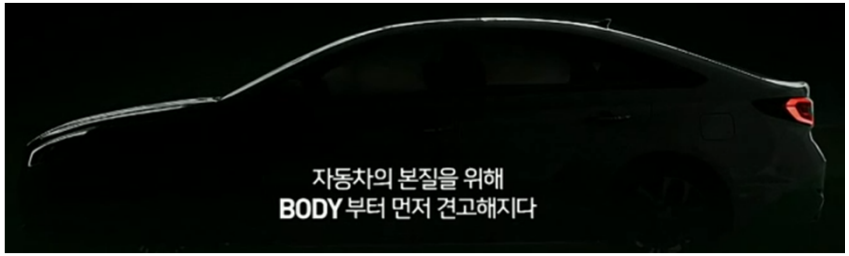
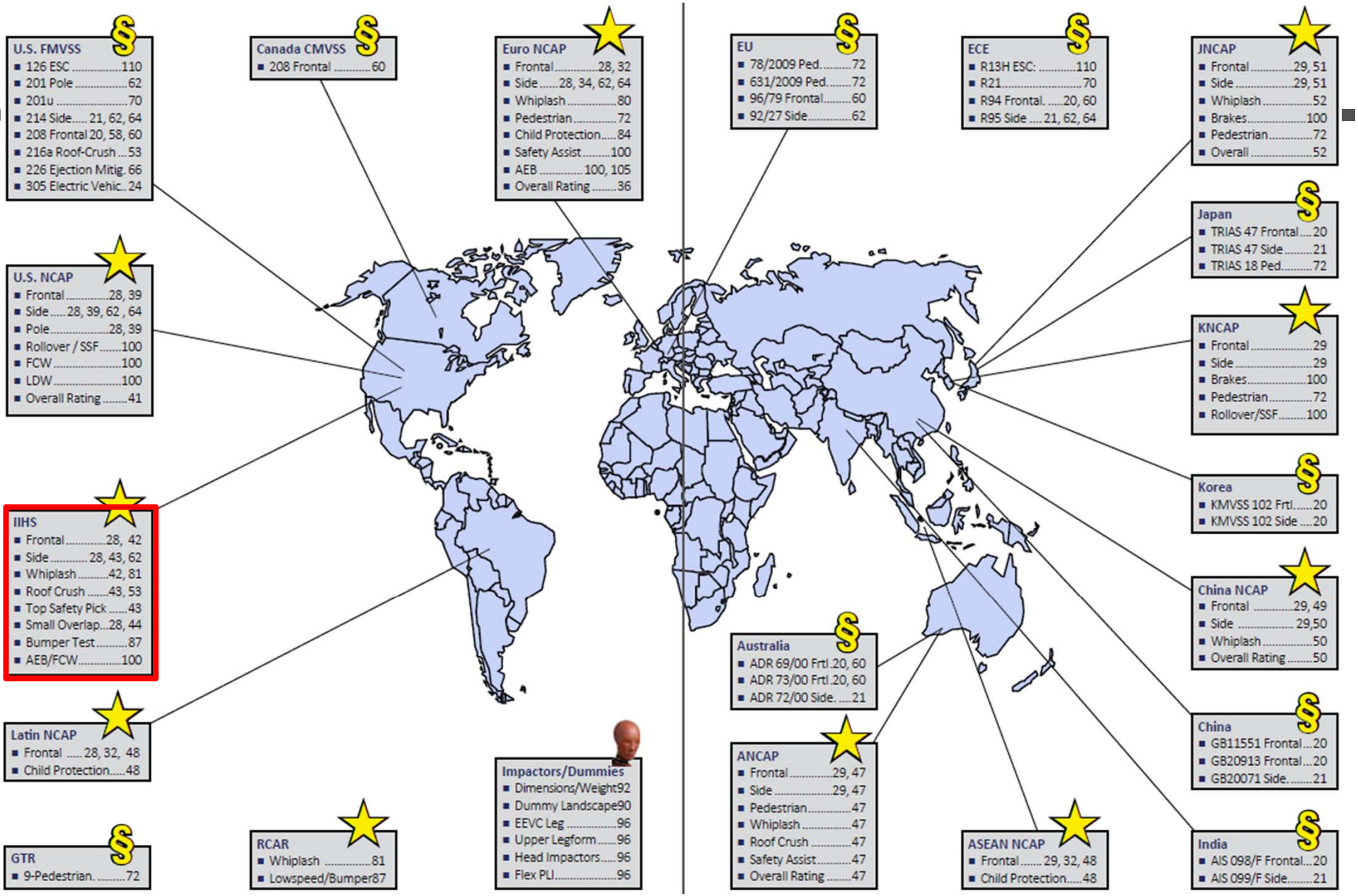
현대자동차 소나타 바디편 (July 2014)




U.S. FMVSS
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201 Pole 62
201u 70
214 Side 21, 62, 64
208 Frontal 20, 58, 60
216a Roof-Crush 53
226 Ejection Mitig. 66
305 Electric Vehic. 24
Canada CMVSS
208 Frontal 60
Euro NCAP
Frontal 28, 32
Side 28, 34, 62, 64
Whiplash 80
Pedestrian 72
Child Protection 84
Safety Assist 100
AEB 100, 105
Overall Rating 36
EU
78/2009 Ped. 72
631/2009 Ped. 72
96/79 Frontal 60
92/27 Side 62
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Pole 28, 39
Rollover / SSF 100
FCW 100
LDW 100
Overall Rating 41
Japan
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TRIAS 47 Side 21
TRIAS 18 Ped 72
KNCAP
Frontal 29
Side 29
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Pedestrian 72
Rollover/SSF 100
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Top Safety Pick 43
Small Overlap 28, 44
Bumper Test 87
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Safety Assist 47
Overall Rating 47
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AIS 098/F Frontal 20
AIS 099/F Side 21
GTR
9-Pedestrian. 72
RCAR
Whiplash 81
Lowspeed/Bumper87
ASEAN NCAP
Frontal 29, 32, 48
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IIHS (Insurance Institute for Highway Safety)

- Crashworthiness: how well a vehicle protects its occupants in a crash (Good/Acceptable/Marginal/Poor)
  - Moderate overlap front
  - Small overlap front
  - Side
  - Roof strength
  - Head restraints & seats
- Crash avoidance and mitigation: technology that can prevent a crash or lessen its severity (Basic/Advanced/Superior)
  - Front crash prevention systems

IIHS Safety Awards

- Top Safety Pick (TSP)
  - Good ratings in the moderate overlap front, side, roof strength and head restraint tests, as well as
  - Good or acceptable rating in the small overlap front test
- Top Safety Pick+
  - Top Safety Pick criteria, plus
  - Basic, advanced or superior rating for front crash prevention

New Challenges: New Structural Concepts

Aixam Mega
Mega E-City

BMW
E-mini

Bolloré/Pininfarina
Blue Car

BYD
E6

Daimler
Smart ed

General Motors
Volt

Heuliez
Will

Mitsubishi
i-Miev

Nissan
E-Cube

Reva
G-Wiz

Subaru
R1e

Tesla Motors
Roadster

Th!nk
City

Volkswagen
Twin Drive

???

Electric Cars

ETC/ACC Technical Paper 2009/4
F. Hacker, R. Harthan, F. Matthes, W. Zimmer

New Challenges: New Structural Concepts

www.loremo.com

(Low Resistance Mobile)

New Challenges: Electromobility

Technical Data

Dimensions:	Microcars
Number of passengers:	2 passengers
Vehicle payload:	2 pieces of luggage
Range:	> 100 km
Costs (TCO):	TCO equal to today´s compact cars
Market	Central Europe
Registration	L7E
Maximum speed	120 km/h
Output at wheel	15 kW
Curb weight	500 kg incl. battery
Energy storage	Rechargeable battery + el. Range Extender

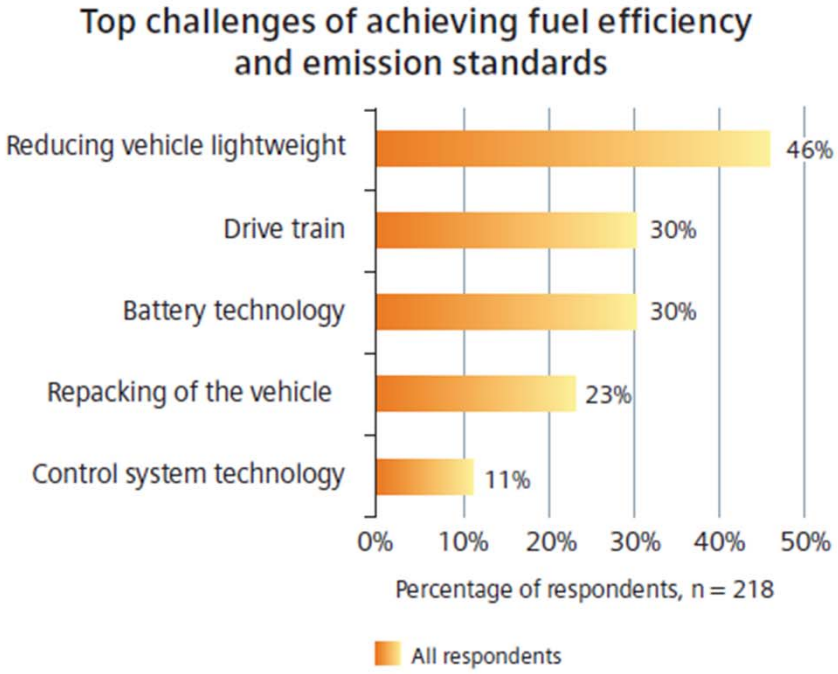
www.mute-automobile.de

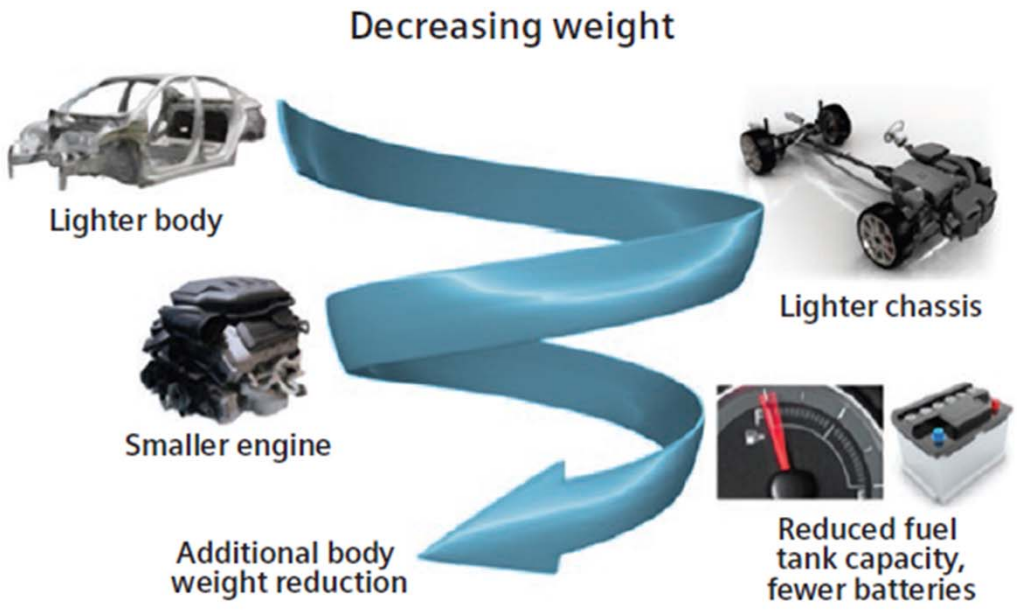
(Technical University of Munich)

New Challenges: New Materials (CFRP)

Reducing Vehicle Weight

- Alternative materials and assembly methods
- Fundamental change in vehicle designs
  - Rely more on engineering tools
  - Impact on part manufacturing, assembly, joining → factory





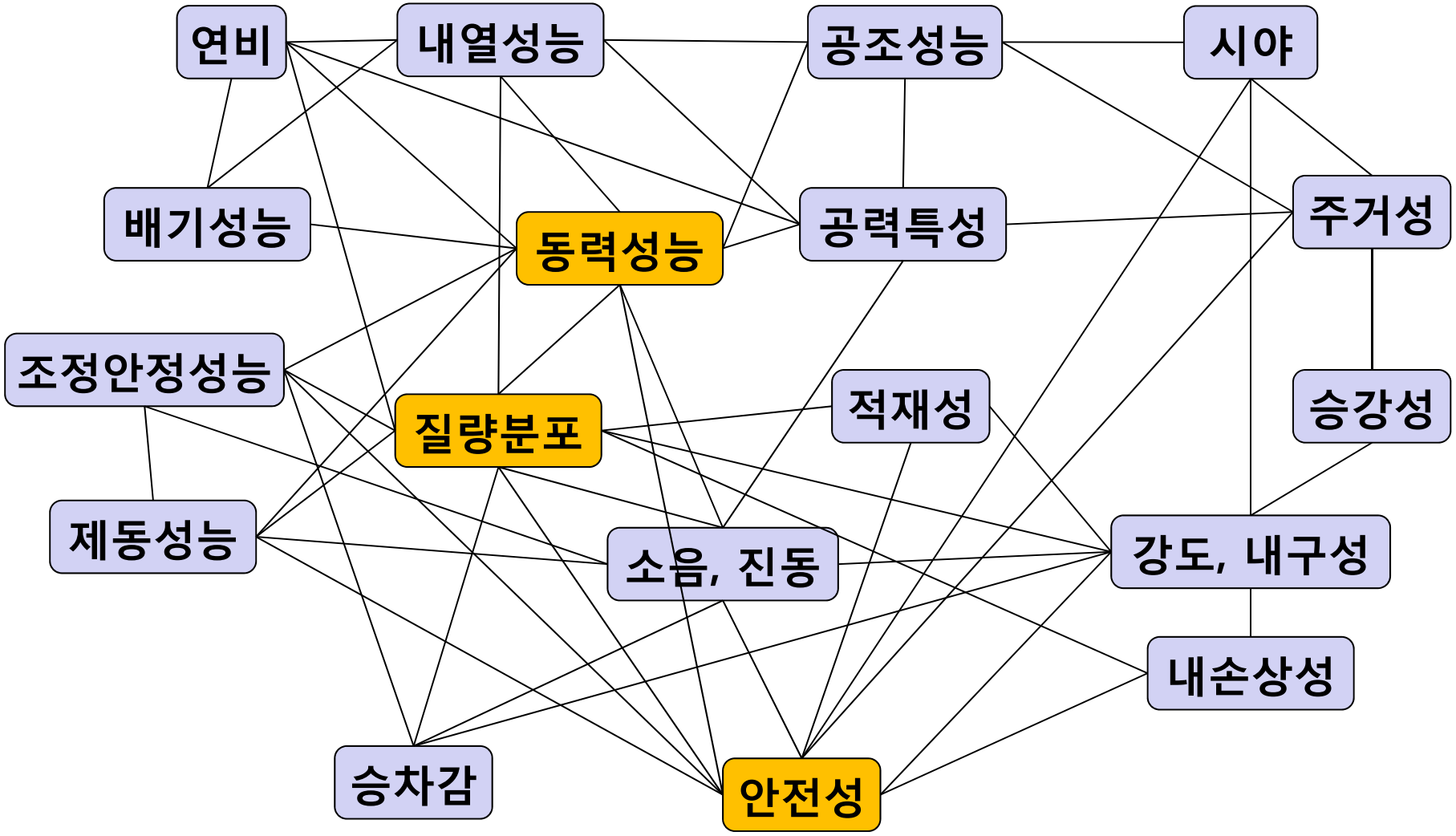
자동차에 요구되는 성능(1)

	성능분류항목	기본성능	쾌적·감성성능
기본이동성능	동력성능	가속성능, 최고속도, 등판성능	운전성, 가속감
	운동성능	조정안정성, 회전성능, 안정경사각	안정감, 직진성, 승차감
	제동성능	제동정지거리, 제동안정성	제동감
편리성·쾌적성	주거성	승원수, 실내공간, 시계성능, 승강성, 환기성능, 저진동·소음	공간감, 좌석/공조/음질쾌적성
	적재성	적재중량/용적, 하역성	
	조작성	운전조작성, 계기류(가시성)	조작감
	외형성능	비례, 공력특성	스타일링
	부가기능	수신/송신기능, 음향재생기능	음향성능

