Cost Solution Systems**
- **Built-up using Low Cost Solution Subsystem Assembly Matrix**

**Example: Brake System**

- **Option #1**
  - FRDSS Option #1 + RRDSS Option #1 + PBAS Option #1 + BAS Option #1 + HPBS Option #1
  - Cost: -0.26/kg

- **Option #2**
  - FRDSS Option #2 + RRDSS Option #2 + BAS Option #3 + BAS Option #4 + HPBS Option #2
  - Cost: 2.33/kg

- **Subsystems Included In System**
  - **Subgroup Ae**
  - **Subgroup Be**
  - **Subgroup Ce**
  - **Subgroup De**
  - **Subgroup Xe**

- **Range "$/kg"**
  - ≤ 0
  - > 0.00 - ≤ 1.00
  - > 1.00 - ≤ 2.50
  - > 2.50 - ≤ 4.88
  - > 4.88
Step 4: Mass-Reduction and Cost Optimization Process

Potential Vehicle Mass-Reduction Solutions

Selection of Target Mass Reduction

- Team selection of target mass-reduction level to proceed with detailed analysis.
- Based on cost impact trade-off.

![Toyota Venza Mass-Reduction Versus $/kg](chart)

**Selected Analysis Point**
Step 5: Detailed Mass-Reduction Feasibility and Cost Analysis

- Detailed Technology Feasibility Analysis
  - Subjective
  - Objective (Crash)
- Detailed Incremental Direct Manufacturing Cost Analysis
- System Ripple Effect on Mass Reduction

Mass-Reduced Toyota Venza
- 19.84% Net Mass Reduction Target
- 1.7% Cost Increase

CAE Models
- Updated CAE models capturing mass-reduction changes directly impacting crash safety

Unsuccessful Idea Implementation

New or Updated Ideas

CAE Models
- Updated CAE models capturing mass-reduction changes directly impacting crash safety
Step 5: Detailed Mass-Reduction Feasibility and Cost Analysis

**Mass-Reduction Idea Generation & Implementation into the Venza Application**

Steel Stamped Fuel Tank Ass'y
Mass = 18.78 kg, TMC = $75.07

HDPE Fuel Tank Ass'y
Mass = 13.02 kg, TMC = $72.17
Supplier Involvement Instrumental in the Analysis

- Idea Generation, Idea Validation and/or Costing
Step 5: Detailed Mass-Reduction Feasibility and Cost Analysis

Mass-Reduction Idea Generation and Implementation (BIW Only)
### High Pressure Fuel Pump Example

<table>
<thead>
<tr>
<th>Material</th>
<th>Labor</th>
<th>Burden</th>
<th>TMC</th>
<th>Scrap</th>
<th>SG&amp;A</th>
<th>Profit</th>
<th>ED&amp;T</th>
<th>Total Mark-up</th>
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<tr>
<td><strong>Base Cost Impact to Vehicle:</strong></td>
<td><strong>$16.99</strong></td>
<td><strong>$8.01</strong></td>
<td><strong>$24.95</strong></td>
<td><strong>$49.94</strong></td>
<td><strong>$0.68</strong></td>
<td><strong>$5.88</strong></td>
<td><strong>$2.32</strong></td>
<td><strong>$14.84</strong></td>
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<tr>
<td><strong>Total Manufacturing Cost:</strong></td>
<td><strong>$0.38</strong></td>
<td><strong>$3.79</strong></td>
<td><strong>$4.33</strong></td>
<td><strong>$2.16</strong></td>
<td><strong>$10.66</strong></td>
<td><strong>$64.79</strong></td>
<td></td>
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</tr>
<tr>
<td><strong>Packaging Cost:</strong></td>
<td><strong>$0.11</strong></td>
<td><strong>$3.79</strong></td>
<td><strong>$4.33</strong></td>
<td><strong>$2.16</strong></td>
<td><strong>$10.66</strong></td>
<td><strong>$64.90</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Net Cost Impact to Vehicle:** $64.90

**SAC** & **T1 or OEM Mark-Up Values:**

- Material: $0.38
- Labor: $3.79
- Burden: $4.33
- TMC: $2.16
- Scrap: $10.66

**T1 or OEM Total Manufacturing Cost:** $54.12

**T1 or OEM Mark-Up Rates:**

- **Material**: 0.70%
- **Labor**: 7.00%
- **Burden**: 8.00%
- **TMC**: 4.00%
- **Scrap**: 19.70%

