AN INTRODUCTION TO RAILWAY ENGINEERING

THE ROLLING STOCK SYSTEM

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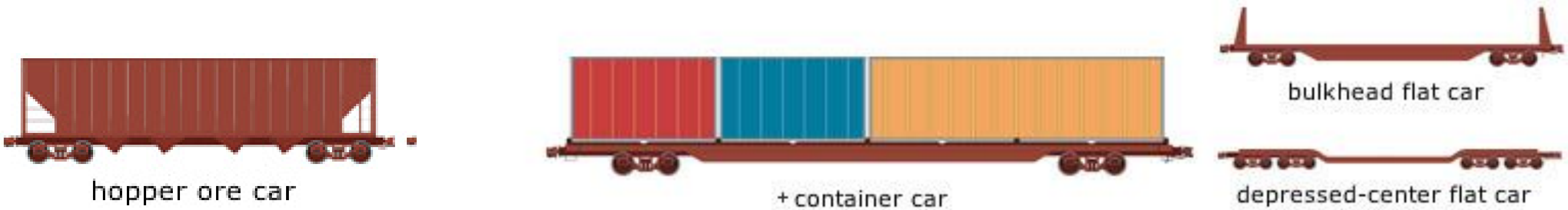
TYPES OF ROLLING STOCK

- Locomotives
  - Diesel
  - Electric
  - Dual Mode or Hybrid
  - Diesel Multiple Unit (DMU)
  - Electric Multiple Unit (EMU)
- Coaches
- Wagons
- Power Generating Cars
- Trolleys
- On Track Machines
- On Track Cranes
- Road Rail Vehicles

LOCOMOTIVES

WAGONS


hopper ore car
+ container car
bulkhead flat car
depressed-center flat car

TROLLEYS

MULTIPURPOSE RAIL VEHICLES

CATENARY INSTALLATION/ RENEWAL MACHINE

CATENARY INSPECTION / TRACK INSPECTION CAR

ROAD RAIL VEHICLES

DIESEL LOCOMOTIVES

DIESEL LOCOMOTIVES

Diesel locomotives are self-sufficient units that combine a prime mover, traction motors, fuel tank, and operator controls to pull or push passenger cars over routes without additional infrastructure to supply power, except for fuel filling yards.

Diesel locomotives are one of the heaviest motive power units and they generate relatively high wheel/rail forces. This leads to increased track and infrastructure maintenance costs, particularly as speeds increase.

Diesel locomotive performance parameters, such as power, acceleration and top speed, are relatively low when compared to electric propulsion. With typical configuration of one locomotive, train performance decreases with additional train length and weight, meaning that different train compositions potentially require different scheduled running times for the same service pattern.

Longer trains may require a second locomotive, or, more practically, shorter trains may be offered more often. The self-sufficient nature of a diesel locomotive allows it to operate on any system track at any time and enhanced flexibility to work through unscheduled track and service issues. Diesel locomotives can be combined with a variety of unpowered coach and cab cars.

DIESEL MULTIPLE UNITS (DMUS)

Single-Level DMU in Ottawa, Canada

Demonstration project of a multi-level DMU LHC Configuration in South Florida, U.S.A

DIESEL MULTIPLE UNITS (DMUS)

- Self-propelled, passenger carrying vehicles that use one or more on-car diesel engines for power.
- Carry their complete propulsion system (i.e. multiple engines, fuel, exhaust treatment, and final drive equipment making them heavier than Electric Multiple Units (EMUs) but reducing the need for off-car infrastructure.
- Some DMUs use hydrodynamic or hydro-mechanic transmissions to directly drive the wheels while others, known as Diesel-Electric Multiple Units (DEMUs), use electric generators and traction motors similar to the diesel-electric locomotives currently used by GO Transit. DMUs can be designed as either single-level or bi-level units.

DIESEL MULTIPLE UNITS (DMUS)

- Consistent, flexible performance as consists can be lengthened or shortened to meet ridership demand.
- By having multiple, distributed diesel engines, DMUs typically can have at least one engine fail without significantly affecting performance and service schedules.
- The combination of multiple engines and drive axles allow DMU consists to accelerate faster than diesel locomotive-hauled coaches.
- Due to the distributed tractive effort (force along the rail) and advances in train transmission design, DMUs are also effective options in low adhesion conditions and moderately steep grades.

