Hindalco Industries Limited

Light weighting in Transport and Railways

INCAL ,January 2019

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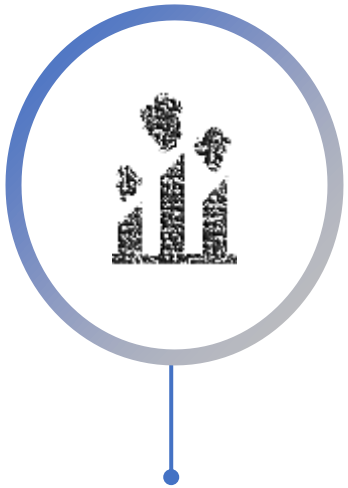
Aluminium advantage for long term sustainability

Light-weighting: Fuel Saving

~40% weight savings in typical compact class car body as compared to Steel



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17% reduction in CO2 emission through light-weighting

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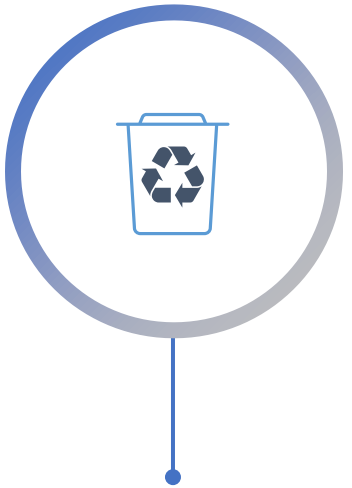
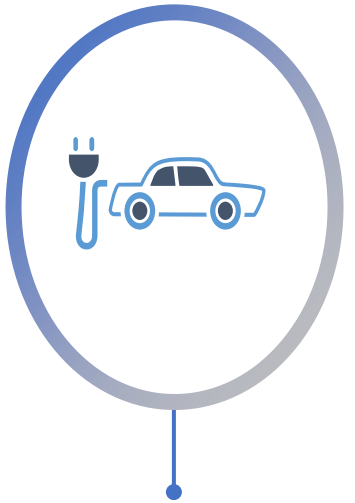
High stiffness, rigidity & crash absorption improves passenger & pedestrian safety



Sustainability: the Circular Ecosystem of aluminium



EV penetration

Greater need for light-weighting, thermal transfer capabilities for battery boxes

Aluminium advantage for long term sustainability

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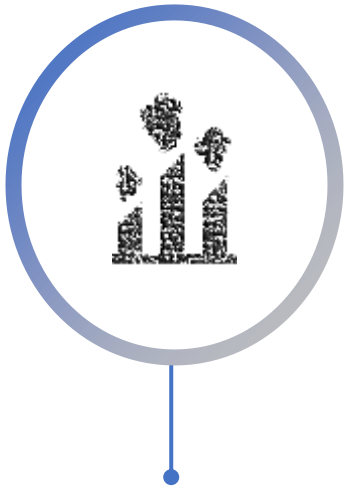

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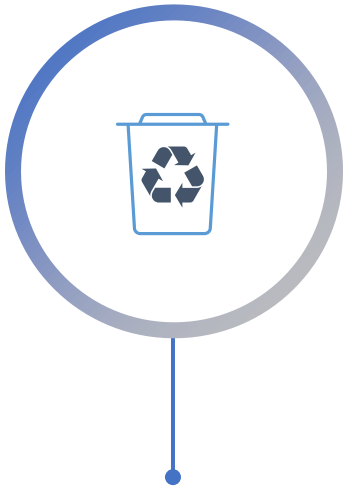

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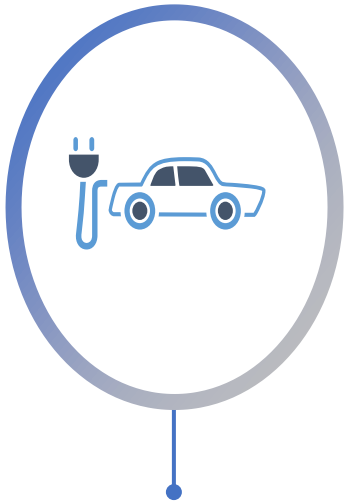

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Light Weighting, Biggest Driver for Aluminium use in Car

Life Cycle Assessment (LCA) enables automakers to consider effects across the whole life of a product.

An aluminum-intensive vehicle can achieve up to a **20% reduction in total life cycle energy consumption**.[1]

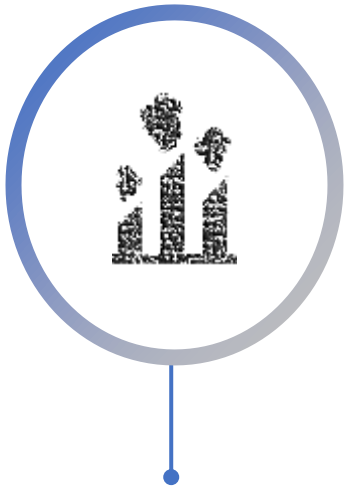
By incorporating aluminum into its design, Jaguar Land Rover lowered the Range Rover's body mass by 420kg.

0.4ltr per 100km per 100kg weight reduction for petrol engine (0.3ltr for diesel)

Utilizing the full potential of aluminium physical properties into long term sustainability

Light-weighting: Fuel Saving

~40% weight savings in typical compact class car body as compared to Steel



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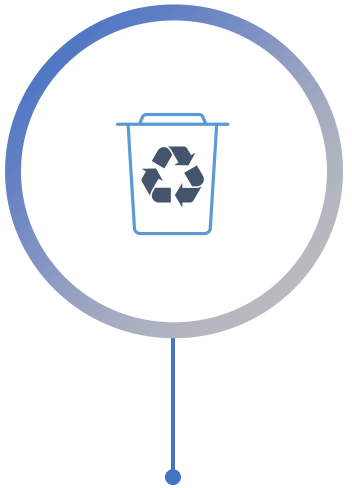

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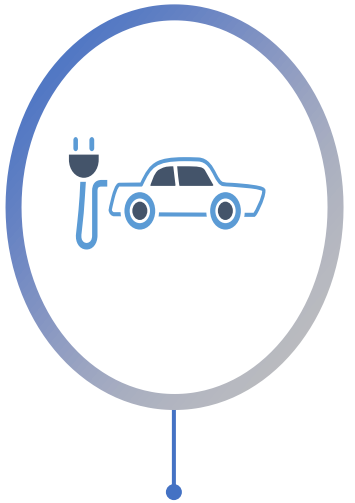

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Light-weighting resulting in reduced CO2 Emission

17% reduction in CO2 emission through light-weighting

- An aluminum-intensive vehicle can achieve up to a 17% reduction in CO_2 emissions, in total life.
- By incorporating aluminum into its design, Jaguar Land Rover lowered the Range Rover's body mass by 420kg and reduced the environmental footprint by 13.8%
- 0.9kg of CO2, exhaust pipe emissions, reduction per 100km per 100kg saved on the mass of a passenger car