**T1 or OEM Mark-Up Values:**

- **Material**: $0.38
- **Labor**: $3.79
- **Burden**: $4.33
- **TMC**: $2.16
- **Scrap**: $10.66

**Total Mark-up:** $64.79

**Packaging Cost:** $0.11

**Net Cost Impact to Vehicle:** $64.90
Cost Analysis Methodology: Detailed Teardown & Costing

Developing Incremental Technology Costs Between Two Competing Technologies: Previous Less Robust Method

Variations in New Technology Costs... Why?
- Assumed production volume
- Competitive market status (supply and demand)
- RD&T amortization schedule
- Supporting supplier infrastructure
- Protection from the unknown... liability, warranty, recall
- Existing product and manufacturing infrastructure protection
- Information is usually CBI

Supply and Demand Unit Cost Adjustments
\[ y = Ax^3 + Bx^2 - Cx^2 + Dx - Ex + F \]

New Technology Cost Increase = +$523 \text{ ?}
New Technology Cost Increase = +$392 \text{ ?}
New Technology Cost Decrease = -$13 \text{ ?}
New Technology Cost Decrease = -$144 \text{ ?}

Production Year

Technology Cost


New - Low
New - High
Base - Low
Base - High
Cost Analysis Methodology: Detailed Teardown & Costing

Developing Incremental Technology Costs Between Two Competing Technologies: New and Improved Methodology

Step 1: Cost Technologies Based on Common Set of Boundary Conditions

- **Same Cost Elements** (Direct/Indirect Costs, OEM/Supplier Costs, Tooling, Packaging, Shipping, etc.)
- **Same Product/Technology Maturity Level**
  - The target is to cost at a level the technology will compete at over the long run
- **Same Manufacturing Volumes** (450K+/year)
- **Same Manufacturing Locations** (supplier and OEM)
- **Same Manufacturing Cost Structure**
  - Timeframe (e.g. material, labor, manufacturing overhead rates)
- **Same Ground Rules for Defining Design and Manufacturing Characteristics** (e.g. Intellectual Property, Platform Synergies, Derivative Model Considerations)

Understanding the Boundary Conditions of the analysis allows the user to make educated assessments of change and adjustment (Guiding Cost Model Principals.....Detailed, Transparent and Flexible Cost Modeling)
Developing Incremental Technology Costs Between Two Competing Technologies: Update EPA Methodology

Step 2: Estimate the Production Year When the Technology has Stabilized at Mass-Production Volumes

- High Production Volumes
- Products in Service for Several Years at High Volumes
- Significant Market Place Competition

Production Year

Technology Cost

$1,850
$1,900
$1,950
$2,000
$2,050
$2,100
$2,150
$2,200
$2,250
$2,300
$2,350
$2,400
$2,450
$2,500
$2,550
$2,600
Developing Incremental Technology Costs Between Two Competing Technologies: Update EPA Methodology

Step 3: NIDMC Adjustments for the Near-Term and Future

Reverse Learning, Market Maturity Adjustments and other Cost Adjustment Factors
- Production volumes
- Competitive market status (supply and demand)
- ED&T amortization schedule
- Supporting supplier infrastructure
- Existing product and manufacturing infrastructure protection

Forward Learning Adjustments
- Continuous Product Learning/Refinement
- On-Going Lean Manufacturing Activities

Technology Cost vs. Production Year

- New - NIDMC
- Low - NIDMC
- New - Reverse
- Base - Reverse
- New - For
- Base - For
Mass-Reduction Results

Production Venza Compared to Mass-Reduced Venza

System Mass-Reduction Comparison

- Production Venza System Mass
- Mass-Reduced Venza System Mass

Vehicle Systems (as defined by FEV)
Body System, Group A: BIW & Closures

- Optimized gauge and material grades for body structure parts
- Laser welded assembly at shock towers, rocker, roof rail, and rear structure subassemblies
- Aluminum material for front bumper, hood, and tailgate parts
- TRBs on B-pillar, A-pillar, roof rail, and seat cross member parts
- Design change on front rail side members

