Session 5

Automotive Packaging

Session Speaker

Mr. V. R. Kiran
Session Objectives

At the end of this session the delegate would have understood

- Definition and different layout sectors in packaging
- Major factors influencing automotive packaging
Session Topics

1. Package Definition
2. Different Layout Sectors
   - Interior Dimensions
   - Front End (Engine Compartment)
   - Rear End (Luggage Space)
   - Underbody
3. Factors Influencing Vehicle Package
4. Regulatory Requirements
Package Definition

• Establishing body shapes and dimensions which defines the space available for all installed vehicle system and components
Package Definition

- First phase is to define the vehicle concept type, exterior dimensions, interior dimensions, and the main components
Layout Sectors

- Interior
- Front end (engine compartment)
- Rear end (luggage space)
- Underbody
Regulatory Requirements

- In United states: SAE standards (Society of Automotive Engineers)
- In Europe: ECIE (European Car Manufactures Information Exchange Group)
- In India: SIAM (Society of Indian Automobile Manufacturers)
Interior Dimensions

- Drivers seating position with seat longitudinal and vertical adjustments.
- For seat adjustment, outward visibility over the instrumental panel, headroom (H75), pedal reach ability, and all sight lines considered.
Interior Dimensions

- Dimensional layout depends upon:
- Body shape
- Type of drive
- Desired interior size
- Luggage compartment volume
- Driving comfort
- Driving safety and operating safety
Interior Dimensions

- Seating positions:
- Body templates or 3D CAD models (DIN, SAE, RAMSIS) were used with ergonomics finding.
- Body templates as per DIN 33 408 for men (5th, 50th and 95th percentile) and women (5th and 95th percentile)
Interior Dimensions

Seating positions:

• 2D manikin were used for comfortable seating position
• Verification for operating parts like steering wheel, gearshift lever and pedal
• Two types of manikins will be used: small female, 5th percentile with the height of 147.8 cm; and the tall male, 95th percentile with a height of 185.7 cm
Visibility Study

- Horizontal and vertical obstructions
- Seating reference point (SgRP)
- Define the position of the eye ellipse (SAE J 941) and eye points (RREG 77/ 649)(V1 and V2 in fig)
- Define hand reach to correctly position controls and actuators
- Determine the accelerator heel point (AEP) as a reference points for positioning the pedals
- Indicates the position of the design H-point position in rear most normal driver seating position in case of adjustable seats.

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Interior Dimensions

- Hip point
- Is the pivoted centre of torso and thigh
- The seating reference point (ISO 6549 and US legislation) or R-point (ECE regulations)

ECE: United Nations Economic Commission for Europe
www.crash-network.com/Regulations/ECE_Regulations/ece_regulations.html
Interior Dimensions

Horizontal Vision

- Traffic Light Vision Angle min. 14°
- Wiperfield Angle 10°
- Transparent Windscreen Area 7° Through V1 (77/649/EWG)
- Horizontal View Through V1
- Steering Wheel Rim Obscuration 1° Through V2 (77/649/EWG)
- Unobstructed Vision 4° Through V2 (77/649/EWG)
- Transparent Windscreen Area 5° Through V2 (77/649/EWG)
Interior Dimensions

Vertical Vision
Interior Dimensions

Gear Shift lever position

- Depends on the SgRP-position and on the torso back angle
Interior Dimensions

Rear Seating arrangement
- Space occupied by the rear axle and the fuel tank location and space
- Longitudinal dimensions are influenced by the height of the seating reference point above the heel point.
- Lower seats require greater interior space because of more stretched passenger seating position

The passenger compartment width depends on:
- Projected exterior width
- Shape of the sides
- Space require for the door mechanism
- Passive restrain system
- Position of propeller shaft tunnel and exhaust system
Interior Dimensions

- Investigate the necessary movement of steering wheel in both longitudinal and height position.
- Package investigation was performed using large male 95% manikin and small female 5% manikin positioned in the fixed seating.
• The rear seating concept features foldable seat back with 1/3: 2/3 split
• Rear end package
• Package the vehicle with or without spare wheel
Luggage-compartment Dimensions

- One of the important sales criterion for customers
- VDA norms the available volume is specified in liters
- Rear seat position determines the resulting luggage compartment volume according to ECIE volume definition
- Position of the fuel tank and its volume
- The position of spare wheel and the location of the muffler
Luggage-compartment Dimensions

- Position of the fuel tank may vary according to the location of the cross member and the rear suspension arrangement.
- The fuel filler routing is integrated into the body structure design with different rear end structures.
Exterior Dimensions

