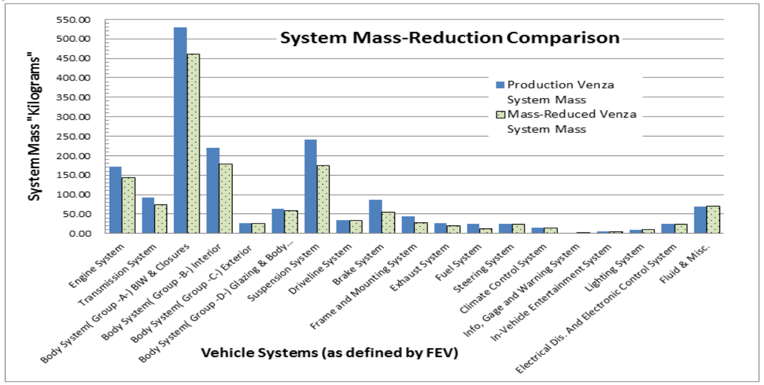
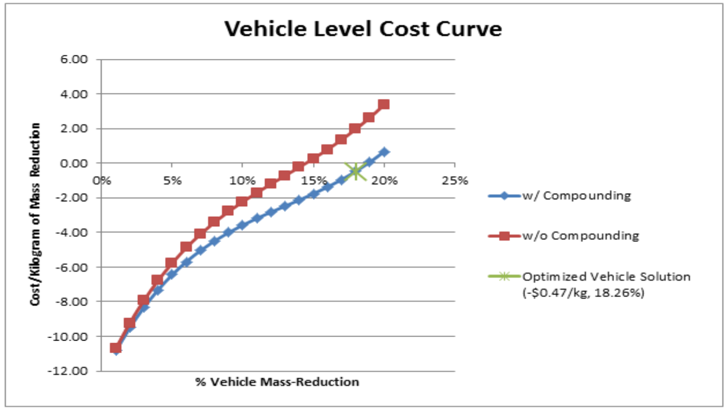
NHTSA's Mass/Size/Safety Workshop

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

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2010 Toyota Venza Mass-Reduction & Cost Overview

- **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**

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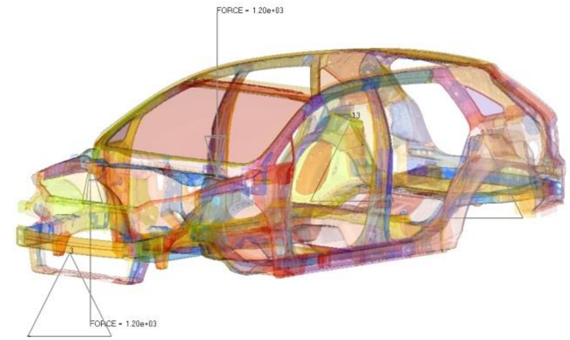
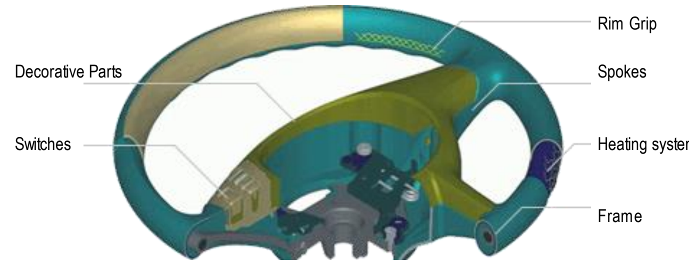
Project Objectives

- 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.

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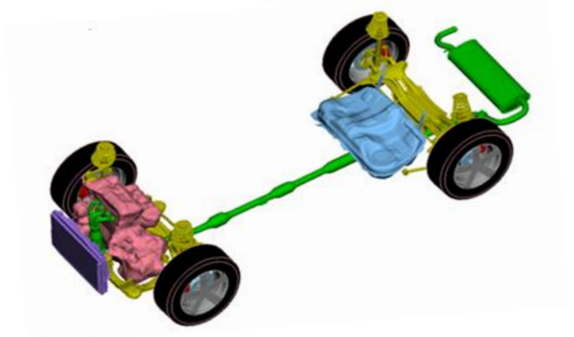
Toyota Venza Vehicle Attributes and Analysis Assumptions

- 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.



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Mass-Reduction and Cost Analysis Methodology

Step 1	Step 2	Step 3	Step 4	Step 5
Baseline Vehicle Finger Printing	Mass-Reduction Idea Generation	Preliminary Mass-Reduction and Cost Estimates	Mass-Reduction and Cost Optimization Process	Detailed Mass-Reduction Feasibility and Cost Analysis

Task 1: Non BIW Analysis Roadmap

Step 1	Step 2	Step 3	Step 4	Step 5
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

Step 1	Step 2	Step 3	Step 4	Step 5
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

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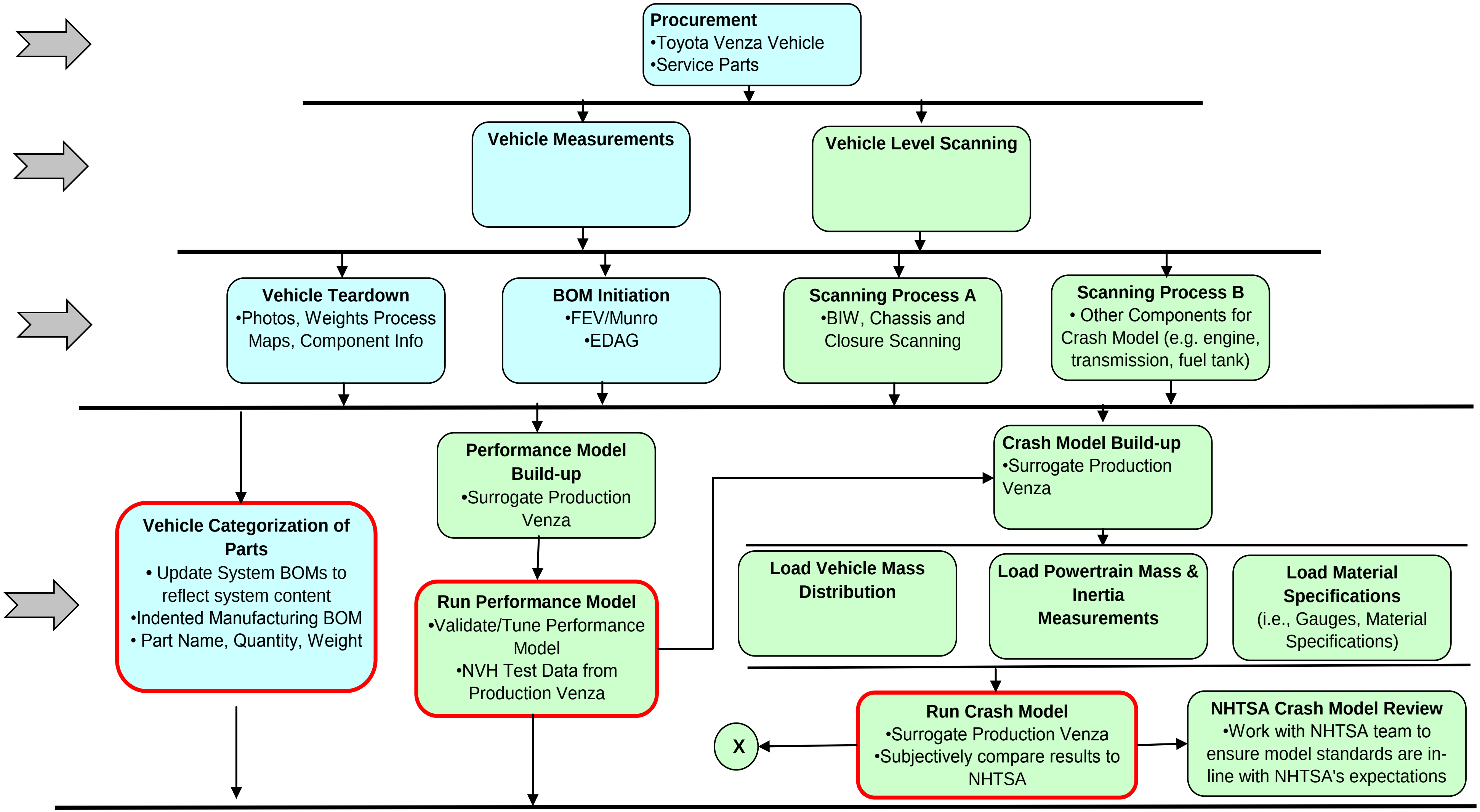
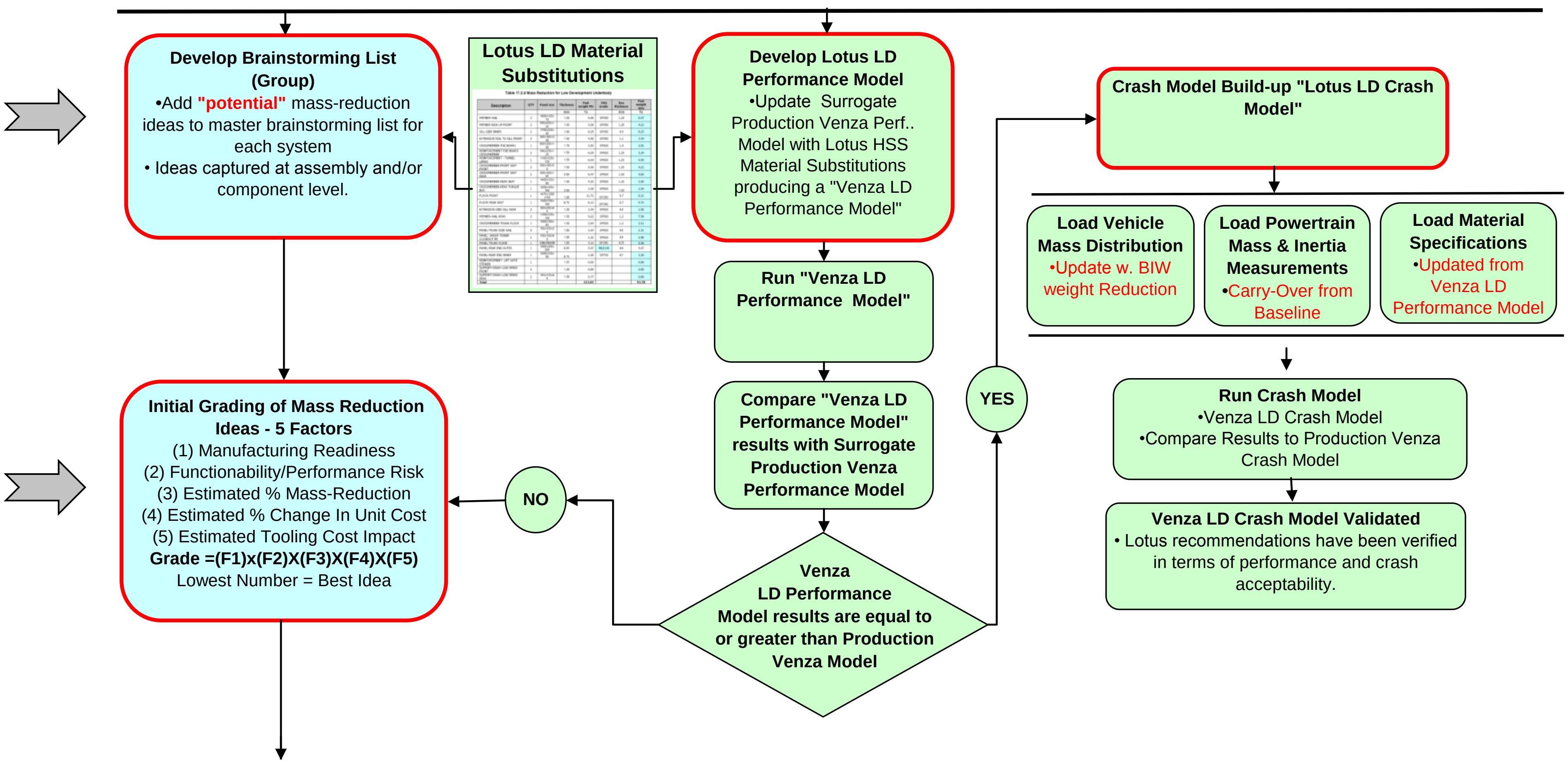
Step 1: Baseline Vehicle Finger Printing