<table>
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<tr>
<th>Description</th>
<th>Estimated Mass Reduction “Kg”</th>
<th>Estimated Cost Impact “$”</th>
<th>Average Cost/Kilogram “$/Kg”</th>
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<td>Body Structure Subsystem</td>
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<tr>
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<tr>
<td>Front Fenders</td>
<td>2.0</td>
<td>-21.85</td>
<td>-10.93</td>
</tr>
<tr>
<td>Bumpers Subsystem</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Front Bumper Asy</td>
<td>0.4</td>
<td>-10.71</td>
<td>-26.78</td>
</tr>
<tr>
<td>Rear Bumper Asy</td>
<td>0.0</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Totals</td>
<td>68.1</td>
<td>-208.26</td>
<td>-3.06</td>
</tr>
</tbody>
</table>

“+” = mass decrease, “-” = mass increase
“+” = cost decrease, “-” = cost increase
## Suspension System

### Net Value of Mass Reduction Idea

<table>
<thead>
<tr>
<th>System</th>
<th>Sub-System</th>
<th>Description</th>
<th>Idea Level Select</th>
<th>Mass Reduction &quot;kg&quot;</th>
<th>Cost Impact &quot;$&quot;</th>
<th>Average Cost/ Kilogram $/kg</th>
<th>Subsys./ Subsys. Mass Reduction &quot;%&quot;</th>
<th>Vehicle Mass Reduction &quot;%&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>04 00</td>
<td>Suspension System</td>
<td>Front Suspension Subsystem</td>
<td>11.572</td>
<td>$3.04</td>
<td>-$0.26</td>
<td>55.40%</td>
<td>0.68%</td>
<td></td>
</tr>
<tr>
<td>04 01</td>
<td>Rear Suspension Subsystem</td>
<td>Rear Suspension Subsystem</td>
<td>8.320</td>
<td>$4.91</td>
<td>-$0.59</td>
<td>41.53%</td>
<td>0.49%</td>
<td></td>
</tr>
<tr>
<td>04 02</td>
<td>Shock Absorber Subsystem</td>
<td>Shock Absorber Subsystem</td>
<td>14.111</td>
<td>$57.99</td>
<td>-$4.11</td>
<td>35.88%</td>
<td>0.82%</td>
<td></td>
</tr>
<tr>
<td>04 03</td>
<td>Wheels And Tires Subsystem</td>
<td>Wheels And Tires Subsystem</td>
<td>32.833</td>
<td>$78.77</td>
<td>-$2.40</td>
<td>25.69%</td>
<td>1.92%</td>
<td></td>
</tr>
<tr>
<td>04 04</td>
<td>Rear Suspension Modules</td>
<td>Rear Suspension Modules</td>
<td>0.000</td>
<td>0.000</td>
<td>$0.00</td>
<td>0.00%</td>
<td>0.00%</td>
<td></td>
</tr>
<tr>
<td>04 05</td>
<td>Rear Suspension Load Leveling Control Subsystem</td>
<td>Rear Suspension Load Leveling Control Subsystem</td>
<td>0.000</td>
<td>0.000</td>
<td>$0.00</td>
<td>0.00%</td>
<td>0.00%</td>
<td></td>
</tr>
<tr>
<td>04 06</td>
<td>Front Suspension Modules</td>
<td>Front Suspension Modules</td>
<td>0.000</td>
<td>0.000</td>
<td>$0.00</td>
<td>0.00%</td>
<td>0.00%</td>
<td></td>
</tr>
</tbody>
</table>

| Total                  |            |                                          | 66.835 (Decrease)  | $144.71 (Decrease) | $0.46 (Decrease) | 26.47%                      | 3.91% (Decrease)                |

(1) "-" = mass decrease, "+" = mass increase

(2) "-" = cost decrease, "+" = cost increase

Wheels and Tires--Normalized with the 2008 Toyota Prius Design (All tires & wheels)

Front & Rear Strut Module Assembly Subsystem Baseline vs. Mass Reduced Configuration Example
## Net Value of Mass Reduction Idea

