
# Trainsets

Silabhadra Das

P(Trainset)/IRIMEE


# What is a Trainset ?

A Trainset is basically a Distributed Power Rolling Stock(DPRS)

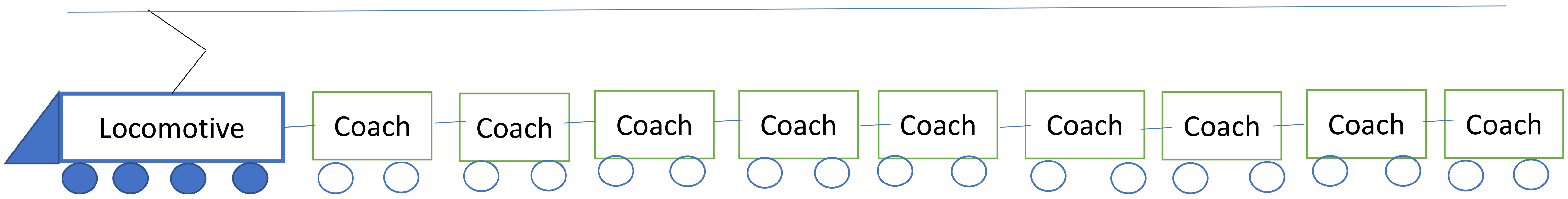
# DPRS

- Stands for Distributed Power Rolling Stock

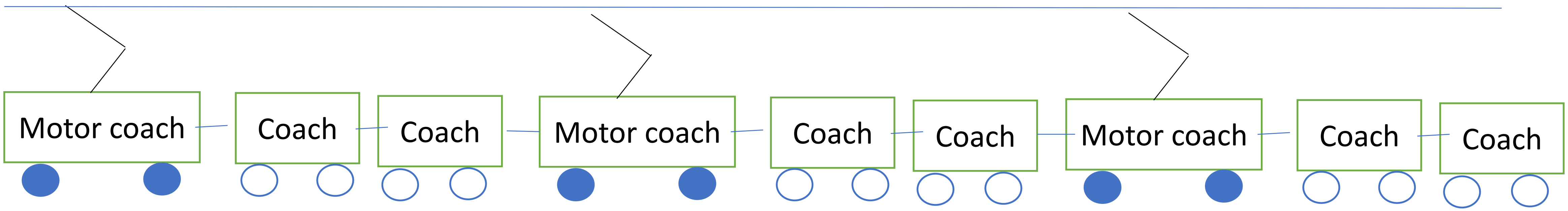
- Class of vehicles fit to move on Railway systems and one where the Propulsion systems and Powered wheels for providing tractive force are distributed over more than one and mostly large number of vehicles

- This is opposed to locomotive hauled trains where the equipment and powered wheels producing Tractive effort are contained in vehicle/ vehicles which are non-passenger carrying and are coupled to passenger cars through mechanical coupling

# Concentrated Power train




# Distributed Power train



# TYPES ON THE BASIS OF POWER SOURCE

Internal Power Source - Diesel Electric and Hydraulic Multiple Unit with AC-DC or AC-AC Drive or Hydraulic Drive.

External Power source - EMU/ MEMU Train sets drawing power from AC OHE with DC Motors or AC Motors OR DC OHE or third rail with AC Motors.

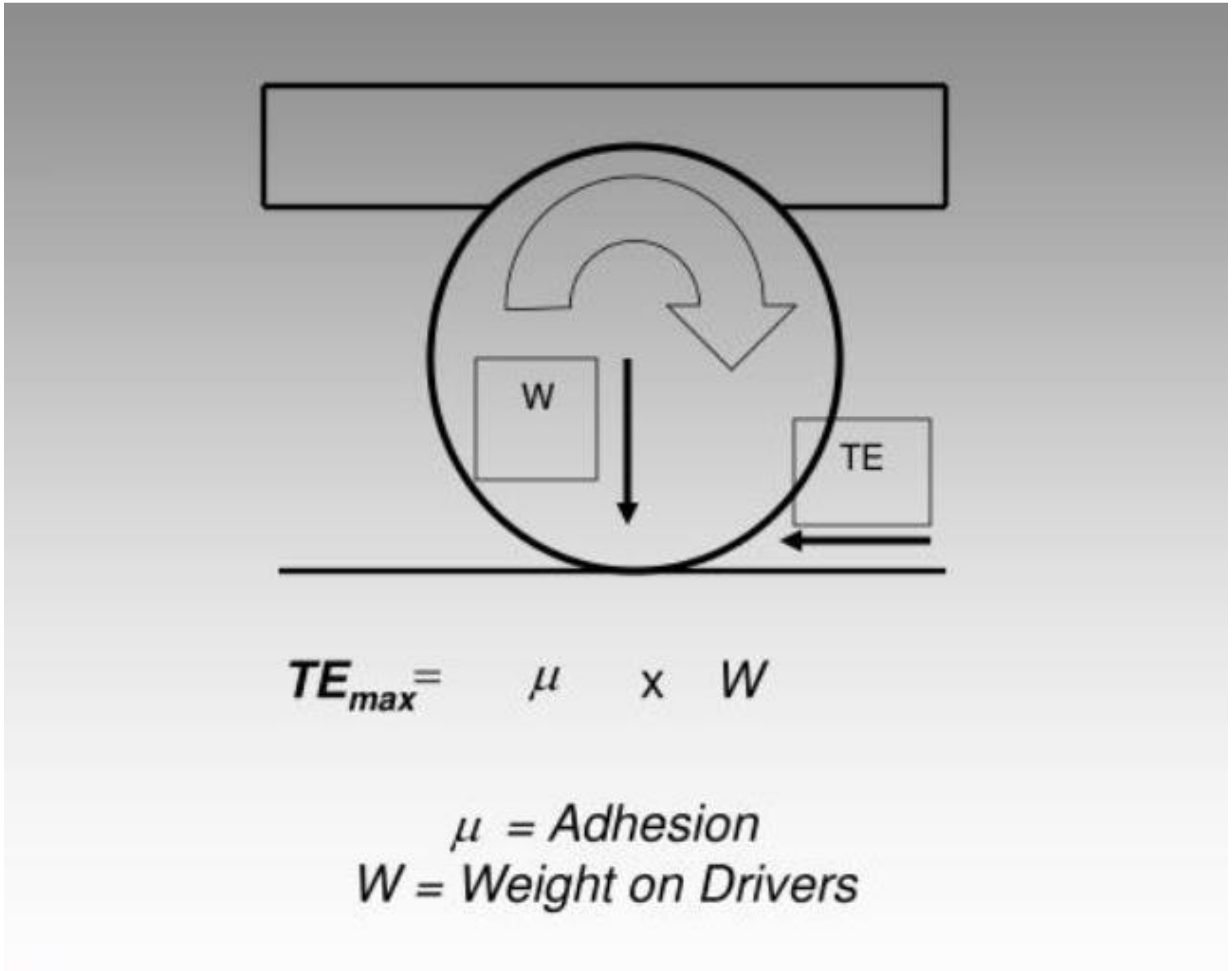
Hybrid – Combination of Internal and external power source

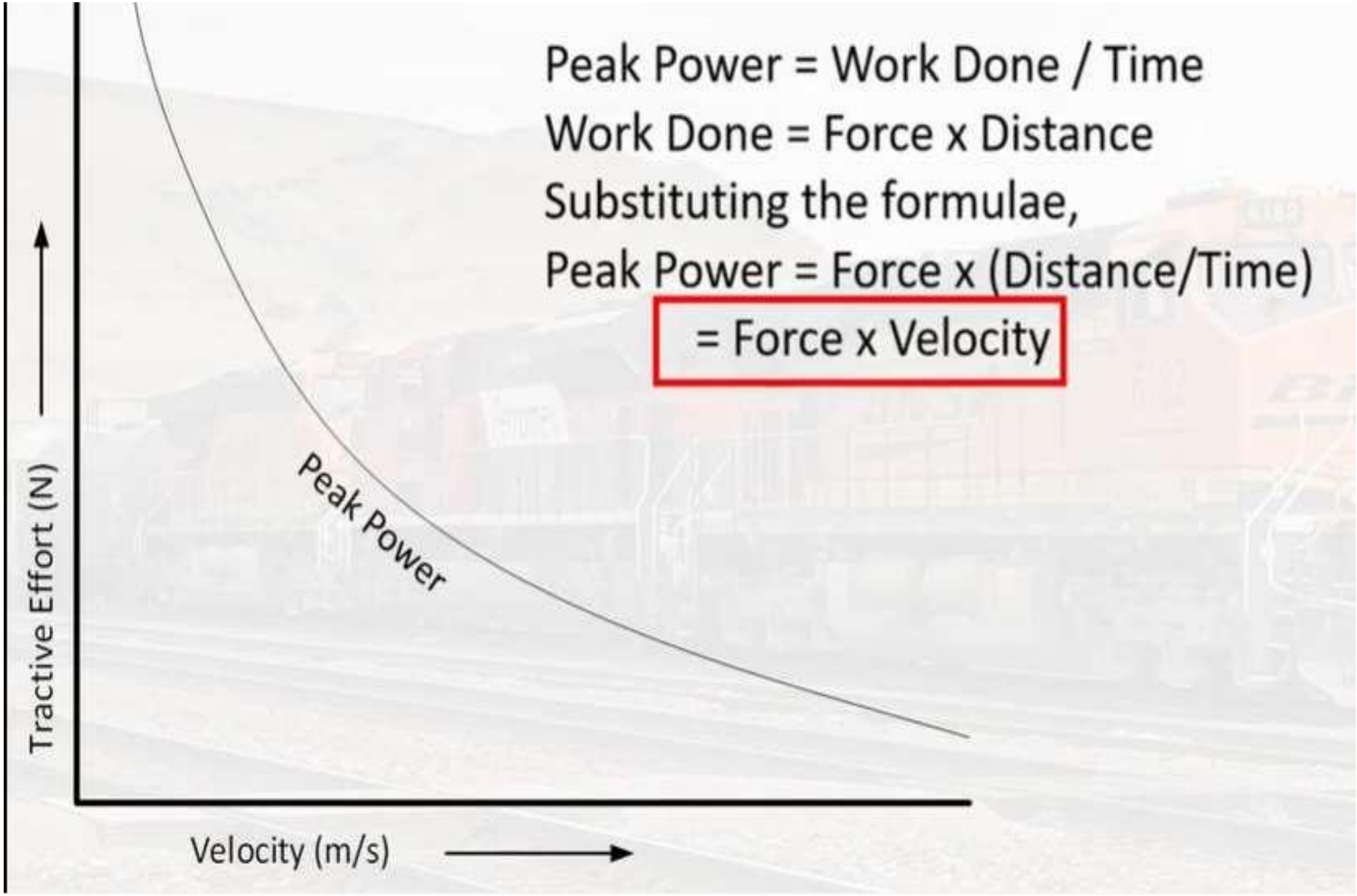

# DELHI METRO

# SHINKANSEN

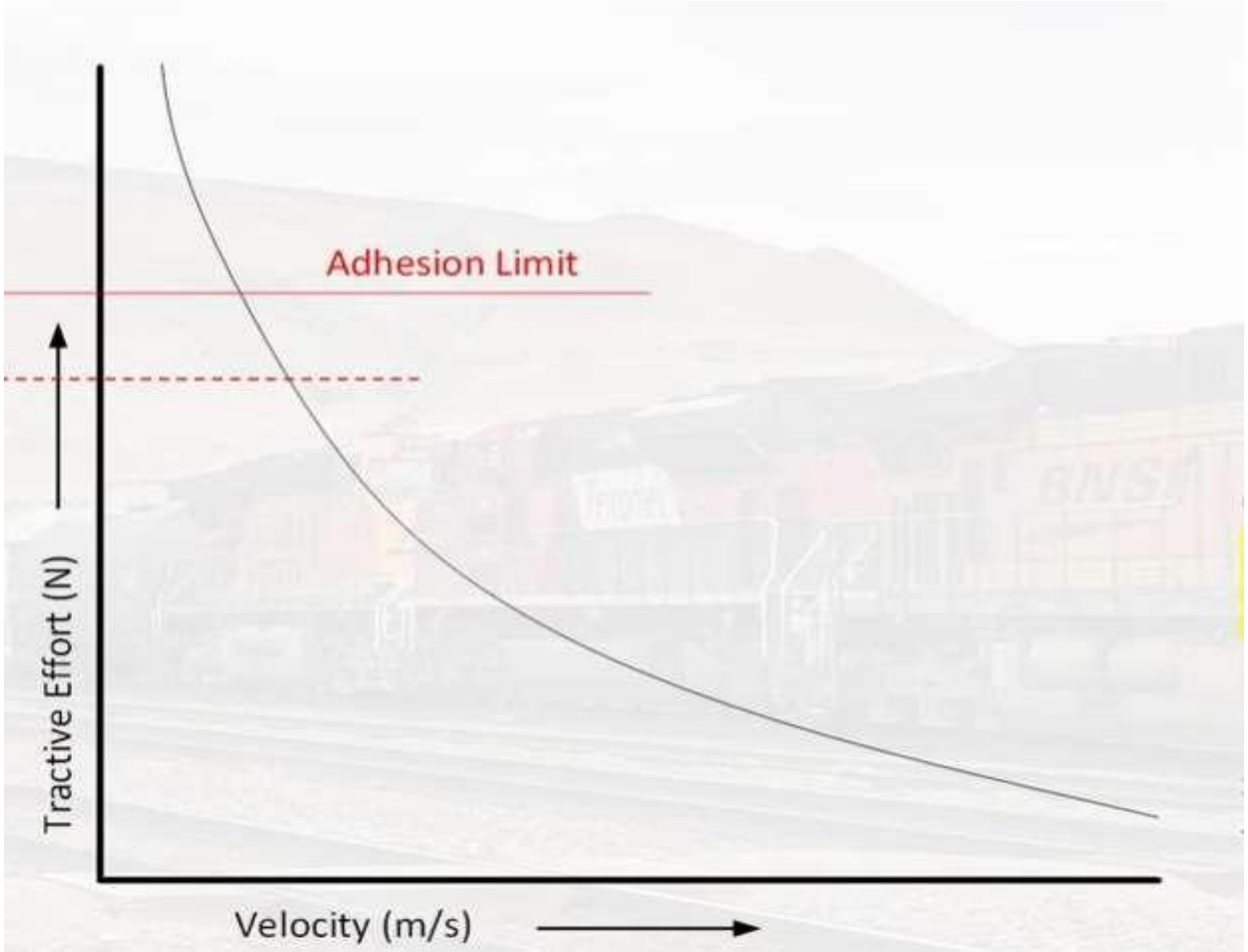
- 100 % powered trainset
- All axles in a bullet train are propelled by a traction motor