DIESEL MULTIPLE UNITS (DMUS)

- DMUs are efficient in small consists, servicing a low-density passenger base. They provide the option of extending or feeding current routes, providing off-peak service, or replacing locomotives in a high-service frequency operating scenario where shorter, more frequent DMUs replace longer, less frequent loco hauled rains. In Europe, some operators have also used DMUs to couple two small trainsets from lower density lines into a mid-sized consist at a feeder station.
- When using longer consists, the benefits of DMUs are overshadowed by their high capital, operating, and maintenance costs. As an alternative, in some areas of the world DMUs pull a limited number of unpowered coach cars similar to their Diesel and Electric Locomotive-hauled Coach counterparts. Although this configuration increases the overall seating capacity and lowers overall capital costs, performance decreases with each additional unpowered coach car added. Thus, when compared to operations that use traditional locomotive-hauled coaches , which benefit significantly from their ability to effectively pull up many coaches, DMUs are typically not an economically viable option when running consists longer than six units.

DUAL MODE LOCOMOTIVES

Rendering of a Dual Mode Locomotive for Montreal's AMT and NJ Transit that will operate under overhead AC catenary

Dual Mode Locomotive operating via Third-rail Electrification, NJ Transit, U.S.A

Single Level Dual Mode MU operated by SNCF, France

DUAL-MODE LOCOMOTIVE

A dual-mode locomotive can operate in electric propulsion mode when in electrified territory, but extend service into non-electrified regions by switching to an onboard diesel engine.

Combines the prime mover, alternator and fuel system of a diesel locomotive with the power collection and conditioning equipment of an electric locomotive.

These systems feed a common traction control and propulsion system.

DUAL-MODE MULTIPLE UNITS

DMMUs can operate under overhead catenary power or from on-board diesel engines.

DMMUs have the same space and weight constraints as the dual-mode and DMU/EMU locomotives. To fit the additional equipment into the DMMU car design, part of the traditional passenger volume is sacrificed for the propulsion

As a result, consists are often configured as power car/trail car/trailer car/power car to balance propulsion performance with seating capacity. Although DMMUs offer significant benefits they carry a significant cost premium due to both their low manufacturing volume and the total amount of equipment that they must contain.

ELECTRIC MULTIPLE (EMUS)

Single Level EMU on the Werribee Railway Line, Australian Railways, Australia

ELECTRIC MULTIPLE (EMUS)

- Self-propelled electric vehicles that do not carry an internal prime mover but instead rely on energy provided by off-car electrification traction power supply and distribution systems. Like other electric locomotives, EMUs are supplied with off-vehicle power (either AC or DC) that is collected, conditioned, and used to power axle-mounted traction motors.
- EMUs are equipped with regenerative braking an energy recovery mechanism that reduces vehicle speed while simultaneously converting some of its kinetic energy into usable energy.

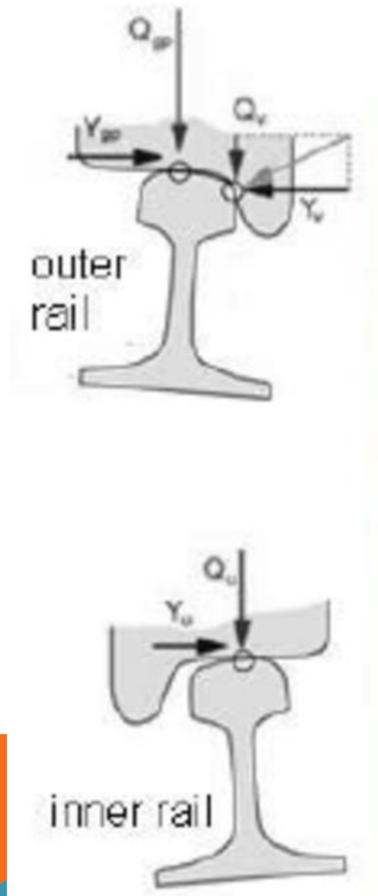
ELECTRIC MULTIPLE (EMUS)