<table>
<thead>
<tr>
<th>Idea Level</th>
<th>Description</th>
<th>Mass Reduction &quot;kg&quot; (1)</th>
<th>Cost Impact &quot;$&quot; (2)</th>
<th>Average Cost/Kilogram $/kg</th>
<th>Subsys./Subsys. Mass Reduction %</th>
<th>Vehicle Mass Reduction %</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Thixomold® Mag Seat Back &amp; Bottom</td>
<td>23.392</td>
<td>$84.55</td>
<td>$3.61</td>
<td>25.28%</td>
<td>1.37%</td>
</tr>
<tr>
<td>A</td>
<td>Lear EVO™ Mini Recliner</td>
<td>8.924</td>
<td>$37.72</td>
<td>$4.23</td>
<td>13.69%</td>
<td>0.52%</td>
</tr>
<tr>
<td>A</td>
<td>ProBax® Structural Foam Insert</td>
<td>6.330</td>
<td>-$12.49</td>
<td>-$1.97</td>
<td>19.36%</td>
<td>0.37%</td>
</tr>
<tr>
<td>A</td>
<td>Woodbridge® PU/EPP Foam</td>
<td>2.029</td>
<td>$15.70</td>
<td>$7.74</td>
<td>24.67%</td>
<td>0.12%</td>
</tr>
<tr>
<td>A</td>
<td>MuCell® Non-Class &quot;A&quot; Surfaces</td>
<td>1.039</td>
<td>-$2.88</td>
<td>-$2.77</td>
<td>5.96%</td>
<td>0.06%</td>
</tr>
<tr>
<td>A</td>
<td>PolyOne® Class &quot;A&quot; Surfaces</td>
<td>0.268</td>
<td>$0.38</td>
<td>$1.40</td>
<td>5.95%</td>
<td>0.02%</td>
</tr>
<tr>
<td>A</td>
<td>Polynomial Processes</td>
<td>41.982</td>
<td>$122.97</td>
<td>$2.93</td>
<td>19.03%</td>
<td>2.45%</td>
</tr>
</tbody>
</table>

(1) "+" = mass decrease, "-" = mass increase
(2) "+" = cost decrease, "-" = cost increase

- Thixomold® Mag Seat Back & Bottom
- Lear EVO™ Mini Recliner
- ProBax® Structural Foam Insert
- Woodbridge® PU/EPP Foam
- MuCell® Non-Class "A" Surfaces
- PolyOne® Class "A" Surfaces
## Brake System

### Net Value of Mass Reduction Ideas

<table>
<thead>
<tr>
<th>System</th>
<th>Subsystem</th>
<th>Description</th>
<th>Description</th>
<th>Idea Level</th>
<th>Select</th>
<th>Mass Reduction “kg” (1)</th>
<th>Cost Impact “$” (2)</th>
<th>Average Cost/ Kilogram $/kg</th>
<th>Subsys./ Subsys. Mass Reduction “%”</th>
<th>Vehicle Mass Reduction “%”</th>
</tr>
</thead>
<tbody>
<tr>
<td>06 00 00</td>
<td></td>
<td>Brake System</td>
<td></td>
<td>A</td>
<td></td>
<td>12.647</td>
<td>$35.91</td>
<td>$2.42</td>
<td>45.01%</td>
<td>0.87%</td>
</tr>
<tr>
<td>06 04 00</td>
<td></td>
<td>Front Rotor/Drum and Shield Subsystem</td>
<td></td>
<td>A</td>
<td></td>
<td>6.242</td>
<td>$17.45</td>
<td>$1.74</td>
<td>44.75%</td>
<td>0.59%</td>
</tr>
<tr>
<td>06 05 00</td>
<td></td>
<td>Rear Rotor/Drum and Shield Subsystem</td>
<td></td>
<td>A</td>
<td></td>
<td>9.635</td>
<td>$82.98</td>
<td>$8.61</td>
<td>71.88%</td>
<td>0.56%</td>
</tr>
<tr>
<td>06 06 00</td>
<td></td>
<td>Parking Brake and Actuation Subsystem</td>
<td></td>
<td>A</td>
<td></td>
<td>2.984</td>
<td>$31.90</td>
<td>$10.69</td>
<td>53.90%</td>
<td>0.17%</td>
</tr>
<tr>
<td>06 07 00</td>
<td></td>
<td>Brake Actuation Subsystem</td>
<td></td>
<td>A</td>
<td></td>
<td>1.196</td>
<td>$1.35</td>
<td>$1.13</td>
<td>42.25%</td>
<td>0.07%</td>
</tr>
<tr>
<td>06 09 00</td>
<td></td>
<td>Power Brake Subsystem (for Hydraulic)</td>
<td></td>
<td>A</td>
<td></td>
<td>0.000</td>
<td>0.000</td>
<td>$0.00</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Brake Controls Subsystem</td>
<td></td>
<td>A</td>
<td></td>
<td>32.703</td>
<td>$169.60</td>
<td>$5.19</td>
<td>51.56%</td>
<td>2.26%</td>
</tr>
</tbody>
</table>

(1) “+” = mass decrease, “-” = mass increase

(2) “+” = cost decrease, “-” = cost increase

Combination. Modify rotors with slotting, cross-drilling, 2-pc design, Al Hat, downsize from Prius, disc material cast iron, change fin design (directional), rotor ID & OD scalloping, holes in rotor top hat surface & side perimeter.