# CONCEPT OF TRACTION

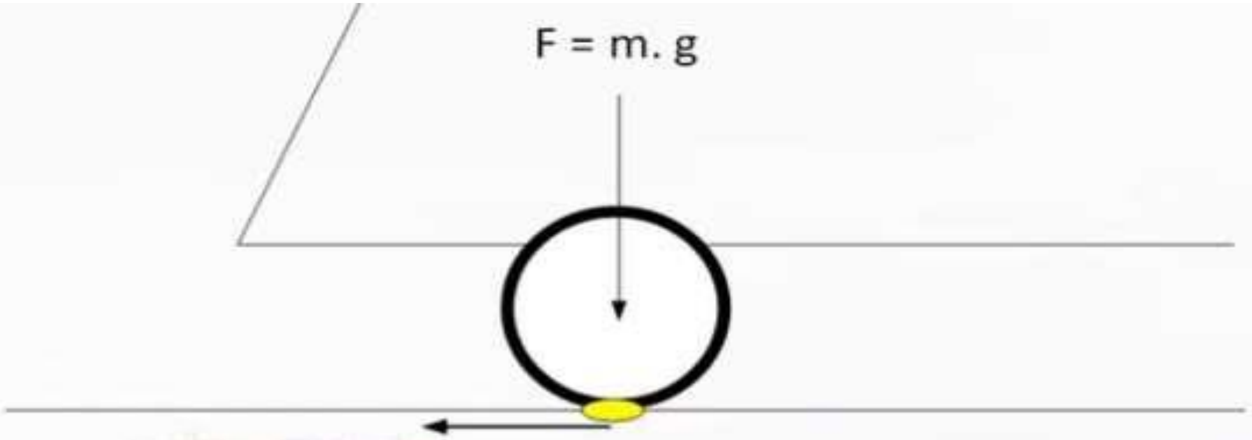





# Peak Power Curve




# Adhesion Limit




Frictional Force = μ. F = Maximum forward force a wheel can apply on rail before it starts slipping

Coefficient of friction: typically on railways it is between 0.35 and 0.5, whilst under extreme conditions it can fall to as low as 0.05. Thus a 100-tonne locomotive could have a tractive effort of 350 kilonewtons, under the ideal conditions (assuming sufficient force can be produced by the engine), falling to a 50 kilonewtons under the worst conditions

# Why is there an Adhesion Limit?

# Factors Affecting Adhesion

## Wheel/Rail Contact Factors

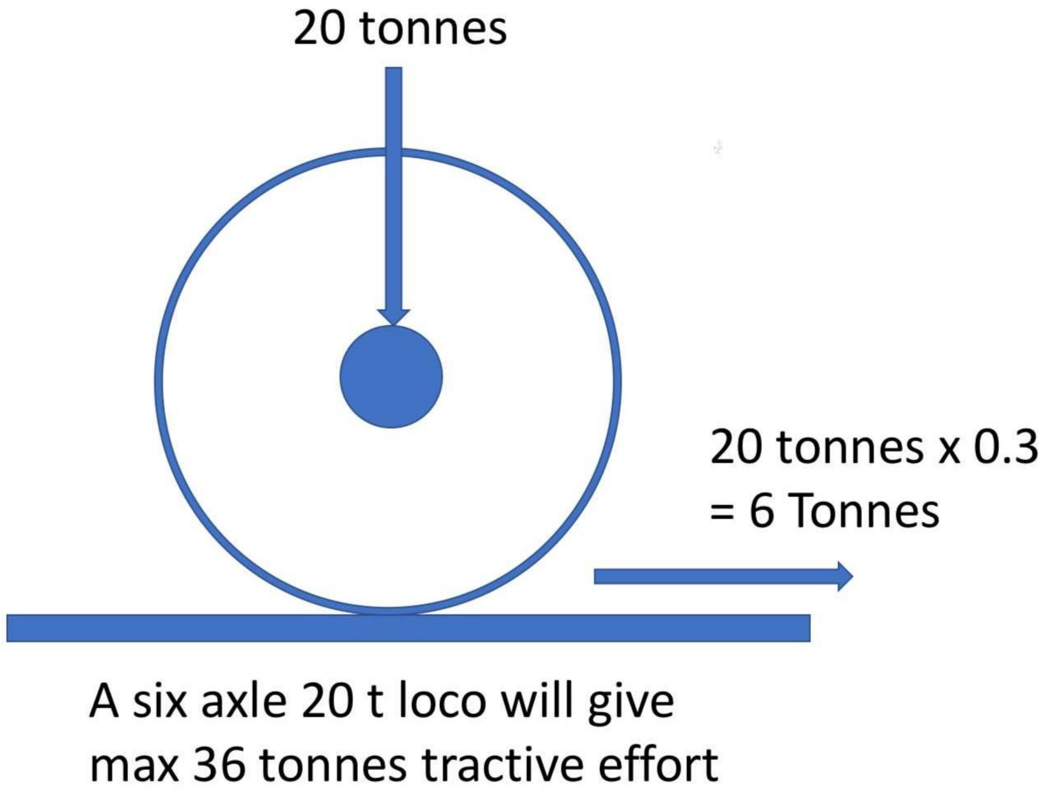
- Wheel-Rail materials
- Hertzian (Rolling Wheel) Stresses
- Rail Metal Creep (Longitudinal Movement)

## Track factors

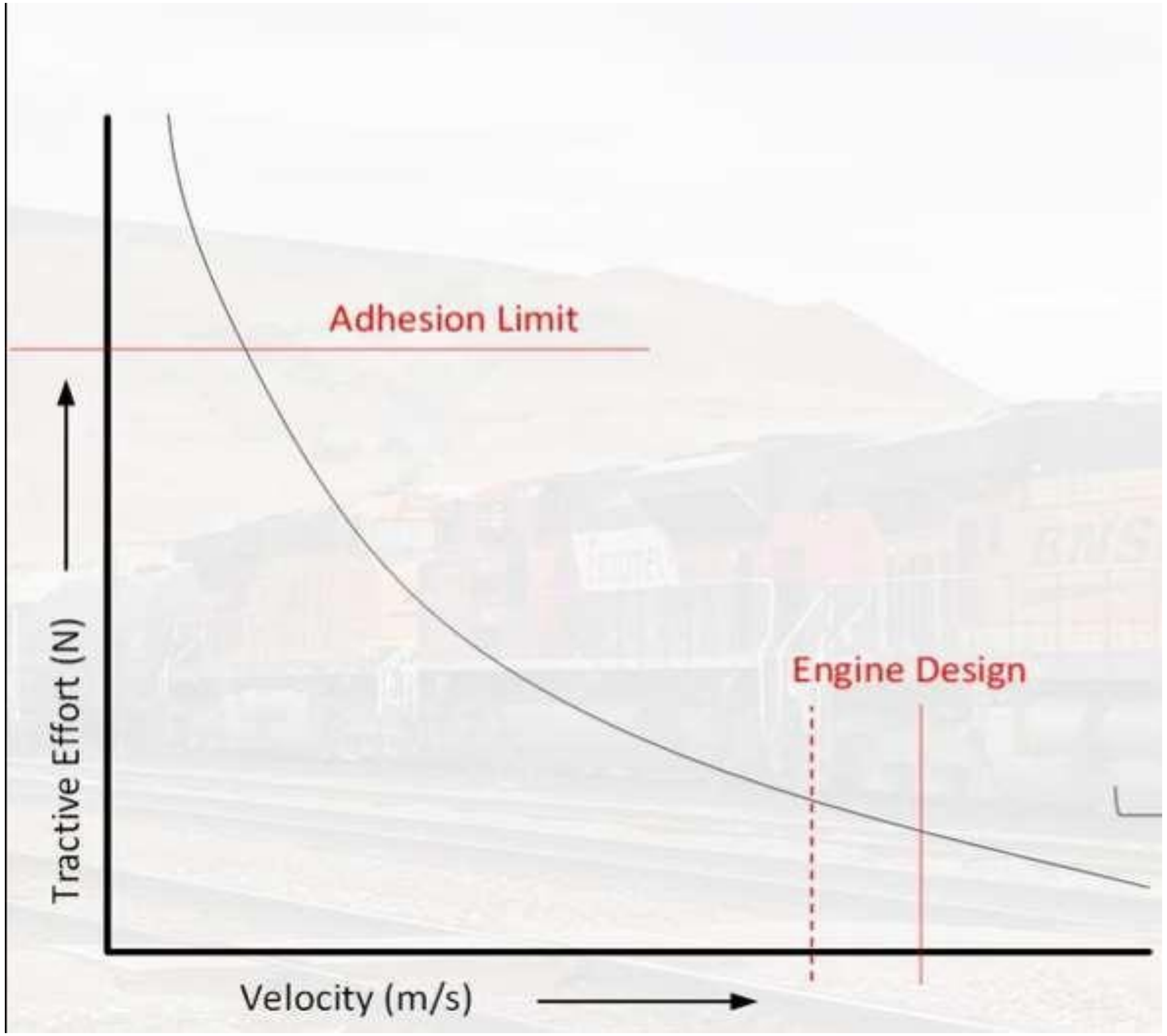
- Rail surface condition
- Rail profile irregularities
- Curvature of track

## Vehicle factors

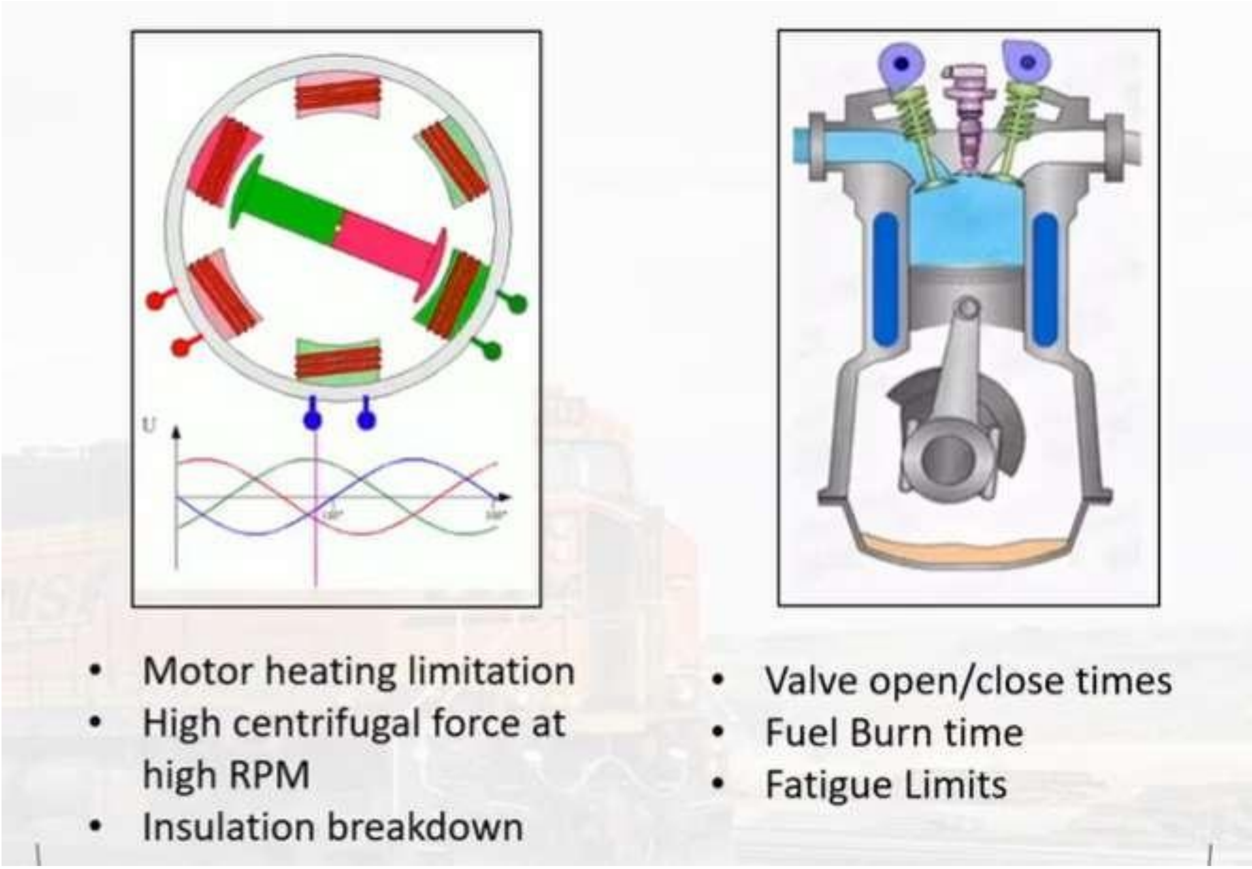
- Mechanical
  - Loco weight and axle weight distribution
  - Weight transfer
  - Speed
  - Wheel size variation
- Electrical
  - Torque control method
  - Traction motor characteristics
  - Power circuit configuration
  - Slip-slide control




# The Law of Rail Traction


Adhesion Limit
Engine Design
Tractive Effort (N)
Velocity (m/s)