CO2 Emission Norms- Global vs India

India much behind other countries- norms and enforceability

	2010-15	2016-20	2021-25	CAGR reduction 15-20	Fines and incentives by regulatory authorities
EU	145-130[1]	130-95	95-78	6.5%	**High Fines**: €5,15 & 25 for first 3 CO2 over limits, €95 from 4th onwards; Higher taxes for less efficient cars
USA	170-140	140-93		4.5%	**High Fines**: $5.5 per tenth of mpg shortfall alongside sales restriction for defaulters
Japan	140-125	125-105		3.5%	**Low Fines but public proclamation of OEM Incentives**: Tax incentives (20-30%) depending on emission levels
China	180-167	167-117		7.5%	**High fines; higher tax for less efficient cars**
India	137-130	130-113		2.5%	**No penalty/incentive structure to support CO2 norms**

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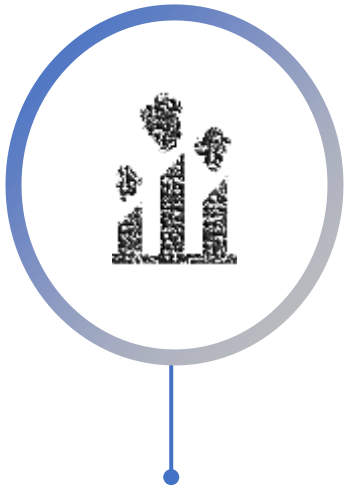

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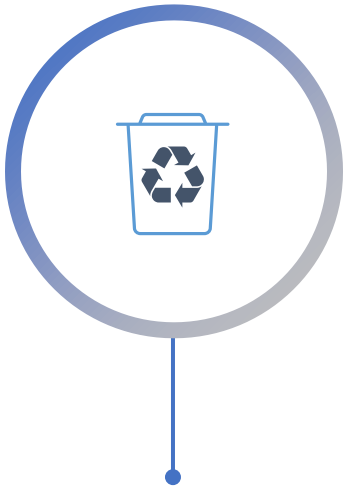

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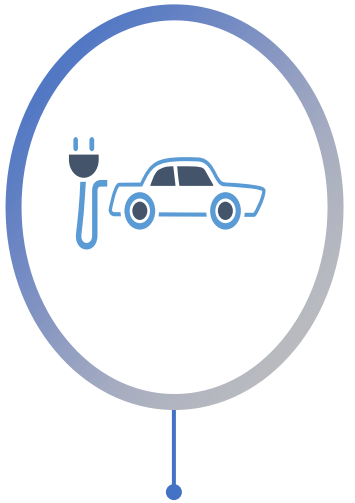

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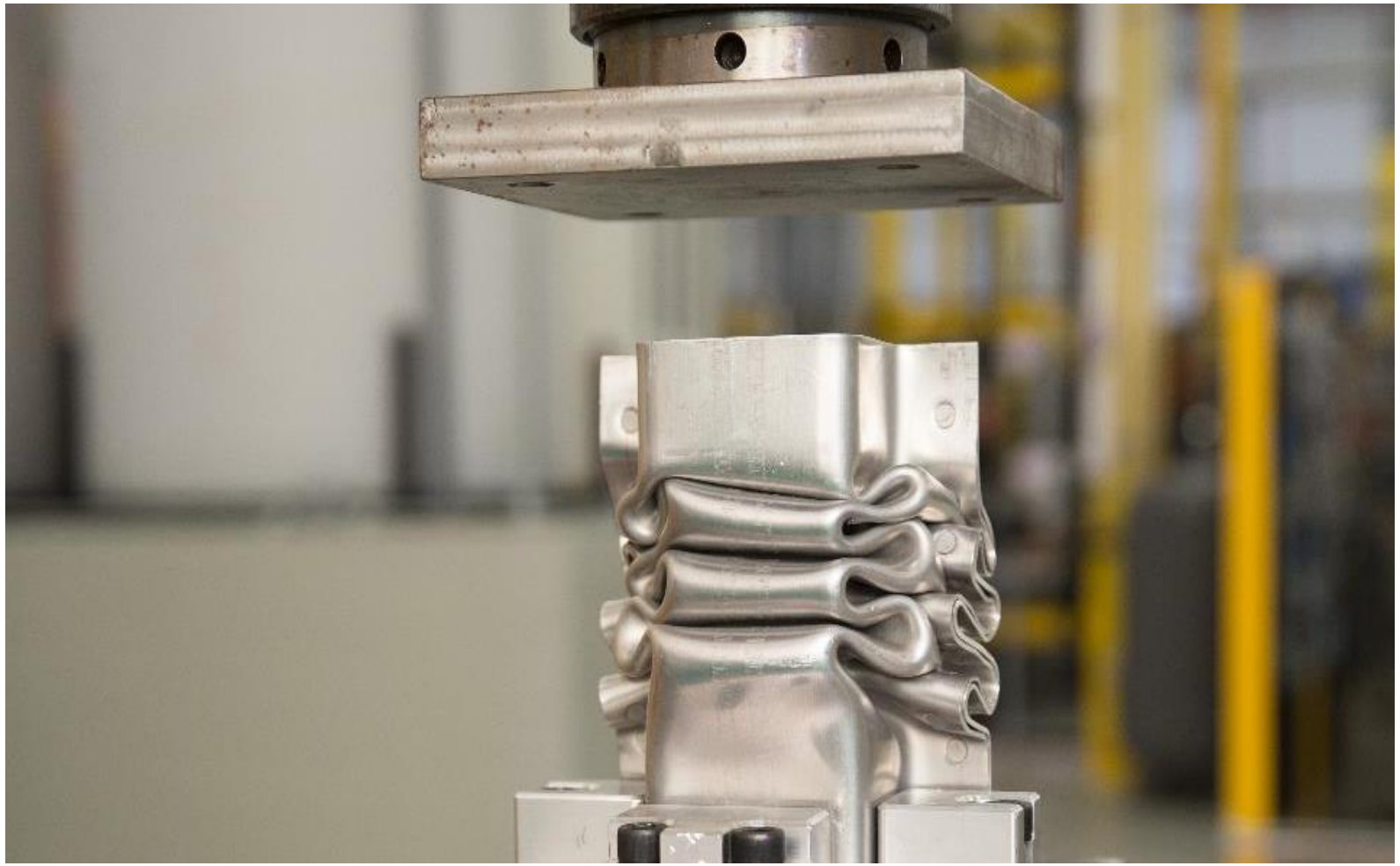
Aluminium is the Choice For Safety

2x energy absorption vs steel



Pound for pound, aluminum can absorb two times as much energy as steel.

Aluminum components can be designed to fold predictably during a crash, allowing the vehicle to absorb a significant amount of crash energy before it impacts the passenger compartment.

Aluminium is the Choice For Safety


The London Free Press

LEADING LADIES

SHINING KNIGHT

Tax hike down to 2.8%

Libraries may dose as a result

Firefighters win police wages

Chilling scene: Surprisingly, nobody was hurt in this automobile sandwich on Highway 402.