Combination. Modify rotors with slotting, cross-drilling, 2-pc design, Al Hat, downsize from Prius, disc material cast iron, rotor ID & OD scalloping, holes in rotor top hat surface & side perimeter.
## Net Value of Mass Reduction Idea

<table>
<thead>
<tr>
<th>Idea Level Select</th>
<th>Mass Reduction &quot;kg&quot; (1)</th>
<th>Cost Impact &quot;$&quot; (2)</th>
<th>Average Cost/ Kilogram $/kg</th>
<th>Subsys./ Subsys. Mass Reduction &quot;%&quot;</th>
<th>Vehicle Mass Reduction &quot;%&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>01 00 00 Engine System</td>
<td>30.248</td>
<td>33.687</td>
<td>1.114</td>
<td>17.53%</td>
<td>1.77%</td>
</tr>
<tr>
<td>01 01 00 Engine Assembly Downsize (2.4L)</td>
<td>A</td>
<td>10.365</td>
<td>38.420</td>
<td>$3.71</td>
<td>6.01%</td>
</tr>
<tr>
<td>01 05 00 Cylinder Block Subsystem</td>
<td>D</td>
<td>7.106</td>
<td>-32.325</td>
<td>-$4.55</td>
<td>23.58%</td>
</tr>
<tr>
<td>01 07 00 Valvetrain Subsystem</td>
<td>D</td>
<td>3.707</td>
<td>-11.133</td>
<td>-$3.00</td>
<td>37.90%</td>
</tr>
<tr>
<td>01 14 00 Cooling Subsystem</td>
<td>A</td>
<td>2.591</td>
<td>4.620</td>
<td>$1.78</td>
<td>18.38%</td>
</tr>
<tr>
<td>01 08 00 Timing Drive Subsystem</td>
<td>A</td>
<td>1.454</td>
<td>47.92</td>
<td>$3.29</td>
<td>33.72%</td>
</tr>
<tr>
<td>01 02 00 Engine Frames, Mounting, and Brackets</td>
<td>A</td>
<td>1.114</td>
<td>-0.087</td>
<td>-$0.08</td>
<td>7.29%</td>
</tr>
<tr>
<td>01 06 00 Cylinder Head Subsystem</td>
<td>A</td>
<td>1.047</td>
<td>11.887</td>
<td>$11.25</td>
<td>4.96%</td>
</tr>
<tr>
<td>01 00 00 Accessory Subsystems (Start Motor, Generator, etc.)</td>
<td>B</td>
<td>0.709</td>
<td>-30.23</td>
<td>-$0.33</td>
<td>4.28%</td>
</tr>
<tr>
<td>01 03 00 Crank Drive Subsystem</td>
<td>A</td>
<td>0.688</td>
<td>6.88</td>
<td>$10.00</td>
<td>2.78%</td>
</tr>
<tr>
<td>01 10 00 Air Intake Subsystem</td>
<td>A</td>
<td>0.510</td>
<td>3.009</td>
<td>$5.90</td>
<td>3.65%</td>
</tr>
<tr>
<td>01 60 00 Engine Management, Engine Electronic, etc.</td>
<td>A</td>
<td>0.388</td>
<td>$1.00</td>
<td>$2.57</td>
<td>0.00%</td>
</tr>
<tr>
<td>01 13 00 Lubrication Subsystem</td>
<td>B</td>
<td>0.234</td>
<td>-0.201</td>
<td>-$0.86</td>
<td>7.00%</td>
</tr>
<tr>
<td>01 17 00 Breather Subsystem</td>
<td>A</td>
<td>0.219</td>
<td>4.93</td>
<td>$22.52</td>
<td>0.00%</td>
</tr>
<tr>
<td>01 11 00 Fuel Induction Subsystem</td>
<td>A</td>
<td>0.115</td>
<td>2.127</td>
<td>$0.00</td>
<td>0.00%</td>
</tr>
<tr>
<td>01 04 00 Counter Balance Subsystem</td>
<td>A</td>
<td>0.000</td>
<td>$0.00</td>
<td>$0.00</td>
<td>0.00%</td>
</tr>
<tr>
<td>01 09 00 Accessory Drive Subsystem</td>
<td>A</td>
<td>0.000</td>
<td>0.000</td>
<td>$0.00</td>
<td>0.00%</td>
</tr>
<tr>
<td>01 12 00 Exhaust Subsystem</td>
<td>A</td>
<td>0.000</td>
<td>0.000</td>
<td>$0.00</td>
<td>0.00%</td>
</tr>
<tr>
<td>01 15 00 Induction Air Charging Subsystem</td>
<td>0.000</td>
<td>$0.00</td>
<td>$0.00</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>01 16 00 Exhaust Gas Re-circulation Subsystem</td>
<td>0.000</td>
<td>$0.00</td>
<td>$0.00</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
</tbody>
</table>