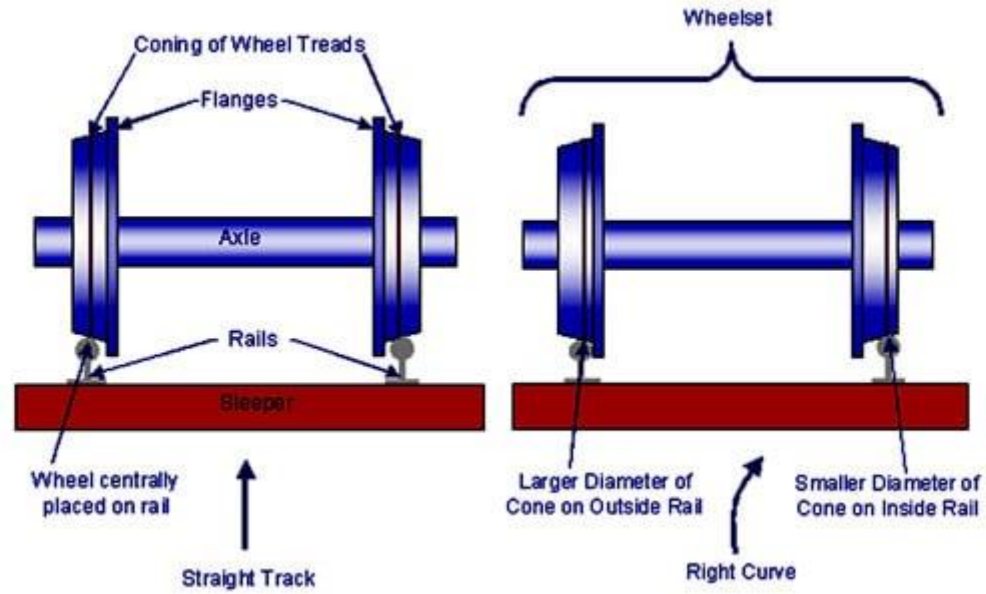
- EMUs are efficient for areas with high ridership and frequent service. They offer high acceleration rates and consistent performance across all trainset lengths as power is supplied to every axle in the train consist.
- As a result of traction motor torque being compatible with local axle loading, EMUs have superior grade-climbing abilities when compared to diesel or electric locomotive-hauled coach trainsets.

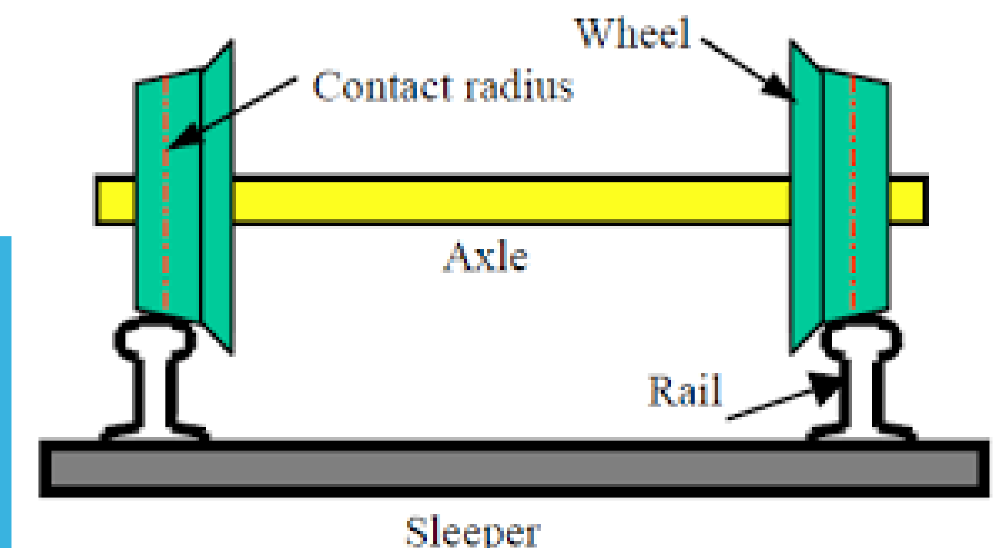
ELECTRIC MULTIPLE (EMUS)

- EMUs are cost competitive with diesel locomotives and diesel multiple units (DMUs) over short to moderate route lengths with high ridership and high service frequency. Similar to DMUs, EMUs costs vary with consist length.
- EMU cost competitiveness is more strongly driven by service frequency and environment than by consist length.
- Modern EMUs also have enough power to pull a limited number of unpowered coach cars, similar to locomotive-hauled coach (LHC) services, thus increasing seating capacity while costing significantly less than EMUs to purchase, operate, maintain. However, consist performance will decrease with each additional unpowered coach car.