Chilling scene: Surprisingly, nobody was hurt in this automobile sandwich on Highway 402.

Photo supplied by OPP

ght in the middle of a chain-reaction crash on Highway 402 yesterday when it collided with a flatbed truck. A Robert Q van then slammed into the car, and landed on top of it before a e rear, Lambton OPP said. Const. John Reurink said miraculously, no one was hurt in the crash. For more on the story, see Page B3.

Thanks to Aluminum, no one was hurt in this accident

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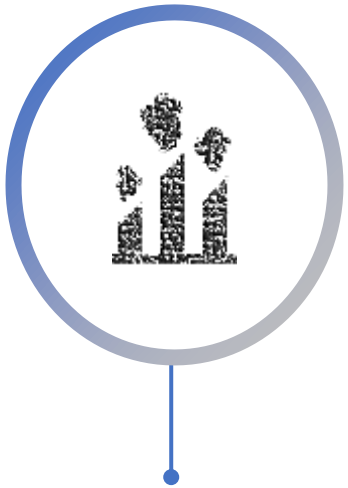

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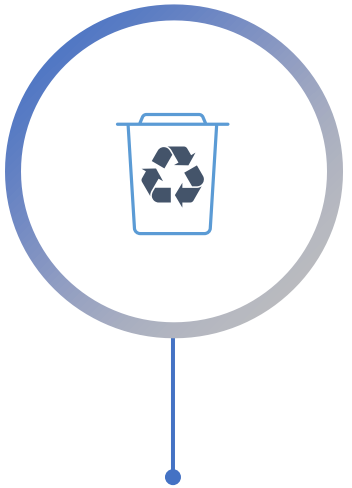

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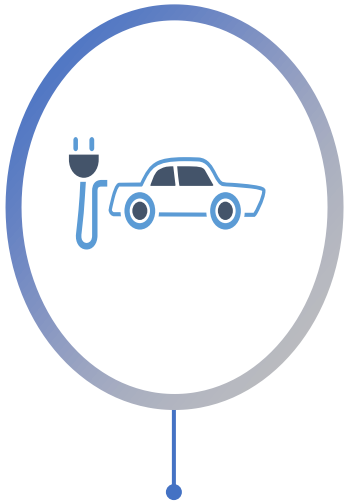

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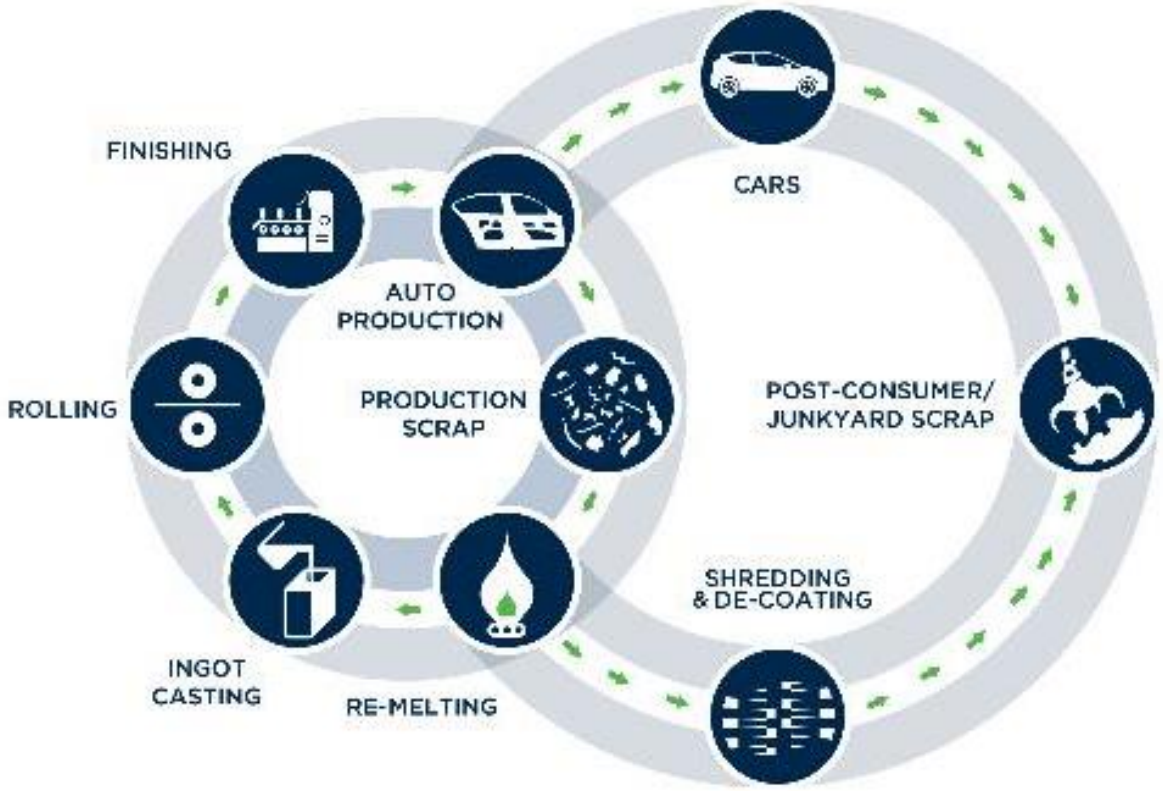
Greater need for light-weighting, thermal transfer capabilities for battery boxes

Creating Sustainable Value Through Closed-Loop systems

Potential to created a closed loop ecosystem- further minimising environmental impact



Novelis and Ford developed the world's largest closed-loop recycling system for their most popular lineup of aluminum-intensive trucks.

As a result, Ford recycles and reuses more than 90% of scrap – enough to produce 30,000 F-150 bodies each month.

- **Aluminum is ~100% recyclable**
- **Reduces life cycle cost, energy consumption, emissions – Minimizes environmental impact**

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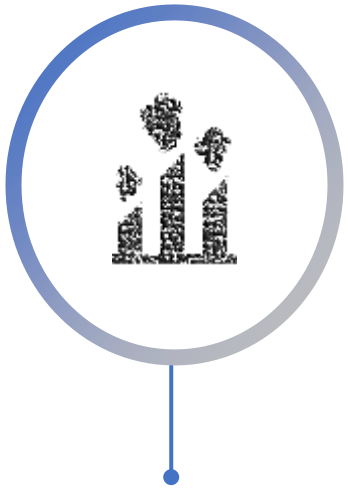

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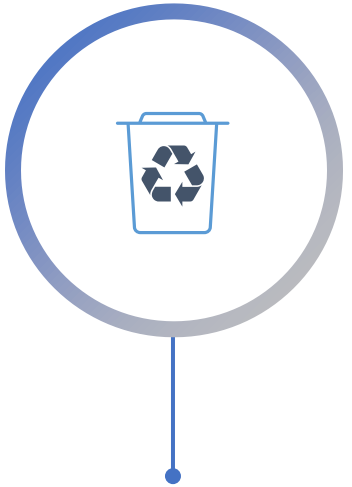

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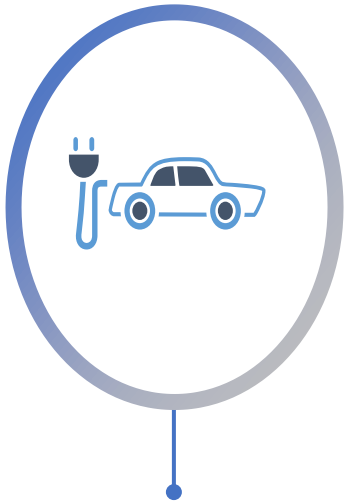

EV penetration

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Aluminium in Electric Vehicle

Reduced Weight and Increased Range

By reducing the weight of an EV by 20%, the driver can go 20% farther on a single charge.