➲Vehicle Attributes, Detailed CBOM, CAE Performance and Crash Model



Step 2: Idea Generation & Initial Idea Validation

➲ Mass-Reduction Idea Generation &Lotus BIW Low Development Validation



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

<u>IDEA GROUPING</u>

●Five cost groups were established to group ideas based on their average cost/kilogram weight save:

Level A: ≤ $0.00/kg (i.e., ideas that either save money or add zero cost)

Level B: >$0.00 to ≤ $1.00

Level C: >$1.00 to ≤ $2.50

Level D: >$2.50 to ≤ $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 systems 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)

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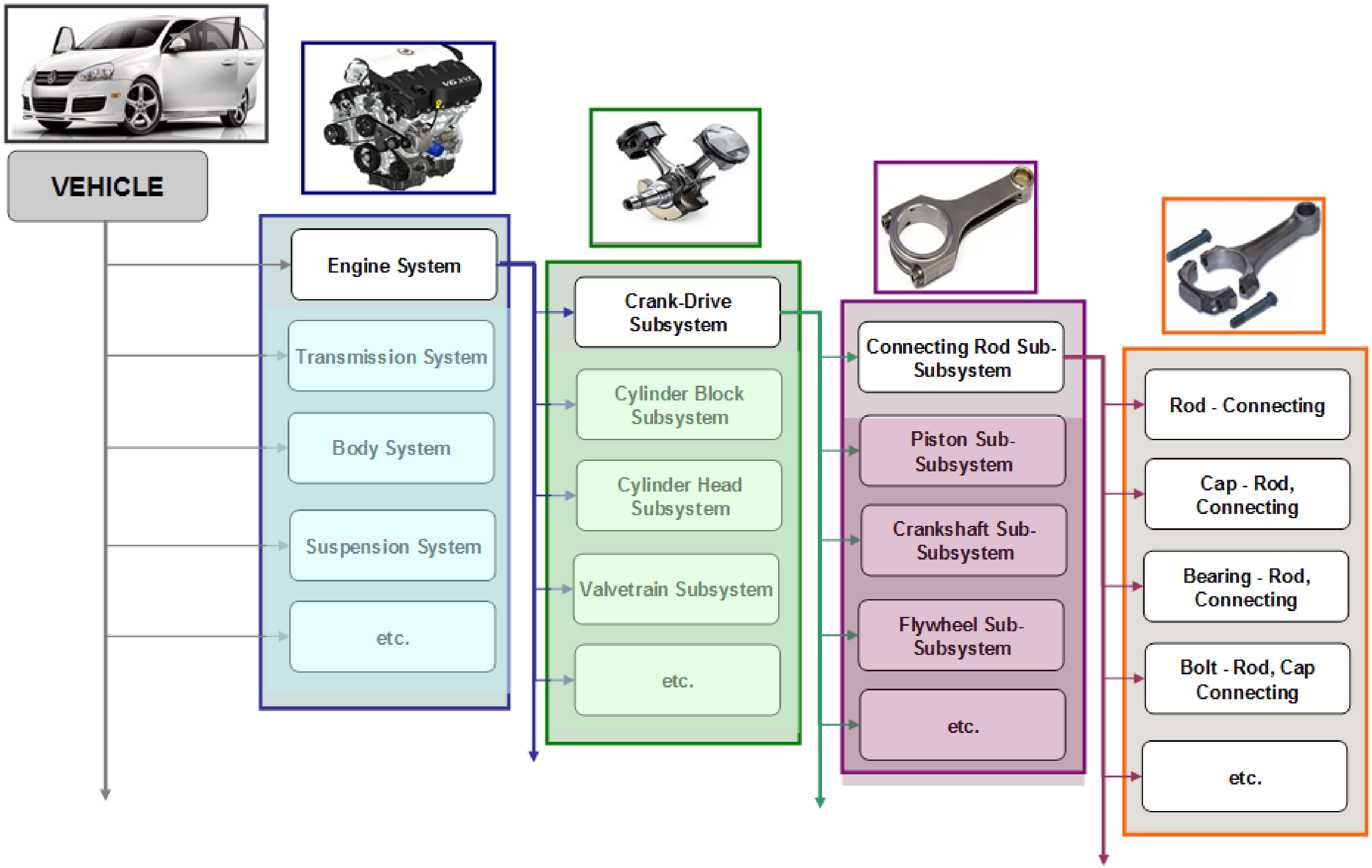
Step 4: Mass-Reduction and Cost Optimization Process

➲ 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

X

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

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

Mass-Reduction Ideas => Mass-Reduced Component/Assembly Options (Example: Front Rotor)

Cost Group: A		Cost Group: B		Cost Group: C		Cost Group: D		Cost Group: X	
Subgroup	A	Subgroup	B	Subgroup	C	Subgroup	D	Subgroup	X
Range "$/kg"	≤ $0	Range "$/kg"	>$0.00 - ≤$1.00	Range "$/kg"	>$1.00 - ≤$2.50	Range "$/kg"	>$2.50 - ≤$4.88	Range "$/kg"	> $4.88
IDEA #1 Reduce Rotor Thickness		**IDEA #3** Vent/Slot Rotor		**IDEA #6** Rotor ID Scaliping (Hat Perimeter)		**IDEA #8** Change to Ceramic Rotor		**IDEA #9** 2 Pc Rotor Design (Iron & CF)	
IDEA #2 Reduce Rotor Diameter		**IDEA #4** Cross-Drill Rotor		**IDEA #7** Rotor OD Scaliping				**IDEA #10** Change to Composite Rotor	
		IDEA #5 Drill Holes in Rotor Top Hat Surface							

Rotor Option #1 is placed in the Low Cost Solution Assembly/ Component Mass Reduciton Matrx

Cost Group: C	
Subgroup	Cc
Range "$/kg"	>$1.00 - ≤$2.50

ROTOR
Option # 1
IDEA #1 +
IDEA #2 +
IDEA #3 +
IDEA #4 +
IDEA #5 +
IDEA #6 +
IDEA #7 +
$1.35/kg

Cost Group: D	
Subgroup	De
Range "$/kg"	>$2.50 - ≤$4.88

ROTOR
Option #2
IDEA #1 +
IDEA #2 +
IDEA #3 +
IDEA #4 +
IDEA #5 +
IDEA #6 +
IDEA #7 +
IDEA #9 +
$3.56/kg

Rotor Option #2 is placed in the Engineered Solution Assembly/ Component Mass Reduciton Matrx

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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

Mass Reduced (MR) Componenets Options => Mass-Reduced Subsystem Options
(Example: Front Rotor/Drum and Shield Subsystem (FRDSS))

Components Included In Subsystem	Cost Group: A		Cost Group: B		Cost Group: C		Cost Group: D		Cost Group: X	
	Subgroup	Ae	Subgroup	Be	Subgroup	Ce	Subgroup	De	Subgroup	Xe
	Range "$/kg"	≤ $0	Range "$/kg"	>$0.00 - ≤$1.00	Range "$/kg"	>$1.00 - ≤$2.50	Range "$/kg"	>$2.50 - ≤$4.88	Range "$/kg"	> $4.88
1. Mass-Reduced Rotors	Rotor Option #2				Rotor Option #3		Rotor Option #4			
2. Mass-Reduced Dust Shields			Dust Shield Option #2				Dust Shield Option #3		Dust Shield Option #4	
3. Mass-Reduced Brake Capilers	Brake Caliper Option #2		Brake Caliper Option #3		Brake Caliper Option #4		Brake Caliper Option #5		Brake Caliper Option #6	
4. Mass-Reduced Pad Kits	Pad Kit Option #2								Pad Kit Option #3	
5. Mass-Reduced Caliper Brackets	Caliper Bracket Option #2		Caliper Bracket Option #3		Caliper Bracket Option #4					

Cost Group: B	
Subgroup	Be
Range "$/kg"	>$0.00 - ≤$1.00
FRDSS Option # 2 Rotor #2 + Dust Shield #3 + Brake Caliper #4 + Pad Kit #2 Caliper Brkt #4 $0.93/kg	