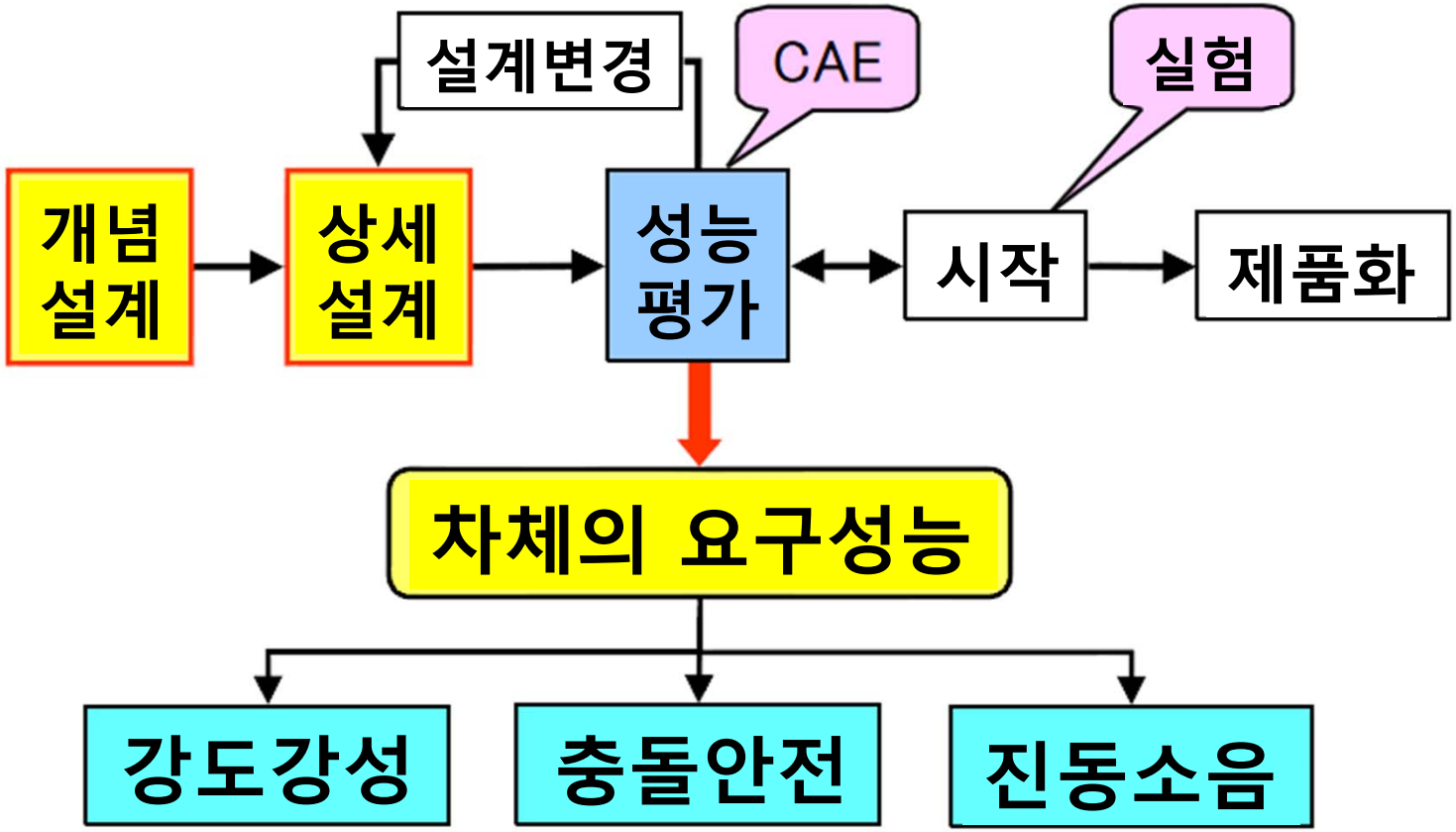
자동차에 요구되는 성능(2)

	성능분류항목	기본성능	쾌적·감성성능
사회성·경제성	안전성능	가시성, 위험회피성능, 충돌안전성	운전성, 가속감
	환경적합성	배기성능, 차외소음성능	여유감, 가시성
	경제성, 신뢰성, 생산성	신뢰성, 내구성, 가격, 연비, 유지비, 생산성, 조립작업성	유지, 고장진단성능

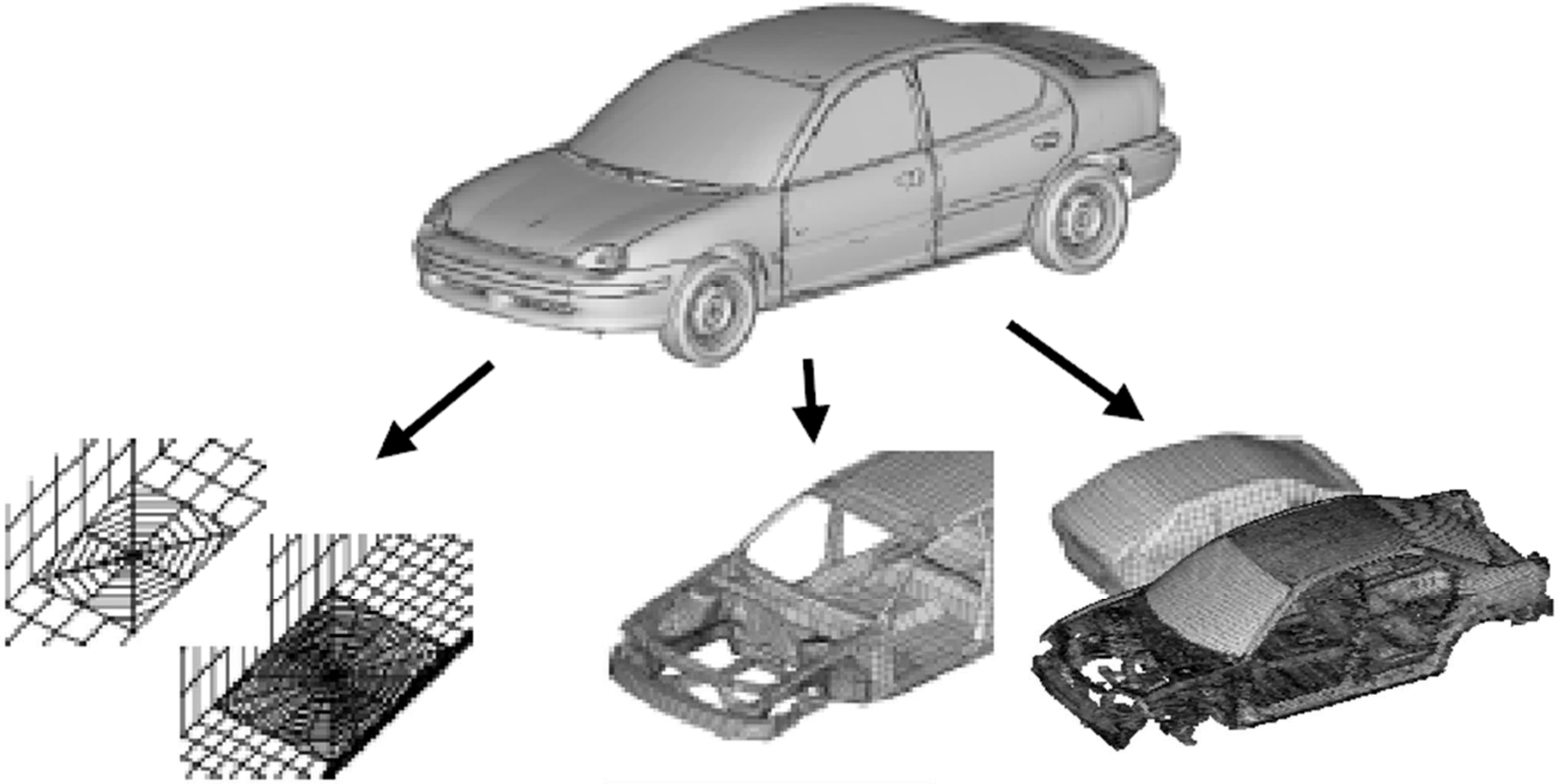
성능간 상관관계


연비
내열성능
공조성능
시야
배기성능
동력성능
공력특성
주거성
조정안정성능
질량분포
적재성
승강성
제동성능
소음, 진동
강도, 내구성
내손상성
승차감
안전성

설계단계와 요구사항



각 성능에 해당하는 CAE 모델



각 성능에 해당하는 CAE의 해석 및 평가

- 강도평가
  - 정적인 선형·비선형(접촉)해석에 의한 응력·변형률해석
  - 피로균열파괴현상의 평가
  - NASTRAN, ABAQUS
- 충돌안전
  - 주로 동적 양해법에 의한 대변형·응력전달해석
  - 캐빈 내로의 침투량에 의한 평가
  - DYNA, PAM-CRASH
- 진동소음
  - 선형고유진동수·주파수응답해석에 의한 미소변위·음압해석
  - 차실내의 가속도응답·음압에 의한 평가
  - NASTRAN

Ch. 1 The Automobile Body

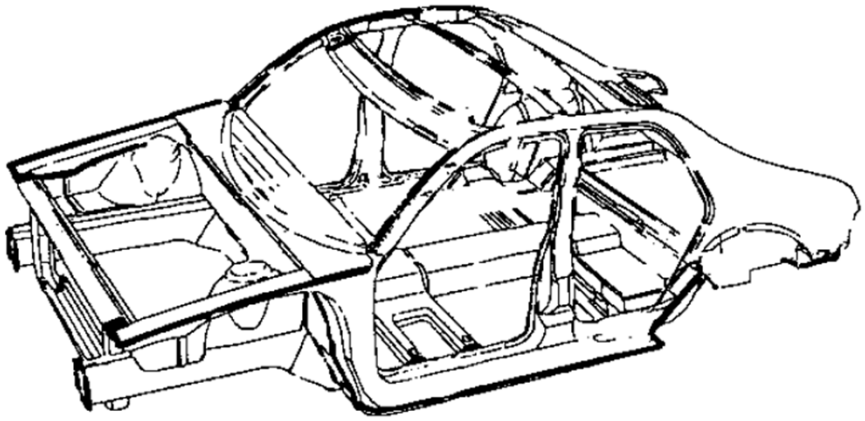
- 1.1 Description of the automotive body types
- 1.2 Body nomenclature
- 1.3 Body mass benchmarking
- 1.4 The body structure as a system
- 1.5 Note on design philosophy

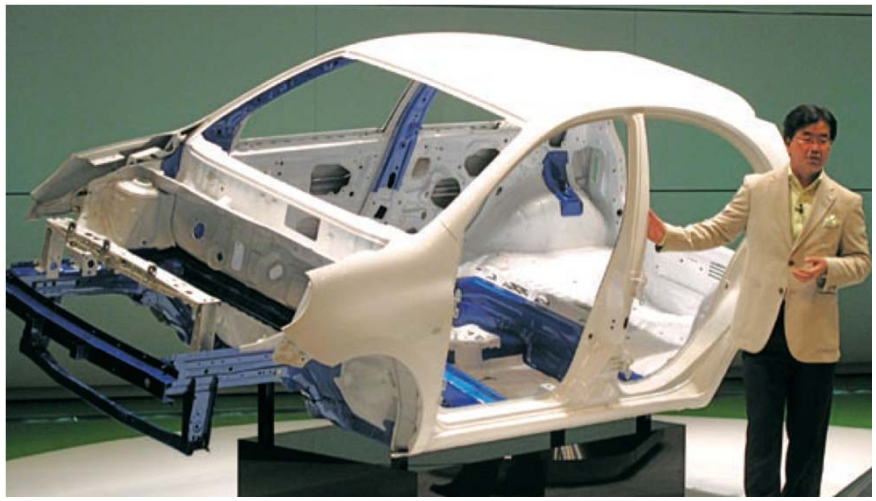
Introduction

- Structure
  - Collection of physical components arranged and supported in such a manner to carry loads
- Load bearing structure in the automotive sense
  - (1) Vehicle body (2) suspension system
- Optimization
  - Mathematical technique for finding the maximum or minimum value of a function of several variables subject to functional constraints, (making the best of anything)
- Vehicle structural design optimization
  - Reduce body weight by making structural design modifications
  - Constraints (performance): strength, durability, crash, handling, comfort

Automobile Body

- Vehicle subsystem that performs many functions
  - Basic: armature holding parts of vehicle
  - Refine: noise and vibration (economy ~ luxury)



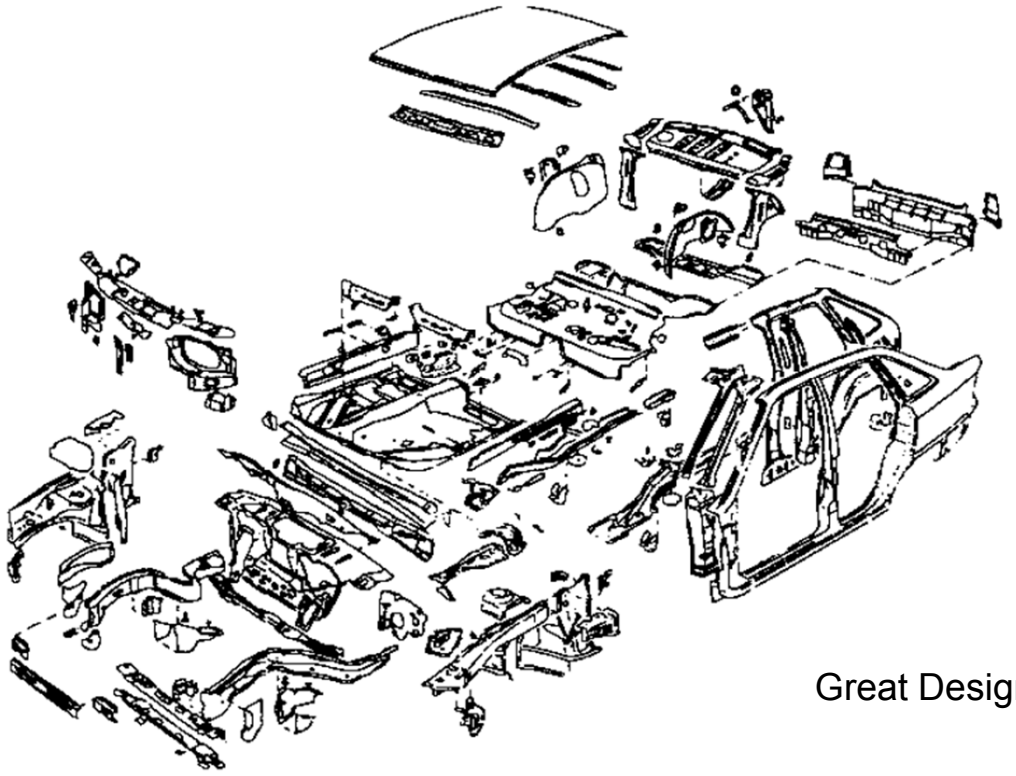


2010 Nissan March

BIW (Body-In-White), 차체

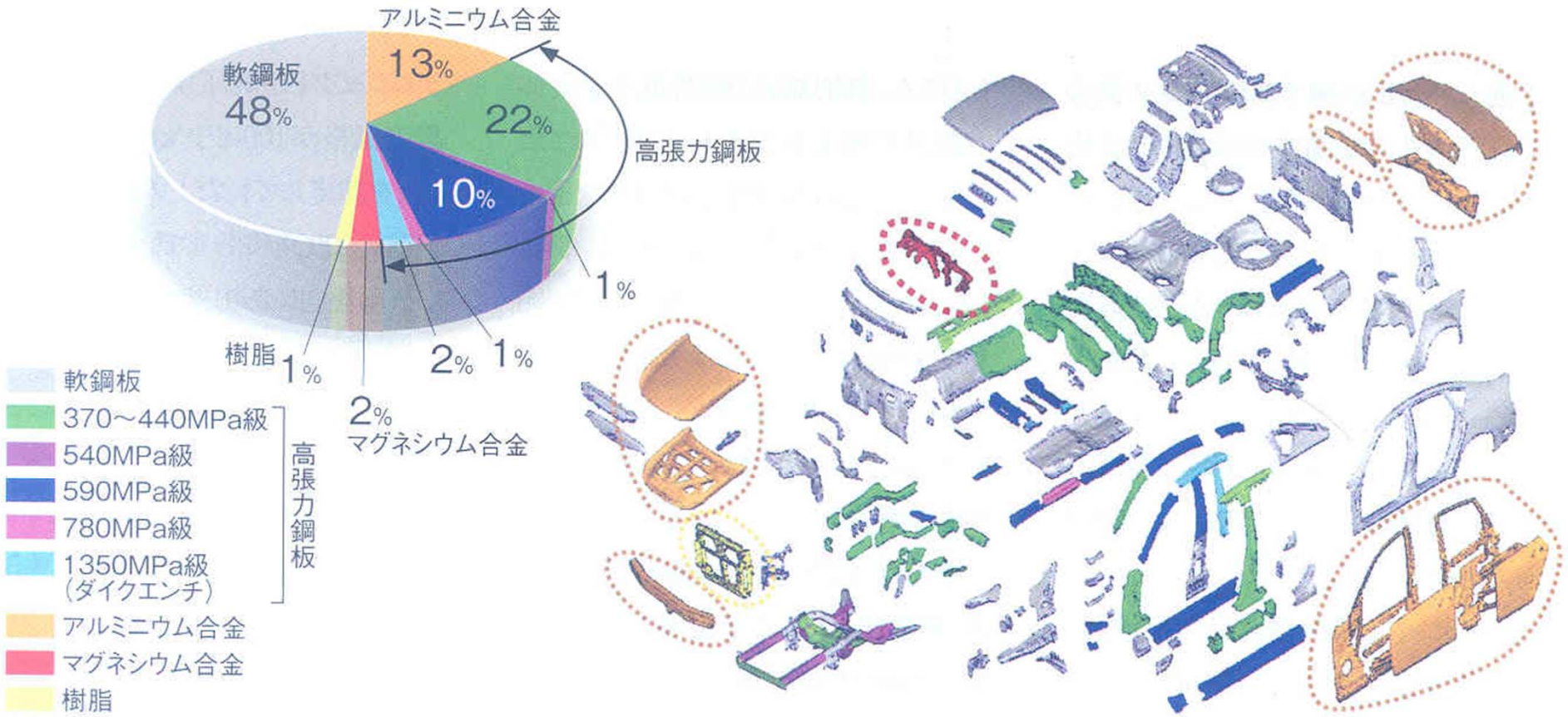
Range of Steel Grades

- Assembly of metal stampings
  - Advanced high-strength steel (AHSS, S_{ut} > 440MPa): 10%
  - High-strength steel (HSS, 240< S_{ut} < 440MPa): 35%
  - Mild steel (S_{ut} < 270MPa): 55%