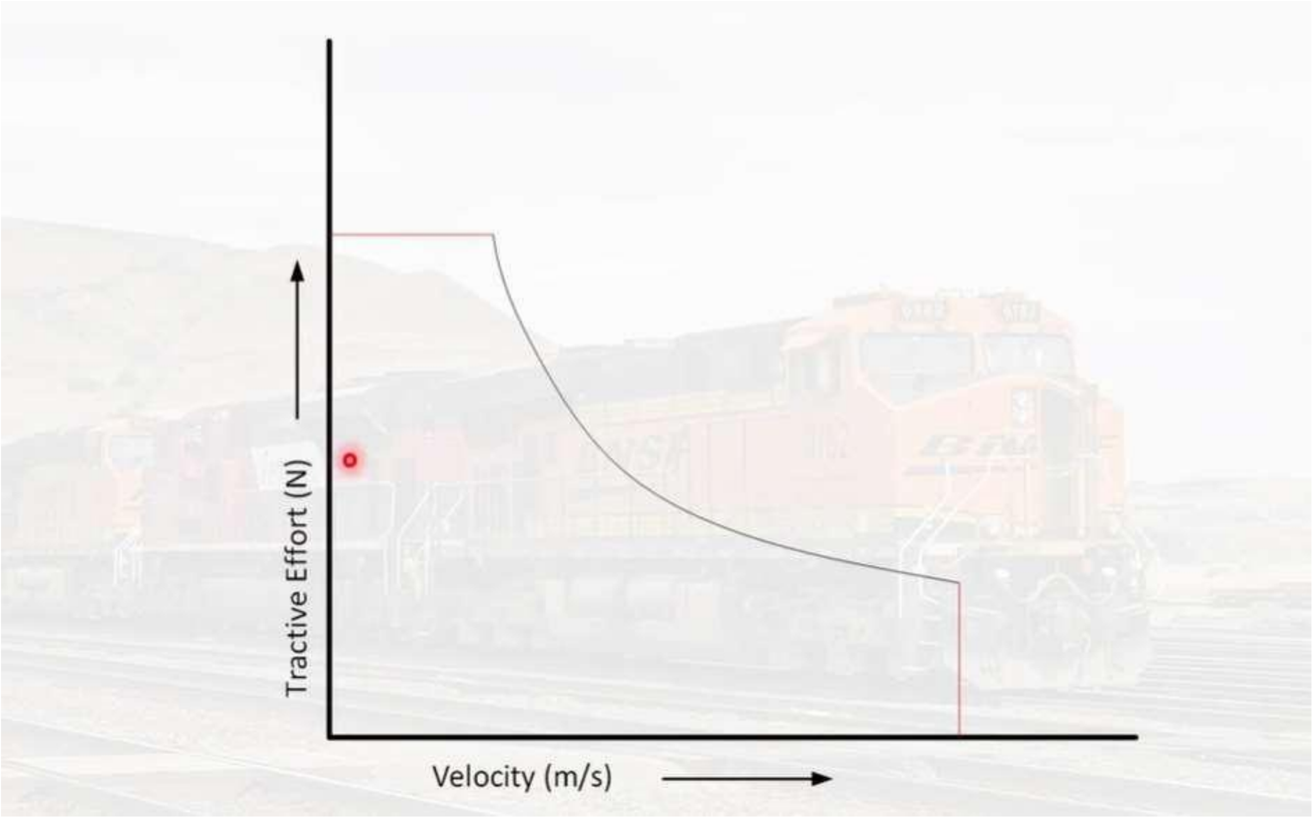
# Speed Limit




# Why is there a Speed Limit?

# Other Factors Limiting Maximum Speed

- **Bearing Design**
- **Vibrations**
- **Mechanical Transmission System**
- **External - Tracks and Structures**



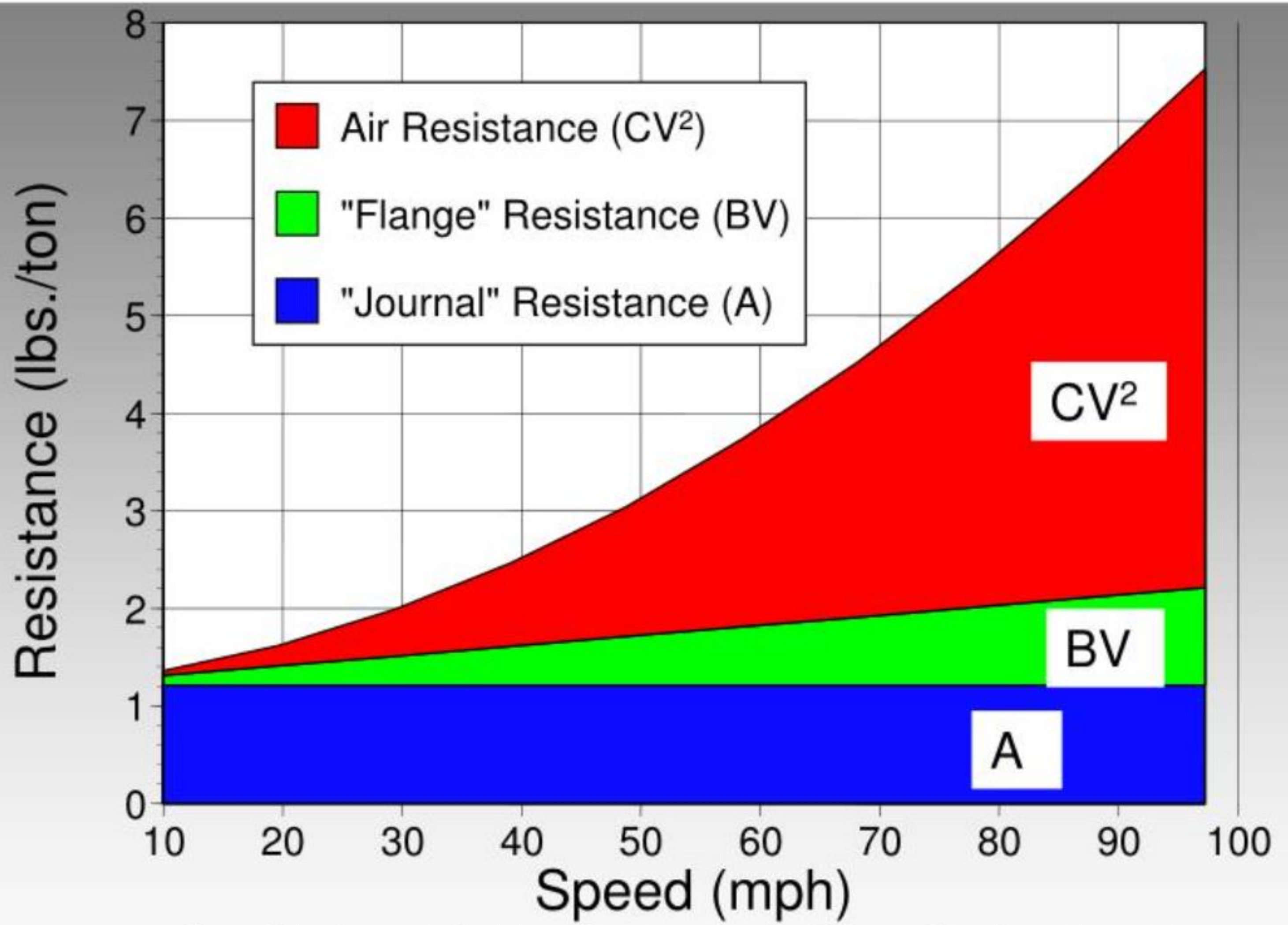

# Tractive Effort of a Powered Rolling stock

Davis Equation: $\boxed{R = A + Bv + CDv^2}$

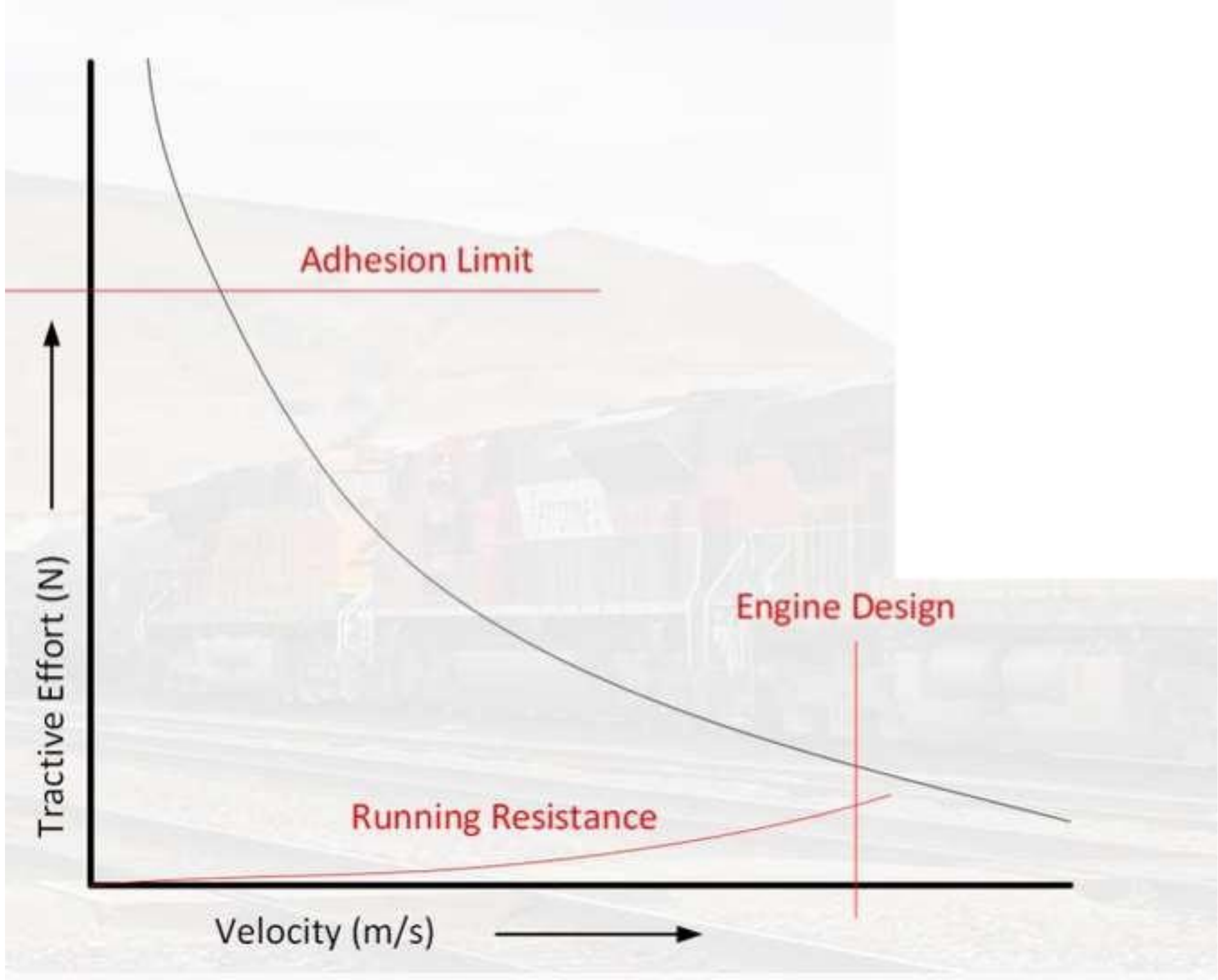
https://www.coalstonewcastle.com.au/physics/resistance/

| A | B | C & D |
|---|---|---|
| Journal / Roller Bearing Resistance | Flange friction | Head-end wind pressure |
| Rolling resistance | Flange impact | Skin friction on the side of the train |
| Track resistance | Rolling resistance wheel/rail | Rear drag |
| | Wave action of the rail | Turbulence between cars |
| | | Yaw angle of wind tunnels |