Cost Group: D	
Subgroup	De
Range "$/kg"	>$2.50 - ≤$4.88
FRDSS Option #4 Rotor #3 + Dust Shield #4 + Brake Caliper #6 + Pad Kit #2 Caliper Brkt #2 $4.40/kg	

- **Same Process Repeated for Low Cost Solution Subsystems**
- **Built-up using Low Cost Solution Component Assembly Matrix**

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Step 4: Mass-Reduction and Cost Optimization Process

➲Mass-Reduction Optimization at the System Level

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

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)**

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

	Cost Group: A		Cost Group: B		Cost Group: C		Cost Group: D		Cost Group: X	
	Subgroup	Ae	Subgroup	Be	Subgroup	Ce	Subgroup	De	Subgroup	Xe
	Range "$/kg"	≤ $0	Range "$/kg"	>$0.00 - ≤$1.00	Range "$/kg"	>$1.00 - ≤$2.50	Range "$/kg"	>$2.50 - ≤$4.88	Range "$/kg"	> $4.88
1. FRDSS	FRDSS Option #1		FRDSS Option #2				FRDSS Option #3			
2. RRDSS	RRDSS Option #1						RRDSS Option #2		RRDSS Option #3	
3. PBAS			PBAS Option #2							
4. BAS	BAS Option #1				BAS Option #2		BAS Option #3		BAS Option #4	
5. HPBS	HPBS Option #1		HPBS Option #2		HPBS Option #3				HPBS Option #4	
6. BCS										

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

Cost Group: A	
Subgroup	Ae
Range "$/kg"	>$0.00 - ≤$1.00

Brake System Option #1
FRDSS #1 +
RRDSS #1 +
PBAS #2 +
BAS #1
HPBS #1
$-0.26/kg

Cost Group: C	
Subgroup	Ce
Range "$/kg"	>$1.00 - ≤$2.50

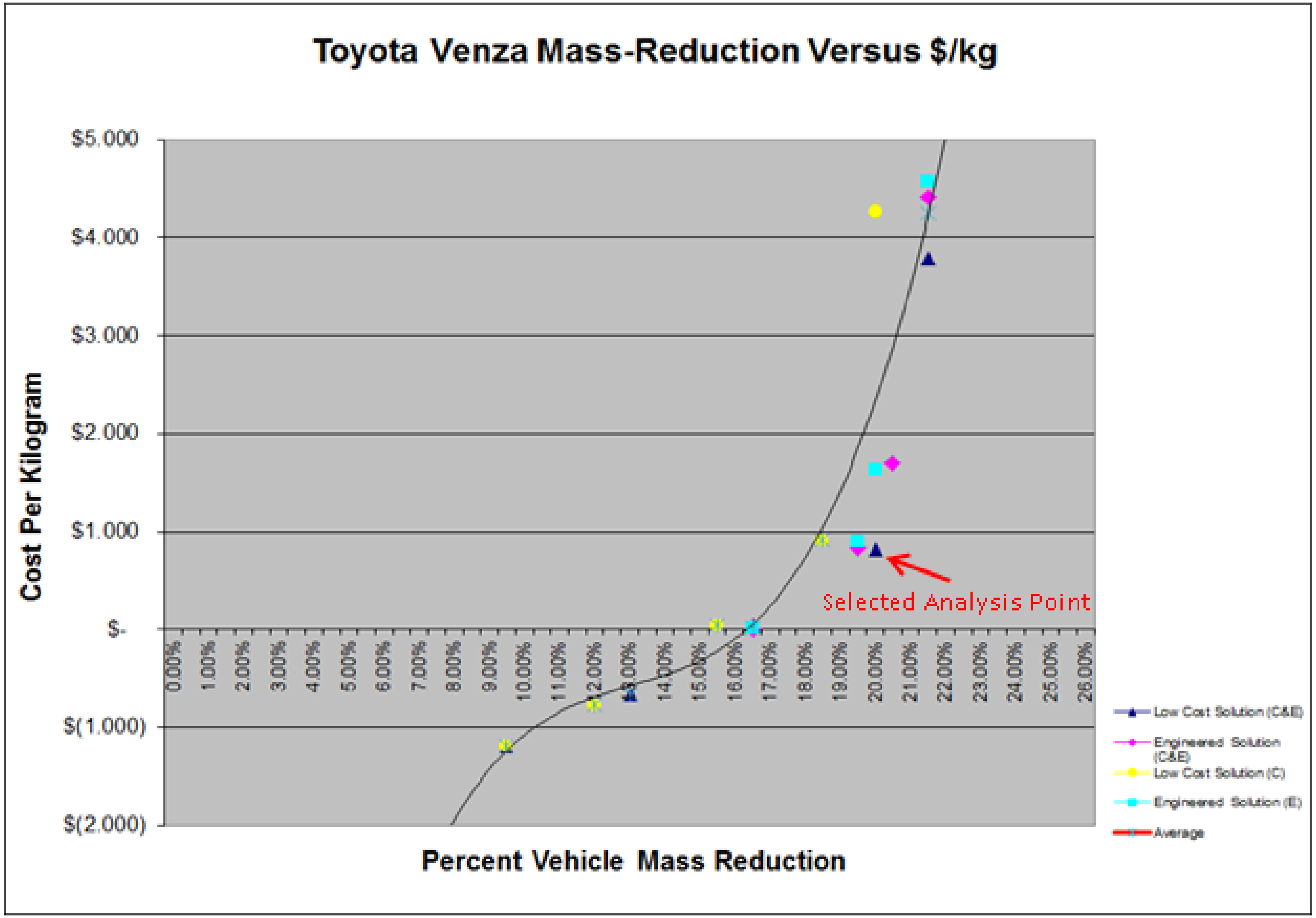
Brake System Option #2
FRDSS #2 +
RRDSS #3 +
PBAS #2 +
BAS #3
HPBS #2
$2.33/kg

Step 4: Mass-Reduction and Cost Optimization Process

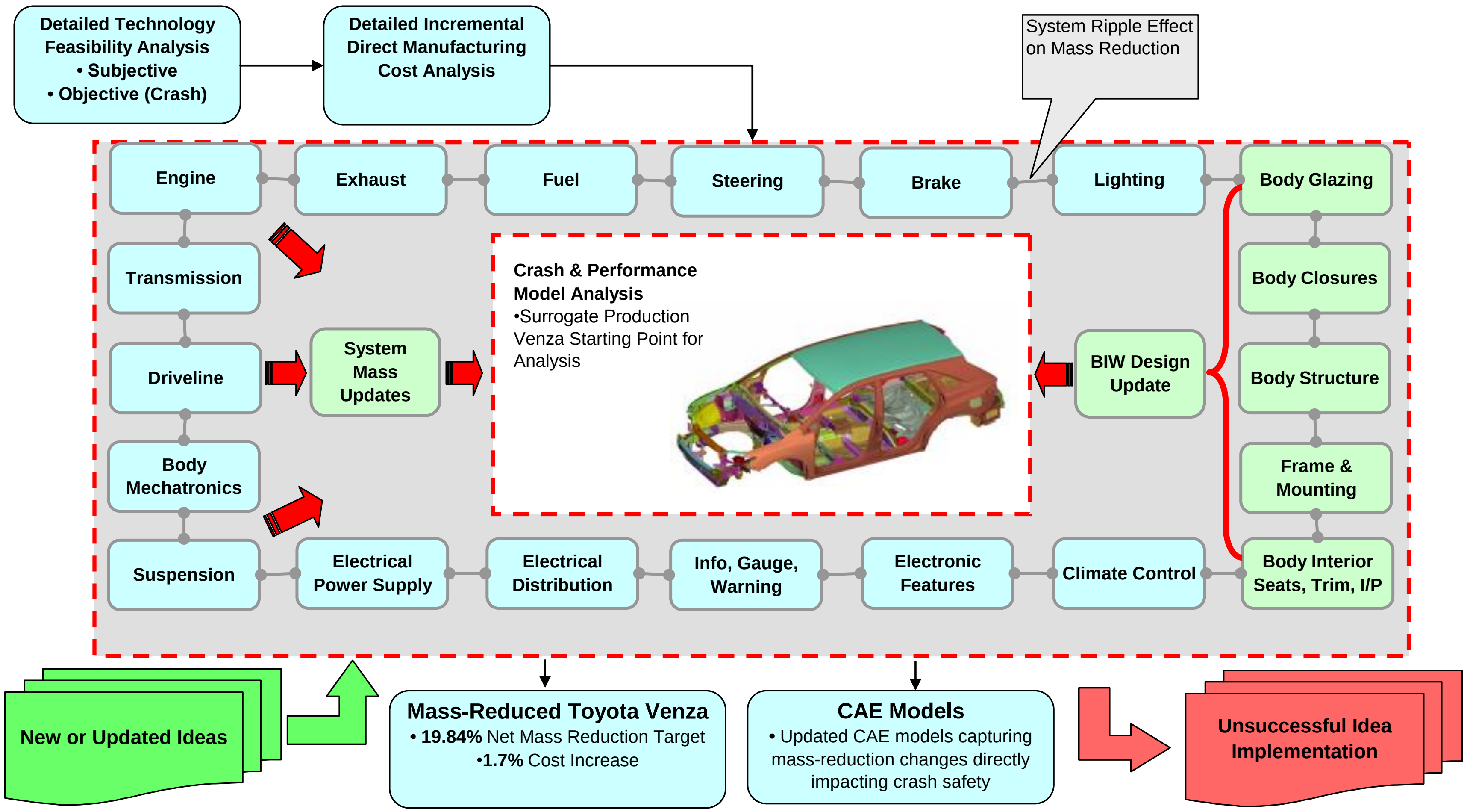
➲ Potential Vehicle Mass-Reduction Solutions