Great Designs in Steel, AISI (2008)

차체 경량화를 위한 재료활용 동향

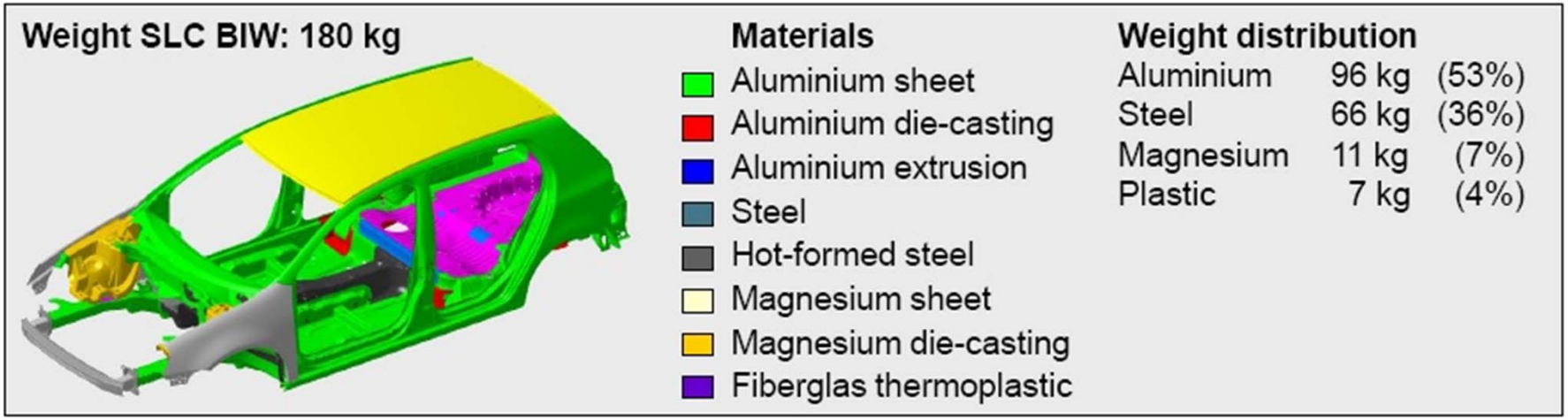


NIKKEI MONOZUKURI (2008.04): Nissan Motors

Super Light Car (SLC)

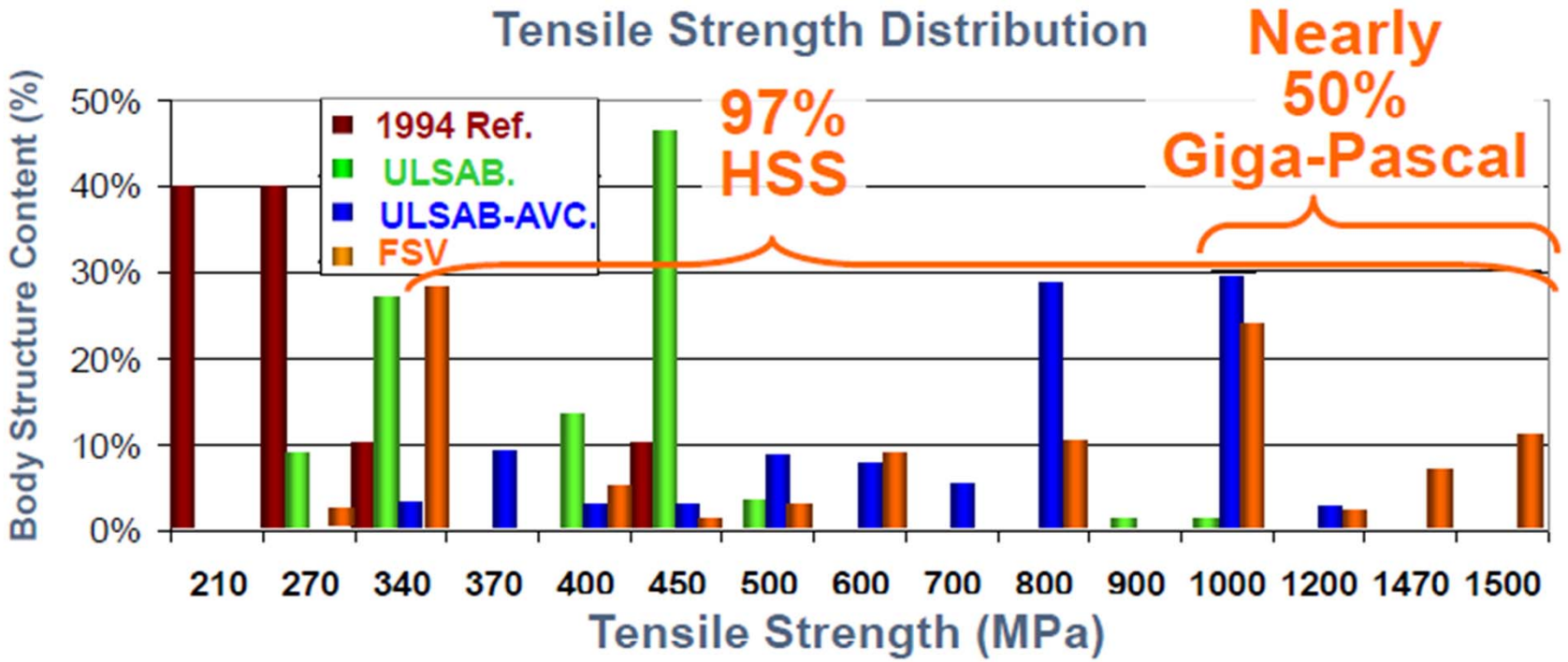
SuperLightCar
VOLKSWAGEN AG

- Multi-material concepts design and optimization
  - Multi-material vehicle concept 35% (101 Kg) weight reduction compared to the reference (VW Golf V, 2004 benchmark)



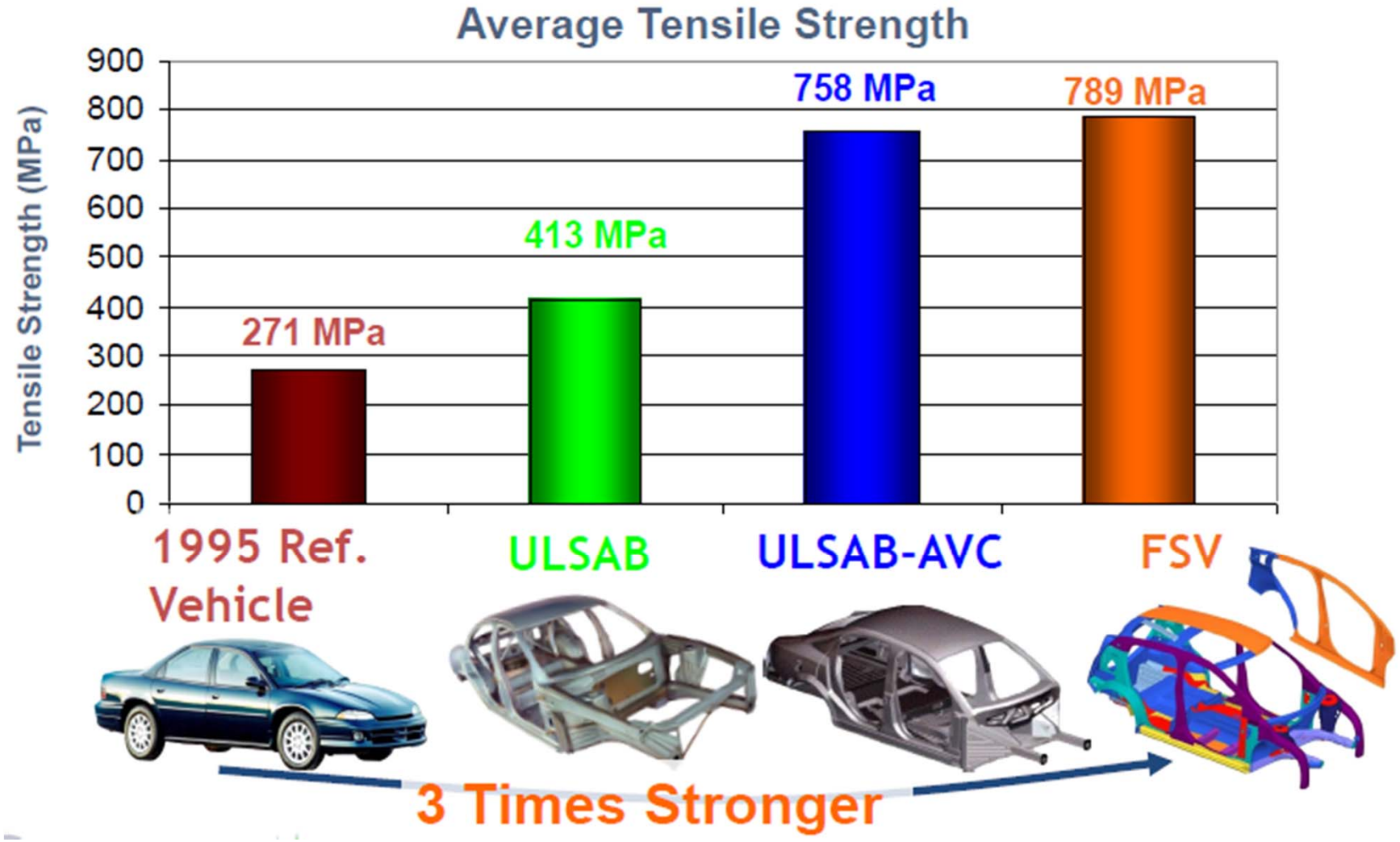
www.superlightcar.com (2009)

FSV vs. UltraLight: Tensile Strength (1)



www.worldautosteel.org (2011)

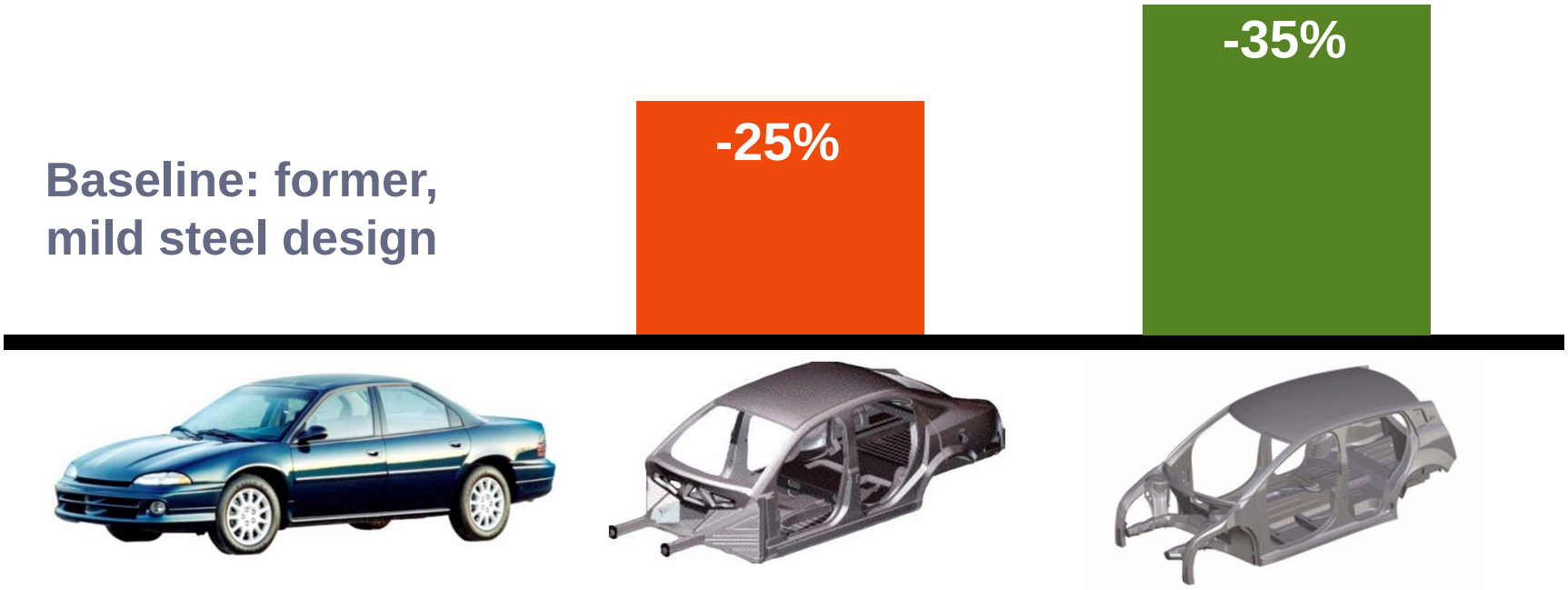
FSV vs. UltraLight: Tensile Strength (2)



www.worldautosteel.org (2011)

Mass Targets

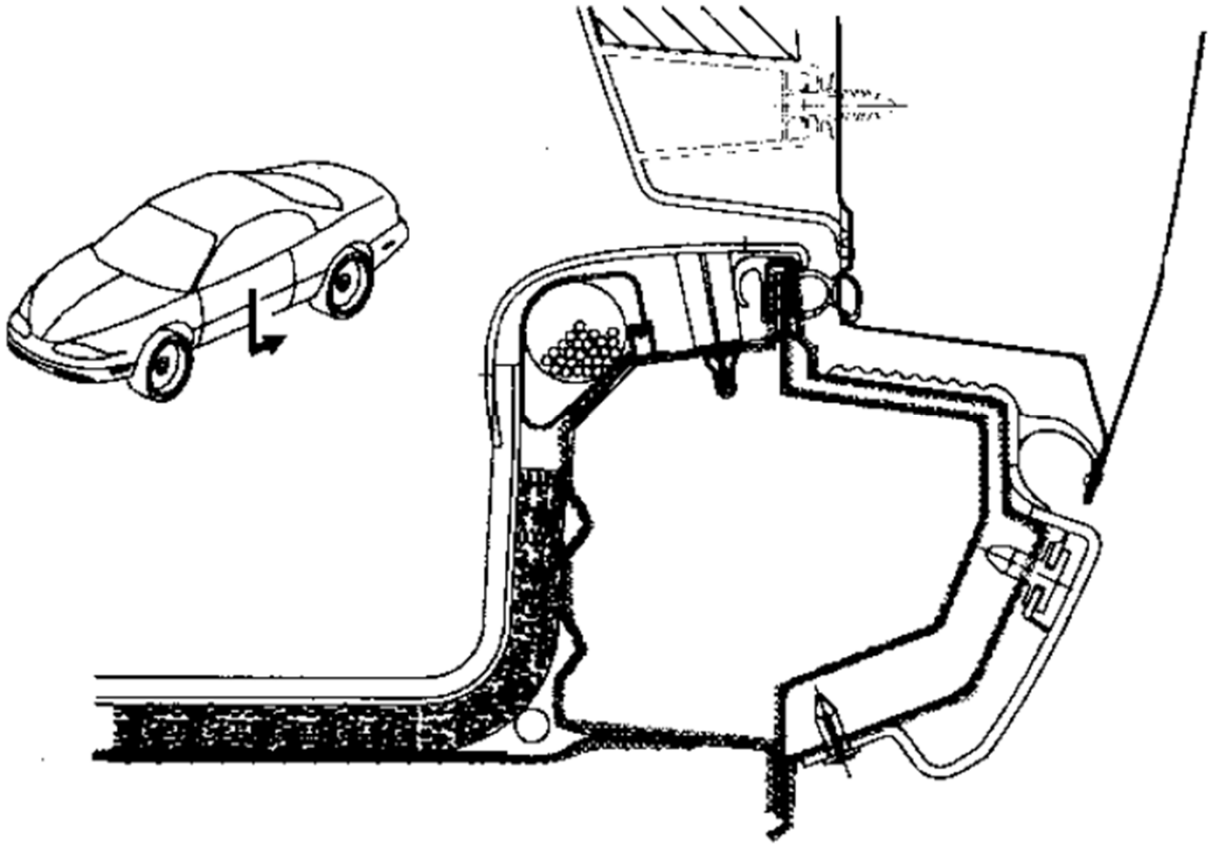
Raising the Bar in Vehicle Mass Reduction