# Resistance to Movement of Rolling Stock

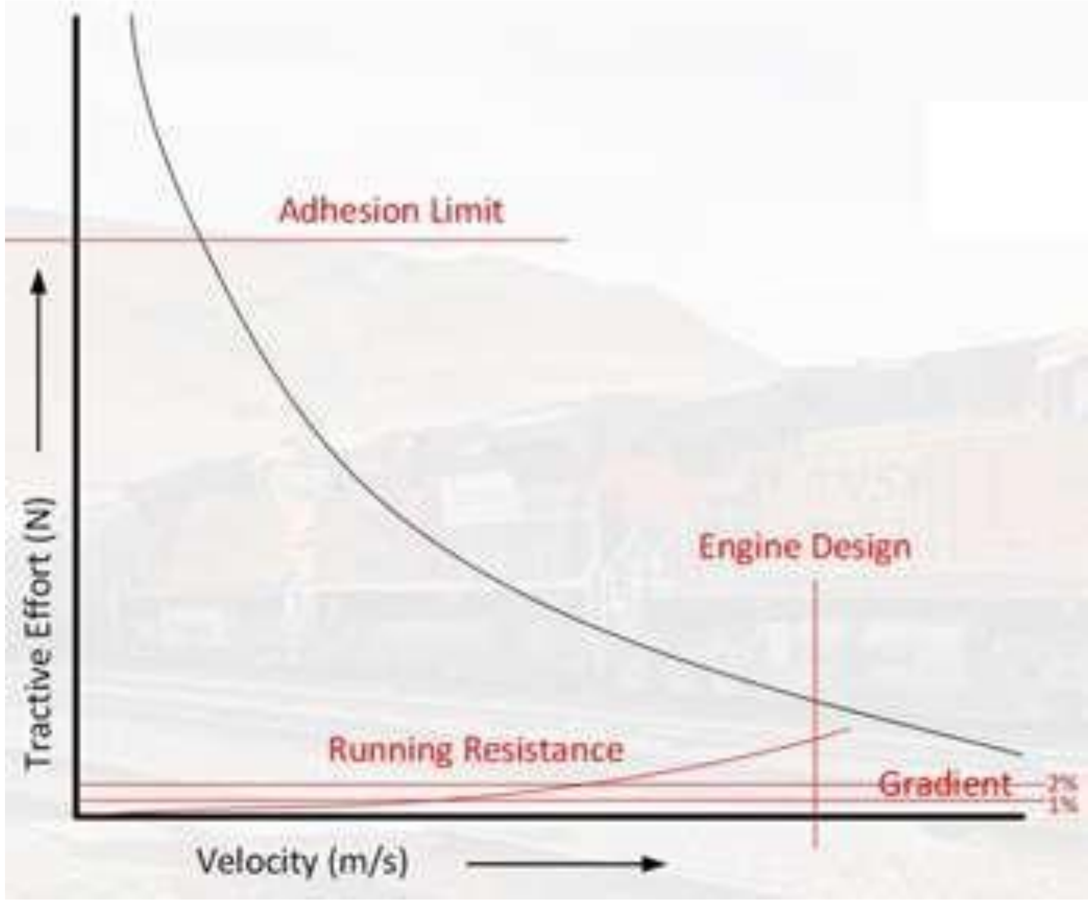



**At low speeds, journal resistance dominates, as speed increases air resistance is increasingly most important**

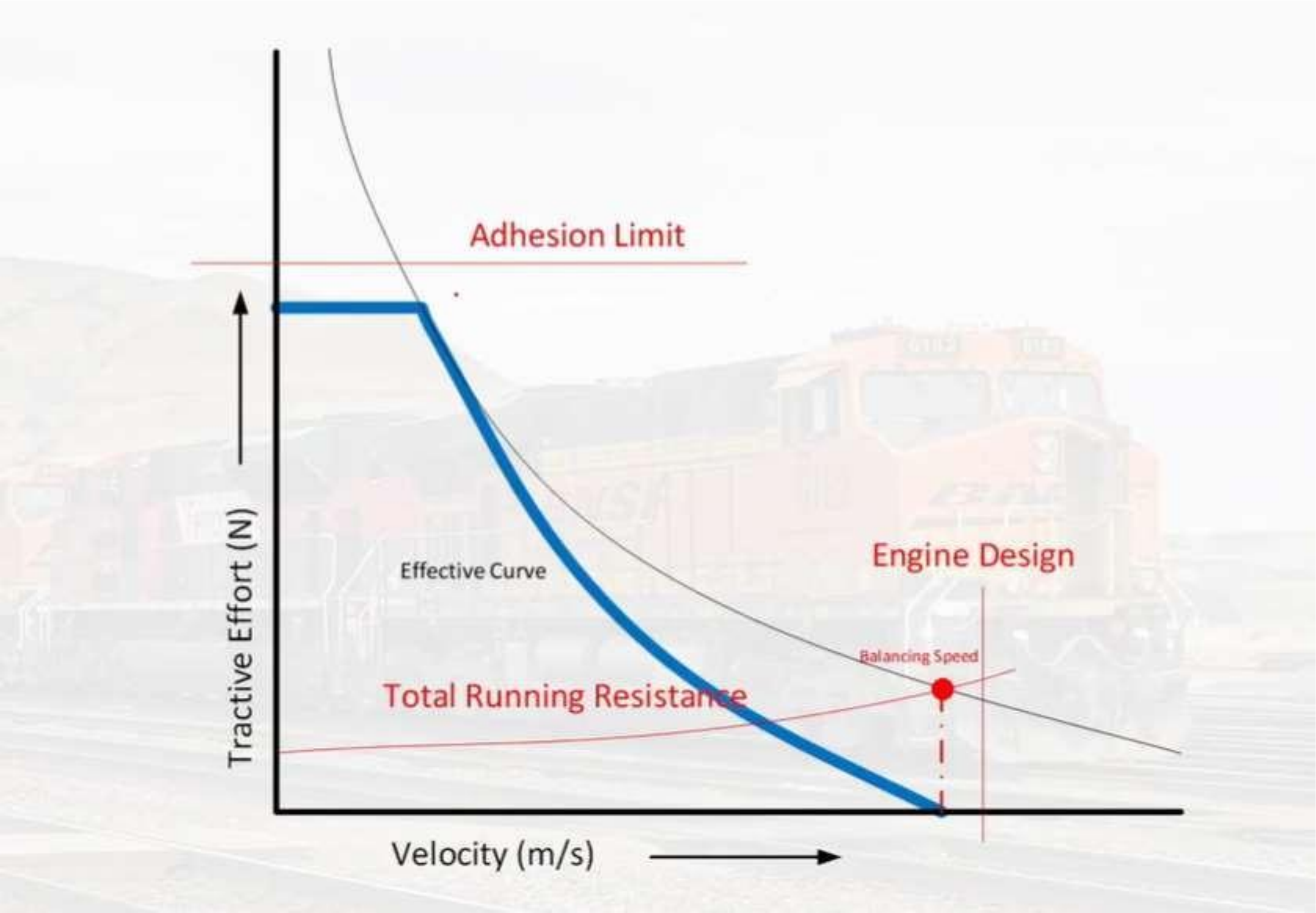



# How the Resistance Behaves

# Vehicle Design to Minimise Air Drag




# Add up All Resistances




# Actual Tractive Effort Available for Haulage

# Why Distributed Power ?


$6F_{\alpha}$- $(D+T_r)$= $m_{tr}\, a_x$

$6\alpha P_i$- $(D+T_r)$= $m_{tr}\, a_x$

$n\alpha P_i$- $(D+T_r)$= $m_{tr}\, a_x$

$\alpha n P_i$- $(D+T_r)$= $m_{tr}\, a_x$

More adhesive mass in case Of DPRS

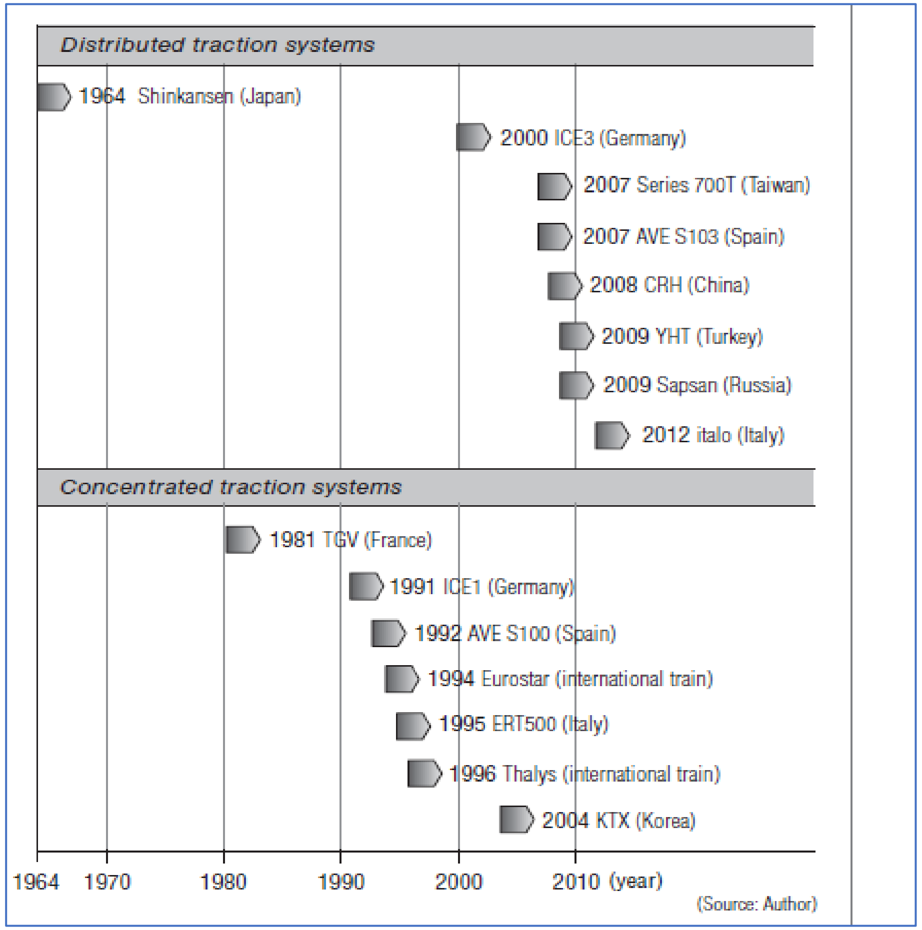
n- number of powered axles $\alpha$- adhesion coefficient $P_i$ – Axle load $F_{\alpha}$ - adhesive mass

D – Rolling resistance, drag resistance etc $T_r$ - Trailing load

From above equation it is clear that greater is the number of powered axles, Greater is the adhesive mass and hence better acceleration

# Distributed Power/Concentrated Power

- The distributed traction system has many advantages
  - energy efficiency
  - light axle weight
  - high acceleration and deceleration due to large number of driving axles
  - more cabin space as there are no locomotives
  - and ability to utilize the energy of regenerative braking efficiently




Ref: Akiyama et al.

# DPRS Types in Indian Railways

- Diesel Multiple Units-DMU/DEMU

- Electrical Multiple Units-EMU


- Mainline Electrical Multiple Units-MEMU


- Train sets -Semi High Speed


- Trainsets - High Speed

# DMU

**DMU(Diesel Multiple Unit)** is a multiple-unit train powered by on-board diesel engines.

A DMU requires no separate locomotive, as the engines are incorporated into one or more of the carriages.

- DIESEL MECHANICAL MULTIPLE UNIT(DMMU)

  rotating energy of the engine is transmitted via a gearbox and driveshaft directly to the wheels of the train

- DIESEL HYDRAULIC MULTIPLE UNIT(DHMU)

  a hydraulic torque converter, a type of fluid coupling, acts as the transmission medium for the motive power of the diesel engine to turn the wheels.

- DIESEL ELECTRIC MULTIPLE UNIT(DEMU)

a diesel engine drives an electrical generator or an alternator which produces electrical energy. The generated current is then fed to electric traction motors on the axles


1600 HP 1DPC+4TC

1400 HP 1DPC+3TC

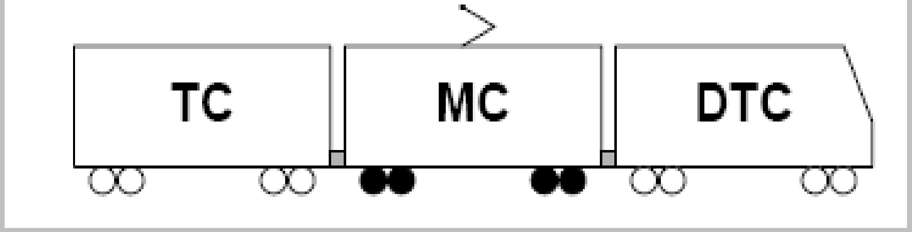
# Diesel Electrical Multiple Unit (DEMU)

- Manufacturer : ICF
- Engine: Kirloskar Cummins, Caterpiller in 1600 HP DEMU
- Transmission: Electric AC- DC in 700 & 1400 HP DEMU,

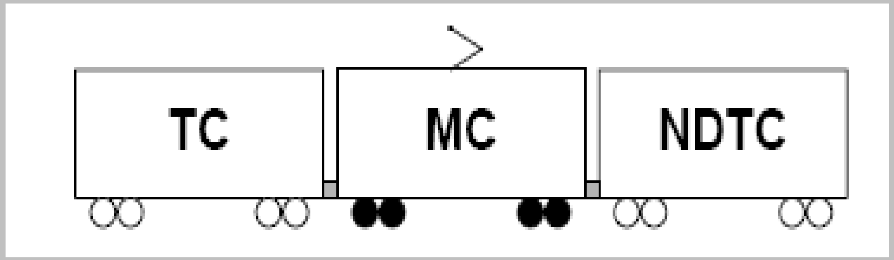
- AC-AC in 1600 HP DEMU
- Bogie: BO-BO (All 04 wheels are powered parallelly)
- Mostly operates in non-electrified plain regions & low traffic density branch line services

# EMU (Electrical Multiple Unit)

- Manufactured at ICF & BEML
- Self propelled electric vehicles
- Obtain power from overhead OHE 25KV single phase AC or 1500 V DC
- Basically consists of
- End basic unit- Motor coach + driving trailer coach + trailer coach
- Middle basic unit – Motor coach + trailer coach + non driving trailer coach
- 3-4 units in train formation
- Generally used in sub-urban railway transport
- Designed for super dense crush load




End basic unit




Middle basic unit

DC EMU

AC-DC EMU

THREE PHASE AC EMU(SIEMENS)

# MEMU (Mainline Electrical Multiple unit)

Manufactured in ICF & RCF
Employed for main line medium distance operations
Consists of a motor car and three trailer cars
Propulsion system, control circuit similar to EMU but dimensional differences are there
Maximum axle load of trailer coach 16.25 T – Not designed for super dense crush load
2 units in a train formation