Selection of Target Mass Reduction

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



Step 5: Detailed Mass-Reduction Feasibility and Cost Analysis



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 =18.78kg, TMC = $75.07

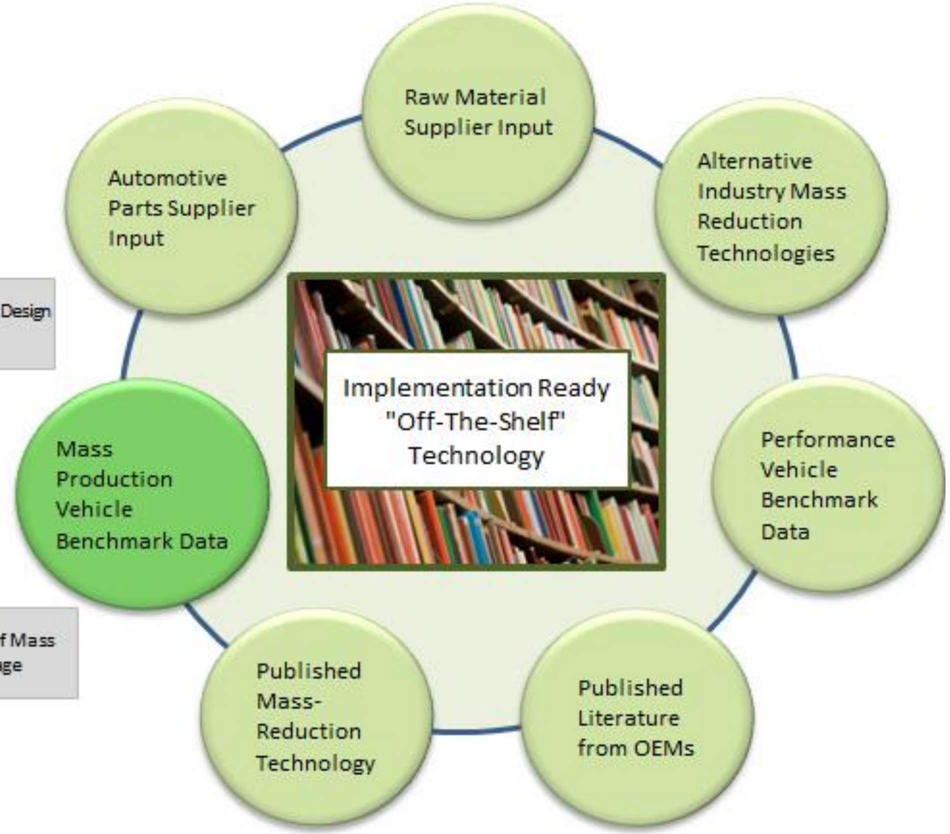
Establish Material Specifications

Engineering Assessment of Design Differences

Normalize to Venza Application

Engineering Assessment of Mass Compounding Advantage

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**

Mubea
engineering for mobility

DUPONT®

JYCO
SEALING TECHNOLOGIES

PILKINGTON

PolyOne™

MuCell® Processes
TREXEL INC.

EXATEC®
inspiring glazing technology

ZOTEFOAMS

TAKATA

MAHLE

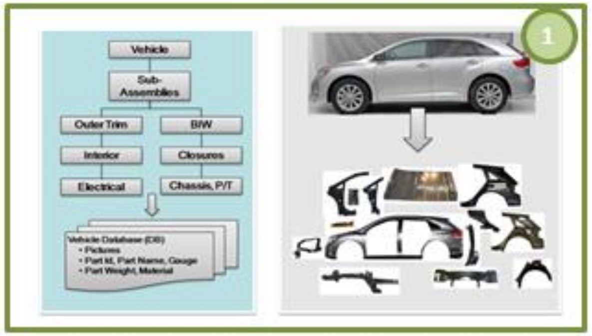
DSM

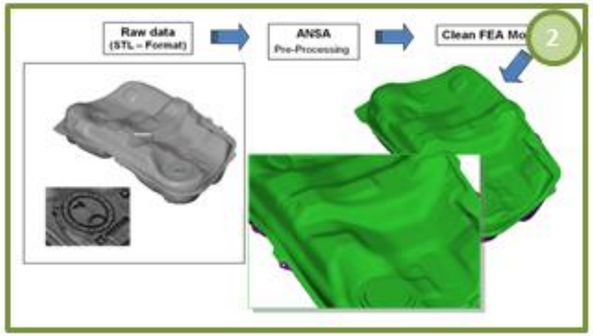
سابك
sabic

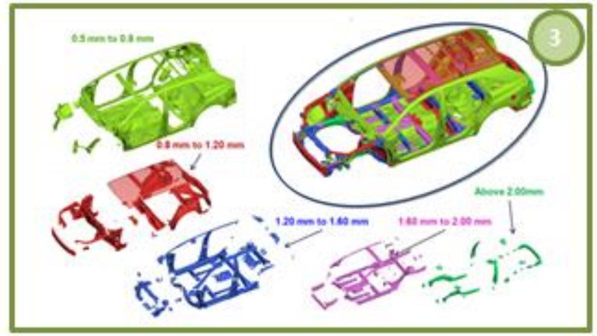
SGF

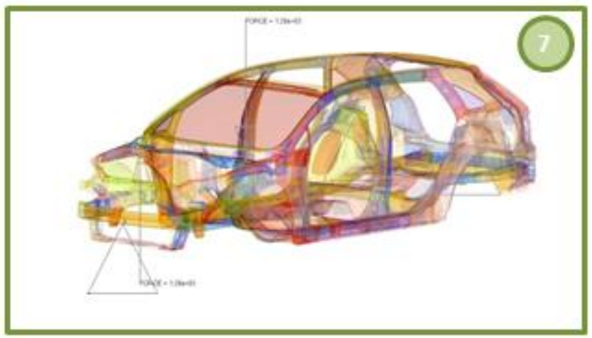
Step 5: Detailed Mass-Reduction Feasibility and Cost Analysis

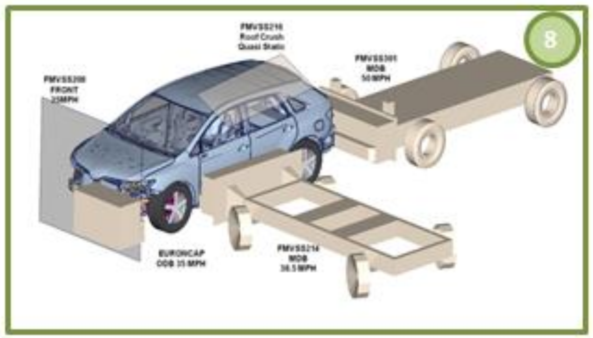
➲ Mass-Reduction Idea Generation and Implementation (BIW Only)

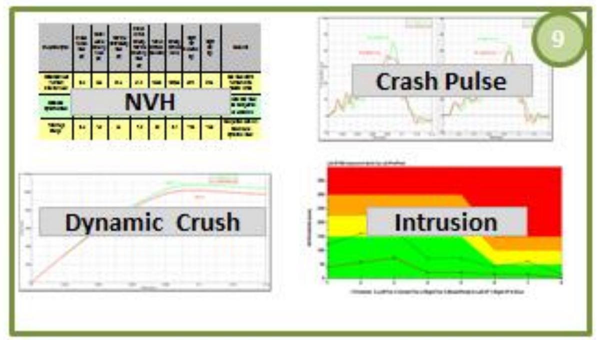








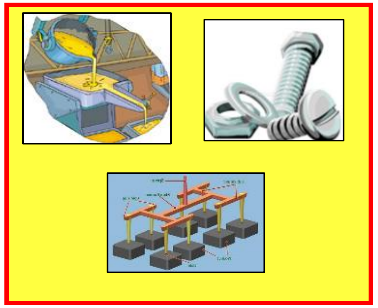




Step 5: Detailed Mass-Reduction Feasibility and Cost Analysis

➲ Costing Methodology is Detail and Transparent

MATERIAL



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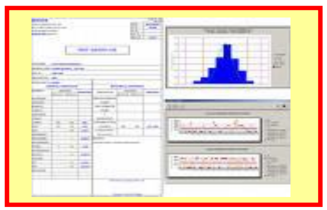
MANUFACTURING OVERHEAD

High Pressure Fuel Pump Example	Material	Labor	Burden	TMC	Scrap	SG&A	Profit	ED&T	Total Mark-up		1	$54.12
T1 or OEM Total Manufacturing Cost:	$16.99	$8.01	$24.95	$49.94	$0.30	$2.09	$1.64	$0.15	$4.18	→	3	$54.12
T1 or OEM Mark-Up Rates:	-----	-----	-----	-----	0.70%	7.00%	8.00%	4.00%	19.70%			
(SAC) &T1 or OEM Mark-Up Values:	-----	-----	-----	-----	$0.38	$3.79	$4.33	$2.16	$10.66			
Base Cost Impact to Vehicle:	$16.99	$8.01	$24.95	$49.94	$0.68	$5.88	$5.97	$2.32	$14.84	→		$64.79
											Packaging Cost:	$0.11
											Net Cost Impact to Vehicle:	$64.90