	WorldAutoSteel		FSV-1
	ULSAB	ULSAB AVC C Class	BEV
	1997	2004	2015-2020
Vehicle Mass kg	1350	966	1232
Powertrain Mass kg		195	449
		20%	36%
References	1994 Ford Taurus (1450kg)	243	268
Reference/Benchmark BIW Mass	271	268	290
ULSAB - Achieved BIW Mass	203		
	25%		
***Mass reduction from ULSAB for C-class target		20	
*Additional mass - Crash requirements for 2004		25	
ULSAB AVC - Target BIW Mass		208 (=203-20***+25*)	
ULSAB AVC - Achieved BIW Mass		202	
		3%	
ULSAB AVC - Achieved BIW Mass relative to Reference Benchmark		25%	
Updates to ULSAB-AVC			
Additional mass - Crash requirements 2020			5
Additional mass for: Higher Mass Powertrain (mass compounding)			38
Mass reduction for 2020 Technology Implementation			-10
Mass reduction Efficient Front-end Package			-11
** Total Updates to ULSAB-AVC for 2020			22
FSV-1 - Interim BIW Mass Target (Current AHSS Steel Solution)			224 (=202+22**)
			-23%
Additional Mass Reduction Advanced Steel Technology	-15%		-33.6
FSV-1 - Final BIW Mass Target (Advanced Steel Solution)			190
			-34%

Automobile Body

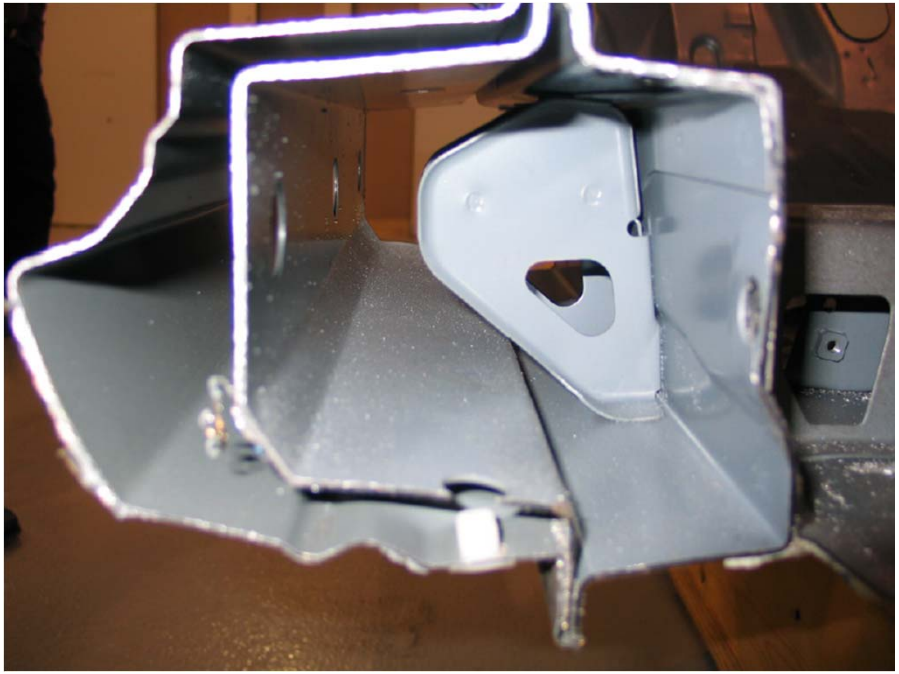
- Thin-walled structural elements



typical section at rocker

Rocker

2004 Hyundai XG350



2003 Toyota Camry SE

Automobile Body Types (1)

- Space frame
  - 3D framework of beams connected at nodes
  - Lower cost tooling: roll forming, hydroforming
  - Lower volume vehicles
- Body-on-frame
  - Predominant passenger car type until the 1980's
  - Predominant type for light trucks
  - Ladder frame to which suspensions and powertrain are attached
  - Body shell connected to the frame by flexible body mounts
- Monocoque
  - Integral structure which forms a shell including exterior panels
  - Predominant type currently, most mass efficient configuration

Automobile Body Types (2)

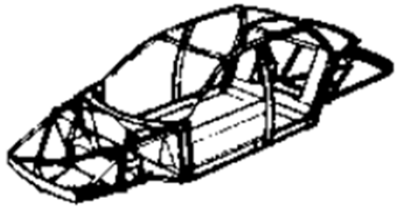
- 모노코크 보디(Monocoque Body, Unit Constraction Body)
  - 자동차의 차체와 프레임을 일체로 제작하여 하중과 충격에 견딜 수 있는 구조로 하여 차의 경량화와 바닥을 낮게 할 수 있다. 차체를 상자형으로 제작하여 외력을 차체 전체에 분산시켜 전체로 힘을 받도록 한 것이며 곡면을 이용하여 강도를 증가하도록 결합되어 있다. 현가장치나 엔진의 설치부와 같은 외력이 집중되는 부분에는 작은 프레임을 두어 이것을 통하여 차체에 힘을 분산시키도록 되어 있다.

Body Configurations

Space Frame

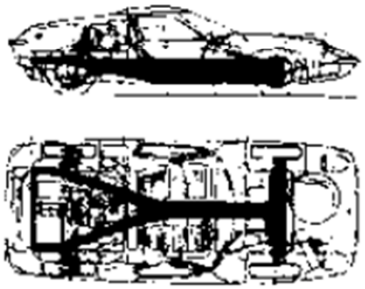
3D network of struts react major loads

unstressed panels



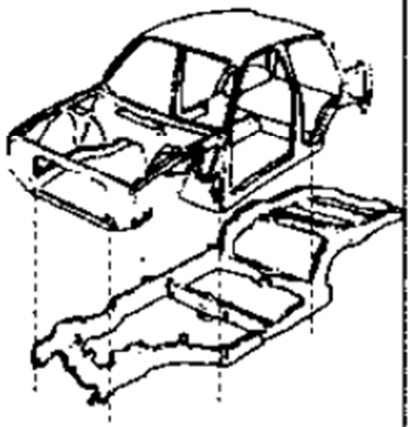
Central Frames

Large tunnel reacts major loads



Body-on-Frame

Frame reacts major loads

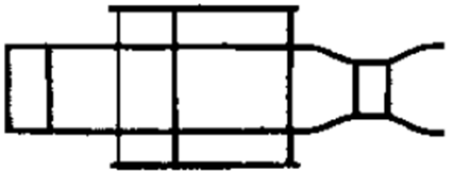


Integral Body-Frame (Monocoque)

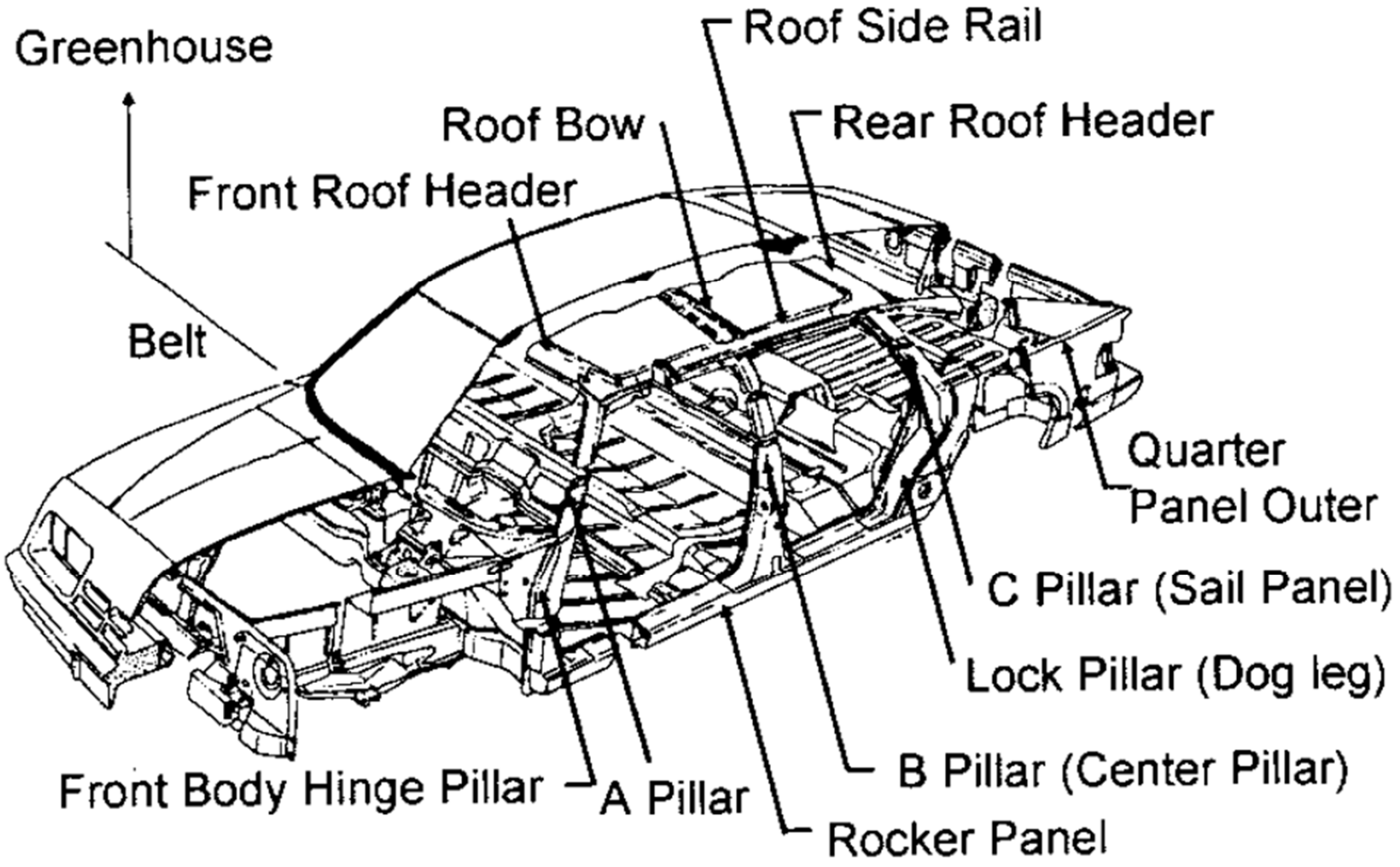
Exterior panels and underbody share loads

Monocoque Typical Topologies

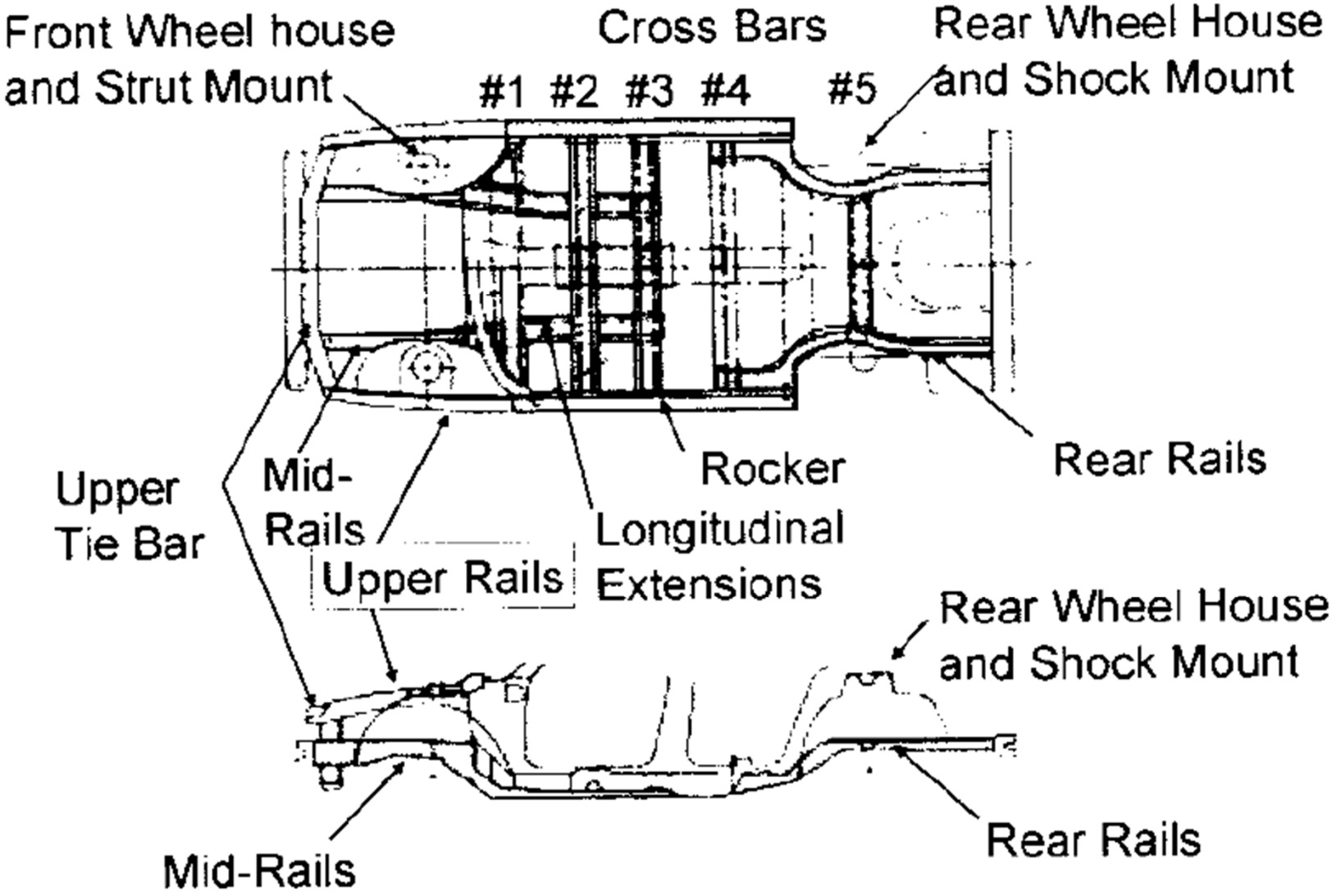
- Topology
  - Arrangement of structural elements (beams/panels) to meet requirements in the most efficient manner
  - Positioning and size of structural elements: package, styling, manufacturing

Extended Longitudinal		1991 Cadillac Seville
Split Load Path		1992 Honda Civic 1992 Accura Vigor 1990 Mercedes Benz 300
Full Longitudinal		1990 Infinity Q45