- Seating arrangement and luggage compartment
- Engine, transmission and Radiator
- Auxiliary and special equipments
- Type and size of drive axle
- Position and volume of fuel tank
- Front and rear bumper position
- Aerodynamic consideration
- Ground clearance
- Effect of body structure width on windshield wiper system
Exterior Dimensions - Engine Bay Package

- Safety
- Vehicle mass distribution
- Auxiliary Mass
- Body structure mass
- NVH
- Wheelbase
Exterior Dimensions - Engine Bay Package

- Auxiliary Mass
  - Short exhaust system with less mass
  - Packaging of Catalytic converter close to the exhaust manifold
- Body Structure Mass
  - Design lightweight front end with engine packaged below the front rails
Exterior Dimensions – Underbody

• Design of underbody based on the drivetrain, exhaust system, lines and hoses, fuel tank, and rear axle

• Mufflers represents the largest volume requirement in the tunnel and rear body area

• Underbody covers helps to reduce the aerodynamic drag in case of high performance cars
Exterior Dimensions – Under Floor Clearance

- Under floor Clearance depends on the vehicle load
- Under floor Clearance is defined as the summery of five different parameters
  - Curb Clearance front/Rear
  - Angle of Approach/Departure
  - Ramp Brakeover Angle
  - Oil pan Clearance
  - Ground Clearance
Exterior Dimensions – Under Floor Clearance

• **Curb weight:**
  
  o Weight of a vehicle equipped for normal driving conditions (Coolant, lubricants, and fuel tank filled up to 90%. Spare tyre, tool kit and car jack)

• **Design weight**
  
  o Vehicle curb weight + weight of the two passengers (68 kg each, with luggage 7 kg)

• **Gross vehicle weight**
  
  o Vehicle curb weight + maximum payload (5 passengers + luggage)
Exterior Dimensions – Under Floor Clearance

- Vehicle is positioned relative to zero grid Z plane

<table>
<thead>
<tr>
<th>Load Case</th>
<th>Distance from Zero Grid Z-Plane</th>
<th>Static Tire Radius</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A (mm) B (mm) R1 (mm) R2 (mm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Curb Weight</td>
<td>395 392 301 308</td>
<td>1350 kg</td>
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</tr>
<tr>
<td>Design Weight</td>
<td>413 417 301 305</td>
<td>1575 kg</td>
<td></td>
</tr>
<tr>
<td>Gross Vehicle Weight</td>
<td>415 462 303 300</td>
<td>1850 kg</td>
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</table>
Exterior Dimensions – Under Floor Clearance

Calculation of Road Surface Positions Relative to the Vehicle

<table>
<thead>
<tr>
<th>Load Case</th>
<th>Distance from Zero Grid Z-Plane</th>
<th>Static Tire Radius</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A (mm)</td>
<td>B (mm)</td>
<td>R1 (mm)</td>
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<tr>
<td>Curb Weight</td>
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<td>Design Weight</td>
<td>413</td>
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<td>301</td>
</tr>
<tr>
<td>Gross Vehicle Weight</td>
<td>415</td>
<td>462</td>
<td>303</td>
</tr>
</tbody>
</table>
Exterior Dimensions – Under Floor Clearance

Curb Clearance front/Rear

Angle of Approach/Departure

With road surface position related to the vehicle, the under floor clearance was determined

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Exterior Dimensions – Under Floor Clearance

Ramp brake over angle

Ground clearance

Oil pan clearance
Exterior Dimensions – Underbody
Exterior Dimensions – Fuel tank and Spare tyre

- Location of the fuel tank is based on the crash protection measures.
- For front engine vehicles, it is placed ahead of the rear axle.
- In rear-wheel-drive vehicles, tank location behind the rear axle would be preferable for better rear axle loading.
Exterior Dimensions – Fuel tank and Spare tyre

- Location of the fuel tank in mid-engined and rear engined vehicles (Porsche) are in a crash protected area behind the front axle
- The spare tyre is a major space consuming element.
- For front-engine vehicles it is located at the rear of the car consuming a space of 50 L to 80 L.
Regulatory requirements

• Direct influence on vehicle concept
  • Bumper height
  • Installation and location of lamps
  • Wiper fields
  • Driver's field of view
  • Interior dimensions
  • License plate location
Regulatory requirements

- Indirect influence on vehicle concept
  - Adequate crash deformation zones
  - Vehicle package locates expensive components in crash protected areas
  - Optimized location of catalytic converters
  - Optimized location of safety related equipments
- Air bag
- Safety belts
- Kneebar
  - Space consideration for activated charcoal canister
Regulatory requirements
Regulatory requirements
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Regulatory requirements
Regulatory requirements