(1) "+" = mass decrease, "-" = mass increase
(2) "+" = cost decrease, "-" = cost increase

Baseline--Die cast aluminum engine block with cast iron cylinder liners
New Design--Magnesium Aluminum Hybrid Engine Block with plasma cylinder liner

Venza Base Engine (Toyota 2.7L 1AR-FE)

Engine Downsize Selection (Toyota 2.4L 2AZ-FE)
### Transmission System

#### Net Value of Mass Reduction Idea

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Case Subsystem</td>
<td>C</td>
<td>02</td>
<td>7.745</td>
<td>-$11.63</td>
<td>-$1.42</td>
<td>31.52%</td>
<td>0.45%</td>
</tr>
<tr>
<td>Launch Clutch Subsystem</td>
<td>A</td>
<td>05</td>
<td>4.904</td>
<td>$45.16</td>
<td>$9.21</td>
<td>50.42%</td>
<td>0.29%</td>
</tr>
<tr>
<td>Gear Train Subsystem</td>
<td>X</td>
<td>03</td>
<td>3.490</td>
<td>-$119.68</td>
<td>-$34.29</td>
<td>8.42%</td>
<td>0.20%</td>
</tr>
<tr>
<td>Driver Operated External Controls Subsystem</td>
<td>X</td>
<td>02</td>
<td>3.490</td>
<td>-$119.68</td>
<td>-$34.29</td>
<td>8.42%</td>
<td>0.20%</td>
</tr>
<tr>
<td>Oil Pump and Filter Subsystem</td>
<td>A</td>
<td>02</td>
<td>1.726</td>
<td>-$29.49</td>
<td>-$17.08</td>
<td>69.55%</td>
<td>0.10%</td>
</tr>
<tr>
<td>External Components</td>
<td>A</td>
<td>01</td>
<td>0.000</td>
<td>$0.00</td>
<td>$0.00</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Mechanical Controls Subsystem</td>
<td>X</td>
<td>02</td>
<td>0.000</td>
<td>$0.00</td>
<td>$0.00</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Electrical Controls Subsystem</td>
<td>X</td>
<td>02</td>
<td>0.000</td>
<td>$0.00</td>
<td>$0.00</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Parking Mechanism Subsystem</td>
<td>X</td>
<td>02</td>
<td>0.000</td>
<td>$0.00</td>
<td>$0.00</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>External Components</td>
<td>X</td>
<td>02</td>
<td>0.000</td>
<td>$0.00</td>
<td>$0.00</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Mechanical Controls Subsystem</td>
<td>X</td>
<td>02</td>
<td>0.000</td>
<td>$0.00</td>
<td>$0.00</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Electrical Controls Subsystem</td>
<td>X</td>
<td>02</td>
<td>0.000</td>
<td>$0.00</td>
<td>$0.00</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Parking Mechanism Subsystem</td>
<td>X</td>
<td>02</td>
<td>0.000</td>
<td>$0.00</td>
<td>$0.00</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>(Decrease)</td>
<td>18.900</td>
<td>-$114.15</td>
<td>-$6.04</td>
<td>20.37%</td>
<td>1.10%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(1) "+" = mass decrease, "-" = mass increase
(2) "+" = cost decrease, "-" = cost increase

Case Subsystem-Replace with a 390 Aluminum casting with Mg Aj62 (Mg-Al-Sr)

Launch Clutch Subsystem-Replace steel torque converter with Aluminum
A significant amount of mass-reduction ideas were considered though were not included in the final vehicle mass-reduction solution (18.3%). Various reasons for not including are as follows: insignificant mass-reduction, significant cost impact and/or concerns with manufacturing readiness in the 2017 timeframe. Many of these additional ideas are discussed in the final report with reasons why they were not included. Examples include aluminum door closures and use of HSS above 700 MPa for the BIW structure.