JAGUAR I-Pace

- **94%** Aluminium construction -use in body structure, suspension links & knuckles
- **Aluminium extrusion battery box** providing advanced thermal management

TESLA Model S

- Body and chassis built entirely from Al
- Total amount of Al used – **200 kg**
- A/B pillars, rocker reinforcements, battery box

NIO 蔚来 ES8

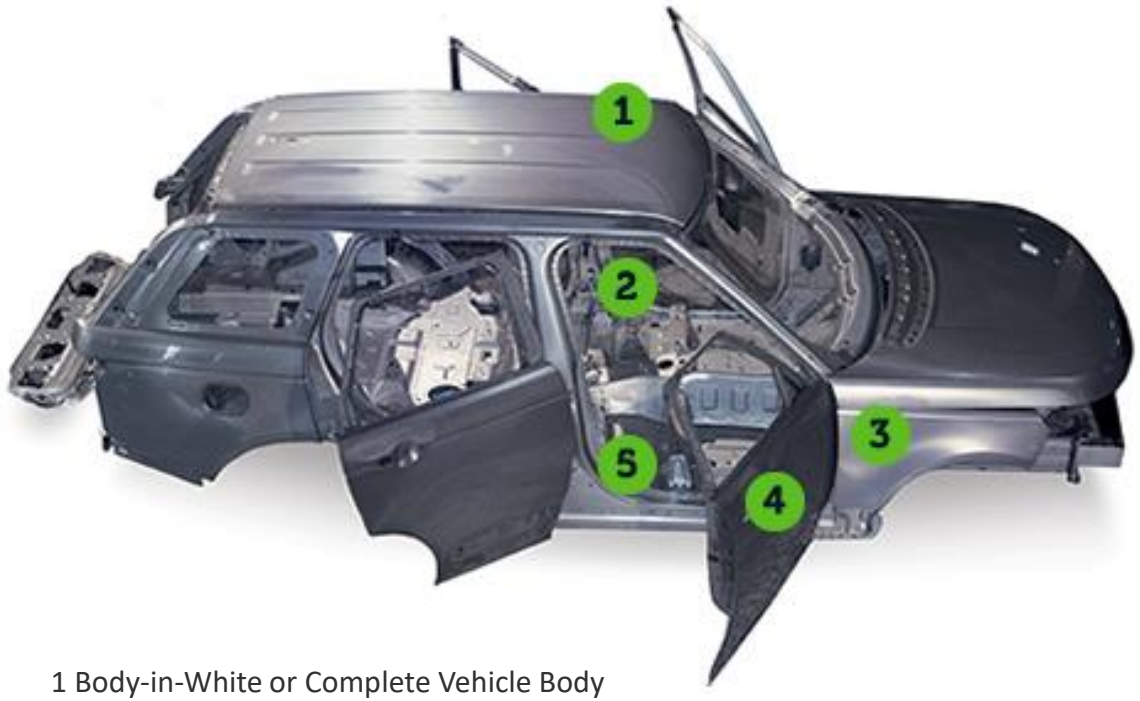
- All Aluminium body & chassis featuring aero grade 7003 alloy
- **Highest amount of Aluminium** for any mass production car

Aluminium in Passenger Vehicles

Aluminium Usage in PV

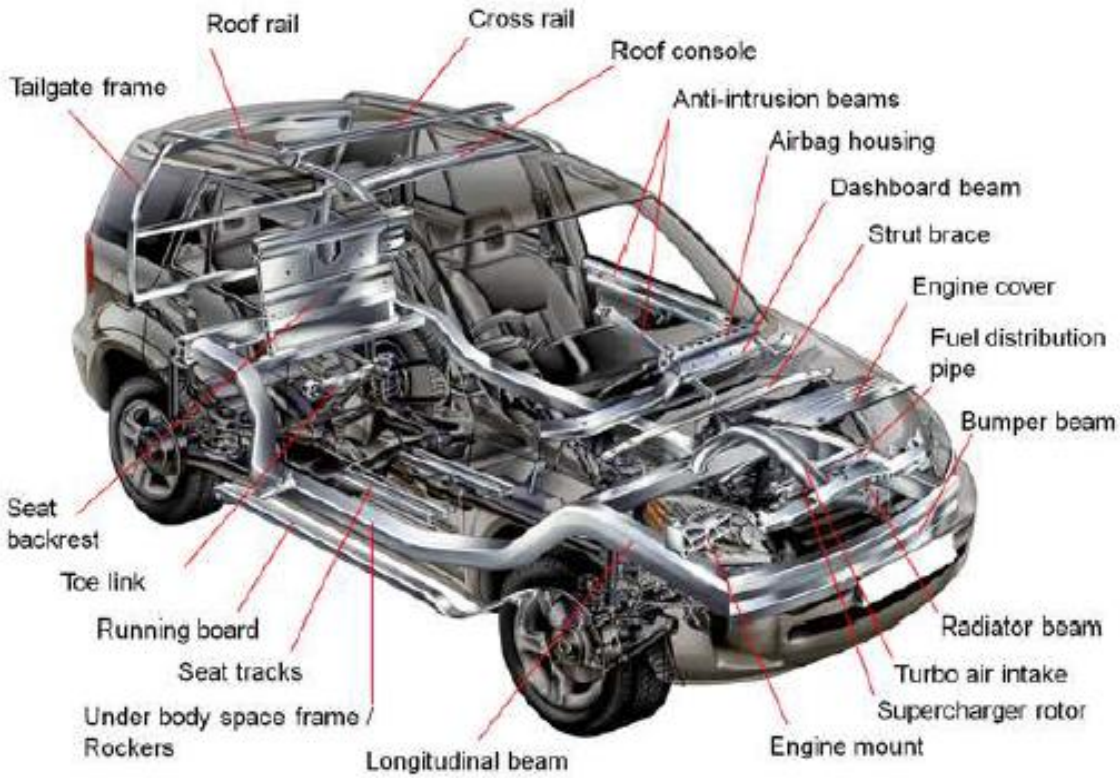
Range of Extrusion & Flat Rolled Product Applications

Usage of Flat Rolled Product



1 Body-in-White or Complete Vehicle Body
2 Structural Components
3 Body Panels and Side Walls
4 Doors, Hood and Trunks
5 Car Trims and Sealing's