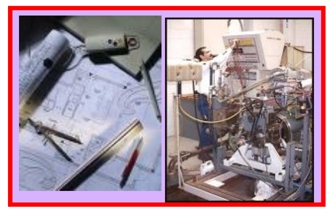
SCRAP



SG&A

PROFIT

ED&T



PACKAGING

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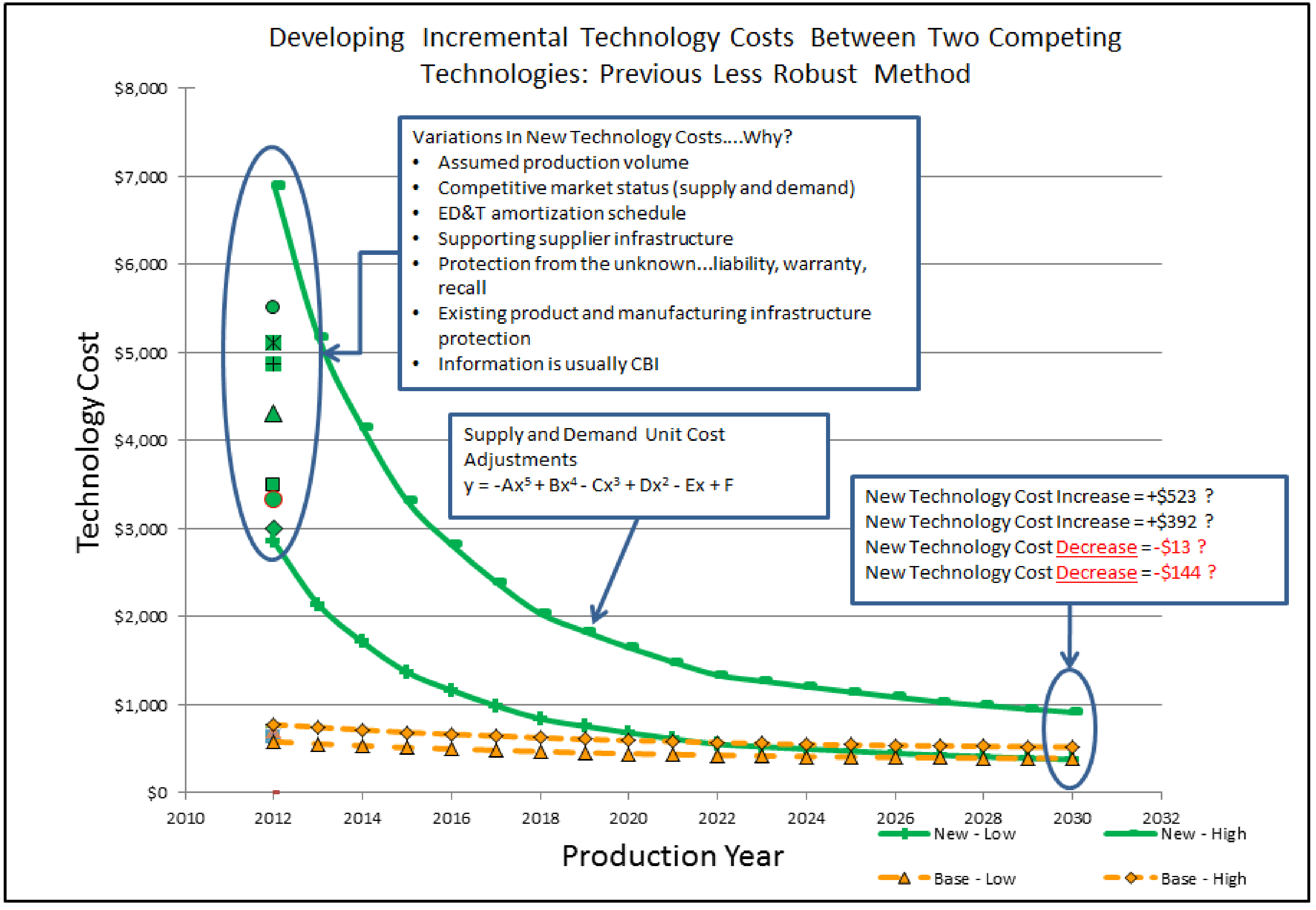
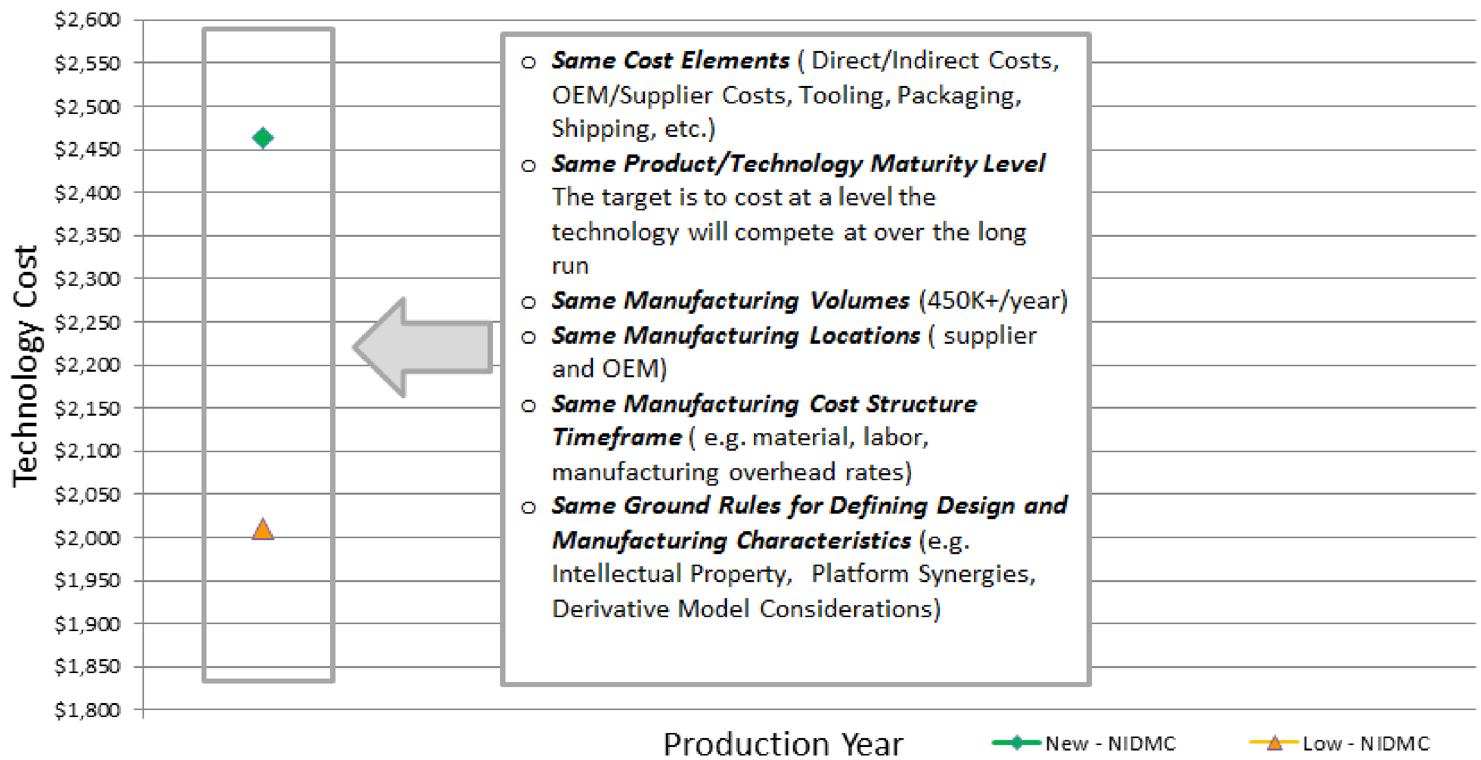
Cost Analysis Methodology: Detailed Teardown & Costing



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



Understanding the Boundary Conditions of the analysis allows the users to make educated assessments of change and adjustment (Guiding Cost Model Principals.....Detailed, Transparent and Flexible Cost Modeling)