Some ideas were not included in the analysis as a result of the defined project boundary conditions. For example, BIW modifications were generally limited to material and gauge substitutions. In a “clean sheet redesign” additional mass-reduction opportunities would likely be available.
### Mass-Reduction Results:

<table>
<thead>
<tr>
<th>Description</th>
<th>2010 Production Toyota Venza System Mass Contributions <em>kg</em></th>
<th>System Incremental Direct Manufacturing Cost Impact <em>$/kg</em> (1)</th>
<th>System Incremental Tooling Impact Cost <em>$/kg</em> (1)</th>
<th>Average System Cost/Kilogram w/o Tooling <em>$/kg</em> (1)</th>
<th>Average System Cost/Kilogram with Tooling <em>$/kg</em> (1)</th>
<th>% System Mass Reduction (1)</th>
<th>% Vehicle Mass Reduction (1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body System (Group A.) BIW &amp; Closures</td>
<td>528.88</td>
<td>(227.45)</td>
<td>(2,900.06)</td>
<td>(3.33)</td>
<td>(3.51)</td>
<td>12.92%</td>
<td>3.99%</td>
</tr>
<tr>
<td>Suspension System</td>
<td>241.49</td>
<td>144.71</td>
<td>(7,544.37)</td>
<td>2.17</td>
<td>2.10</td>
<td>27.68%</td>
<td>3.91%</td>
</tr>
<tr>
<td>Body System (Group B.) Interior</td>
<td>220.61</td>
<td>122.98</td>
<td>9,366.15</td>
<td>2.53</td>
<td>3.06</td>
<td>19.04%</td>
<td>2.45%</td>
</tr>
<tr>
<td>Brake System</td>
<td>86.71</td>
<td>169.56</td>
<td>(4,126.12)</td>
<td>5.18</td>
<td>5.15</td>
<td>37.77%</td>
<td>1.91%</td>
</tr>
<tr>
<td>Engine System</td>
<td>172.60</td>
<td>33.69</td>
<td>5,892.30</td>
<td>1.11</td>
<td>1.22</td>
<td>17.55%</td>
<td>1.77%</td>
</tr>
<tr>
<td>Transmission System</td>
<td>92.76</td>
<td>18.90</td>
<td>(114.15)</td>
<td>6.04</td>
<td>(6.29)</td>
<td>20.37%</td>
<td>1.10%</td>
</tr>
<tr>
<td>Frame and Mounting System</td>
<td>43.73</td>
<td>16.34</td>
<td>(3.28)</td>
<td>(3.70)</td>
<td>(0.32)</td>
<td>48.54%</td>
<td>0.95%</td>
</tr>
<tr>
<td>Fuel System</td>
<td>24.28</td>
<td>3.91</td>
<td>1,625.30</td>
<td>0.31</td>
<td>0.38</td>
<td>52.33%</td>
<td>0.74%</td>
</tr>
<tr>
<td>Exhaust System</td>
<td>25.62</td>
<td>7.52</td>
<td>2.47</td>
<td>0.33</td>
<td>0.33</td>
<td>28.25%</td>
<td>0.44%</td>
</tr>
<tr>
<td>Body System (Group D.) Glazing &amp; Body Mechanics</td>
<td>63.46</td>
<td>(15.25)</td>
<td>0.00</td>
<td>(2.48)</td>
<td>(2.48)</td>
<td>9.71%</td>
<td>0.36%</td>
</tr>
<tr>
<td>Climate Control System</td>
<td>15.66</td>
<td>2.44</td>
<td>386.00</td>
<td>3.83</td>
<td>3.92</td>
<td>15.55%</td>
<td>0.14%</td>
</tr>
<tr>
<td>Body System (Group E.) Exterior</td>
<td>25.57</td>
<td>7.52</td>
<td>0.00</td>
<td>3.17</td>
<td>3.17</td>
<td>8.92%</td>
<td>0.14%</td>
</tr>
<tr>
<td>Steering System</td>
<td>24.23</td>
<td>11.05</td>
<td>1,352.70</td>
<td>6.00</td>
<td>6.48</td>
<td>7.50%</td>
<td>0.11%</td>
</tr>
<tr>
<td>Driveline System</td>
<td>33.65</td>
<td>1.50</td>
<td>(685.85)</td>
<td>(0.11)</td>
<td>(0.38)</td>
<td>4.47%</td>
<td>0.09%</td>
</tr>
<tr>
<td>In-Vehicle Entertainment System</td>
<td>4.58</td>
<td>2.35</td>
<td>1,175.60</td>
<td>2.19</td>
<td>2.79</td>
<td>23.38%</td>
<td>0.06%</td>
</tr>
<tr>
<td>Electrical Dls. And Electronic Control System</td>
<td>23.94</td>
<td>1.35</td>
<td>103.50</td>
<td>1.52</td>
<td>1.58</td>
<td>3.71%</td>
<td>0.05%</td>
</tr>
<tr>
<td>Lighting System</td>
<td>10.04</td>
<td>0.53</td>
<td>400.00</td>
<td>(1.42)</td>
<td>(1.01)</td>
<td>5.79%</td>
<td>0.03%</td>
</tr>
<tr>
<td>Info, Gear and Warning System</td>
<td>1.96</td>
<td>0.19</td>
<td>0.00</td>
<td>2.45</td>
<td>2.45</td>
<td>4.01%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Fluid &amp; Misc.</td>
<td>69.66</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Vehicle</td>
<td>1711.38</td>
<td>312.48</td>
<td>$146.06</td>
<td>(23,005.09)</td>
<td>0.47</td>
<td>0.43</td>
<td>18.26%</td>
</tr>
</tbody>
</table>