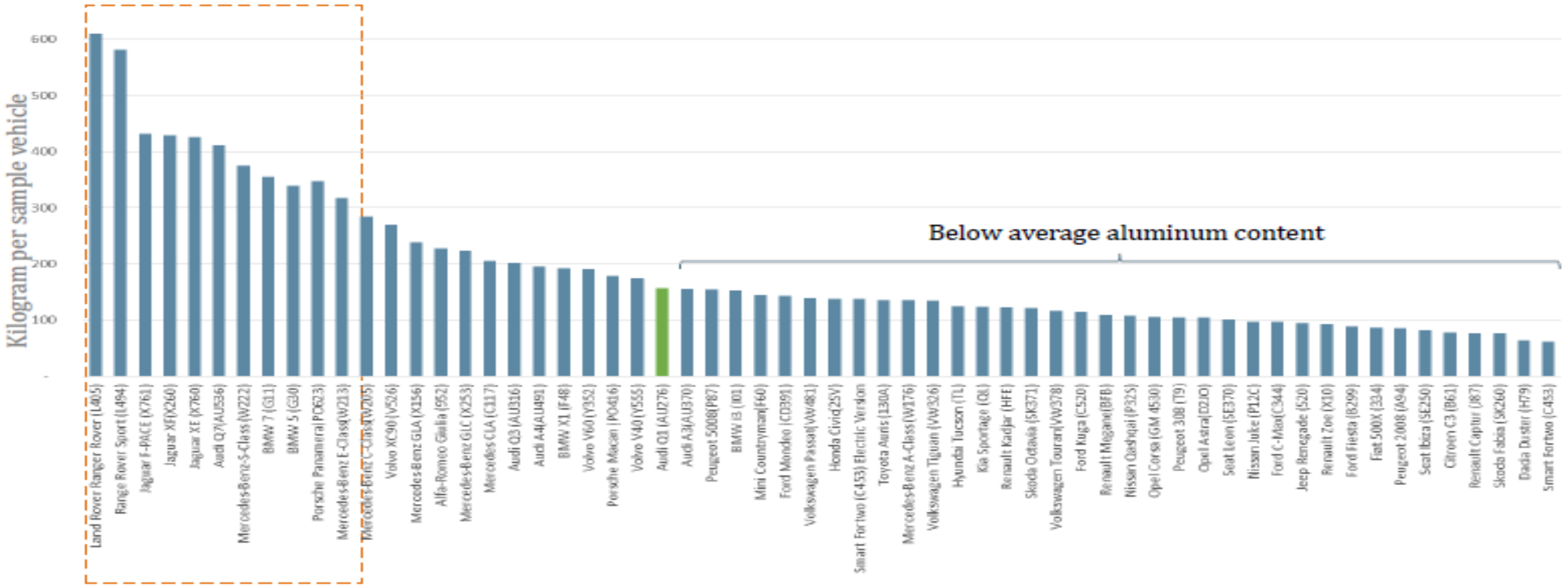
Usage of Extrusion



Using advanced lighter-weight aluminum body structures can save up to $3,000 per vehicle

Aluminium Content in PV

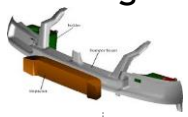
Ranges from 62kgs to 610 kgs; AIV average of RS 412 kgs



Evolution of Aluminium Usage in Passenger Vehicles

Sub-segment

~1985
Crash Management systems



~2000
Cradles & sub-frames

~2015
Battery boxes

Heat exchanger
1980

Extruded forging stock
1990

Body structure
~2000

Specialty accessories
~2005

Brakes & Suspension
~2010

OEM early adopters

Chevrolette Corvette
Al extrusion in wind-shield and front-end

BMW 5 Series
Use of Al in the front suspension

Ford F150
Whole Al body
SAPA - structural tubing

Tesla Model S
Body and Chassis, battery box
>100 kg extrusion

Audi A8
First car to use Al extrusion

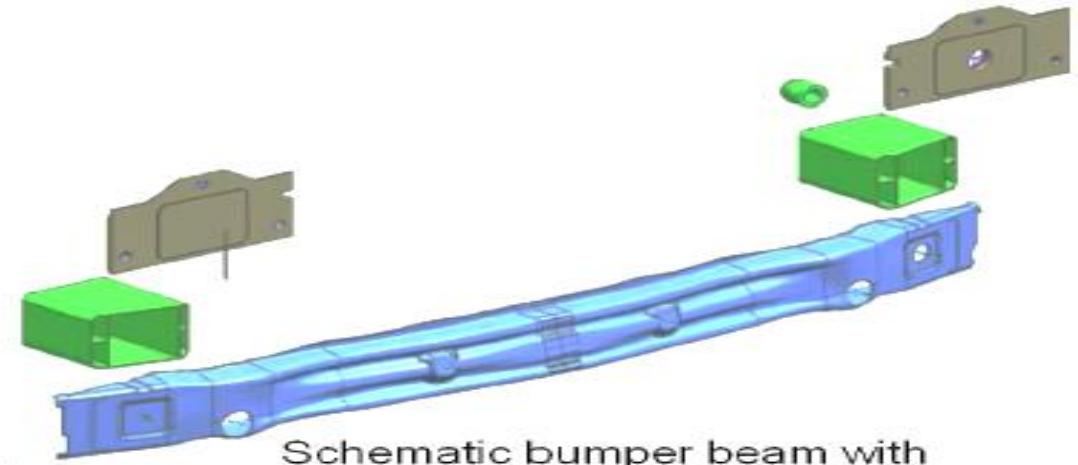
BMW Z8
2500-3000 annual prodn.