# EMU v/s MEMU

**GENERAL DATA**

| S/ no | Description | EMU M/C | EMU T/C | MEMU M/C | MEMU T/C | Reference |
|---|---|---|---|---|---|---|
| 1 | Type of Stock | AC BG EMU WAU4 | | AC BG MEMU | | |
| 2 | Coach Builder | ICF & BEML | | ICF & RCF | | |
| 3 | Manufacturer of Traction equipments including Tr. Motor, Transformer etc. | BHEL & CGL | | BHEL | | |
| 4 | Unit formation | DMC+TC+TC | | DMC+TC+TC+TC | | |
| 5 | Train formation | 3/4 units | | 2 units | | |
| 6 | No. of Driving Cabs | 2 | | 2 | | |
| 7 | Type of Traction | 25 KV AC | | 25 KV AC | | |
| 8 | Wheel arrangement | Bo-Bo | | Bo-Bo | | |
| 9 | Brake system | Self lapping electro pneumatic brake system | | | | |
| 10 | Axle Load capacity in Tonnes<br>i) Conventional EMU/MEMU<br>ii) HCC | <br>20.32<br>20.32 | <br>13.0<br>20.32T | <br>20.32<br>-- | <br>13.0<br>-- | RDSO specification no. K3-B-01, Feb'03 & for EMU T/C- EMU-2/A-9-0-501 and EMU-2/D-9-0-503. |
| 11 | Wheel Diameter (New) mm. | 952 | | 952 | | RDSO manual no. CMI-K001 (Apr'2000) |
| 12 | Wheel Diameter (Condemning) mm.<br>HCC | 877<br>865 | 857<br>865 | 877<br>-- | 857<br>-- | |
| 13 | Gear ratio | 20:91 | | 20:91 | | |
| 14 | Train performance per unit rating<br>Horse power<br>Tractive effort (T) | Cont.<br>896<br>4.8 | 1 hr.<br>1004<br>5.8 | | | ACTM Volume-III, 1994 |
| 15 | Traction motor rating:<br>Type<br>Volts (V)<br>Current (A)<br>Output (KW)<br>RPM | 4601AZ/BZ/BX/BY 4303AZ/CZ<br>Cont. 1hr.<br>535 535<br>340 380<br>167 187<br>1260 1182 | 4303BY (BHEL)<br>Cont. 1hr.<br>535 535<br>425 465<br>207 227<br>1170 1120 | C1005 TM (CGL)<br>Cont. 1hr.<br>563 563<br>415 455<br>210 228<br>1170 1135 | | ACTM Volume-III, 1994 & Manufacturer's maintenance manual. |
| 16 | KVA rating of transformer | 1000 | | | | |
| 17 | Normal acceleration to 40 Kmph<br>Level track, CLR set at 500 Amps. | 1.6 Km/Hr./Sec | | | | BHEL Maintenance Manual no. MM/AC-M/EMU/003, Jan'01 |
| 18 | No. of pass./unit - Normal<br>Crush<br>Dense crush | 400<br>774<br>1148 | | | | ACTM Volume-III, 1994 |

| S/ no | Description | EMU MC | EMU TC | MEMU MC | MEMU TC | Reference |
|---|---|---|---|---|---|---|
| 19 | Tare weight | 59.3T | C-30.5T<br>D-31.5T | 61 T | 33.15T | For MEMU (M/C)- Drg. No. MEMU/DMC-9-0-012 |
| 20 | No. of Seats<br>Vendor Coach | 98<br>-- | 112<br>(C type)<br>88<br>(D type) | 68/81<br>-- | 80/108<br>No Vendor | (i) Drg. No. MEMU/TC2-9-0-201,<br>(ii) MEMU/DMC2-9-0-201,<br>(iii) MEMU/TC-9-0-001,<br>(iv) EMU-2/A-9-0-501,<br>(v) EMU-2/D-9-0-503 |
| 21 | Max. height above rail to top of roof | 3810 mm | | 3886 mm | | i) Drg. No. MEMU/DMC2-9-0-201<br>ii)EMU/M-9-0-006 |
| 22 | Max. length of the body | 20726 mm | | 215 67 mm | 21337 mm | i) EMU/M-9-0-006<br>ii)EMU-2/A-9-0-501<br>iii)MEMU/DMC2-9-0-201<br>iv)MEMU/TC-9-0-001 |
| 23 | Max. width of the body | 3658 mm | | 3245 mm | | -- do -- |
| 24 | Floor height from rail level | 1197mm | | 1278mm | | i) Drg. No. MEMU/DMC2-9-0-201,<br>ii) EMU/M-9-0-006. |
| 26 | Height of coach (rail level to panto at home) | 4398mm | | 4255mm | | i) Drg. No. MEMU/DMC2-9-0-201,<br>ii) EMU/M-9-0-006. |
| 27 | Min. height above rail level to the lowest fitting on under frame under tare | $210^{+5}_{-0}$ mm<br>188 (for air spring coaches) | | $210^{+5}_{-0}$ mm | | i) Drg. No. DMU/DPC3-2-6-301,<br>ii) Drg. No. EMU-2-6-046. |
| 28 | Length of 9 car rake<br>Length of 8 car rake<br>Length of 12 car rake | 194.12m<br>172.638m.<br>258m. | | 177.616m. | | As measured. |
| 29 | Distance between front & rear pantographs:<br>12 car rake<br>9 car rake<br>8 car rake | <br>226.5 m (approx.)<br>162 m (approx.)<br>-- | | <br>--<br>--<br>140 m (approx.) | | -Do- |

# Trainset – Semi High Speed T-18

- Train-18 is 16 car train with 4 basic unit i.e. Two number of end basic unit (DTC-MC-TC-MC) and two number of middle basic unit (NDTC-MC-TC-MC)
- Semi-high speed (160 kmph) multiple unit train-set.
- Train-18 is provided with **IGBT** based energy efficient 3 phase propulsion system and regenerative braking
- **Stainless steel c**ar body with **continuous window glasses**
- All **propulsion equipments** are shifted from **onboard to under-slung**. All power components such as **line & traction converters**, **auxiliary converter**, **air compressor, battery box, battery charger, brake chopper resister** are mounted **under the frame**
- **Zero discharge vacuum-based bio-toilets**
- Modern **bolster-less** design bogies with **fully suspended traction motors**,
- Train-18 has 50% powering i.e. Every alternate coach is powered
- Ethernet backbone

# Trainset -High Speed

- Operational speed greater than 200 Kilometer per hour on existing track
- Operational speed greater than 250 Kilometer per hour on new track
- Significantly faster than traditional railway trains
- E.g.- Bullet Train (Japan)

  - ICE (Germany)

  - TGV (France)

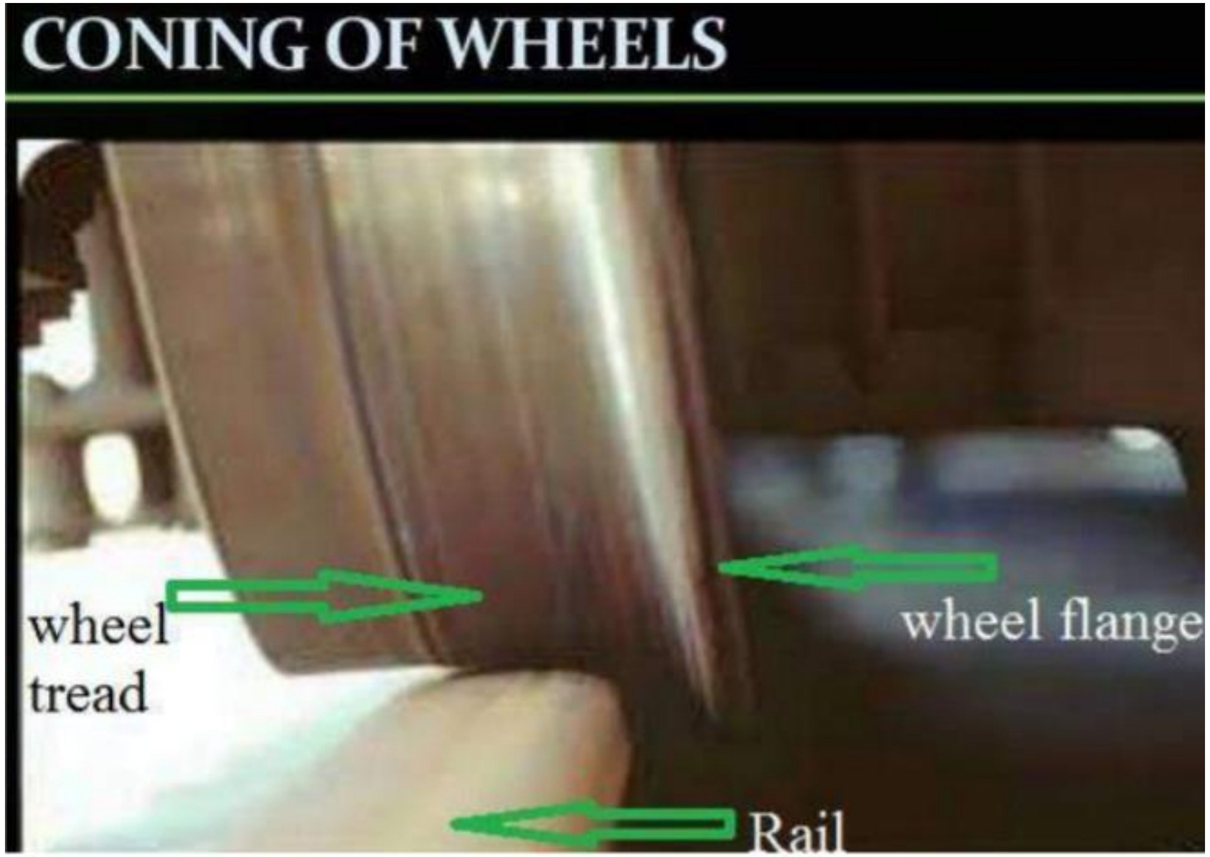
  - CRH (China)

# Rolling stock requirement

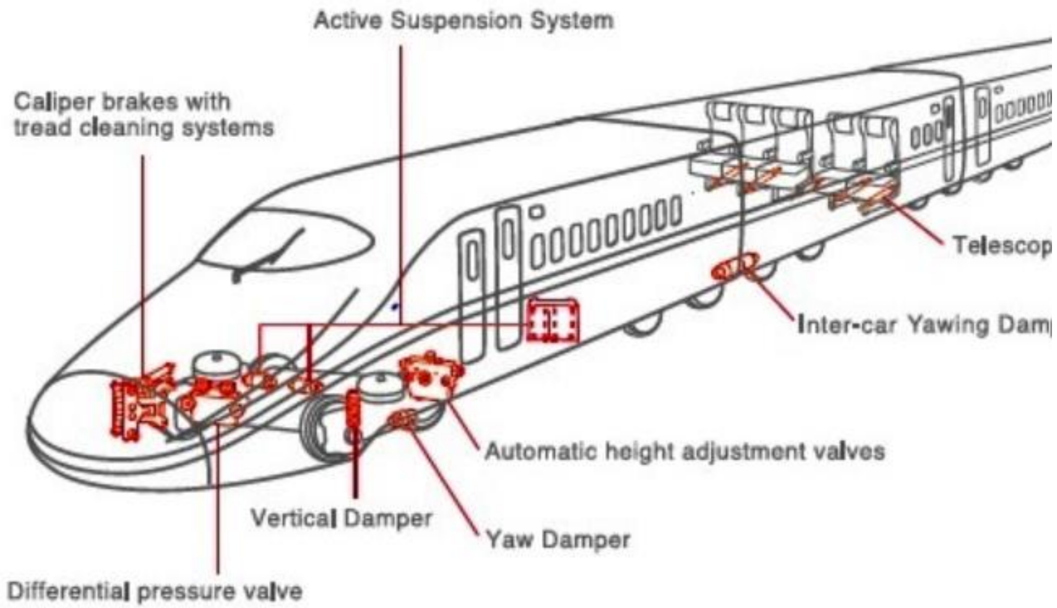
- Self propelled, fixed composition and bi-directional
- High level of technology
- Limited axle load (11 to 17 tons for 300 km/h)
- High traction power (approx. 11 to 24kW per ton)
- 3 Phase Propulsion System
- Power electronic equipment: GTO, IGBT based Control circuits
- Computer network. Automatic diagnostic system
- Optimised aerodynamic shape
- In-cab signalling system/s
- Several complementary braking systems
- High level of RAMS (Reliability, Availability, Maintainability and Safety)
- Airtight structure