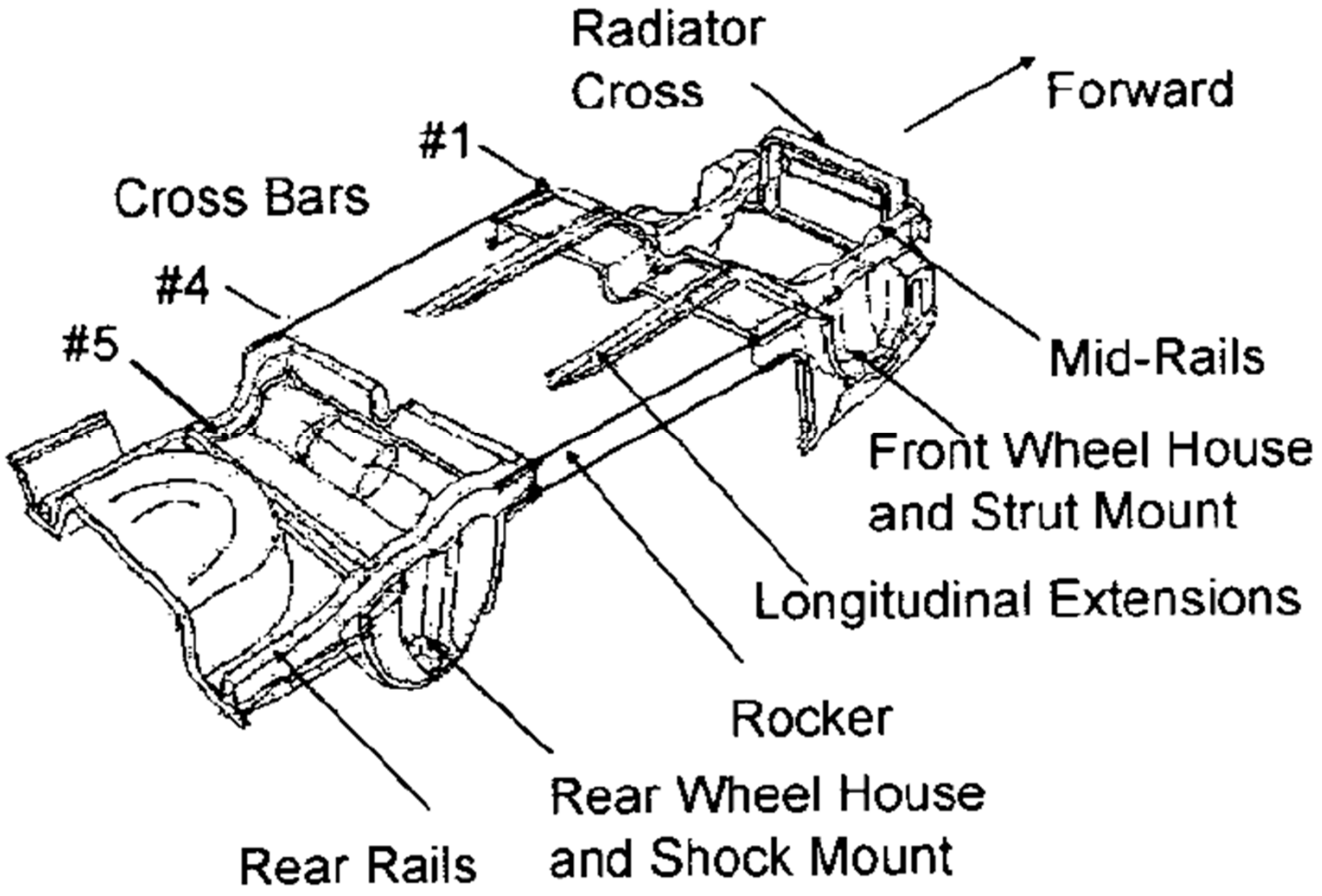
Body Nomenclature



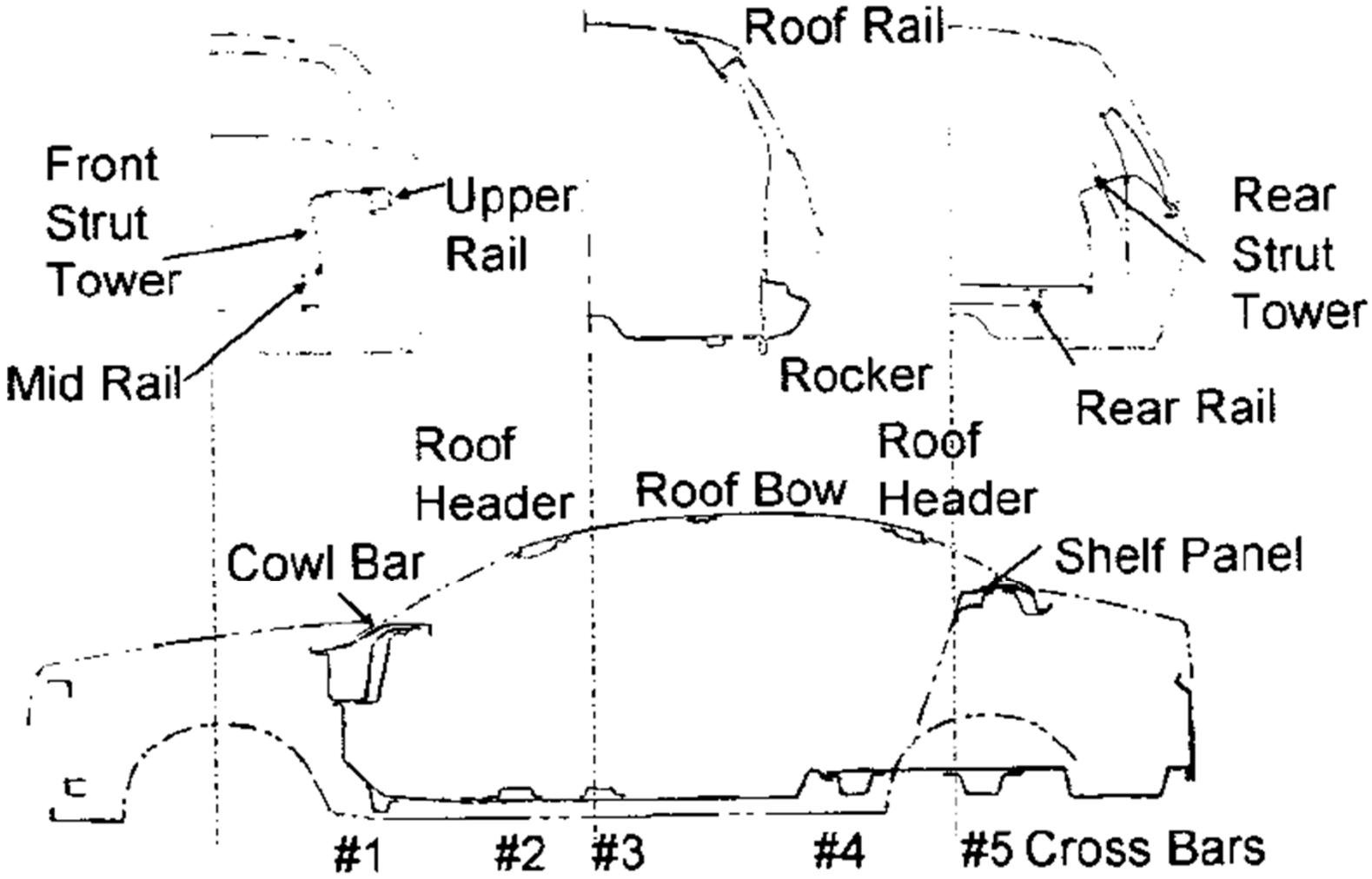
Underbody Members



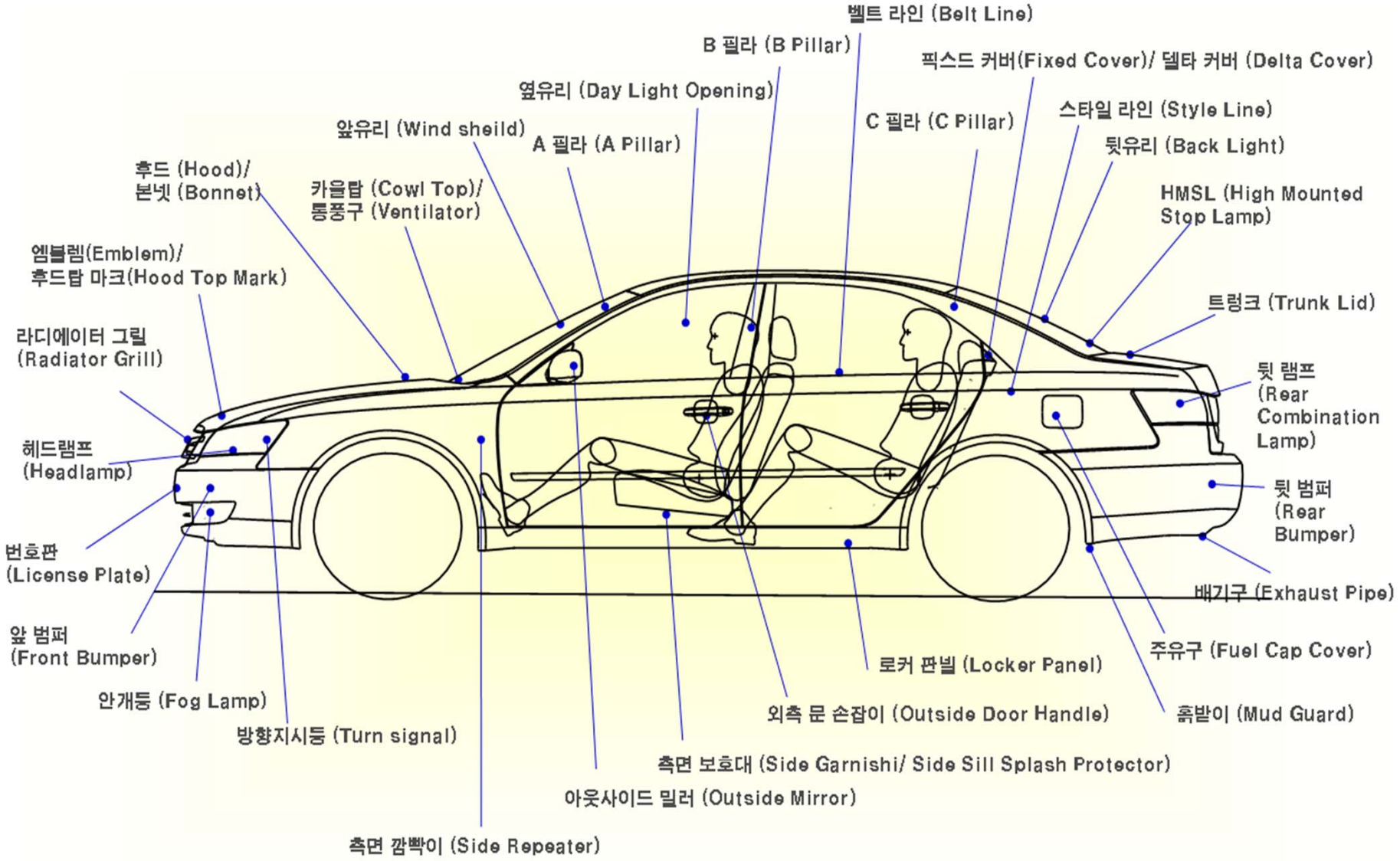
Underbody Members: Bottom View



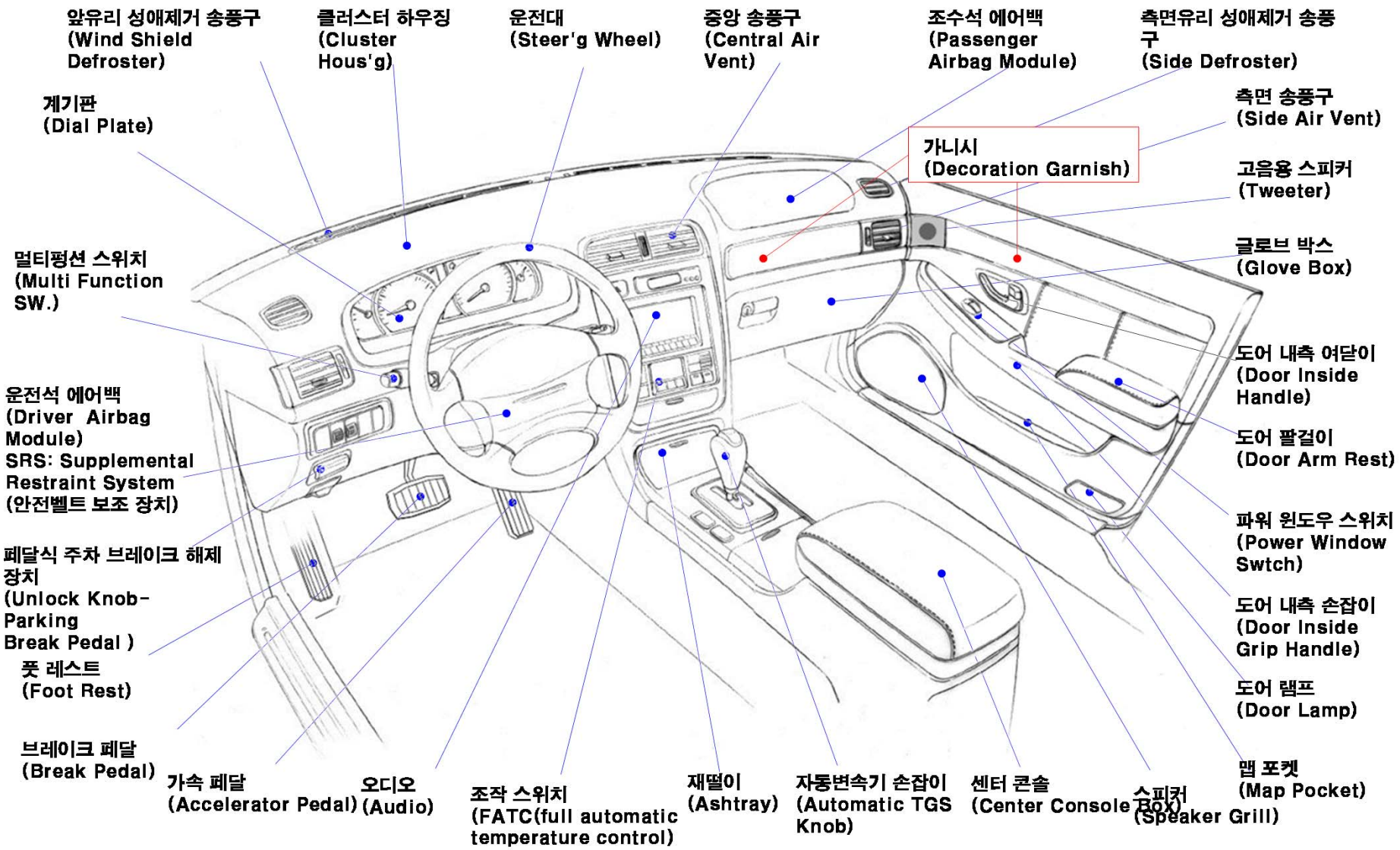
Cross Sections



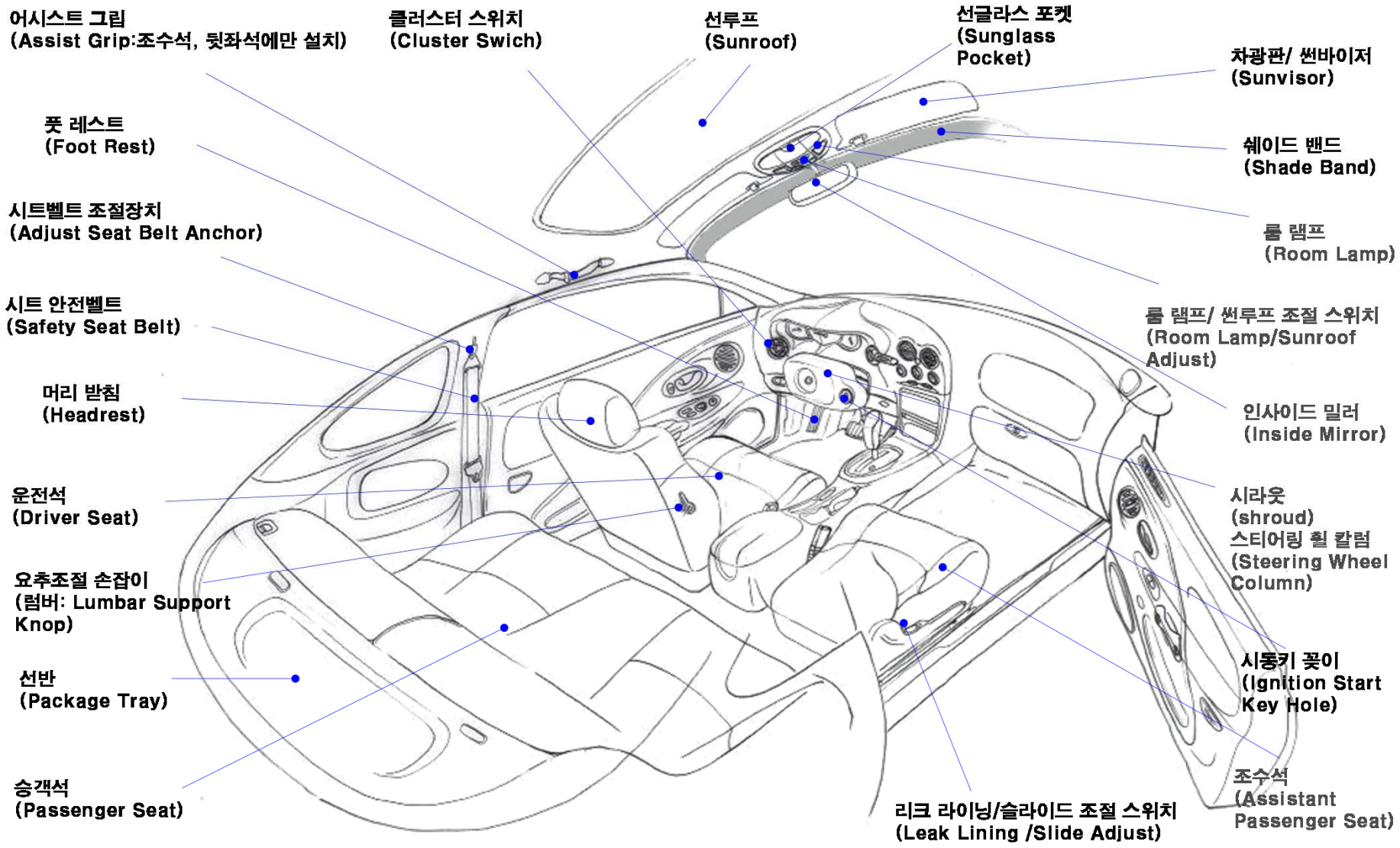
Exterior Nomenclature



Interior Nomenclature: Crash Pad, Console, Door Trim

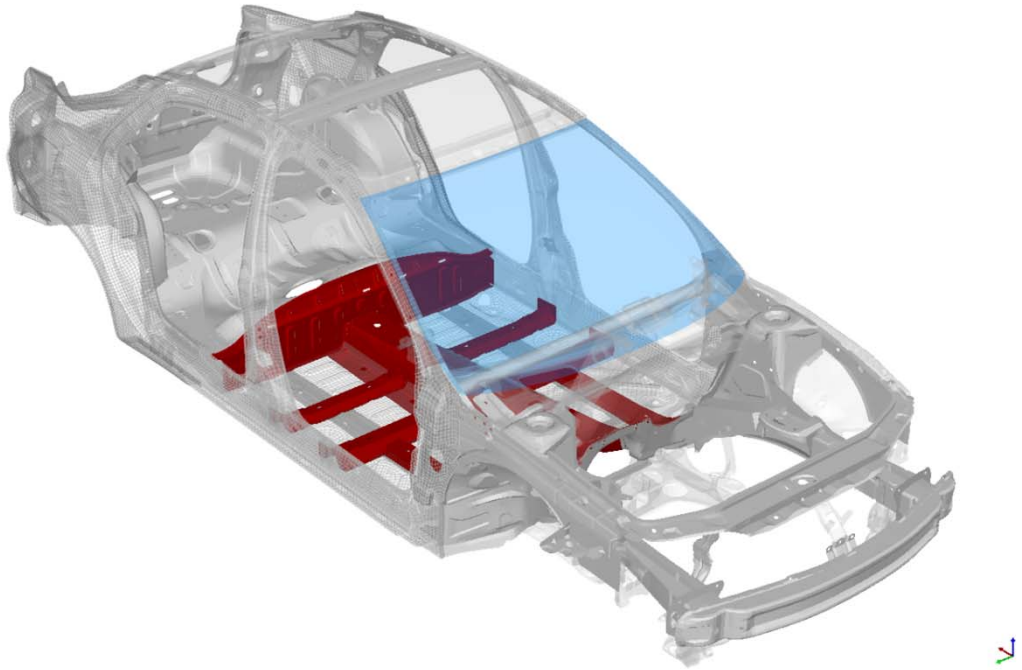


Interior Nomenclature: Seat, Head Lining, Pillar Trim