- **H114** : Cowl Point Z Coordinate
- **A106 -1** : Angle of Approach **H106**
- **A147** : Ramp Breakover Angle **H147**
- **H156** : Ground Clearance
- **H107** : Angle of Departure
- **H195** : Liftover Height
- **H100 Body Height** : The vertical distance from the ground to the highest point on the body in white. Exclude all hardware and trim from this measurement (e.g., roof tracks, running lamps, antennas, spoilers)
- **H127** : Headlamp Height
- **H103 -1** : Fascia (Bumper) to Ground - Front **H103 24 23**
- **H103 -2** : Fascia (Bumper) to Ground - Rear
- **H128** : Taillamp Height
- **H503** : Pickup Box Height
Regulatory requirements

- L101 Wheel Base L101
- L103 Vehicle Length L103
- L104 Overhang – Front L104 17 21
- L105 Overhang – Rear L105
- L508 Minimum Loading Length (Width) Of Side Cargo Door
- L504 Cab to Pickup Body
- L507 Cargo Body Overall Length
- L506 Pickup Body Length at Top of Body
- L404 Cab to Rear Axle (CA)
- L505 Pickup Body Length at Floor
Regulatory requirements

- **W101** Track Width - Front
- **W102** Track Width - Rear
- **W103** Vehicle Width, Maximum
- **W106** Fender Width - Front
- **W107** Fender Width – Rear
- **W116** Body Width
- **W117** Body Width at SgRP – Front
- **W104** Vehicle Width, Including Mirrors
- **W105** Vehicle Width, Mirrors Folded
## Regulatory requirements

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Compact</th>
<th>Lower mid-range</th>
<th>Mid-range</th>
<th>Upper mid-range</th>
<th>Upper range</th>
<th>Vans</th>
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</thead>
<tbody>
<tr>
<td>Exterior dimensions (mm)</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Length (L103)</td>
<td>3,600–3,800</td>
<td>3,800–4,400</td>
<td>4,300–4,700</td>
<td>4,300–4,700</td>
<td>4,700–5,100</td>
<td>4,500–4,800</td>
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<tr>
<td>Wheelbase (L101)</td>
<td>2,350–2,500</td>
<td>2,400–2,700</td>
<td>2,500–2,700</td>
<td>2,500–2,700</td>
<td>2,700–3,000</td>
<td>2,700–3,000</td>
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<tr>
<td>Width (W103)</td>
<td>1,550–1,650</td>
<td>1,670–1,740</td>
<td>1,670–1,770</td>
<td>1,670–1,770</td>
<td>1,800–1,900</td>
<td>1,750–1,900</td>
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<tr>
<td>Height (H100)</td>
<td>1,350–1,480</td>
<td>1,330–1,440</td>
<td>1,360–1,430</td>
<td>1,360–1,430</td>
<td>1,400–1,500</td>
<td>1,650–1,800</td>
</tr>
<tr>
<td>Interior dimensions (mm)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Legroom, front (L34)</td>
<td>960–1,080</td>
<td>970–1,080</td>
<td>1,000–1,100</td>
<td>1,000–1,100</td>
<td>1,000–1,100</td>
<td>970–1,080</td>
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<td>Headroom, front (H61)</td>
<td>920–1,000</td>
<td>940–1,010</td>
<td>950–1,010</td>
<td>950–1,010</td>
<td>980–1,020</td>
<td>1,000–1,050</td>
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<tr>
<td>Shoulder room, front (W3)</td>
<td>1,280–1,360</td>
<td>1,340–1,440</td>
<td>1,340–1,460</td>
<td>1,340–1,460</td>
<td>1,450–1,500</td>
<td>1,500–1,650</td>
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<tr>
<td>Legroom, rear (L51)</td>
<td>730–920</td>
<td>760–880</td>
<td>750–920</td>
<td>750–920</td>
<td>900–1,000</td>
<td>800–900</td>
</tr>
<tr>
<td>Headroom, rear (H63)</td>
<td>900–970</td>
<td>900–980</td>
<td>910–980</td>
<td>910–980</td>
<td>950–990</td>
<td>950–1,000</td>
</tr>
<tr>
<td>Luggage capacity (liters)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trunk volume</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>Representative vehicles (2000)</td>
<td>VW Polo 3</td>
<td>VW Golf 4</td>
<td>Audi A4</td>
<td>BMW 5 Series</td>
<td>Mercedes S Class</td>
<td>VW Sharan</td>
</tr>
</tbody>
</table>

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Package Drawings

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Package Drawings
Package Drawings
Factors Influencing Vehicle Package

Vehicle Concept

Major characteristic are :

- Power plant location (front, rear or mid-engine)
- Drivetrain concept (front, rear, all-wheel drive)
- Power plant orientation (transverse, longitudinal)
- Number of seats
- Comfort characteristics (e.g. leg room)
- Storage capacities
Engine Location

- Front engine
- Mid-engine
- Rear engine
- Mid engine configurations
Front Mounted Engine

Characteristics

• Engine and transmission are conjoined and mounted ahead of passenger compartment (either longitudinally or transversely).