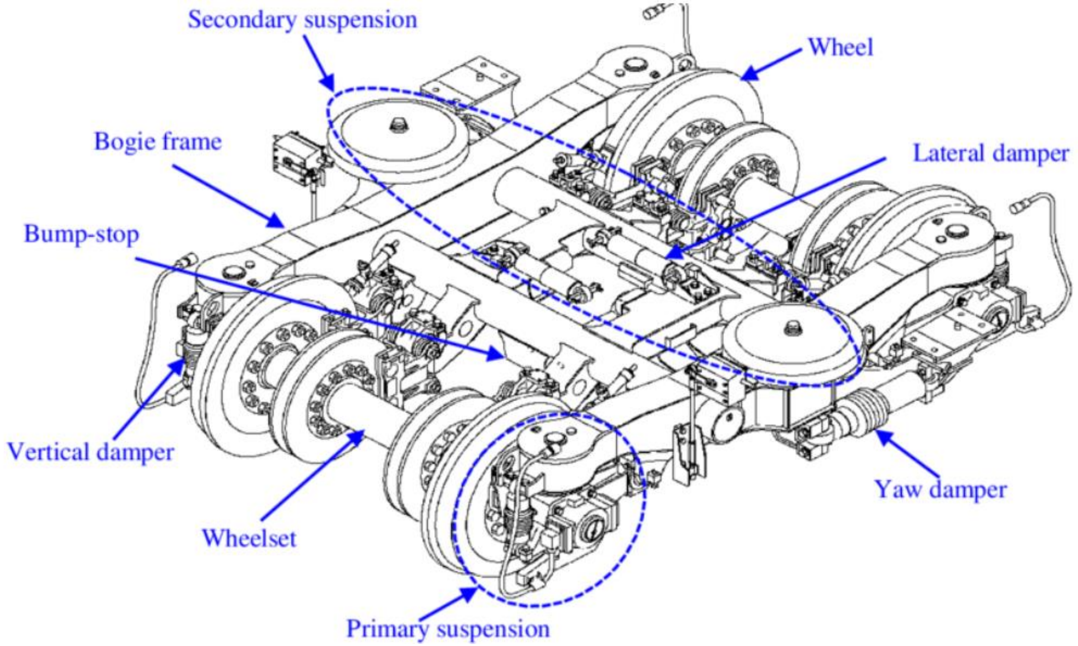
# Wheel

- Flatter tread, Wheel conicity should be 1:40, 1:60 or 1:80

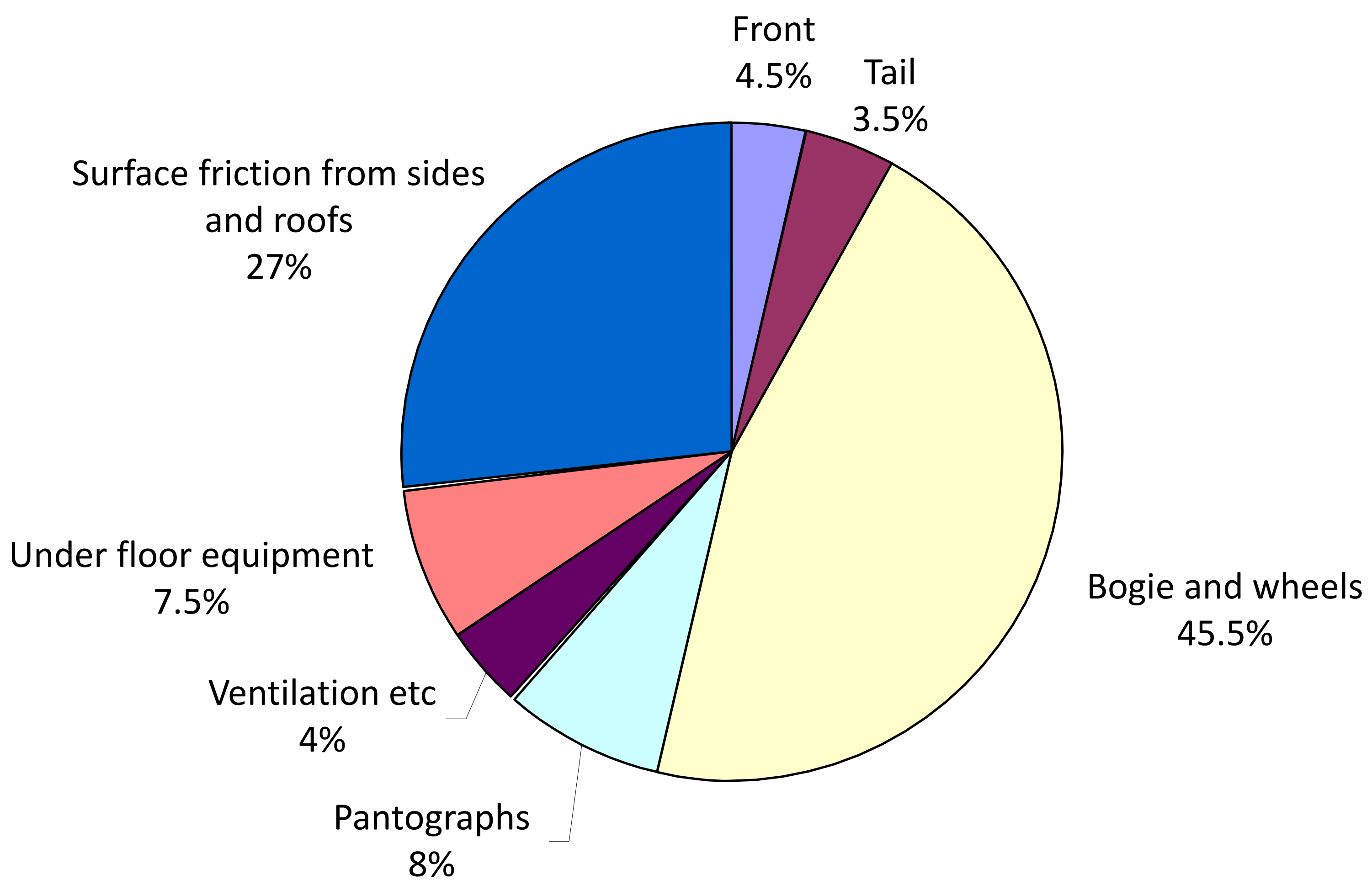


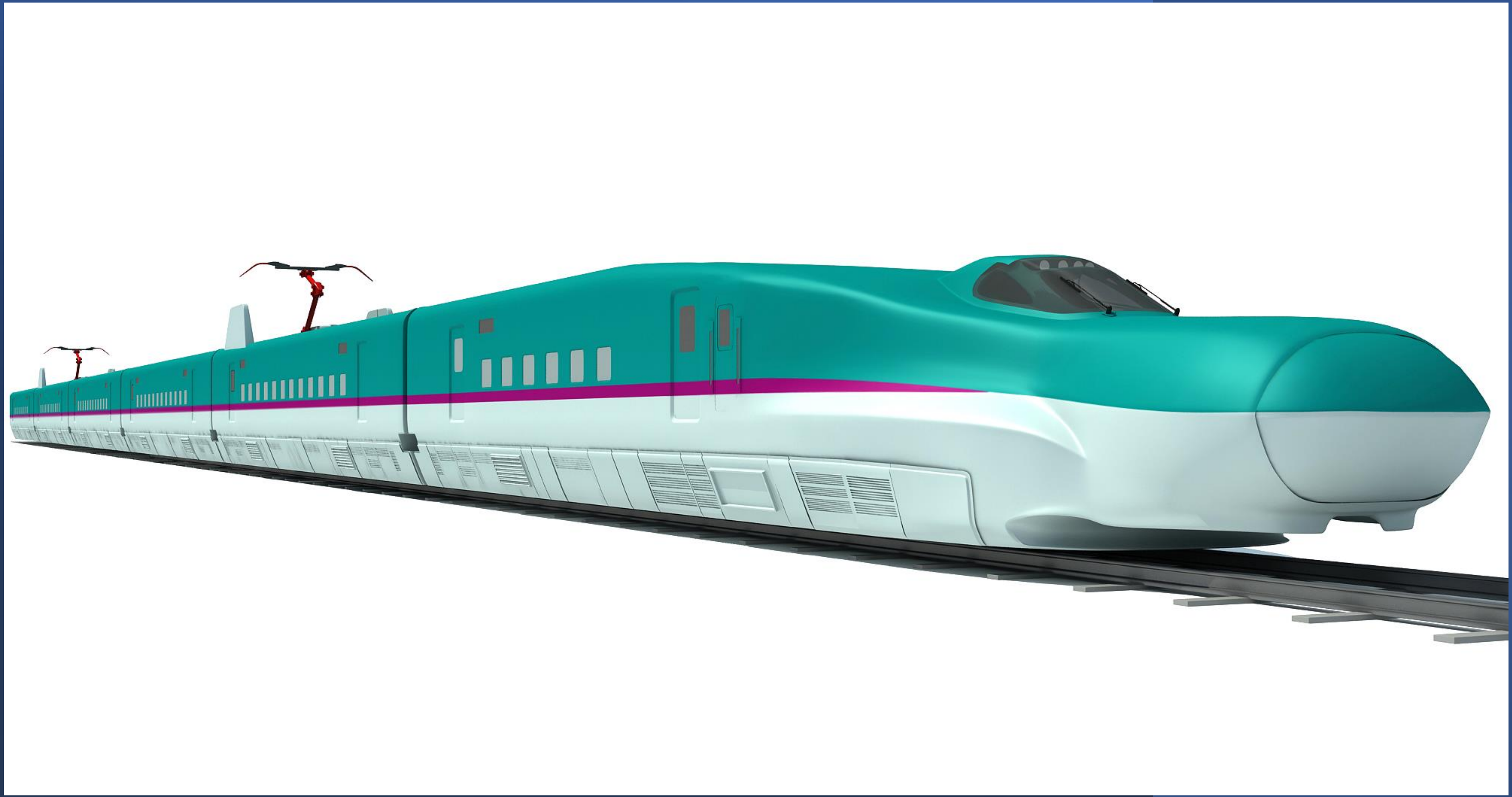
# SUSPENSION


Active Suspension System
Caliper brakes with
tread cleaning systems
Telescop
Inter-car Yawing Dam
Automatic height adjustment valves
Vertical Damper
Yaw Damper
Differential pressure valve

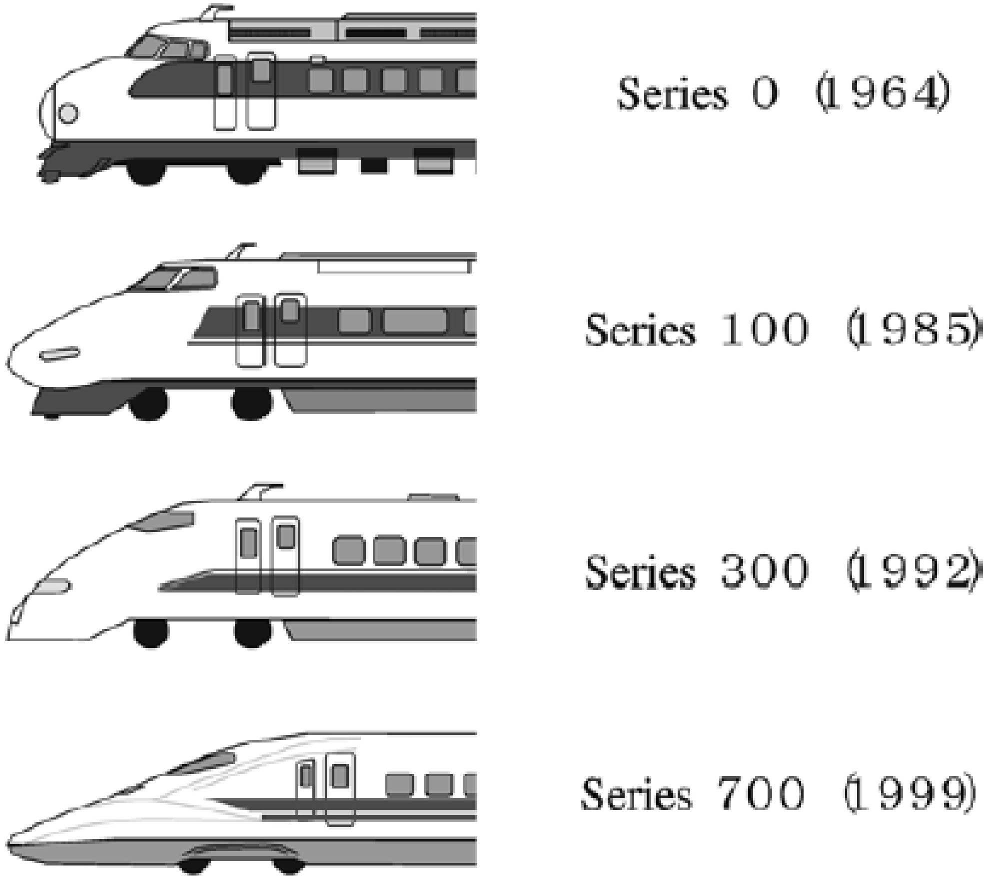

Secondary suspension
Wheel
Bogie frame
Lateral damper
Bump-stop
Vertical damper
Wheelset
Yaw damper
Primary suspension

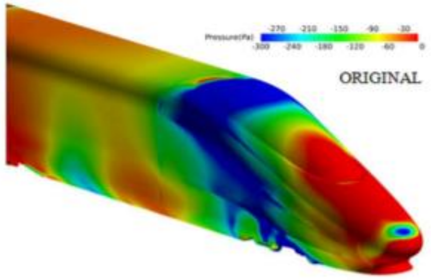
# Aerodynamic drag of a typical train

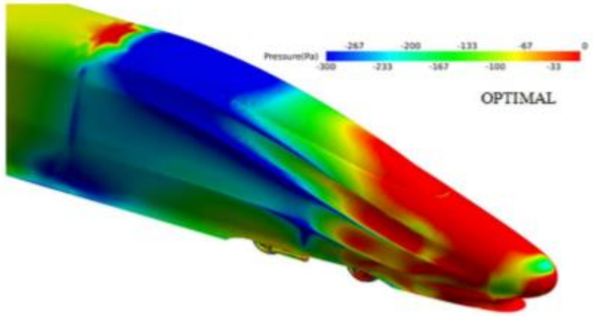




# AERODYNAMIC BODY DESIGN



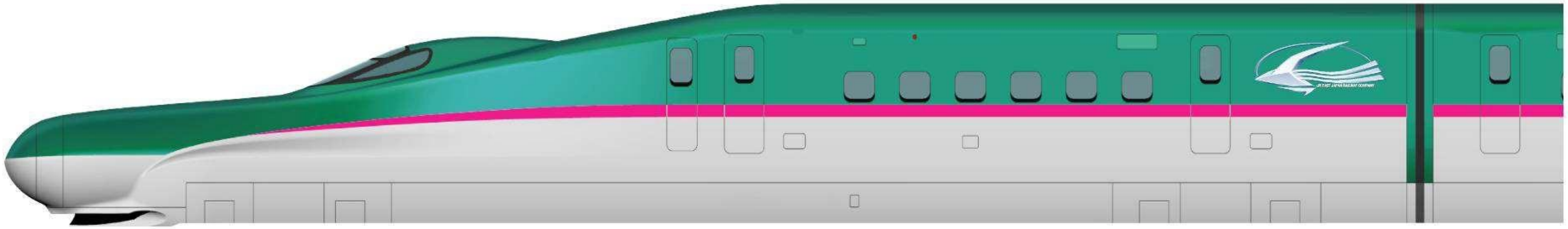



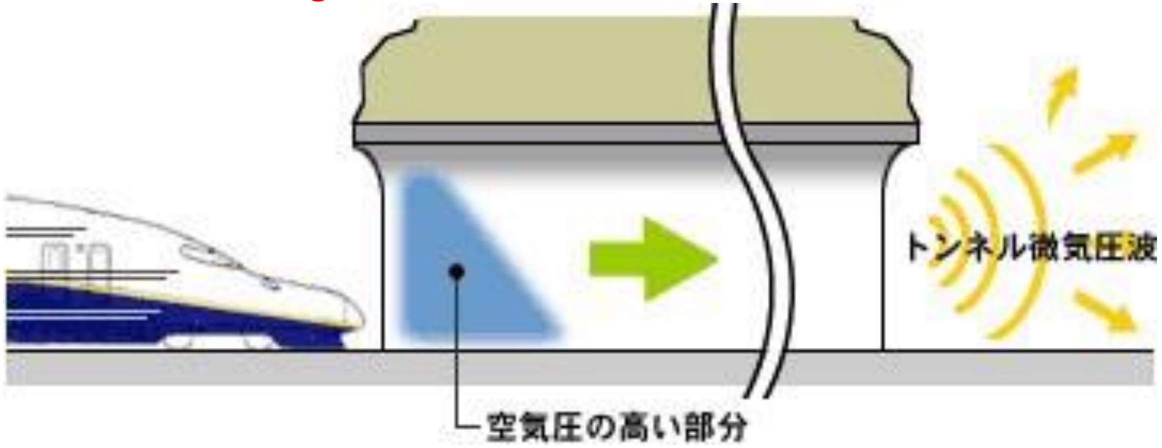

# Achieving High Speed

## Aerodynamic Design

For high speeds, air drag is to be minimized.
Aerodynamically designed Car body with long nose to reduce drag