Rolls-Royce Phantom

Jaguar XJ
First use of all-alloy Al monocoque

Crash Management System

Increased safety + Weight Reduction



Schematic bumper beam with open section

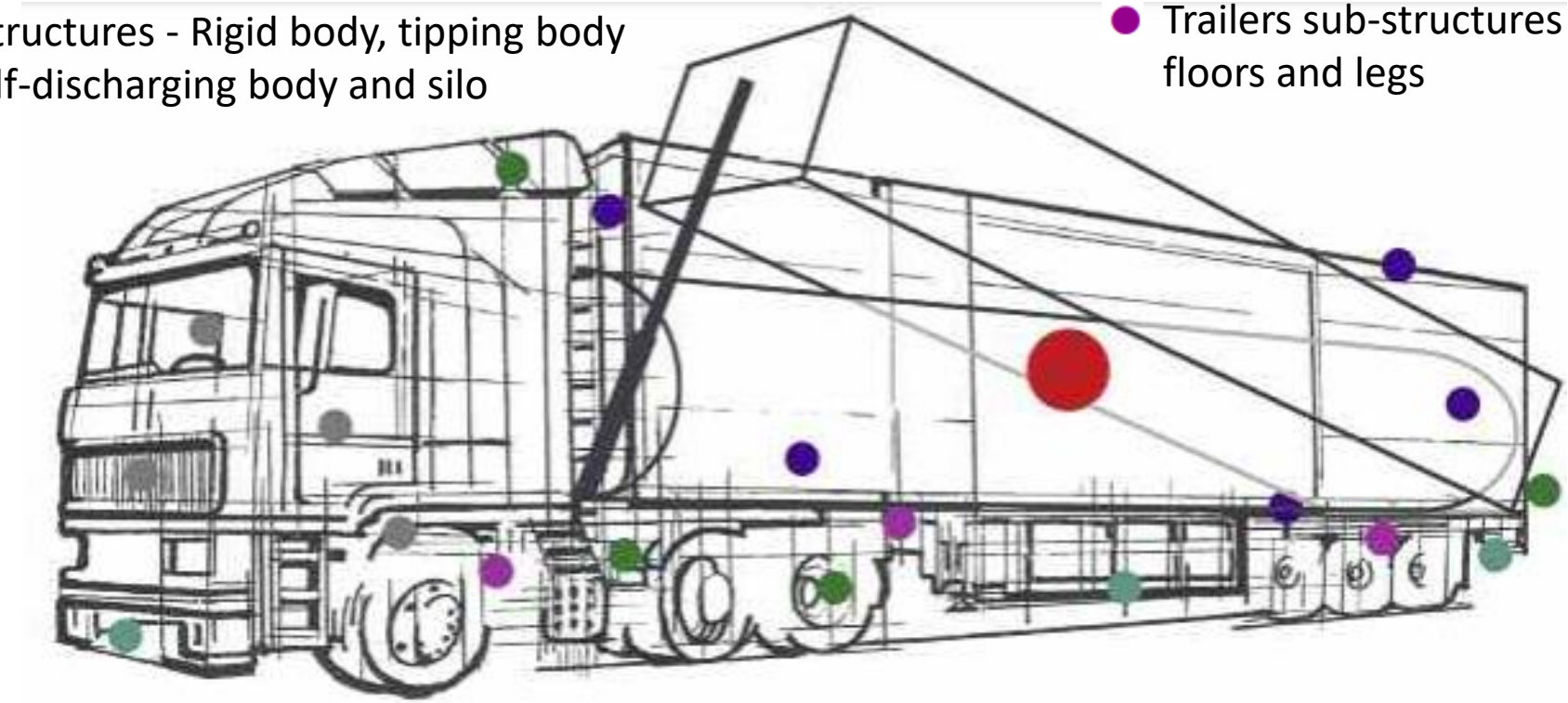
- **Bumper systems** – Al can achieve **30-40% weight reduction at little incremental cost**
- Greatest need for light-weighting in front section of car
- Need for higher strength and energy absorption in CMS – Aluminium is ideal solution
- Crush cans – right area of car to substitute steel with Aluminium, minimal incremental cost
- **Weight of Steel bumper system[2] - ~25 kg**
  Weight of Al bumper system - ~15 kg

Aluminium in Commercial Vehicles

Application Segments in CV

Used across segments

- Components for tractors & rigid trucks - Cabin & door, Chassis, powertrain parts and suspension parts
- Complete superstructures - Rigid body, tipping body ADR fuel tank, self-discharging body and silo
- Components for superstructure - Curtain rails, front wall, side boards, stanchions and rear door
- Safety parts – Bumper, front and rear under-run protections
- Trailers sub-structures – Chassis, floors and legs
- Accessories - Air pressure vessels, diesel tank, toolbox, tail lift and wheels



Evolution of Aluminium Usage in Commercial Vehicles

Parisian bus
First Al usage in bus
1910

Al used for superstructure components, cabin & door
1930

First use of Al in tanker, vans, tippers
1950

Diesel tank
tail lift
tool box

Doors/Window frames
beading joints

Widespread usage of Al starts
1980s

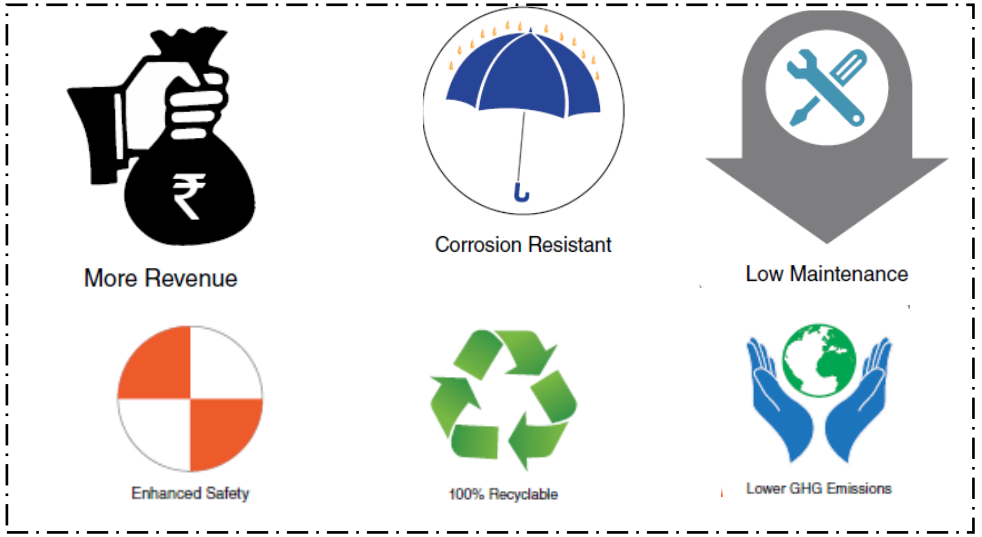
Complete superstructure made of AL
1990

Curtain rails
Front wall
Rear door
Side- boards

Front/rear/side bumper
Under-run protection

Al used for safety parts
2000s

Make in India - Aluminium in Commercial vehicle applications



“ cradle to cradle” life cycle analysis- City Passenger Bus

Liter/Kwh saved/100 km*100 kgs weight reduction	Mixed use	Urban	Highway
City Bus Diesel	0.10	0.17	0.08
City Bus electric	0.31	0.60	0.19

Ton Co2 saved /100 kg Weight Reduction	Diesel Bus			Electric		
	Mixed	Urban	Highway	Mixed	Urban	Highway
10 lakh Km @75000 Km/per year for 12 years	3.2	5.5	2.43	3.4	5.0	2.28

More energy saving and Less carbon foot prints in urban regions

Savings & Payback Period

Sn.	Aluminimu Applications Passenger Bus	Savings/yr (Rs. Lacs)	Savings in 11 yrs (Rs.Lacs)	Payback period (days)
1	Aluminium super structure Floor, Skin , Windows and interior fitments	3	33	< 1 Year

Increasing use of aluminium results in significant increase in savings and reduction of payback period

Aluminium Penetration in CV

India lags behind US & Europe in the enactment & enforcement of regulations

	USA	Europe	India
Fuel Energy Efficiency	Phase 1 launched in 2011. Phase 2 in 2014	No	Heavy Duty Fuel consumption regulation
Emission standards (RDE based on Euro VI)	Since 2012	Since 2014	Proposed in 2020; Expected to be launched in April 2018; postponed indef.
Maximum Axle Loads	Strong implementation	Strong implementation	Up to 25% overloading allowed as per new Road transport guidelines
	China recently revised its CV policy (GB1589) to ensure stronger checks for overloading		
Crash Testing regulation	Very stringent on crash load bearing capacity	Very stringent on crash load bearing capacity	Regulations inspired from Euro NCAP but much more lenient