Notes:

1. For the mass-reduction analysis, differential values were calculated by subtracting the baseline vehicle component weights from the mass-reduced vehicle component weights. Therefore a mass reduction is represented by a positive "+" value and a negative value "-" represents a mass increase.

2. For the cost analysis, differential values were calculated by subtracting the baseline vehicle component costs from the mass-reduced vehicle component costs. Therefore a cost reduction is represented by a positive "+" value and a negative value "-" represents a cost increase.
Mass-Reduction Results

Net Incremental Direct Manufacturing Cost Curve

Vehicle Level Cost Curve

- Trendline Based On Venza Results, Includes Secondary Mass Savings (No Tooling)
- Trendline Based On Venza Results, No Secondary Mass Savings (No Tooling)
- Optimized Venza Solution (-$0.47/kg for 18.26% Vehicle Mass Reduction)
- Optimized Venza Solution w/ Aluminum Doors and Run Flat Tires (-$0.11/kg for 20.2% Vehicle Mass Reduction)
Mass-Reduction Results

Learning Factors and Indirect Cost Multipliers

Indirect Cost Factors are handled through the application of "Indirect Cost Multipliers" (ICMs) which are not included as part of this analysis. The ICM covers items such as:
- OEM corporate overhead (sales, marketing, warranty, etc.)
- OEM engineering, design and testing costs (internal & external)
- OEM depreciations and amortization costs
- Dealership selling costs

Mature technology assumptions, as defined within this analysis, includes the following:
- Well developed product design
- High production volume (200K-450K/year)
- Products in service for several years at high volumes
- Significant market place competition

Mature technology assumptions establishes a consistent framework for costing. For example, a defined range of acceptable mark-up rates:
- End-item scrap 0.3-0.7%
- SG&A/Corporate Overhead 6-7%
- Profit 4-8%
- ED&T (Engineering, Design and Testing) 0-6%
Conclusion and Recommendations

- The FEV, Munro, and EDAG team view mass-reduction as a viable and cost competitive methodology for improving fuel economy and reducing greenhouse gas (GHG) emissions in addition to the other potential vehicle technologies.

- The preliminary engineering assessment, indicates mass-reduction can be implemented without diminishing the function and performance of a stock production vehicle; in this case a 2010 Toyota Venza.

- The team would recommend the continued, industry wide, engineering efforts and corresponding investments into mass-reduction research and development in an effort to meet the fuel economy and GHG emission requirements of tomorrow.

Links to Venza Reports


- The peer review report and the team’s responses to the peer review comments are available at www.regulations.gov in EPA docket EPA-HQ-OAR-2010-0799.
Questions and Answers

Q&A