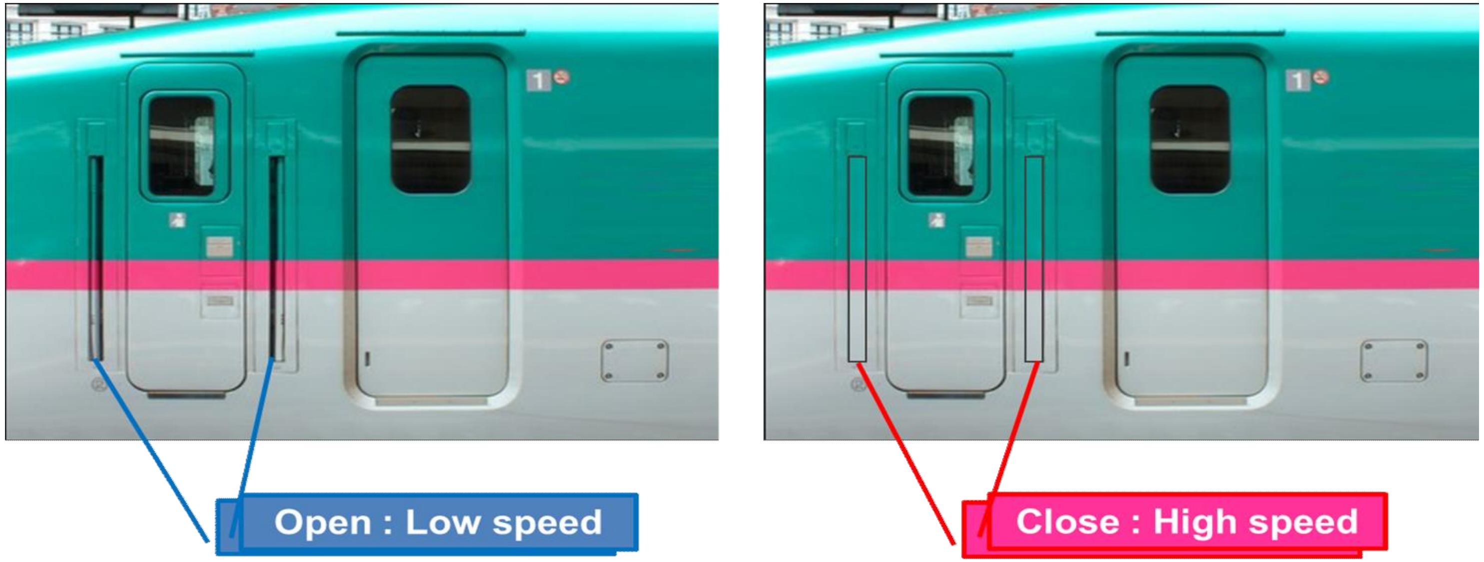


When high speed train exits a tunnel, a blasting sound is generated due to micro pressure waves. To reduce this micro pressure, the front car is designed with a nose section.



# Achieving High Speed

## Reducing Air Drag




Side and Bottom covers for Bogies and other underframe mounted equipment

Fairings fitted all around the gaps between cars

# Passenger Comfort

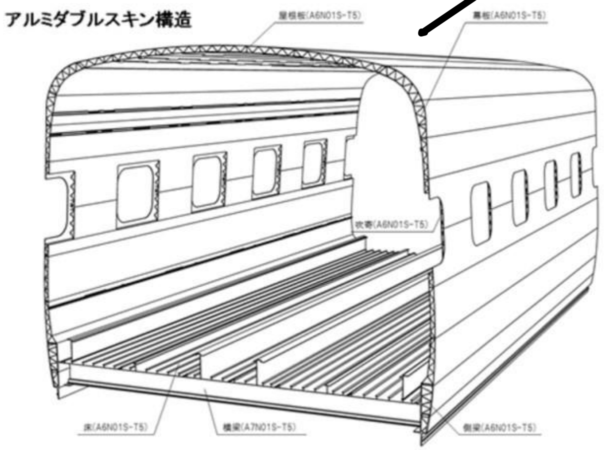
## Avoiding Ear Pressure in tunnels

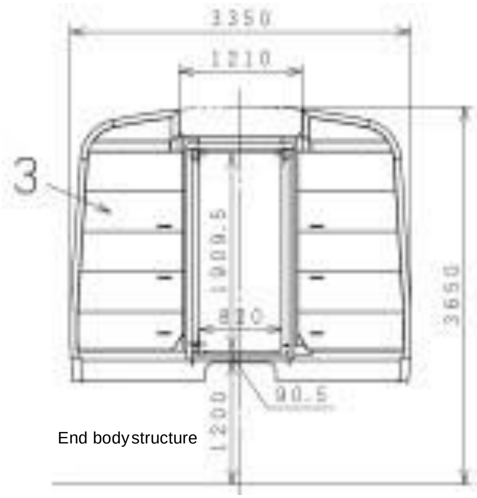
- The car body is pressurized to avoid discomfort to passengers due to drop in pressure inside the passenger cabin in tunnel.

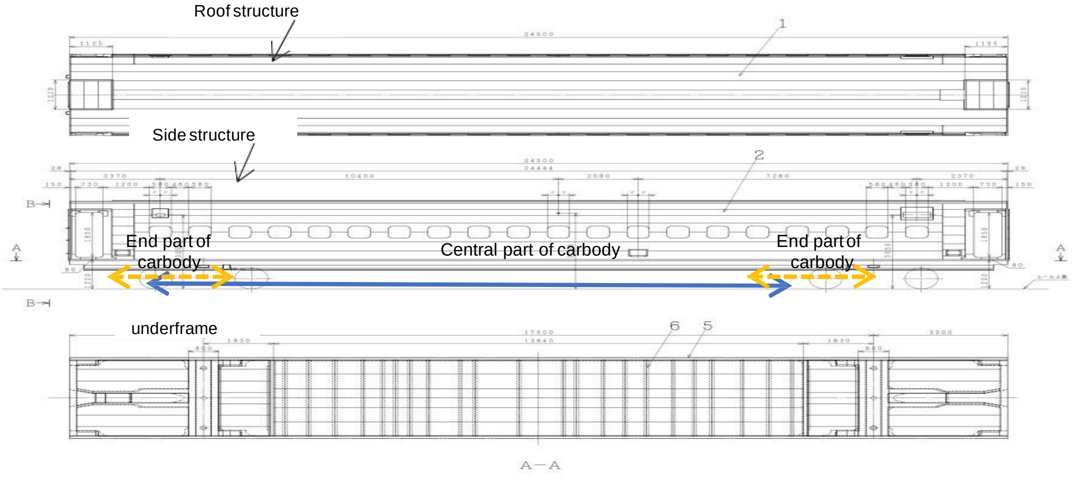
- To achieve this complete car body is made air tight and a pressure inside the car is kept above the atmospheric pressure.