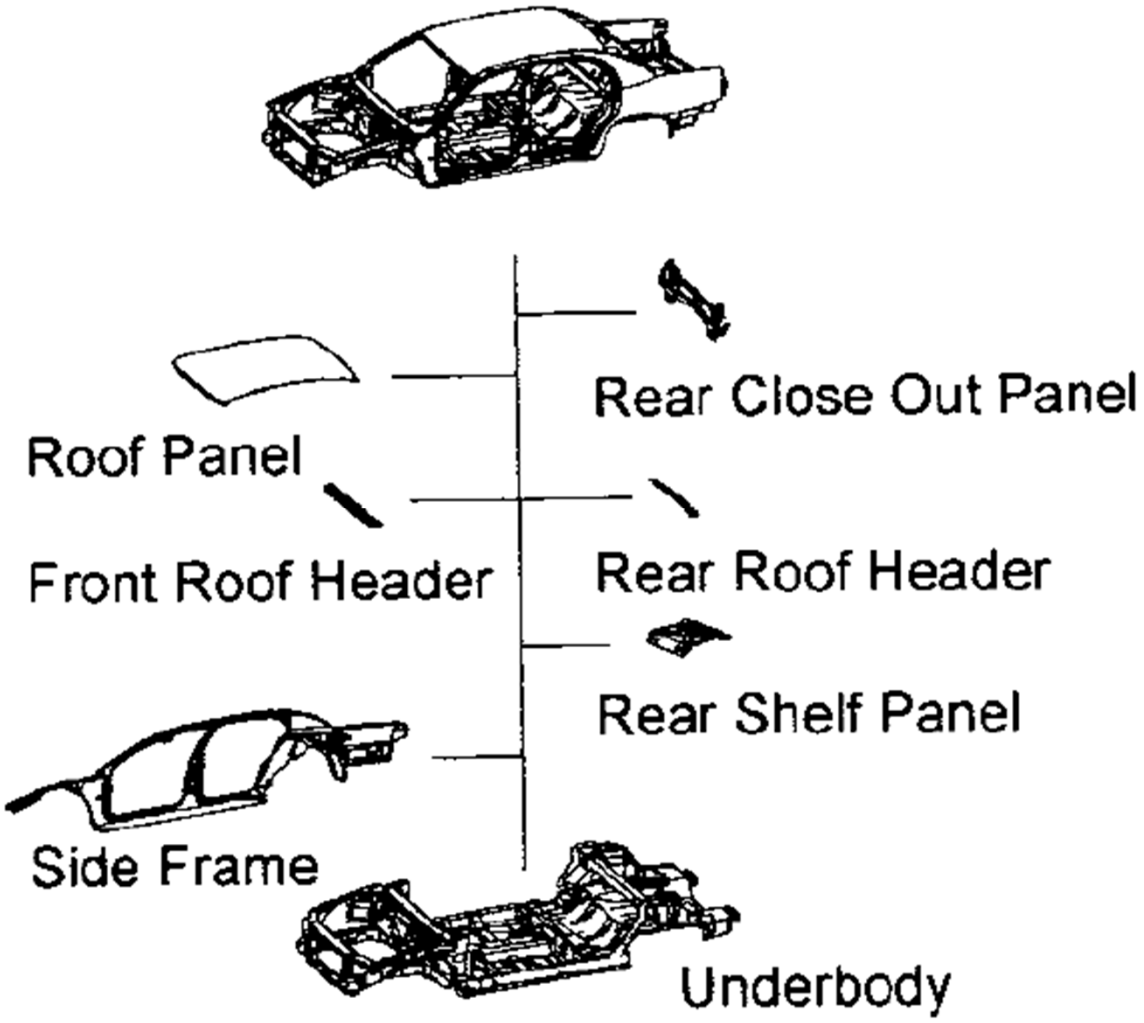


BIW (1)

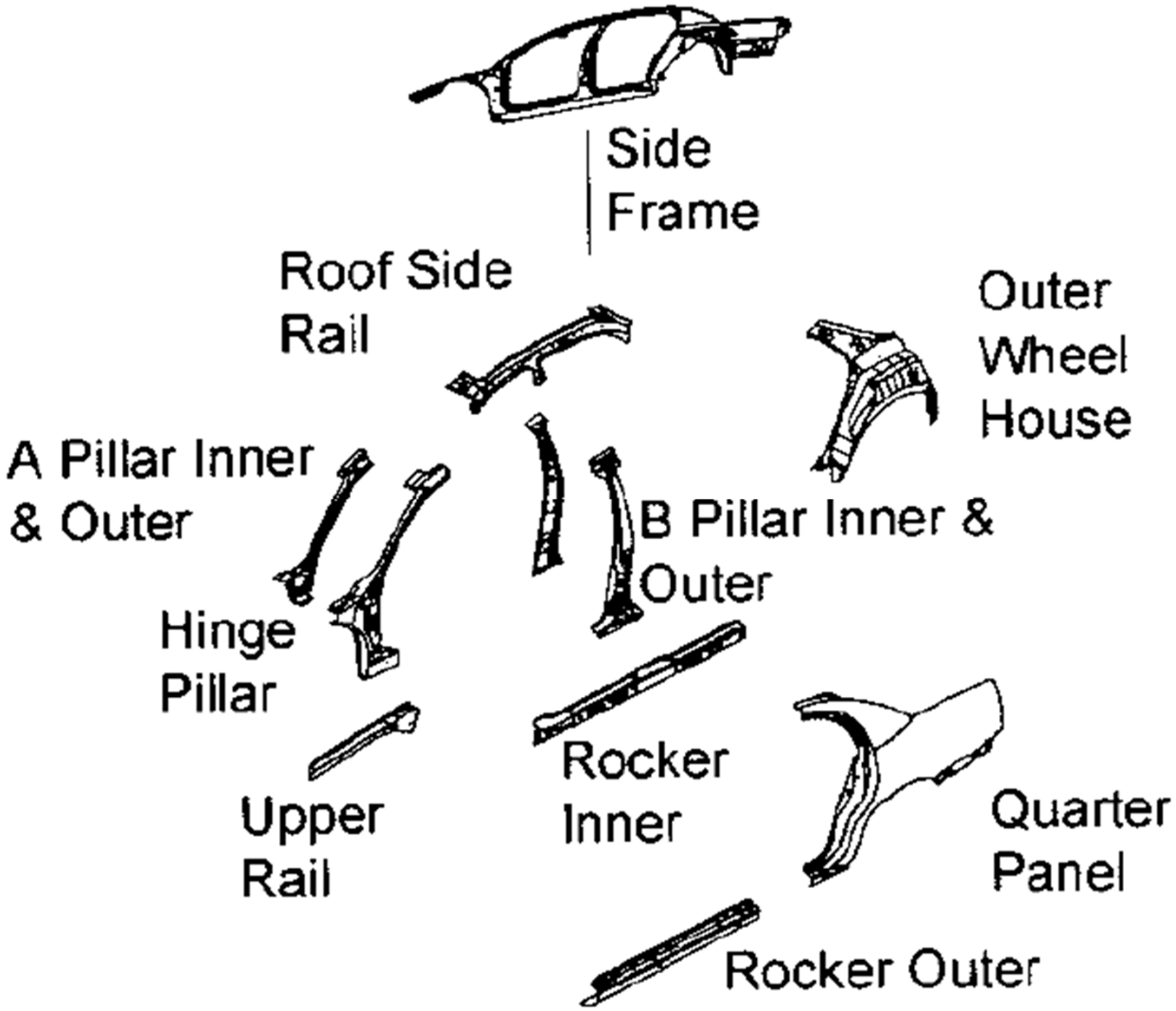
- Stage in vehicle assembly comprising the assembled but unpainted panel-work, extruding trim and chassis items
  - Side frame
  - Underbody
  - Roof panel
  - Front/Rear roof header
  - Rear close out panel
  - Rear shelf panel



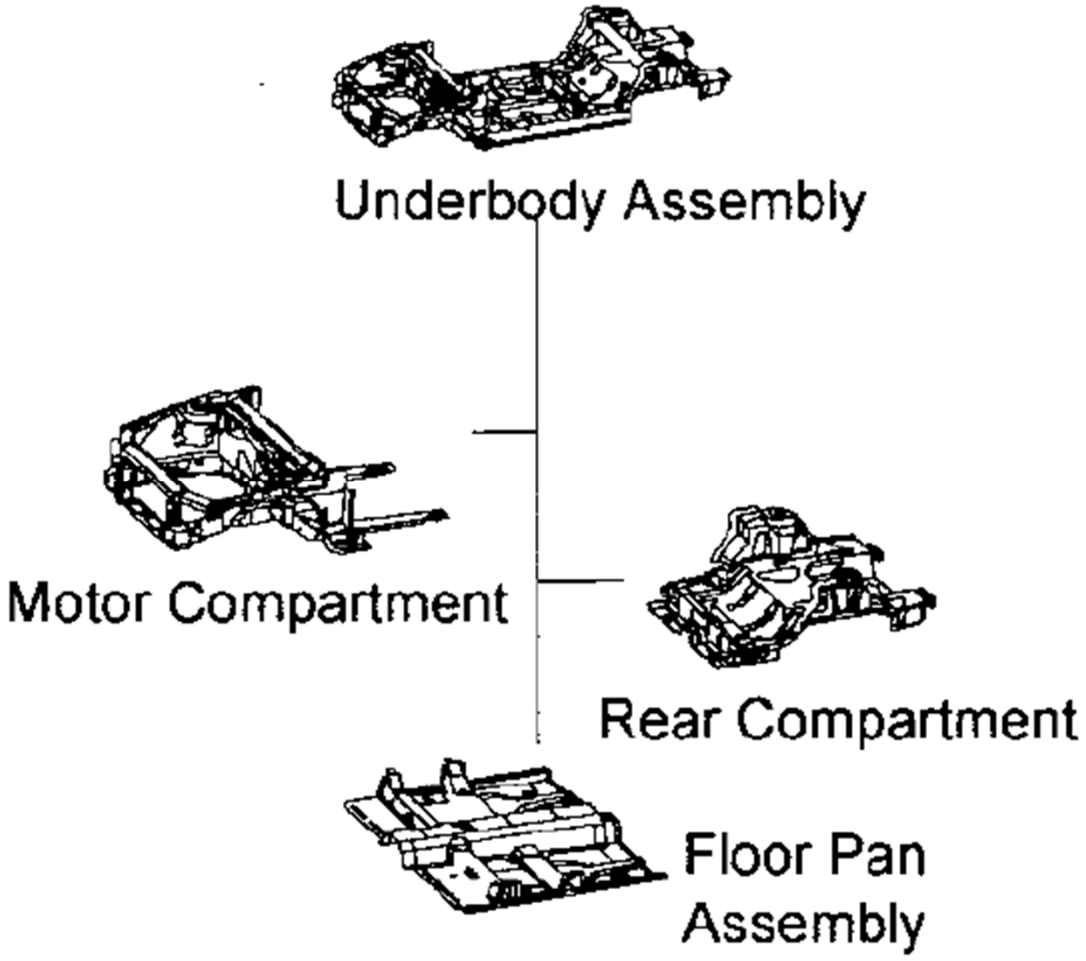
BIW (2)


Rear Close Out Panel
Roof Panel
Front Roof Header
Rear Roof Header
Rear Shelf Panel
Side Frame
Underbody