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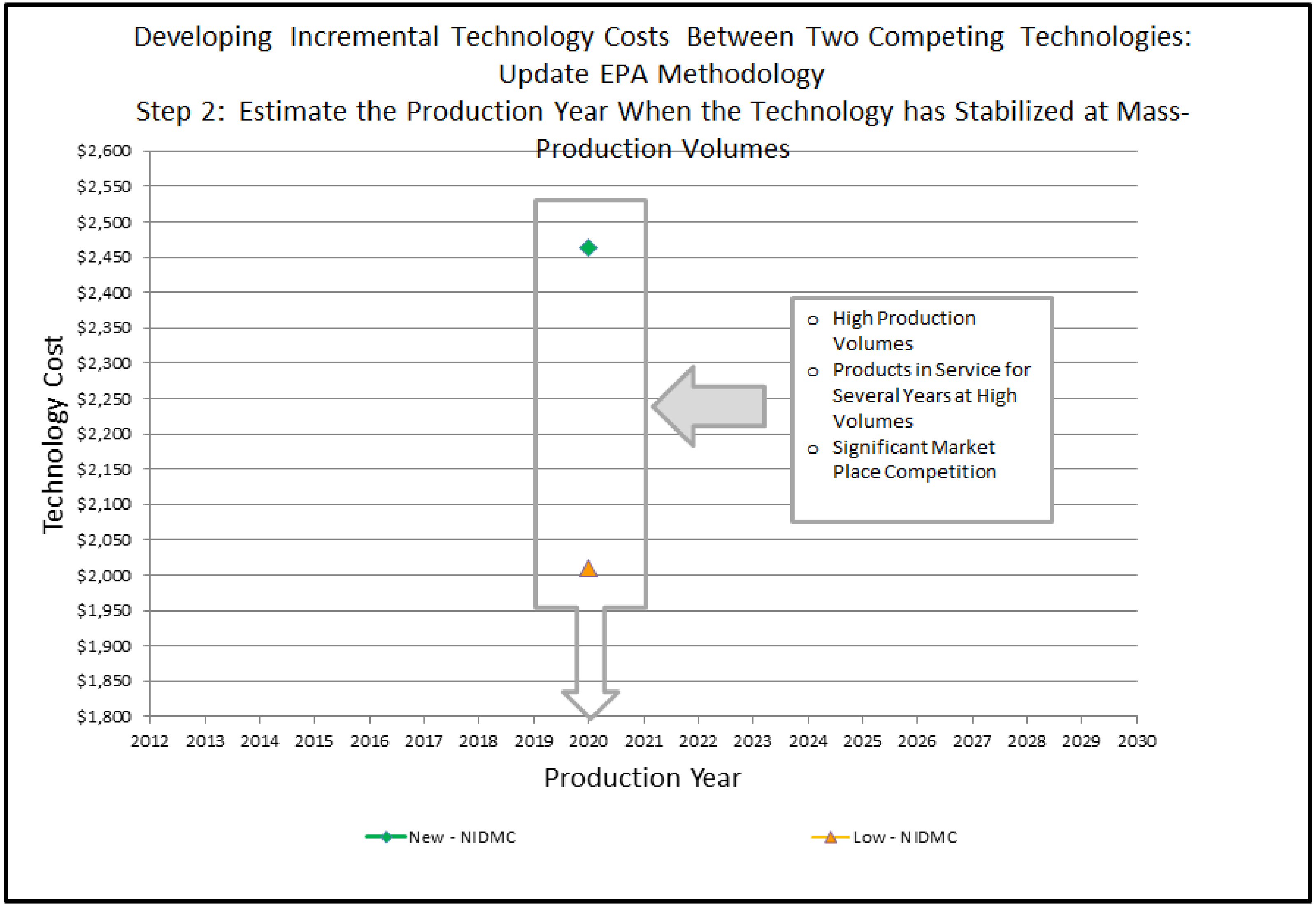
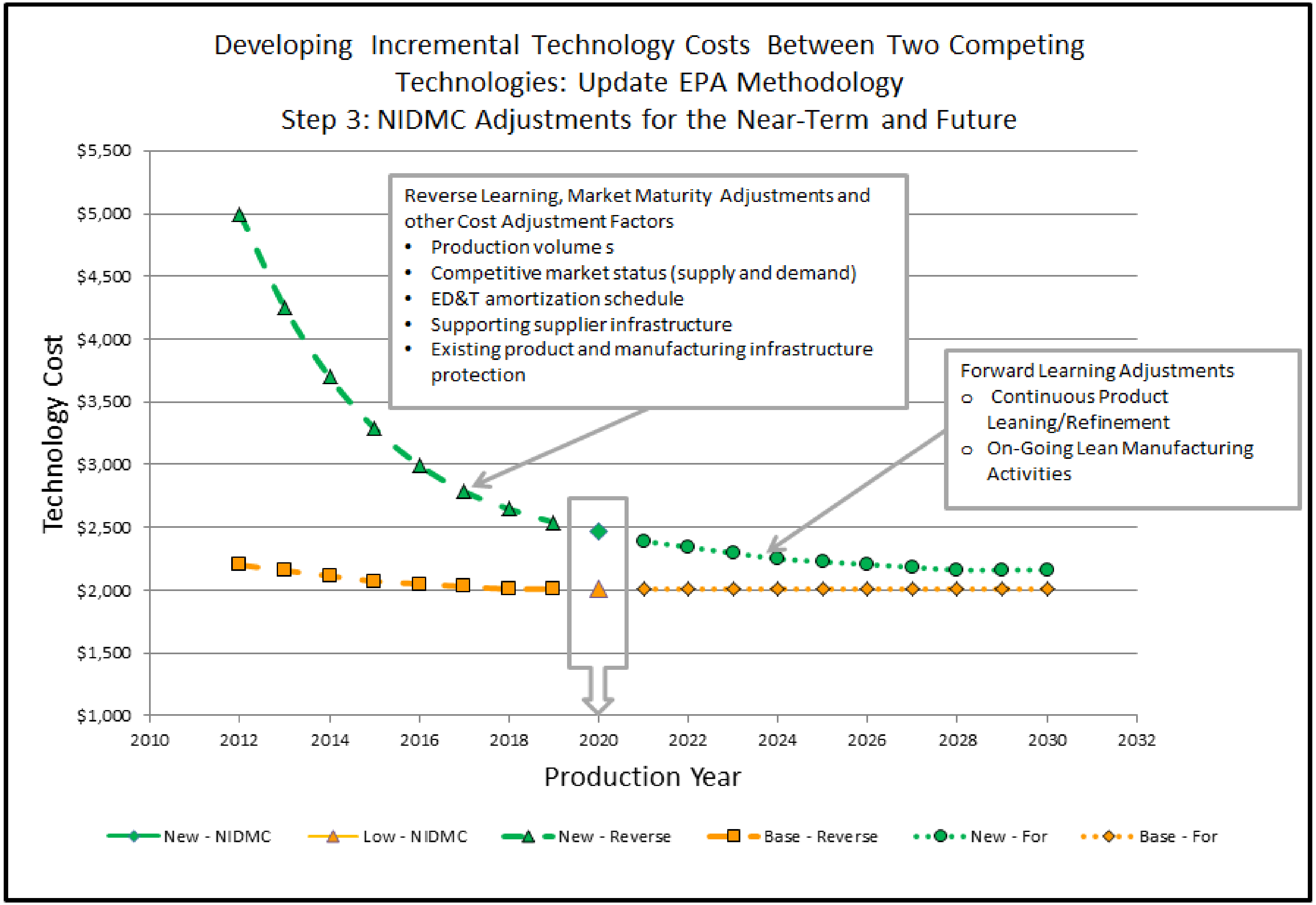
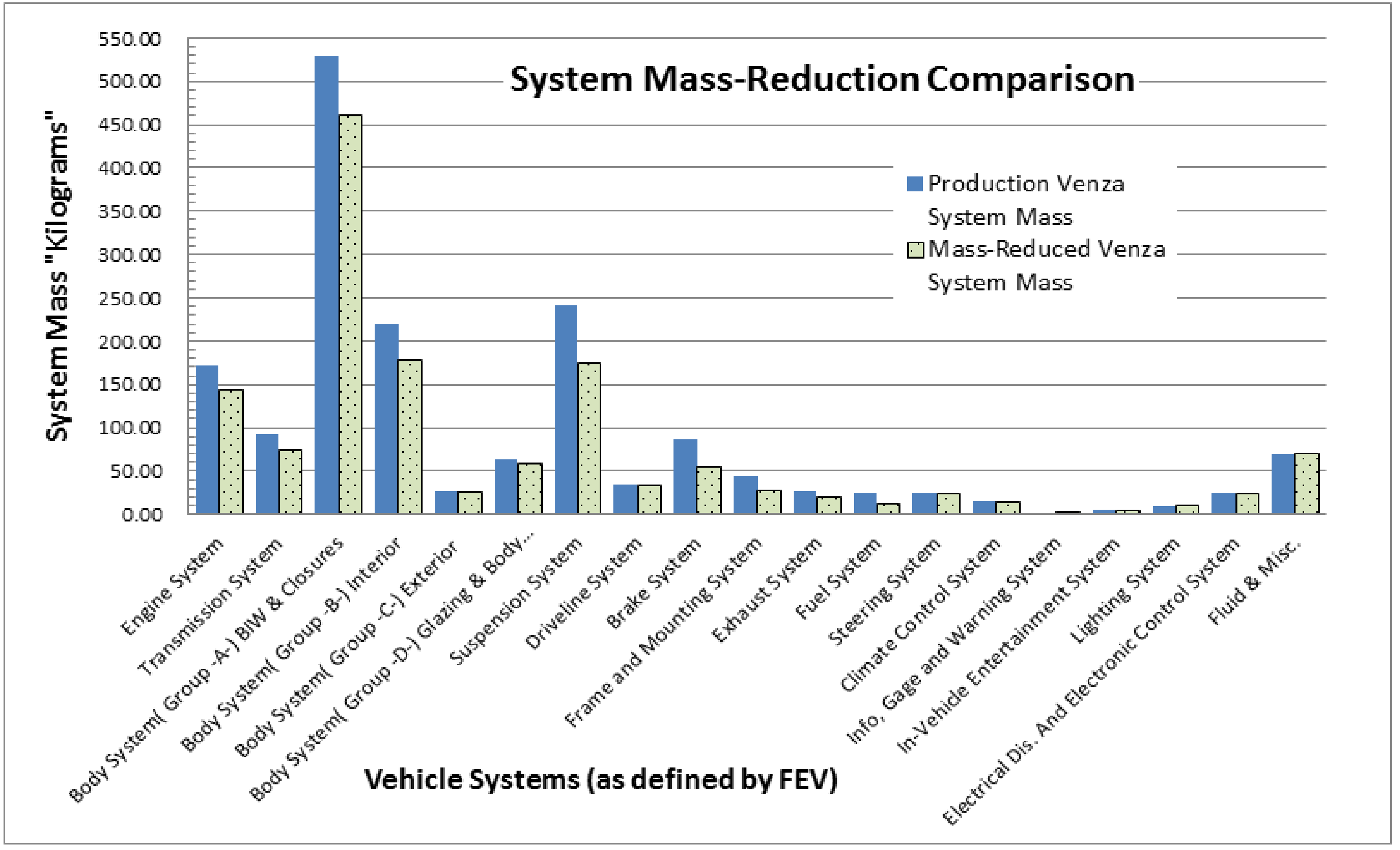
Cost Analysis Methodology: Detailed Teardown & Costing



Cost Analysis Methodology: Detailed Teardown & Costing



Mass-Reduction Results
➲ Production Venza Compared to Mass-Reduced Venza



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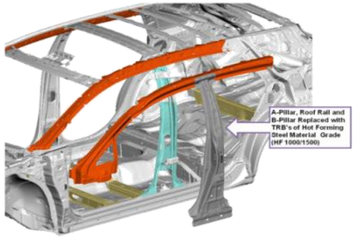
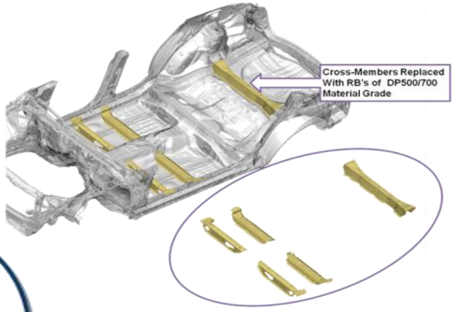
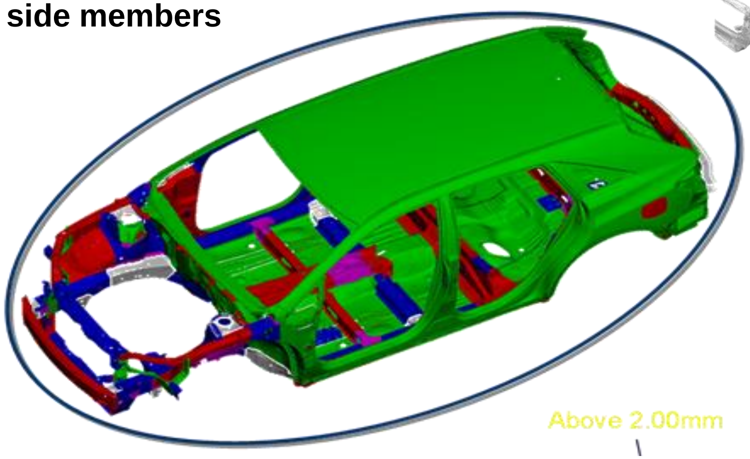
Body System, Group A:BIW & Closures