• The radiator and air conditioning condenser are mounted ahead of engine at the front of the vehicle.

• Drive train may be front, rear or all-wheel drive.

• Transverse mounting is used for front- wheel drive vehicles.

• For rear- wheel drive, longitudinal mounting is employed exclusively due to its simpler drive train and vibration advantages.
Front Mounted Engine

Advantages:

• Compact package permits short lines to all auxiliary devices, radiator, and heat exchangers.

• In the case of frontal impact, early contact of power plant blocks with the crash partner receives loading of body shell structure by power plant inertia force.

• This configuration provides adequate space for exhaust system and fuel tank in the underbody area and at the rear of the vehicle.
Front Mounted Engine

Disadvantages:

• Transverse engine installation are limited to a maximum of six cylinder
• Transmission size is also severely restricted by installation length limitations (direct effect on vehicle width)
• Reduced traction potential with increased rear wheel loading due to dynamic load transfer under acceleration and ascending grades.
Front Mounted Engine

VW Golf (Traverse front engine, front-wheel drive)
Front Mounted Engine

Audi A6 (Longitudinal front engine, front-wheel drive)
Front Mounted Engine

BMW 3 Series (Longitudinal front engine, rear-wheel drive)
Rear Mounted Engine

Porsche 911 Carrera (Longitudinal rear engine, rear-wheel drive)
Rear Mounted Engine

Characteristics

• The radiator and air conditioning condenser are mounted ahead of the engine at the front of the vehicle.
• The transmission is mounted ahead of the longitudinal engine.
• Best e.g. Porsche 911 Carrera.
Rear Mounted Engine

Advantages:

• Compact package permits short lines to all auxiliary devices, radiator, and heat exchangers.

• Engine location behind rear axle leads to high rear end weight distribution (>60%) and therefore outstanding traction.

• No heat loading of the interior occurs through thermal radiation from power plant.

• Flat tunnel (no driveshaft or exhaust pipe).

• Longitudinal installation of power plant permits simple realization of all-wheel drive to front axle.
Rear Mounted Engine

Disadvantages:

- Need for sophisticated suspension concept to achieve good vehicle dynamics.
- Long lines are required for water cooling with front-mounted radiators as well as for heating and air conditioning system.
- Body variability at the rear of the car is restricted by power plant space requirement.
Mid - Mounted Engine

Porsche Boxster (Longitudinal mid-engine, rear-wheel drive)
Mid - Mounted Engine

Characteristics:

• Classic sport car configuration with engine located ahead of the rear axle

• Engine may be mounted longitudinally (transmission behind the engine) or transversely (analogous to transverse front engine).

• Due to the space requirement of engine and transmission unit, only two seat design are practical.
Mid - Mounted Engine

Advantages:

• Relatively high rear weight distribution (>52%) due to the engine location ahead of the rear axle provides very good traction characteristics.

• Low heat loading of the interior occurs due to thermal radiation from power plant.

• Additional trunk at rear is possible; and tunnel is flat.
Mid - Mounted Engine

Disadvantages:

• Body variability at the rear of the car is restricted by power plant space requirement.

• This configuration is exclusively limited to two seat vehicle.

• With longitudinal mounting, placing the transmission behind the engine requires long shifter cable and make all-wheel drive impossible.
Front Engine/ Under floor Concept

• This structure is called "Sandwich" because the horizontal-orientated engine is placed above the floorpan but under the cabin.

• The cabin is raised by a massive 200 mm and so is the roof.

• Made the car more compact than any other cars but simultaneously offers class-leading cabin space by providing very compact and space saving engine location

• Providing flat engine and transmission that fit within the available space between firewall and front axle.
Front Engine/ Under floor Concept

Mercedes-Benz A-Class (Transverse front underfloor engine, front-wheel drive)
Front Engine/ Under floor Concept

- It provides exceptional crash-protection. Under crash, the engine will be pushed underneath the cabin instead of pushed towards the driver's legs as conventional cars.

- Due to the inherent advantage in crash-protection, no additional crash structure is needed, thus a lot of weight is saved.
Rear Engine/ Underfloor Concept

• Transverse engine, transmission, and rear axle are combined into very compact assembly.

• This concept is a solution for urban problem of inadequate parking space.

• This concept strictly meant for two seater configuration like microcar.
Rear Engine/ Underfloor Concept

Smart (Transverse underfloor rear engine, rear-wheel drive)
Summary / Conclusion

- Definition and different layout sectors in packaging have been discussed
- Major factors influencing automotive packaging and the regulatory requirements have been introduced