Double skin hollow Aluminum extrusions with truss section

Cross section area = 10.8m$^2$



# Passenger Comfort

## Noise Mitigation

Bogie covers
Sound-absorbing construction

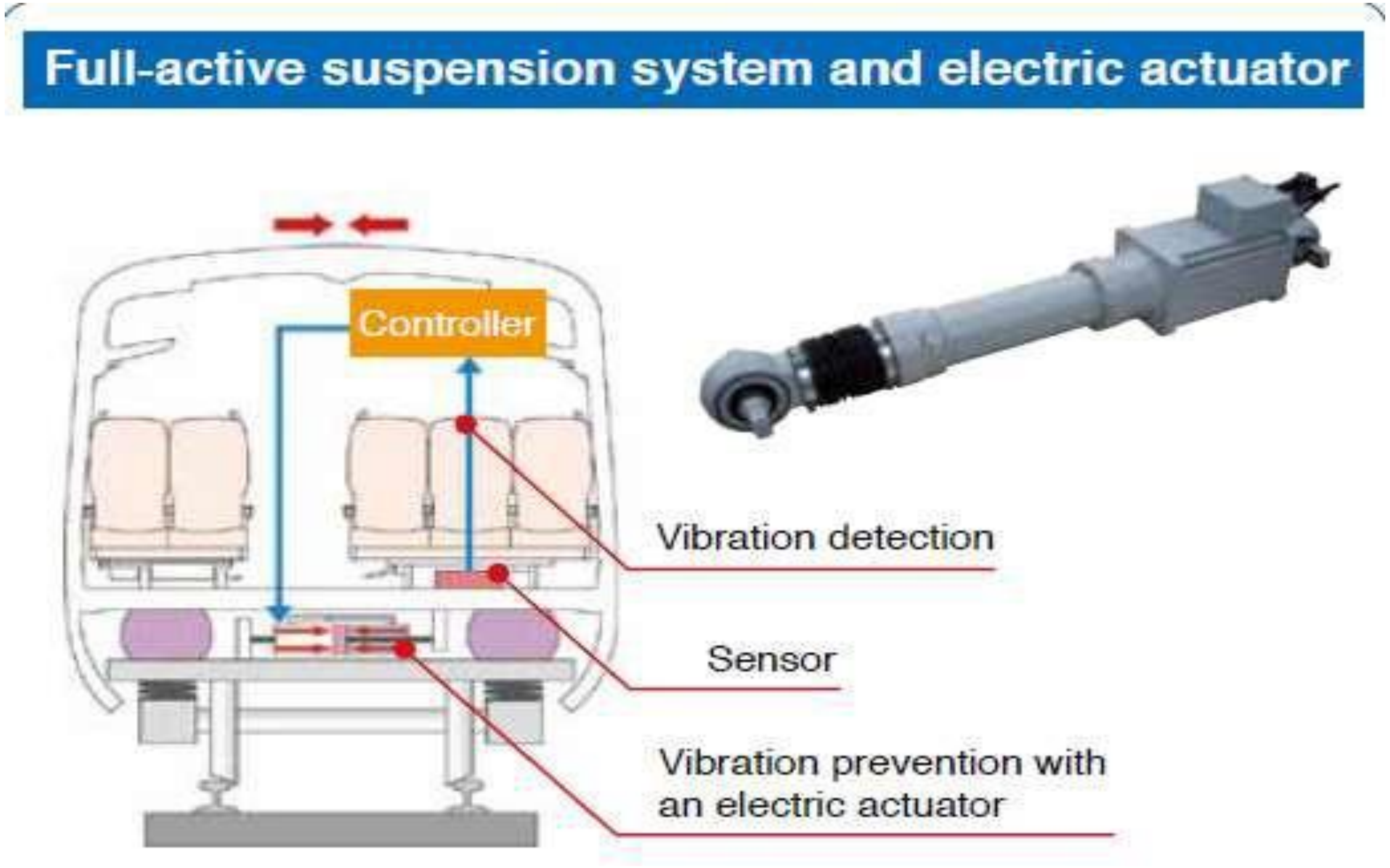
Fairing (Smooth covers) between cars

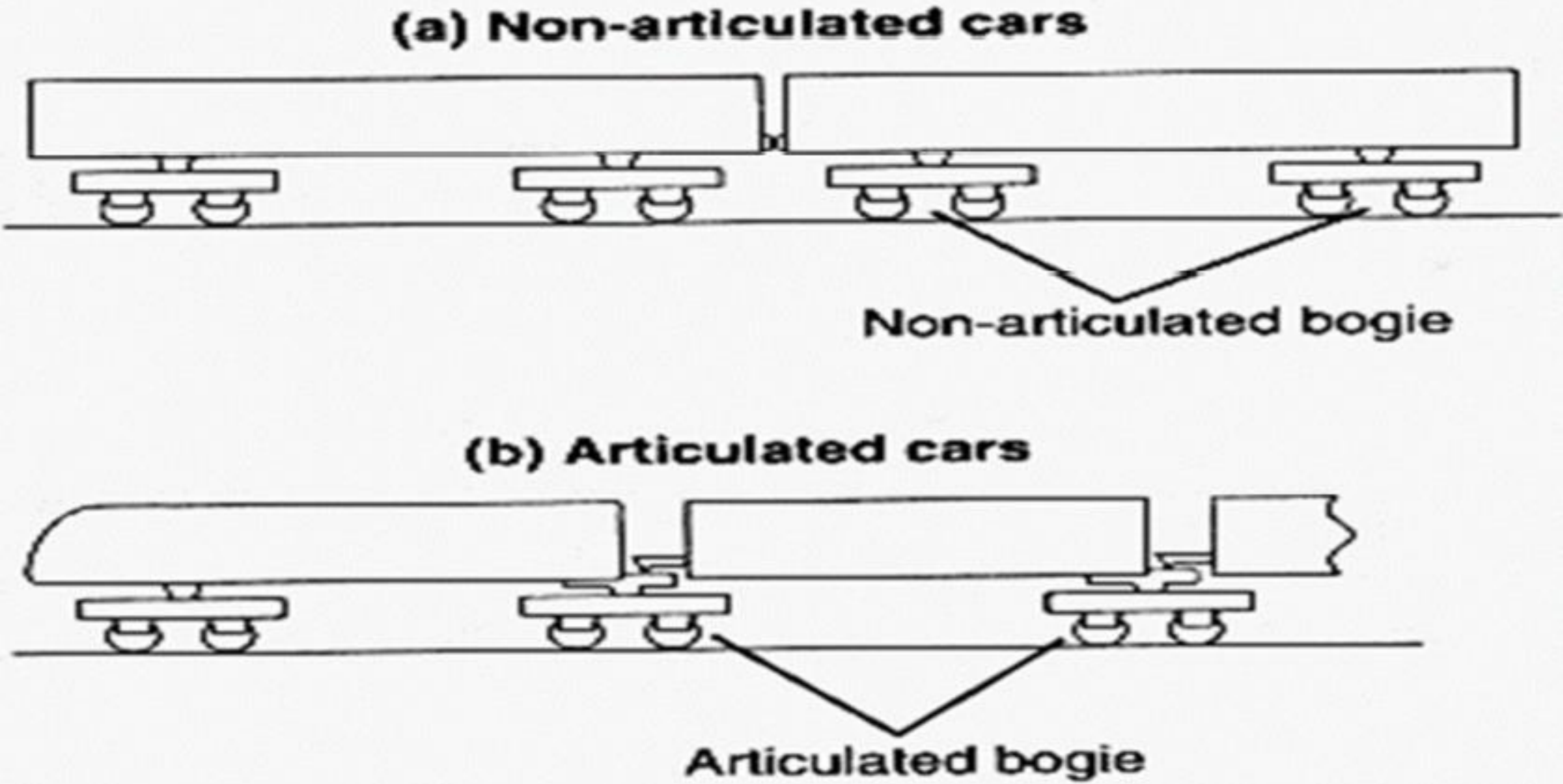
Pantograph noise insulation panel

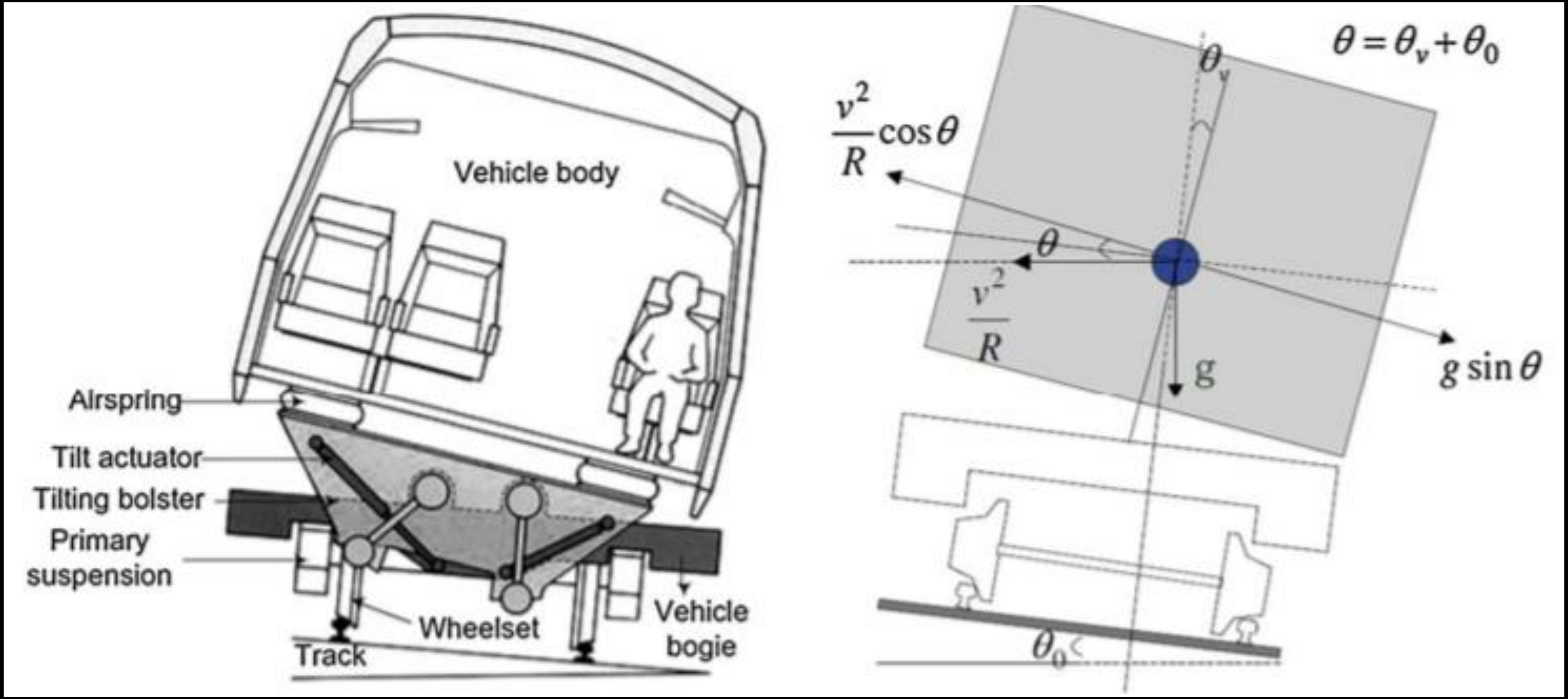
# Passenger Comfort

## Special Lurch Control System

Intelligent control system that detects car body swaying and then reduces lateral vibrations.




(a) Non-articulated cars
Non-articulated bogie
(b) Articulated cars
Articulated bogie



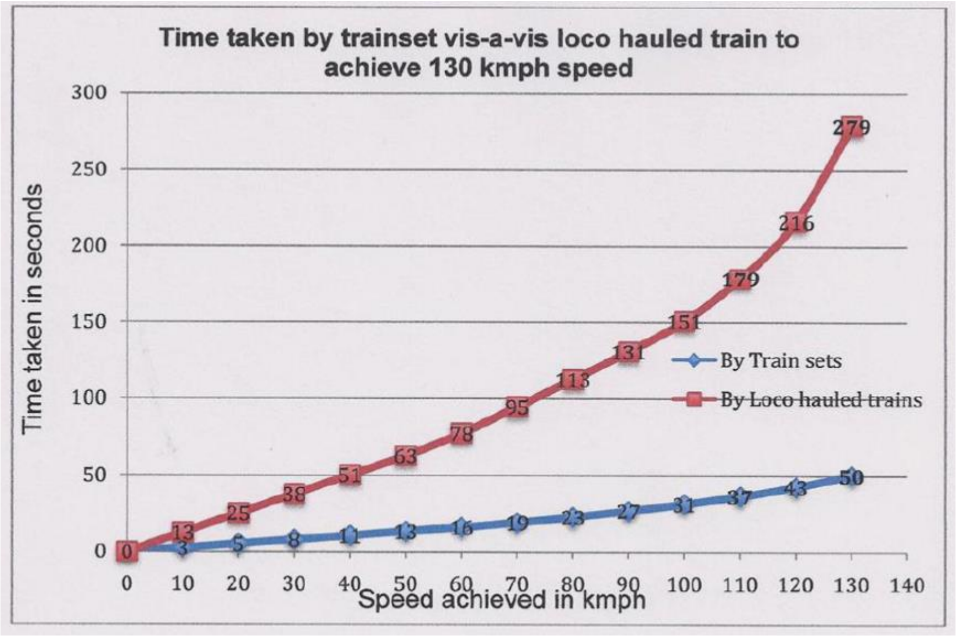

Carbody Tilting

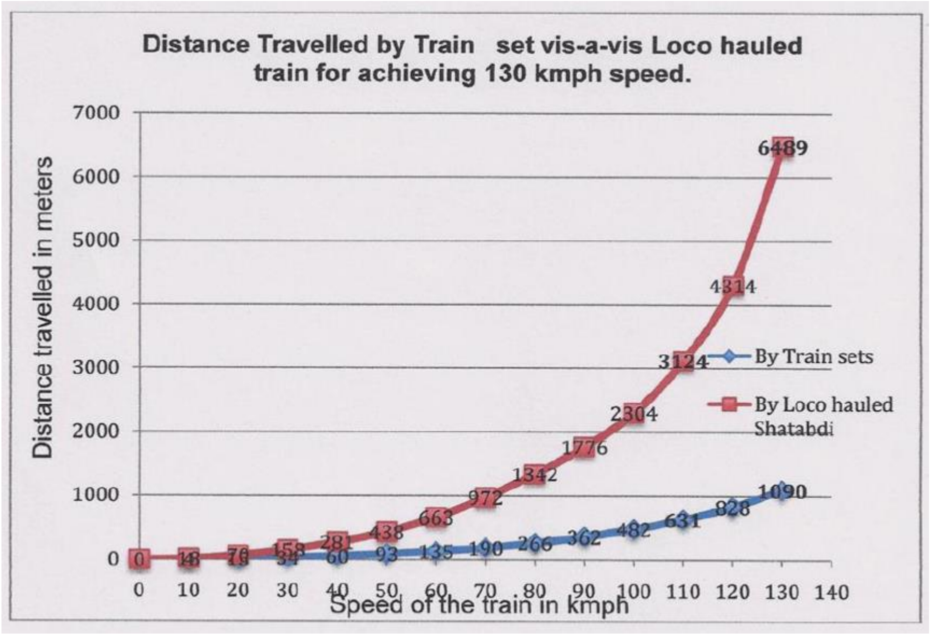
# Advantages of Trainsets

- Better acceleration and deceleration
- Saving in run time
- Energy efficient
- Enhanced safety
- Reduced maintenance
- Improved reliability
- Reduction in pollution
- Improved passenger comfort
- Improved line capacity
- Designed to handle super dense crush load

# Better acceleration and deceleration

| **Operational Characteristics** | **Loco Hauled 21 coach Rajdhani Train** | **Rajdhani run with EMU Train set** |
|---|---|---|
| Acceleration (Starting) | 0.22 $m/s^2$ | 1.0 $m/s^2$ |
| Deceleration | 0.20 $m/s^2$ | 1.0 $m/s^2$ |
| Time to achieve 130 kmph | 279 seconds | 50.3 seconds |
| Distance required to travel to attain a speed of 130 kmph | 6489 meters | 1089.7 meters |
| Additional time required for acceleration and deceleration for a halt with maximum speed of 130 kmph | 216 seconds | 41 seconds |


Time taken by trainset vis-a-vis loco hauled train to achieve 130 kmph speed
Time taken in seconds
Speed achieved in kmph
By Train sets
By Loco hauled trains


Distance Travelled by Train set vis-a-vis Loco hauled train for achieving 130 kmph speed.
Distance travelled in meters
Speed of the train in kmph
By Train sets
By Loco hauled Shatabdi

# Saving in run time

**Reduction in run time between New Delhi and Howrah with Train sets**

| Speed Restrictions kmph | Time Loss in Acceleration and deceleration | | Time saved by Train sets vis-a-vis Loco hauled train (Sec) | No of speed restrictions | Total time Saving with train sets(in sec) |
|---|---|---|---|---|---|
| | By Loco hauled trains (Seconds) | By Train sets with acceleration and deceleration @ 1 $m/s^2$ (Sec) | | | |
| Halts | 216 | 41 | 175 | 6 | 1050 |
| 10 | 198 | 36 | 162 | 6 | 972 |
| 20 | 180 | 30. | 150 | 13 | 1950 |
| 30 | 162 | 24. | 138 | 31 | 4278 |
| 40 | 144 | 20 | 124 | 6 | 744 |
| 50 | 126 | 16 | 110 | 6 | 660 |
| 60 | 111 | 13 | 98 | 4 | 392 |
| 70 | 93 | 10 | 83 | 19 | 1577 |
| 80 | 75 | 7 | 68 | 4 | 272 |
| 90 | 57 | 5 | 52 | 4 | 208 |
| 100 | 39 | 3 | 36 | 17 | 612 |
| 110 | 27 | 2 | 25 | 5 | 125 |
| 120 | 9 | 1 | 8 | 14 | 112 |
| Total Time savings | | | | 135 | 12952 |

**Savings in run time** **216 minutes or 3 hours and 36 minutes**

# Energy efficiency

- Propulsion equipment is mounted on coach, hence requirement of locomotives and power car is eliminated.
- Weight of locomotives and power cars is 1/3$^{rd}$ of the total formation. Hence, removing them saves energy.
- The space of locomotives and power cars may be utilized to augment more coaches in DPRS leading to greater Passenger Km
- Aerodynamically much more stable and lesser air resistance

# Enhanced safety

- Most DPRS have regenerative and Electro pneumatic braking features, Emergency braking distance is reduced
- Reduce jerks due to smoother acceleration and deceleration due distributed power and traction forces
- Anti-telescopic design

# Reduced maintenance

- Reduced wear of track and wheels since power is distributed
- Regenerative & EP braking improves wheel life
- 3 phase IGBT VVVF propulsion
- AC asynchronous traction motor

# Improved reliability

3 PHASE IGBT TECHNOLOGY IS HIGHLY RELIABLE

DISTRIBUTED POWERING HAS A LOT OF IN BUILT REDUNDANCY, SINCE 50-60 % OF AXLES ARE POWERED.

MAN MACHINE INTERFACE GIVES APT FEEDBACK ABOUT ANY ISSUES IN THE PROPULSION SYSTEM.

IN-BUILT FAULT DIAGNOSTICS.

# Improved line capacity

Faster acceleration & deceleration leads in time required to clear a critical section

Higher carrying capacity of DPRS will reduce number of trains required for same throughput.

# THANK YOU