Description	Estimated Mass Reduction "Kg"	Estimated Cost Impact "$"	Average Cost/ Kilogram "$/Kg"
Body Structure Subsystem			
Underbody Asy	8.1	-5.84	-0.72
Front Structure Asy	5.7	-7.14	-1.25
Roof Asy	7.2	4.61	0.64
Bodyside Asy	17.8	-81.40	-4.57
Ladder Asy	12.1	-2.11	-0.17
Bolt on BIP Components	-0.1	-14.75	147.50
Body Closure Subsystem			
Hood Asy	7.7	-39.11	-5.08
Front Door Asy	0.0	0.00	0.00
Rear Door Asy	0.0	0.00	0.00
Rear Hatch Asy	7.2	-29.96	-4.16
Front Fenders	2.0	-21.85	-10.93
Bumpers Subsystem			
Front Bumper Asy	0.4	-10.71	-26.78
Rear Bumper Asy	0.0	0.00	0.00
Totals	68.1	-208.26	-3.06
"+" = mass decrease, "-" = mass increase			
"+" = cost decrease, "-" = cost increase			

- 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







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Suspension System

System	Subsystem	Sub-Subsystem	Description	Idea Level Select	Mass Reduction "kg" (1)	Cost Impact "$" (2)	Average Cost/ Kilogram $/kg	Subsys./ Subsys. Mass Reduction "%"	Vehicle Mass Reduction "%"
					Net Value of Mass Reduction Idea				
04	**00**	**00**	**Suspension System**						
04	01	00	Front Suspension Subsystem		11.572	$3.04	-$0.26	55.40%	0.68%
04	02	00	Rear Suspension Subsystem		8.320	$4.91	-$0.59	41.53%	0.49%
04	03	00	Shock Absorber Subsystem		14.111	$57.99	-$4.11	35.88%	0.82%
04	04	00	Wheels And Tires Subsystem		32.833	$78.77	-$2.40	25.69%	1.92%
04	05	00	Suspension Load Leveling Control Subsystem		0.000	0.000	$0.00	0.00%	0.00%
04	06	00	Rear Suspension Modules		0.000	0.000	$0.00	0.00%	0.00%
04	07	00	Front Suspension Modules		0.000	0.000	$0.00	0.00%	0.00%
					66.835 (Decrease)	**$144.71** (Decrease)	**$0.46** (Decrease)	**26.47%**	**3.91%**

(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

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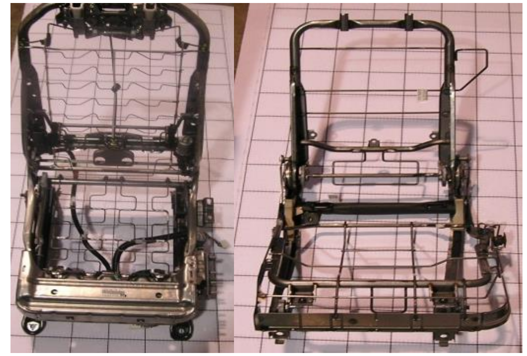
Body System, Group B:Interior

				Net Value of Mass Reduction Idea					
System	Subsystem	Sub-Subsystem	Description	Idea Level Select	Mass Reduction "kg" (1)	Cost Impact "$" (2)	Average Cost/ Kilogram $/kg	Subsys./ Subsys. Mass Reduction "%"	Vehicle Mass Reduction "%"
03	00	00	**Body**						
03	10	00	Seating Subsystem	A	23.392	$84.55	$3.61	25.28%	1.37%
03	05	00	Interior Trim and Ornamentation Subsystem	A	8.924	$37.72	$4.23	13.69%	0.52%
03	12	00	Instrument Panel and Console Subsystem	C	6.330	-$12.49	-$1.97	19.36%	0.37%
03	07	00	Sealing Subsystem	A	2.029	$15.70	$7.74	24.67%	0.12%
03	20	00	Occupant restraining Device Subsystem	D	1.039	-$2.88	-$2.77	5.96%	0.06%
03	06	00	Sound and Heat Control Subsystem (Body)	A	0.268	$0.38	$1.40	5.95%	0.02%
				A	**41.982** (Decrease)	**$122.97** (Decrease)	**$2.93** (Decrease)	**19.03%**	**2.45%**

(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**

MuCell® Processes TREXEL INC.

PolyOne OnCap™ CFA Solutions

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Brake System

				Net Value of Mass Reduction Ideas					
System	Subsystem	Sub-Subsystem	Description	Idea Level Select	Mass Reduction "kg" (1)	Cost Impact "$" (2)	Average Cost/ Kilogram $/kg	Subsys./ Subsys. Mass Reduction "%"	Vehicle Mass Reduction "%"
06	**00**	**00**	**Brake System**						
06	03	00	Front Rotor/Drum and Shield Subsystem	A	12.647	$35.91	$2.42	45.01%	0.87%
06	04	00	Rear Rotor/Drum and Shield Subsystem	A	6.242	$17.45	$1.74	44.75%	0.59%
06	05	00	Parking Brake and Actuation Subsystem	A	9.635	$82.98	$8.61	71.88%	0.56%
06	06	00	Brake Actuation Subsystem	A	2.984	$31.90	$10.69	53.90%	0.17%
06	07	00	Power Brake Subsystem (for Hydraulic)	A	1.196	$1.35	$1.13	42.25%	0.07%
06	09	00	Brake Controls Subsystem		0.000	0.000	$0.00	0.00%	0.00%
				A	**32.703** (Decrease)	**$169.60** (Decrease)	**$5.19** (Decrease)	**51.56%**	**2.26%**

(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.

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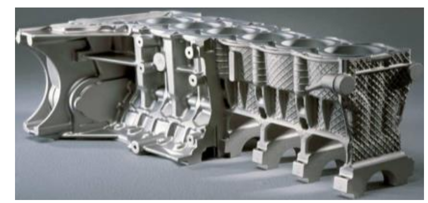
Engine System

System	Subsystem	Sub-Subsystem	Description	Net Value of Mass Reduction Idea					
				Idea Level Select	Mass Reduction "kg" (1)	Cost Impact "$" (2)	Average Cost/ Kilogram $/kg	Subsys./ Subsys. Mass Reduction "%"	Vehicle Mass Reduction "%"
01	**00**	**00**	**Engine System**						
01	01	00	Engine Assembly Downsize (2.4L)	A	10.365	38.420	$3.71	6.01%	0.61%
01	05	00	Cylinder Block Subsystem	D	7.106	-32.325	-$4.55	23.58%	0.42%
01	07	00	Valvetrain Subsystem	D	3.707	-11.133	-$3.00	37.90%	0.22%
01	14	00	Cooling Subsystem	A	2.591	4.620	$1.78	18.38%	0.15%
01	08	00	Timing Drive Subsystem	A	1.454	4.792	$3.29	33.72%	0.09%
01	02	00	Engine Frames, Mounting, and Brackets	A	1.114	-0.087	-$0.08	7.29%	0.07%
01	06	00	Cylinder Head Subsystem	A	1.047	11.887	$11.35	4.96%	0.06%
01	70	00	Accessory Subsystems (Start Motor, Generator,	B	0.709	-$0.23	-$0.33	4.28%	0.04%
01	03	00	Crank Drive Subsystem	A	0.688	$6.88	$10.00	2.78%	0.04%
01	10	00	Air Intake Subsystem	A	0.510	3.009	$5.90	3.65%	0.03%
01	60	00	Engine Management, Engine Electronic,	A	0.388	$1.00	$2.57	0.00%	0.00%
01	13	00	Lubrication Subsystem	B	0.234	-0.201	-$0.86	7.00%	0.01%
01	17	00	Breather Subsystem	A	0.219	$4.93	$22.52	0.00%	0.00%
01	11	00	Fuel Induction Subsystem	A	0.115	2.127	$0.00	0.00%	0.00%
01	04	00	Counter Balance Subsystem	A	0.000	$0.00	$0.00	0.00%	0.00%
01	09	00	Accessory Drive Subsystem	A	0.000	0.000	$0.00	0.00%	0.00%
01	12	00	Exhaust Subsystem	A	0.000	0.000	$0.00	0.00%	0.00%
01	15	00	Induction Air Charging Subsystem		0.000	$0.00	$0.00	0.00%	0.00%
01	16	00	Exhaust Gas Re-circulation Subsystem		0.000	$0.00	$0.00	0.00%	0.00%
				A	**30.248** (Decrease)	**33.687** (Decrease)	**1.114** (Decrease)	**17.53%**	**1.77%**

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

Venza Base Engine (Toyota 2.7L 1AR-FE)
Engine Downsize Selection (Toyota 2.4L 2AZ-FE)



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

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Transmission System

System	Subsystem	Sub-Subsystem	Description	Idea Level Select	Mass Reduction "kg" (1)	Cost Impact "$" (2)	Average Cost/ Kilogram $/kg	Subsys./ Subsys. Mass Reduction "%"	Vehicle Mass Reduction "%"
				Net Value of Mass Reduction Idea					
02	00	00	**Transmission System**						
02	02	00	Case Subsystem	C	7.745	-$11.03	-$1.42	31.52%	0.45%
02	05	00	Launch Clutch Subsystem	A	4.904	$45.16	$9.21	50.32%	0.29%
02	03	00	Gear Train Subsystem	X	3.490	-$119.68	-$34.29	8.42%	0.20%
02	20	00	Driver Operated External Controls Subsystem	X	1.726	-$29.49	-$17.08	69.55%	0.10%
02	06	00	Oil Pump and Filter Subsystem	A	1.034	$0.90	$0.87	15.84%	0.06%
02	01	00	External Components		0.000	$0.00	$0.00	0.00%	0.00%
02	07	00	Mechanical Controls Subsystem		0.000	$0.00	$0.00	0.00%	0.00%
02	08	00	Electrical Controls Subsystem		0.000	$0.00	$0.00	0.00%	0.00%
02	09	00	Parking Mechanism Subsystem		0.000	$0.00	$0.00	0.00%	0.00%
				X	**18.900** (Decrease)	**-$114.15** (Increase)	**-$6.04** (Increase)	**20.37%**	**1.10%**

(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

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Additional Mass-Reduction Concepts

- 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.