Other structural changes (India specific)	**Introduction of GST regime** – Shift in truck/trailer fabrication to organised sector (Factory Built) **Adoption of truck/trailer body design standards** – Similar to AIS 052 standards for buses **Growth in e-commerce/delivery of perishable goods in urban areas** – impetus for closed container segment growth, larger fleet sizes **Govt.bus for low-floor e-bus for intra-city transport** – Budgetary support/subsidy for large scale adoption of electric buses (recent order placed for ~ 400 buses across 10 cities under FAME-2 subsidy scheme)

Government Initiative- Aluminium Adoption in Passenger Buses

State of art Aluminium bus designed , developed and tested by ARAI ,Pune locally under DHI funded project

Advantages of Aluminium Bus

- **37% lighter** Superstructure for its class of buses leads to improvement in fuel economy
- 100% mechanically jointed superstructure - Simple and fast assembly – No Welding - HAZ
- Rugged ,Durable and safe design to handle Indian road conditions
- Meets Strength **(UBS-II), NVH(AIS:153) & Bus Body Code (AIS:052)** requirements
- Corrosion resistant material used- Ideal for coastal regions reduces maintenance and repair cost
- **Easy adoptability for EV, HEV & CNG** bus application

Challenges for Aluminium adaption in CV

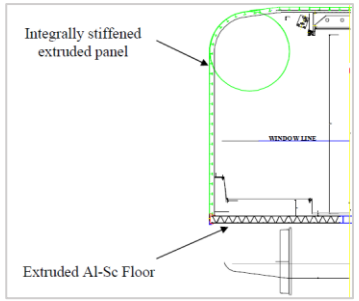
Collaboration in area of fabrication , distribution and promotion of Aluminium CV

To change customers Perception about High cost of Light weighting

Aluminium in Railways

Aluminium Components in Railways

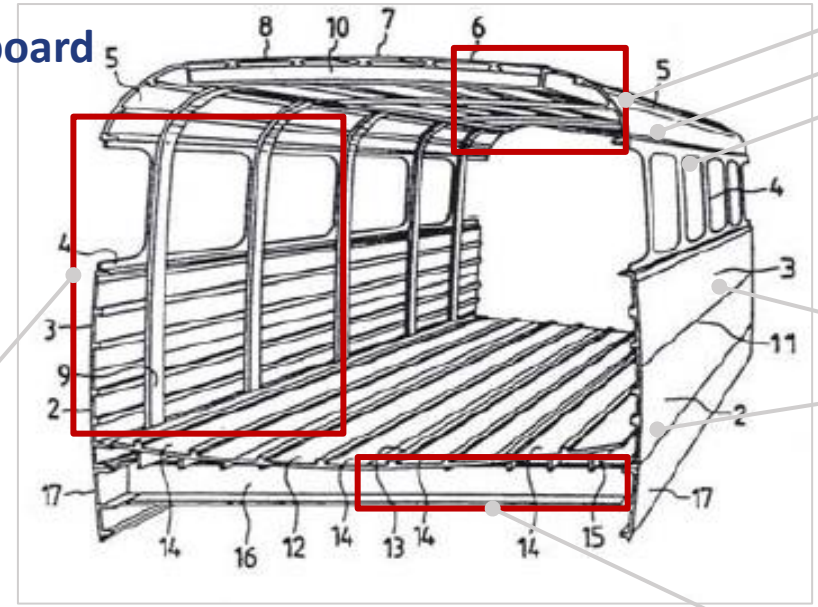
Train body is the largest segment -usage in Roof panels, Floor Panels and Side Board



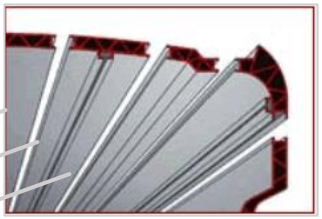
Net-shaped extrusion concept

Side-board

Roof panel

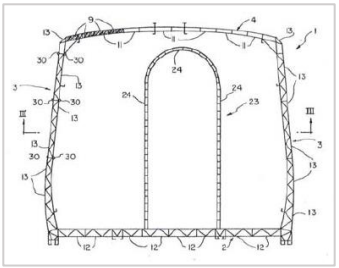


Floor-panel



Hollow double-skin extrusion

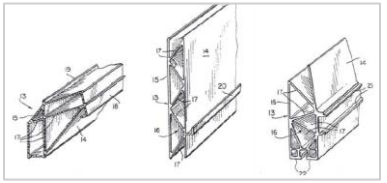
Usage of Flat Rolled Products



Integrally stiffened U-shaped extrusions

Movable side-walls for freight car

Hollow integrally stiffened extrusion



Evolution of Aluminium Usage in Railways

Started with application in components in early 90s- to entire rail-car body

	Pre-1980s	1980-2000		2000-Current
Freight Train	 Al hopper cars **1931**	 **Singel-wall Al roof panels** Mfg by Hydro for Alstom for Danish State Railways **1997**	 **First Auto Vehicle Carrier** Built by Johnston America for Amtrak **1999**	 **Coal wagon** C-80 Al Alloy open-top wagons **2005**
High-Speed Trains	 **Chicago World's Fair** First all Al passenger car **1934**	 **Shikansen N 300** All Al trainset **1992**	 **ETR 460** Pendolino type train **1994**	 **Hitachi's A-train** FSW welded Al side panels **2000**	 **Shanghai Maglev** (>400kmph) All Al construction **2004**
Metro	 **Automatic door closures** Al extrusions used **~1975**	 **Washington DC Metro** First all Al car body **1980**	Al based metro car bodies expands to Europe, Canada	 **China** Al car body by Midas **~2005**

FSW appl.in rail starts
Mfg full body becomes feasible

Aluminium Penetration in Railways-Global

Globally, a material of choice across segments

Sub-segment		China	USA	EU	Thesis for Al adoption
Freight	Coal	30%-70%			• **Increased payload** (5-10%) • **Reduced maintenance costs** - less bogie & track wear & tear
	Car Carrier	40-60%			• **Corrosion resistance** - prevents car damage • Rapid loading & unloading due to efficient design (e.g. sliding doors)
High-speed trains	High-speed (>200 kmph)	100%			• Train **speeds** > 200 km/hr not achievable with steel Pendolino trains for negotiating curves demand light-weighting • **Improved aerodynamics** - lesser drag
	Semi-high speed (100-200 kmph)	70%	60%	50%	• **Light-weighting** - resultant increased speed & carrying capacity / Lower power consumption for same distance • **Passenger safety** - improved crashworthiness
Subway/ Metro		50-80%			• Significant **saving on electricity costs** due to light-weighting - large chunk of power in metro consumed during acc & deceleration • Overall **reduction in running costs**