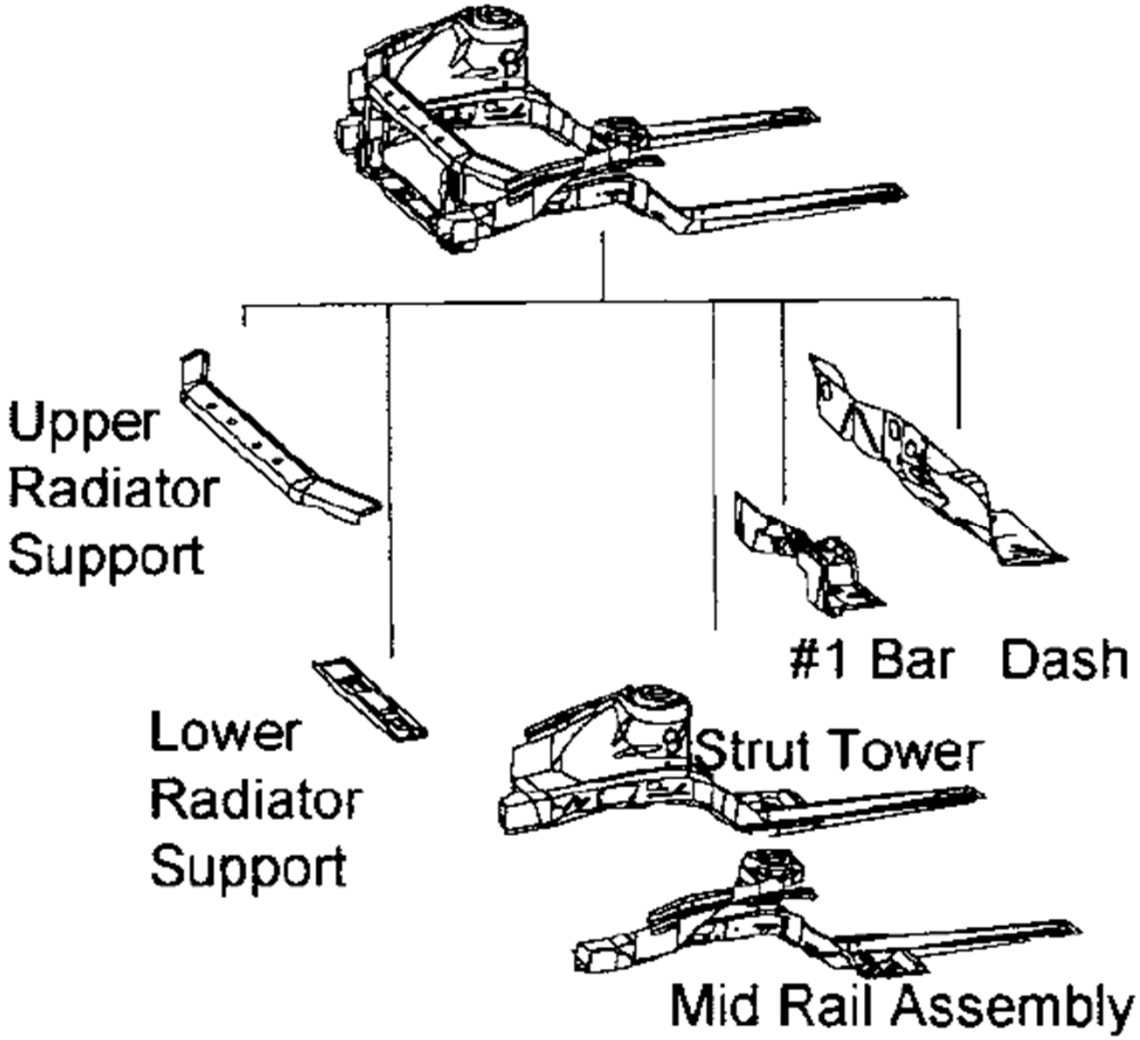
Side Frame


Side
Frame
Roof Side
Rail
Outer
Wheel
House
A Pillar Inner
& Outer
B Pillar Inner &
Outer
Hinge
Pillar
Rocker
Inner
Quarter
Panel
Upper
Rail
Rocker Outer

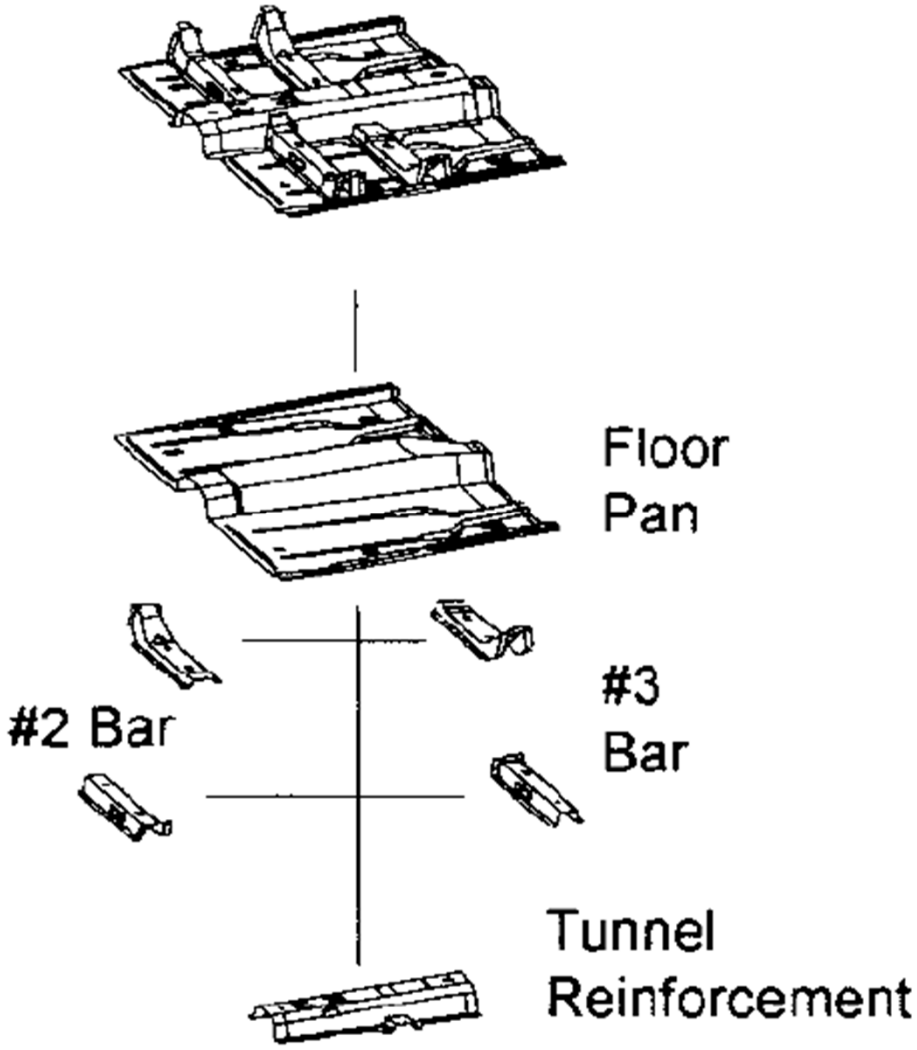
Underbody


Underbody Assembly
Motor Compartment
Rear Compartment
Floor Pan
Assembly

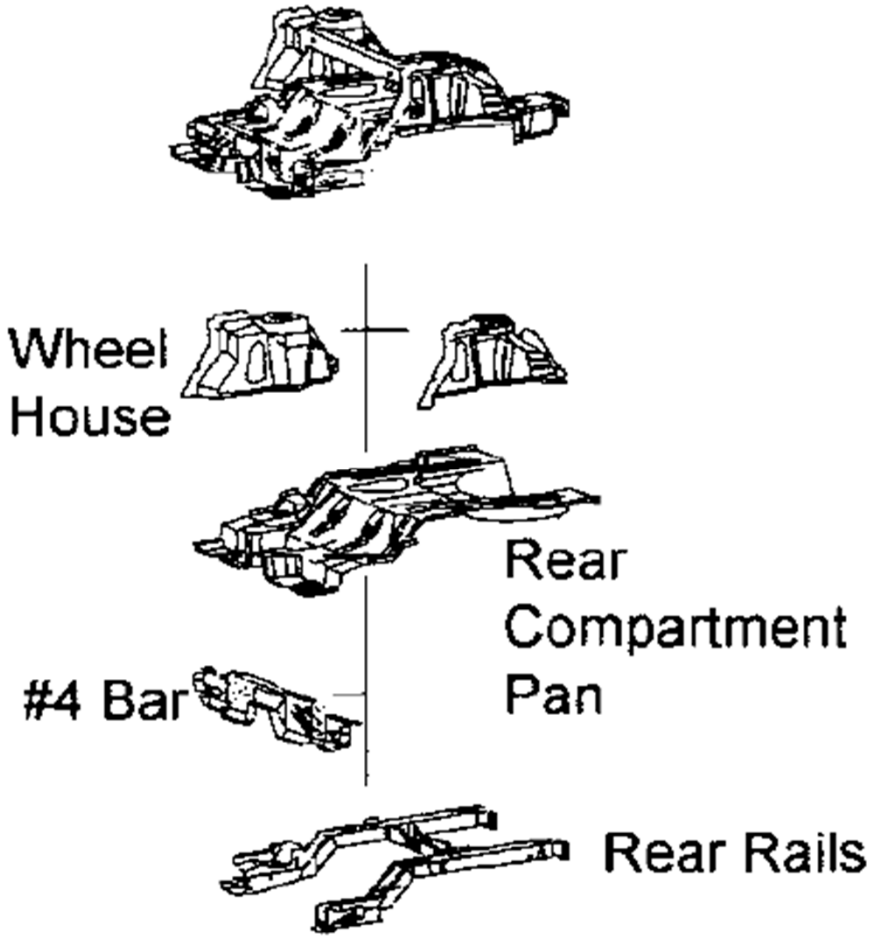
Motor Compartment



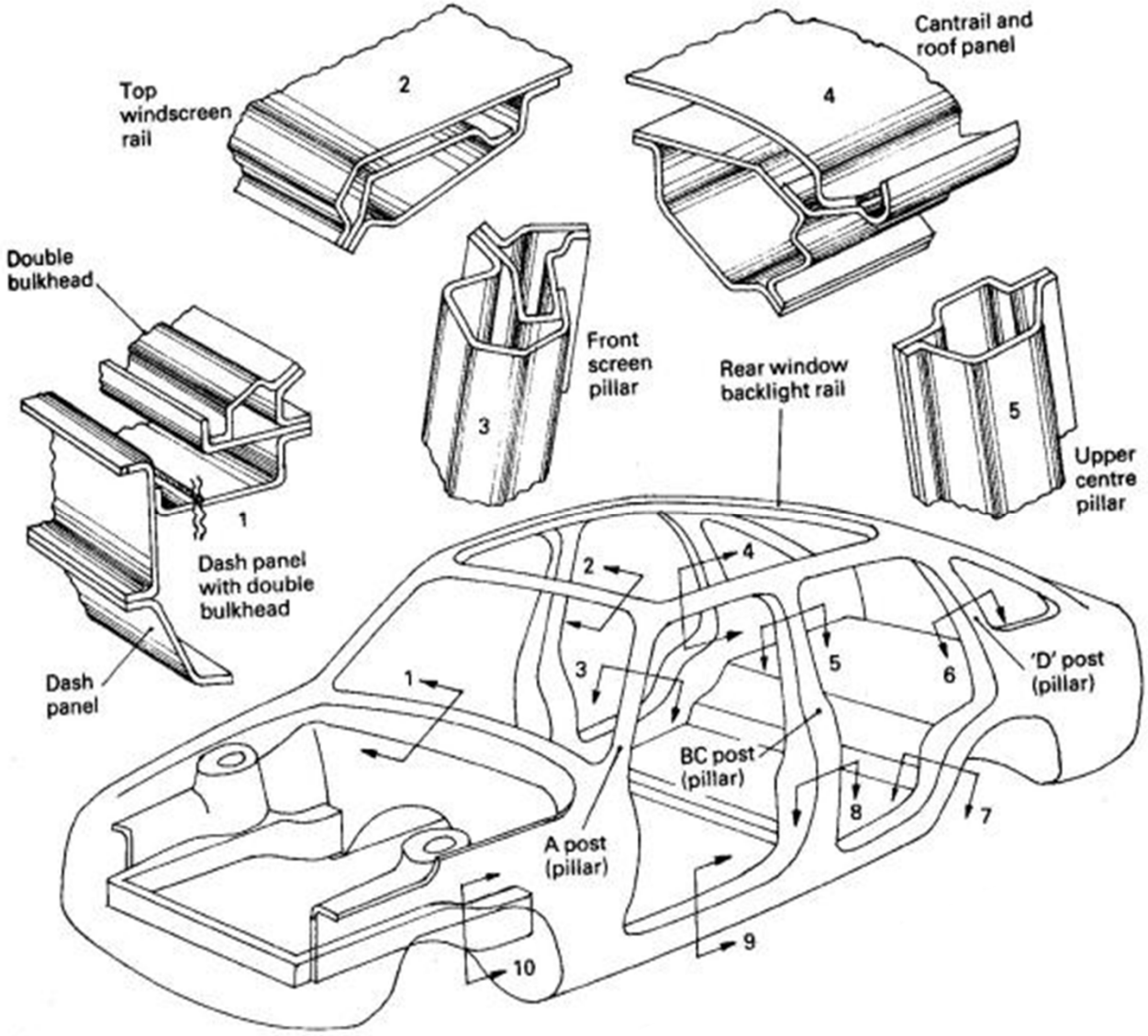
Floor Pan



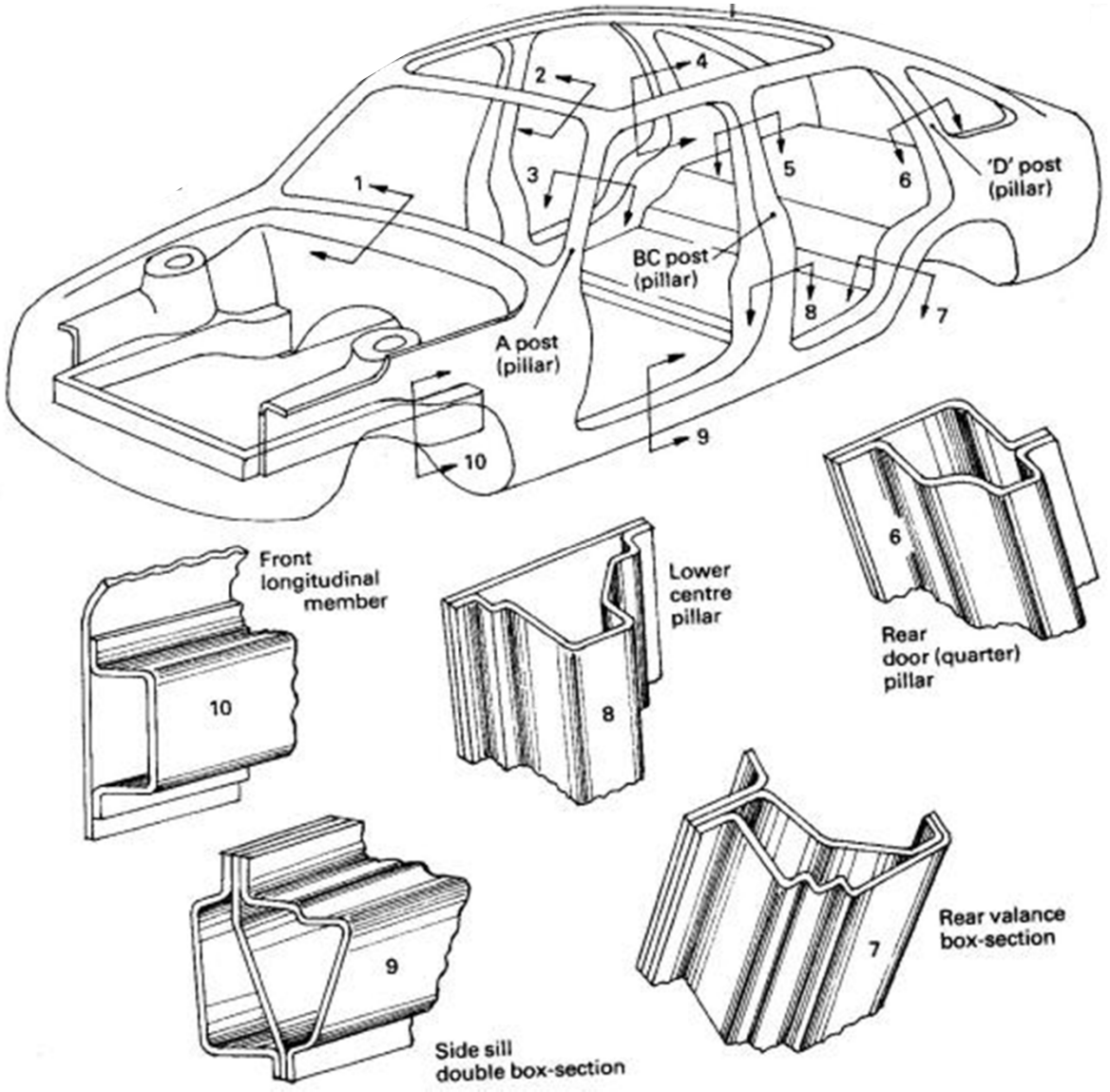
Rear Compartment



Load Bearing Body Box-Section Members

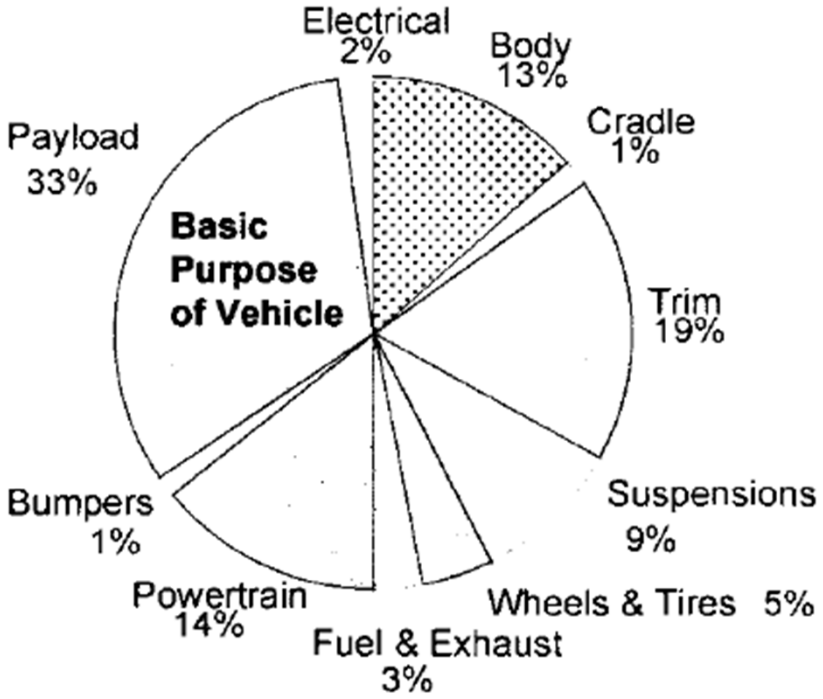


Load Bearing Body Box-Section Members



Body Mass Benchmarking: A2Mac1.com

- Mass ≈ 325 kg (100 sedans: 2002-2008 Model Year)
  - Body shell: no trim(내장), glass, closure(도어, 트렁크, 본닛)
  - Functions: fuel economy, acceleration performance, handling
- Structural efficiency < 0.2
  - (body structure mass)/(gross vehicle mass)



typical mid-size vehicle
- Integral body
- Front wheel drive

Mass Estimates (kg): small car

	ICE 1 2010	ICE 1 2020	HEV 1 2010	HEV 1 2020	FSV 1 $PHEV_{20}$	FSV 1 BEV
 Body Non-Structure	245	190	215	190	190	190
 Body Structure	272	241	272	237	173	190
 Front Suspension	59	40	62	45	40	45
 Rear Suspension	53	39	61	37	26	35
 Steering	17	17	17	17	16	16
 Brakes	38	31	40	33	29	32
 Drivetrain	222	197	297	252	215	78
 Fuel, Battery, Exhaust	48	55	104	105	98	347
 Wheels and Tires	78	59	68	55	38	44
 Air Conditioning	32	42	27	33	36	36
 Electrical	55	63	55	66	63	58
 Bumpers	26	21	23	24	20	23
 Closures	54	48	49	44	46	46
TOTAL	1199	1044	1290	1138	990	1,137