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Mass-Reduction Results:

➲ Net Incremental Direct Manufacturing Cost Impact by Vehicle System

Description	2010 Production Toyota Venza System Mass Contributions "kg"	System Mass Reduction "kg"(1)	System Incremental Direct Manufacturing Cost Impact "$" (2)	System Incremental Tooling Impact Cost "$" (x1000)(2)	Average System Cost/Kilogram w/o Tooling "$/kg" (2)	Average System Cost/Kilogram with Tooling "$/kg" (2)	% System Mass Reduction (1)	% Vehicle Mass Reduction (1)
Body System(Group -A-) BIW & Closures	528.88	68.32	(227.45)	(22,900.00)	(3.33)	(3.51)	12.92%	3.99%
Suspension System	241.49	66.83	144.71	(7,544.37)	2.17	2.10	27.68%	3.91%
Body System(Group -B-) Interior	220.61	42.00	122.98	9,966.15	2.93	3.06	19.04%	2.45%
Brake System	86.71	32.75	169.56	(1,426.12)	5.18	5.15	37.77%	1.91%
Engine System	172.60	30.25	33.69	5,892.20	1.11	1.22	17.53%	1.77%
Transmission System	92.76	18.90	(114.15)	(7,650.80)	(6.04)	(6.26)	20.37%	1.10%
Frame and Mounting System	43.73	16.34	(3.28)	(3,700.39)	(0.20)	(0.32)	48.54%	0.95%
Fuel System	24.28	12.70	3.91	1,625.30	0.31	0.38	52.33%	0.74%
Exhaust System	26.62	7.52	2.47	0.00	0.33	0.33	28.25%	0.44%
Body System(Group -D-) Glazing & Body Mechatronics	63.46	6.16	(15.25)	0.00	(2.48)	(2.48)	9.71%	0.36%
Climate Control System	15.66	2.44	9.34	386.00	3.83	3.92	15.55%	0.14%
Body System(Group -C-) Exterior	26.57	2.37	7.52	0.00	3.17	3.17	8.92%	0.14%
Steering System	24.23	1.82	11.05	1,352.70	6.08	6.48	7.50%	0.11%
Driveline System	33.66	1.50	(0.16)	(685.86)	(0.11)	(0.36)	4.47%	0.09%
In-Vehicle Entertainment System	4.59	1.07	2.35	1,175.60	2.19	2.79	23.39%	0.06%
Electrical Dis. And Electronic Control System	23.94	0.89	1.35	103.50	1.52	1.58	3.71%	0.05%
Lighting System	10.04	0.53	(0.76)	400.00	(1.42)	(1.01)	5.29%	0.03%
Info, Gage and Warning System	1.90	0.08	0.19	0.00	2.45	2.45	4.01%	0.00%
Fluid & Misc.	69.66	0.00	0.00	0.00	0.00	0.00	0.00%	0.00%
Vehicle	1711.38	312.48 (Decrease)	$148.06 (Decrease)	($23,006.09) (Increase)	0.47 (Decrease)	0.43 (Decrease)	-	18.26%

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.

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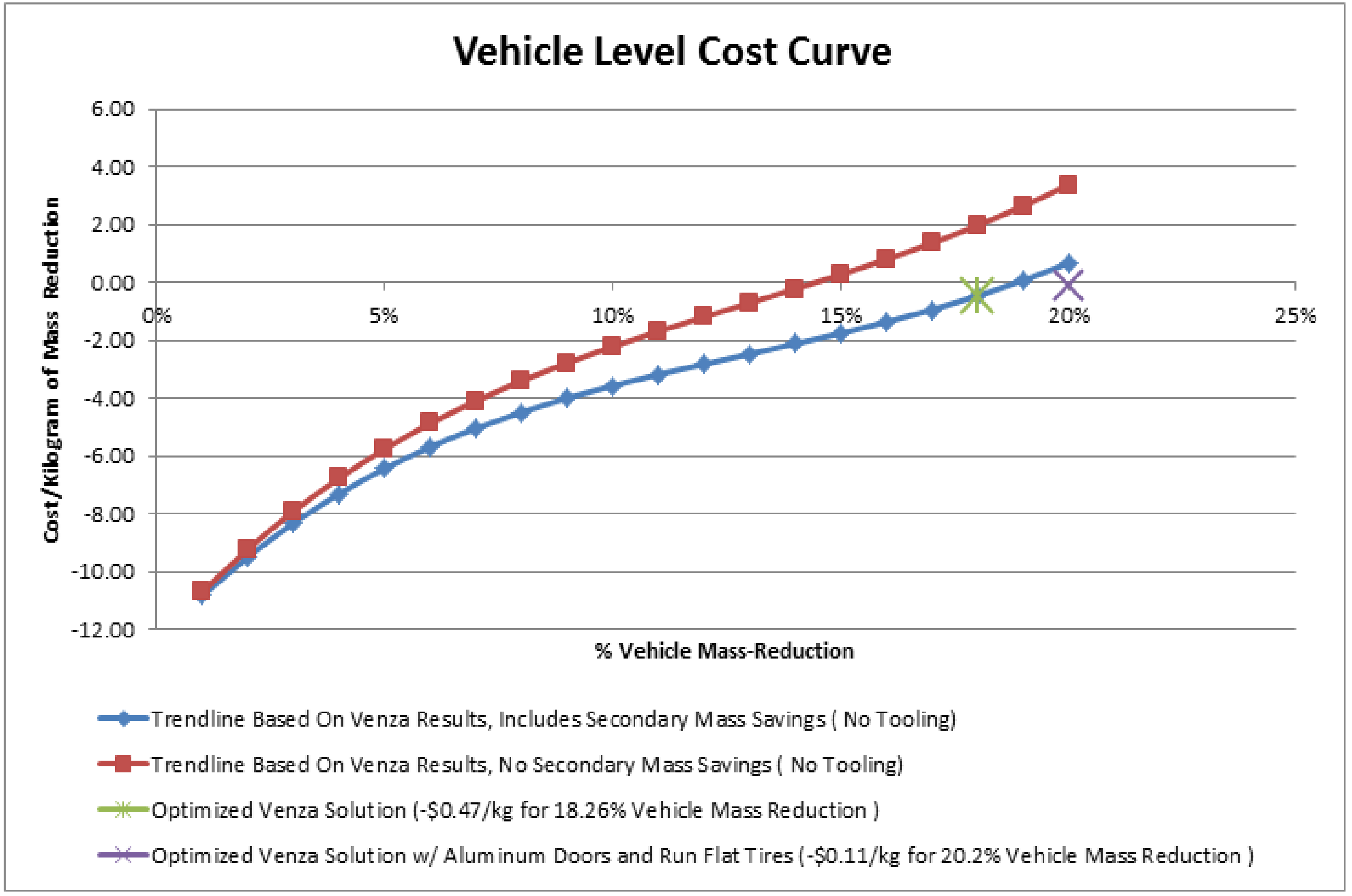
Mass-Reduction Results
➲ Net Incremental Direct Manufacturing Cost Curve



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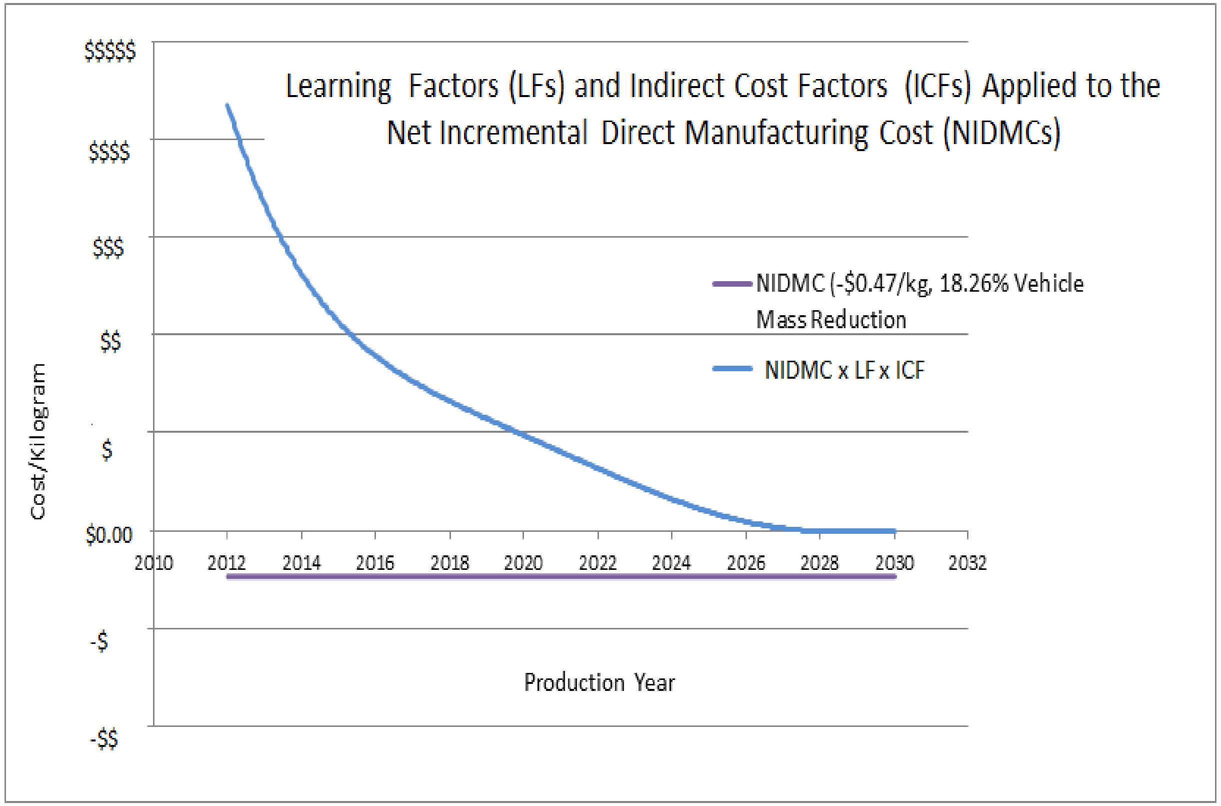
Mass-Reduction Results
➲Learning Factors and Indirect Cost Multipliers



- 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 .....
  a. OEM corporate overhead (sales, marketing, warranty, etc.)
  b. OEM engineering, design and testing costs (internal & external)
  c. OEM depreciations and amortization costs
  d. Dealership selling costs

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

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

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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

- “Light-Duty Vehicle Mass Reduction and Cost Analysis – Midsize Crossover Utility Vehicle” is available at http://www.epa.gov/otaq/climate/solutions-vehicle.htm
- 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.

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Questions and Answers

Q&A