Aluminium Penetration in Railways-India

Negligible usage of Aluminium in India

Sub-segment	Current Penetration	Current application
 Freight		• No operational wagon uses Al • Concept Al bodied wagon developed by BESCO in collaboration with Hindalco
High-speed train (>200 kmph)		• All routes to be Al bodied, but initial wagon manufacturing likely to happen in Japan
 Semi-high speed (Rajdhani)		• No current usage in train-body • Current usage in luggage racks, ventilation grille, lighting systems
Subway/ Metro		• Most routes use steel bodies • Newer projects (e.g Gurgaon Rapid Metro – CSR Zhuzhou, Delhi Airport Express Line – CRRC) are using Al bodies

Aluminium in Railways-India: Cost-Benefit

Exemplary cost-benefit in Indian scenario for coal freight & semi-HST coaches

Particulars	Semi HST Coaches		Coal Wagons	
	New Al coaches	Current LHB coaches	New Al wagons	Current BOXN wagon
Material used	Stainless steel and Al	Stainless Steel	HSLA and Al	HSLA Steel
Avg. loaded weight (tons)	40 (28 steel, 8 Al, 4 payload)	49 (45 material, 4 payload)	100 (18 tare, 82 payload)	100 (22 tare, 78 payload)
Average Speed (km/hr)	150	90	25 loaded, 80 unloaded	25 loaded, 60 unloaded
Incremental up-front cost	Rs. 1.5 Cr		Rs. 40L	
Incremental Revenue + Power Savings	**Rs 25-70L p.a.** (Higher speed, Network optimization)		**Rs. 25-30 L p.a.** (6% payload improvement, Higher speed)	
Pay-back period	**2-6 years** depending on the level of optimization		**1-2 years**	

Aluminium in Indian Railways : First Indigenous Coal Hopper Wagon

Botton Discharge coal wagon :Developed by Hindalco -BESCO

Design Approved by RDSO

- 45% reduction in superstructure weight
- High strength alloy plate and profiles used for constructing the superstructure
- Fabrication by applying welding and mechanical joining

Aluminium in Railways-India: Challenges

Government support need to overcome low adoption of Aluminum in Railways

Lengthy tendering/design approval process

Inertia to change

Knowledge gap
Lack of supply ecosystem

Support indigenization

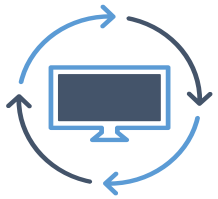
Promote benefits of Aluminum usage in Railways

Collaborate with international experts
Develop ancillary industry

Aluminium in Railways-India: Government Initiatives

Government has taken several steps to bolster case for Aluminium adoption in rail in India

Several railway ministry initiatives to bolster case for Al adoption in rail

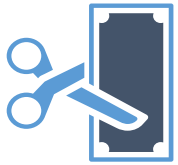


Supply ecosystem buildup

- Train 20 project ~2700 Cr INR global tender floated for manufacture of 300 Al bodied trainsets by 2020, with mfg expected to commence from 2021
- Rs 500 cr fund allocation for Al coach mfg facility for 300 coach / yr annual capacity; Announced in Rail budget 2018-19

High-speed railway infrastructure development

- High speed rail corridors - Mumbai – Ahmedabad HSRC to come up by 2022. Feasibility studies in process for six more HSRC's in diamond quadrilateral connecting metros
- Dedicated Freight Corridor- 3300 km long eastern and western DFC expected to be complete by 2020, 25% completion by Nov 2018
- Semi High speed Corridors- 9 routes covering around 7000 km planned for upgrading the track to run trains at 160-200 kmph



Need for power cost reduction

- Surging thermal power costs - Transport costs ~50-60% of landed coal cost, higher speed & lower operation costs for coal freight can reduce transport bottlenecks and reduce dependence on imports
- IR plan to reduce electricity bills by INR ~41K Cr on over next 10 yrs, 3-8% energy savings from using Al. w.r.t conventional steel rolling stock.

The Journey for Aluminium in Railways in India has begun…….

- "Many countries have adopted aluminum coaches as they are rusting free, can last longer; their cost of maintenance is also less. This is the right time to go for Aluminium coaches," - **R K Singh, Former Chairman , Railway Board of India – *Hindustan times , August 27, 2018***
- Government Allocated Rs 27,000 Crore To Boost Rail Infrastructure In Uttar Pradesh- Piyush Goyal , Railway Minister – *Deccan Chronicle – Sept 4, 2018*
- Railways set to give nod to make aluminium coaches to increase train speed." Aluminium coaches have the advantage of lesser weight and better corrosion resistance. Lesser weight results in savings in haulage costs and better acceleration/deceleration. Better corrosion resistance would result in lesser maintenance requirements in the workshops"- **Mr Rajesh Aggarwal, General manager Modern Coach Factory Raibarielly – *Financial express , Aug 27,2018***
- The factory now plans to manufacture light body Aluminium trains based on European standards. "The Aluminium train set is likely to roll out in 2020 and it will be much more energy-efficient and will follow the European standards and will be kind of a leapfrog for rail technology in India-**Mr Sudhanshu Mani , General Manager – Integrated Coach Factory , Chennai . *The Indian express , March 17, 2018***
- Officials said the Railway Board is set to approve MCF's project report for manufacturing the aluminium carriages. They added that the MCF will have to bring the technology either from Europe or Japan. A global tender for it will be floated once MCF gets the go-ahead- ***Hindustan times , 26 Aug , 2018***
- India on track to buy 18 bullet trains from Japan for Rs 7000 Crore- *Economic times , Sep 05, 2018*

Policy Support

Key Policy Support

		Short Term (1-2 yrs)	Mid- Term (2-4 yrs)	Long Term (4 yrs +)
Passenger Vehicles	**Emission/ Crash-Safety Regulations**	CO2 emission norms • Mandatory fines to be imposed for missing CO2 emission targets Passenger safety/crash regulations implemented in line with Euro NCAP	• Adoption of stricter emission standards in line with RoW	
Commercial Vehicles	**Axle-load regulations/ agenda of fuel-savings reduction**	• Push for stricter axle-load regulations/ emission norms & clampdown on rampant overloading • Create awareness among STU's of fuel spend savings achievable by adopting Al bodies bus • Advocacy with state transport on alu adoption in govt buses / e-buses: Plank on reduced fuel costs and hence impact on fuel bill		
Rail	**Advocacy for Al adoption in coal wagons & indigenization of coach mfg**	Coal wagon and DFC push • Push agenda on adoption of Al in coal wagons with govt highlighting increased payload, short pay-back and reduced power consumption	• Drive advocacy with large coach mfg (ICF, RCF) to support indigenization of Al coach manufacturing for semi-high-speed trains & metros	• Continue pursuing adoption of Alu in HST, sponsor studies on benefits of light-weighting and network optimization

Charles "Boss" Kettering

Engineering is a combination of brains & materials…

… the more the brains, less the materials

ADITYA BIRLA
HINDALCO

Brighter and better world with aluminum

Thank You