Source: Future Steel Vehicle: Phase I – Executive Summary (2009)

Mass Estimates (kg): mid-class car

	ICE 2 2010	ICE 2 2020	HEV 2 2010	HEV 2 2020	FSV 2 $PHEV_{40}$	FSV 2 FCEV
 Body Non-Structure	302	210	257	210	210	210
 Body Structure	337	298	337	303	198	175
 Front Suspension	73	49	76	55	51	44
 Rear Suspension	65	45	73	44	52	34
 Steering	21	21	21	21	19	19
 Brakes	47	37	49	40	37	34
 Drivetrain	274	244	359	304	261	177
 Fuel, Battery, Exhaust	59	68	125	127	178	114
 Wheels and Tires	96	72	80	73	70	61
 Air Conditioning	40	52	35	46	47	47
 Electrical	68	78	68	82	83	93
 Bumpers	33	25	31	28	26	22
 Closures	67	59	62	55	48	48
TOTAL	1,483	1,260	1574	1388	1279	1079

Source: Future Steel Vehicle: Phase I – Executive Summary (2009)

Lightweight Development (1)

Audi 80

Year of construction 1972

ca. 850kg

Audi A4

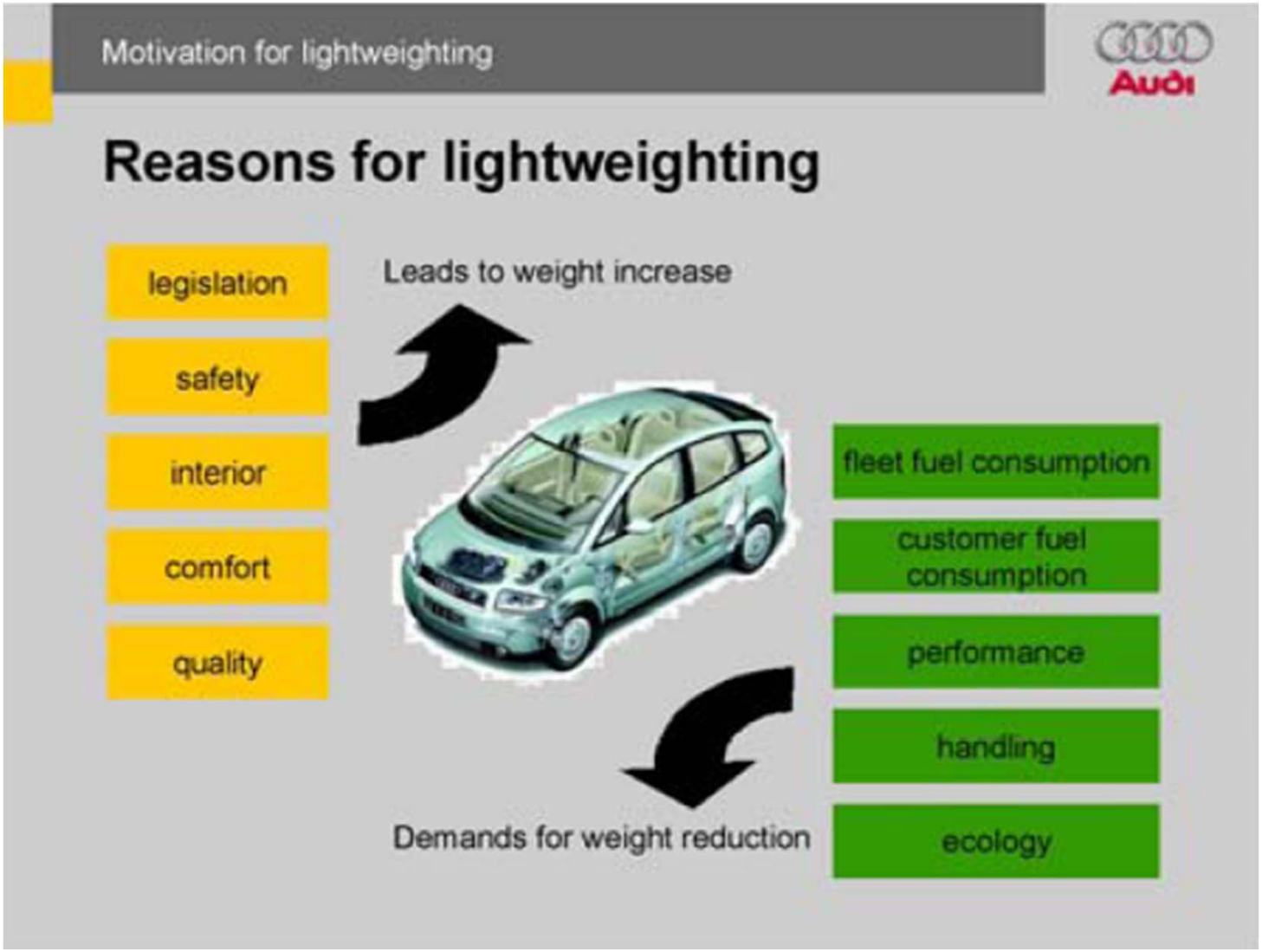
Year of construction 2007

ca. 1440kg

Example for drivers-assistant systems		
Comfort	**Safety**	**Infotainment**
Electric adjustment of: front seats steering column exterior mirrors	Speed and distance control system Adaptive Cruise Control (ACC) Electronic Stabilization Program (ESP) Anti-lock Brake System (ABS)	Radio Data System (RDS) Traffic Massage Channel (TMC)
Seat heating / ventilation / memory	Electro mechanical parking brake	Dynamic navigation
Power steering	Airbag	Emergency call
Air-conditioning	Seatbelt	Voice control
Auxiliary heating	Light and Rain sensor	
Coming home leaving home	Dynamic headlight range control	
Keyless entry	Lane change assistant	
Central locking system	Tire pressure monitoring system	

Source: Vieweg Handbuch Kraftfahrzeugtechnik, 3. Auflage

Lightweight Development (2)



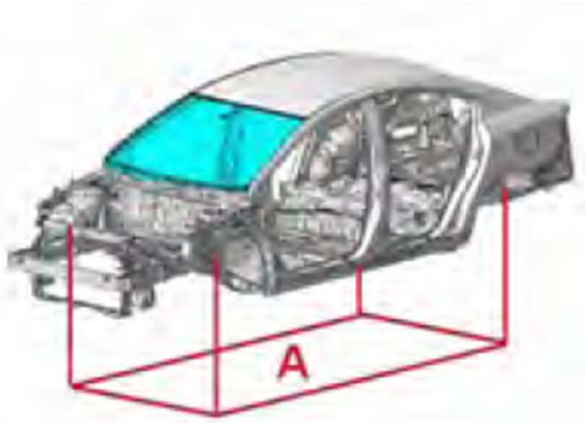
Body Structure - Lightweight Index

$$\frac{M_{BIW}}{C_T \cdot A}\left[\frac{kg}{N \cdot m/\deg \cdot m^2} \cdot 10^3\right] = 4.01$$

M_{BIW} [kg]: BIW mass including bolted elements and glued windscreen

C_t[kNm/deg] : Torsion stiffness of BIW including bolted elements and glued windscreen

A [m^2]: Projected area (wheel base · tread)



Vehicle	Lightweight Index (L)	Torsional Stiffness (kN-m/deg)	Body Mass (kg)	Contact Area (m^2)
FSV-BEV	2.56	20	190	3.71
SLC	1.8	25.5	180	3.9
VW Polo V (2010)	3.5	18	227	3.6
VW Golf V	2.88	25	281	3.9
Toyota Avensis (2008)	4.01	n/a	n/a	3.99

Lightweight Quantification

Lightweight quality $$L = \frac{m_{Ger}}{c_T * A}\left[\frac{kg}{\frac{Nm}{\circ} * m^2} * 10^{-3}\right]$$

m_{ger} = Body structure weight (without doors and closures)

c_T = Torsion stiffness (with screens)

A = contact patch (wheel track x wheel base)

Example: BMW 3rd series

316 (E30) – 1982

m_{leer} = 1030kg

m_{Ger} = 260kg

c_T = 6500Nm/°

L = 8,60

316i (E36) – 1990

m_{leer} = 1266kg

m_{Ger} = 310kg

c_T = 10300Nm/°

L = 5,67

316i (E46) – 1998

m_{leer} = 1385kg

m_{Ger} = 284kg

c_T = 20000Nm/°

L = 3,02

316i (E96) – 2005

m_{leer} = 1320kg

m_{Ger} = 267kg

c_T = 25000Nm/°

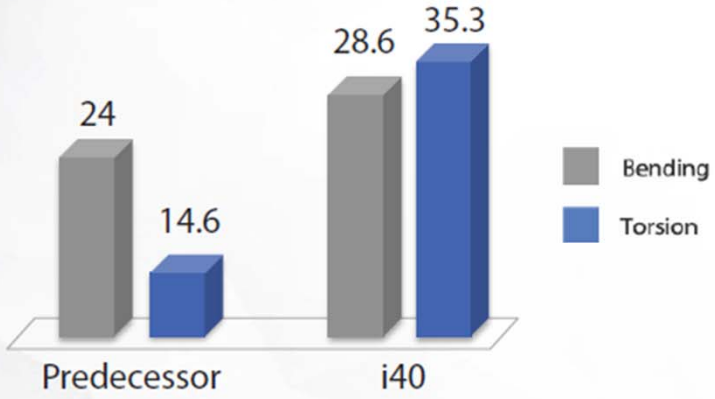
L = 2,58

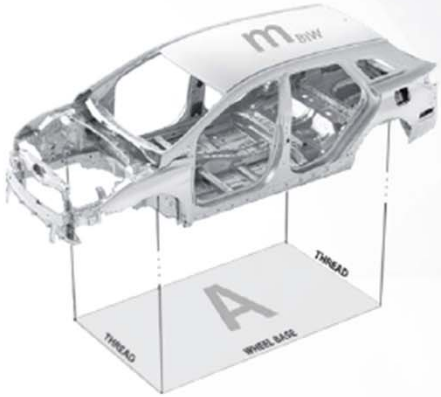
Source: B. Lüdtke, 1999

Body stiffness & lightweight index

- Increased the torsional stiffness by **141%** and the bending stiffness by **19%.**
- Achieved **11%** more torsional and **23%** more bending stiffness compared to competition

	i40	Predecessor
LIGHTWEIGHT INDEX	2.09	4.41
BIW WEIGHT	325.6	302.3
TORSIONAL STIFFNESS	35.3	14.6
AREA	4.415	4.69



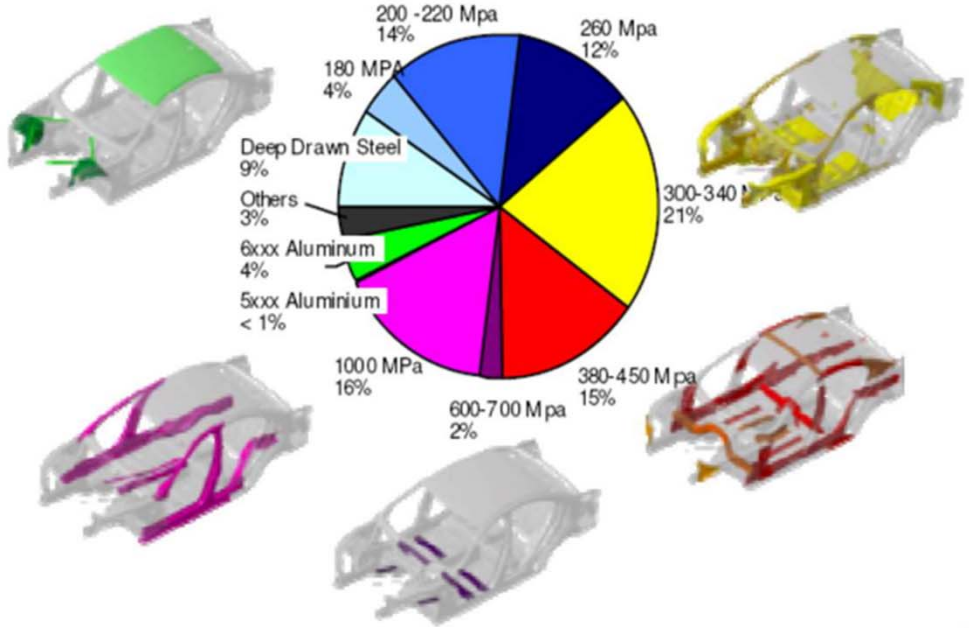


$$L = \frac{m_{BIW}}{C_T A} \times 10^3$$

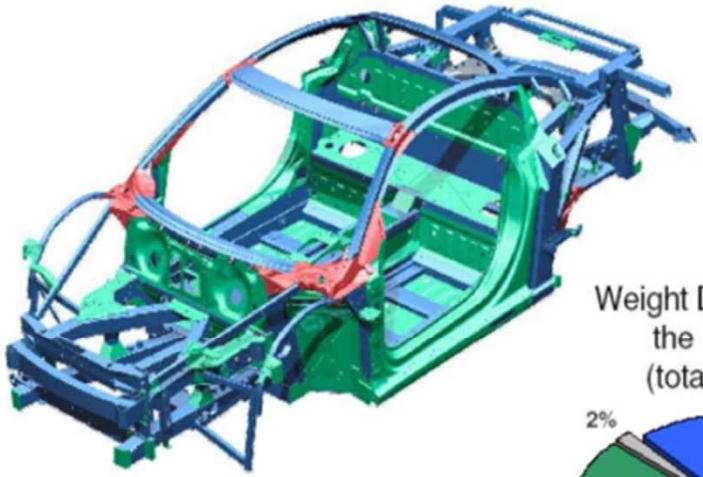
L	Body stucture efficiency index
m_{BIW}	BIW weight
CT	Body torsional static stiffness
A	Body projection area considering vehicle spec.

Lightweight Hybrid-Structure

BMW 7er

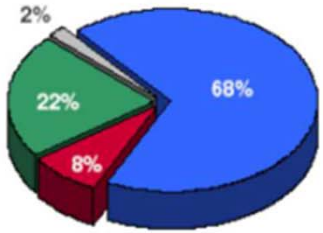


Audi R8



Vacuum die casting (aluminium)
Extrusions (aluminium)
Sheet (aluminium)
Vacuum die casting (magnesium)

Weight Distribution of the R8 ASF® (total: 210 kg)



Source: ATZ

Note

- System engineering approach to treat automobile body design
  - Breakdown of its physical parts or subsystems
  - Examining the functions the system must provide
- Design philosophy: primary design stage
  - Identify the small set of topology-defining structural requirements
  - Gain an intuitive feel for thin-walled structure behavior
  - Develop simple analytical models (first-order models) to approximate structure sizing
  - Gain an appreciation for the vehicle and manufacturing context of body design and the common trade-off issues which must be balanced