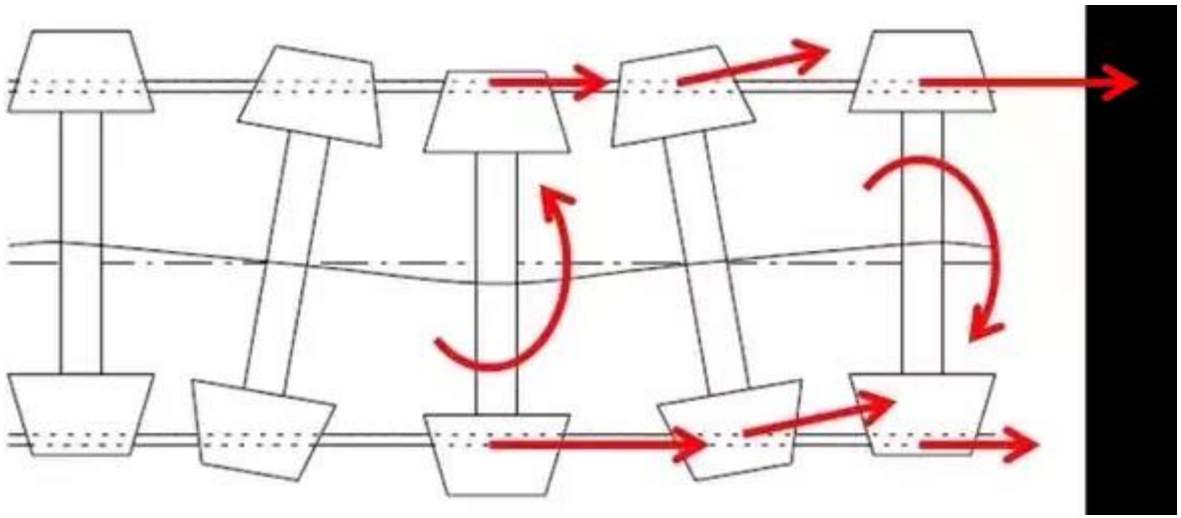
THE SHAPE OF THE WHEEL AND THE RAIL – THEIR INTERFACE

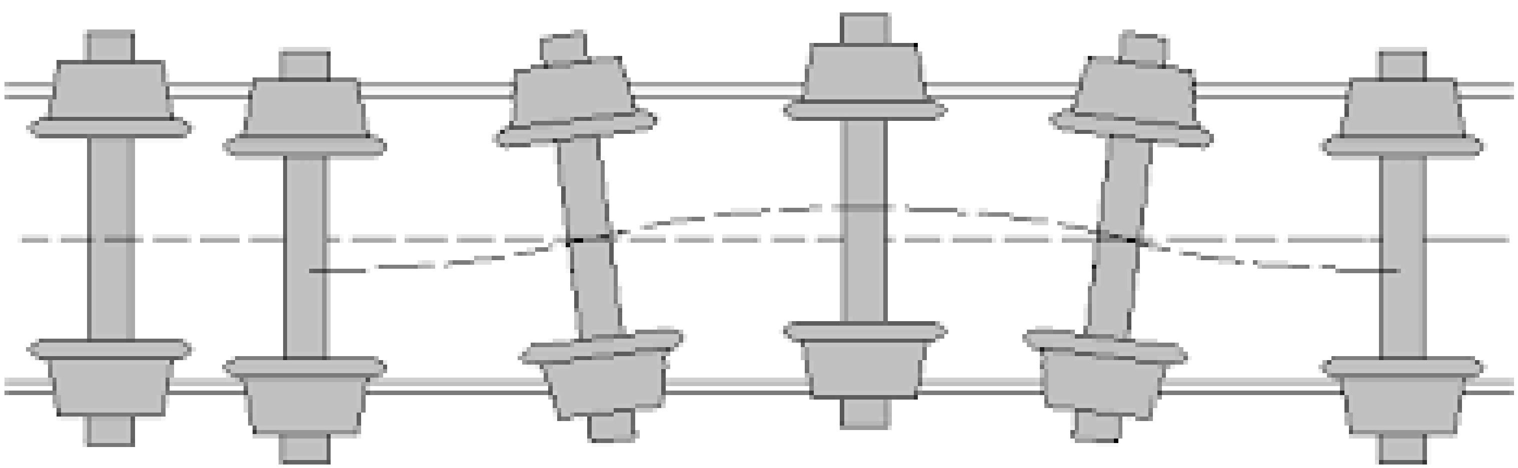






THE HUNTING OSCILLATION OF THE WHEEL

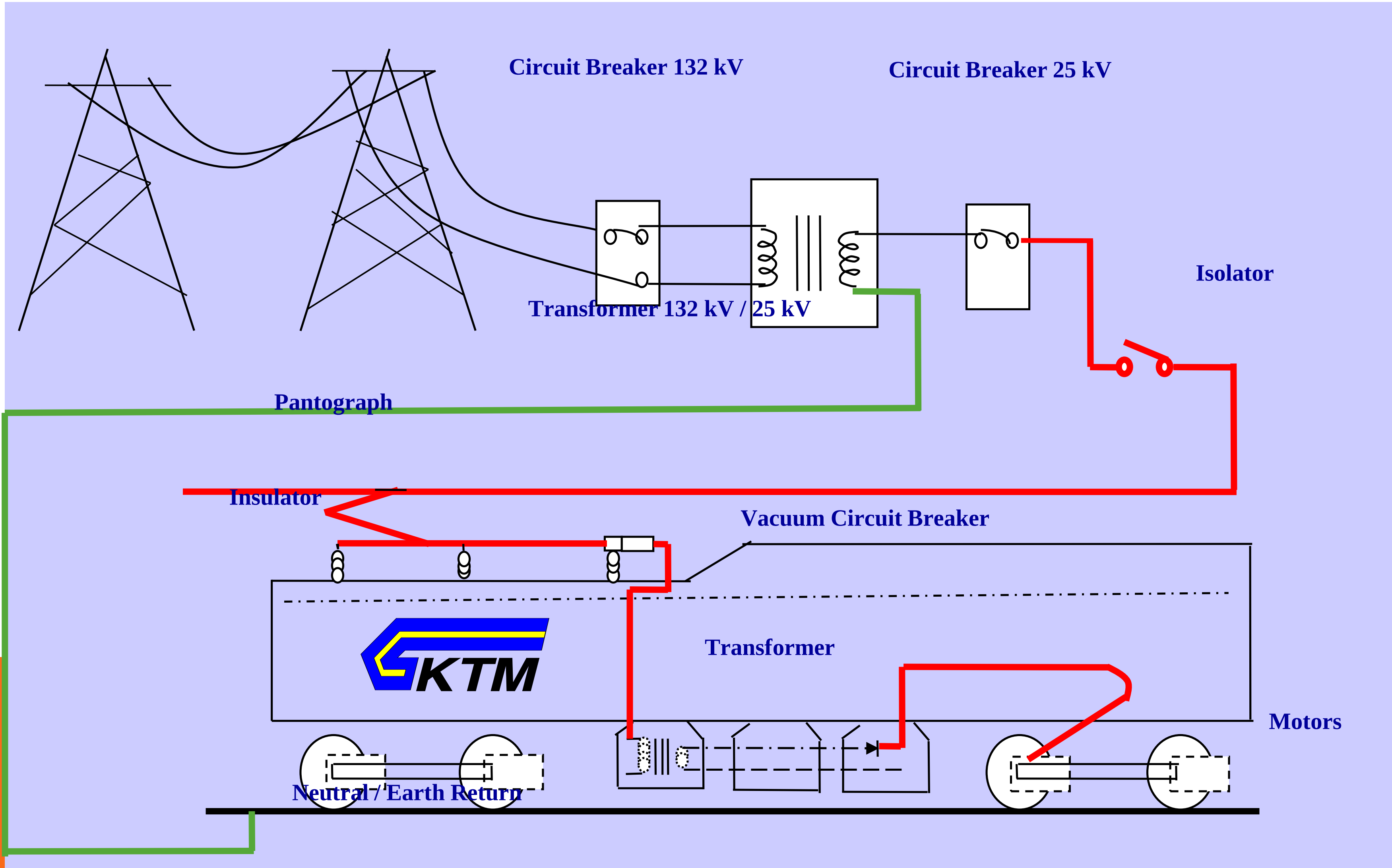




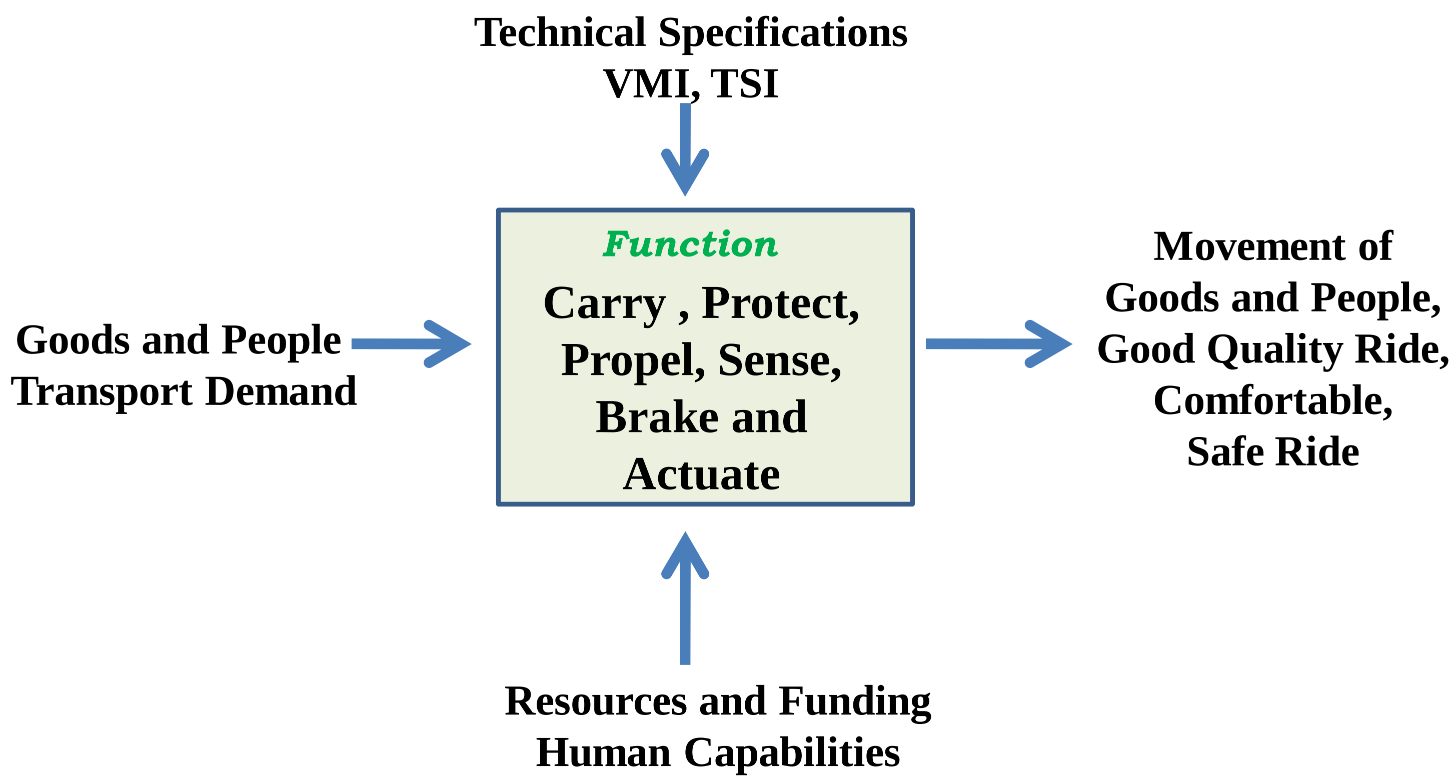
1. The axle trajectory.

VIDEO SHOWING IMPORTANCE OF CONING OF WHEEL

EMU POWER SUPPLY FOR KTMB (SOURCE: KTMB, 2010)



THE ROLLING STOCK SYSTEM



Energy Efficiency of the Railways transport

A broad comparison with Road transport

Motive power	Capacity	Weight that can be hauled	Horsepower /ton	Remarks
Locomotive	3300 HP	2500 tons	1.32	Locomotive is more efficient than the other types of motive powers
Road truck	280 HP	15 tons	18.00	
Family car	90 HP	1.75 tons	51.00	

'Power to load carried factor' is much less for Railways than Road ways

Notes:

- “American / European high powered electric locomotives weigh between 90 and 180 metric tons and provide about 6000 to 7000 horsepower (4.5 - 5.2MW).“

  2400HP= 1.8MW

  3000HP= 2.25MW (KTMB High powered Locomotives)

  1333Hp= 1.0 MW
- A locomotive's diesel-electric power plant is usually about 3,000 horsepower *(This is termed as Locomotive rating)*
- As a comparison, an automobile can reach about 130 horsepower.
- For a typical High Speed EMU:
  - 240 kW (321.8 **HP**) per motor, 5,760 kW (7,724 **HP**) per set
- For a Commuter EMU 800-1000HP

Notes (typical examples)

	STANDARD GAUGE LOCO	NARROW /METRE GAUGE
Power systems	15kV AC (16.7Hz) 25kV AC (50Hz) 3kV DC 1.5kV DC	Diesel Electric Traction
Max Speed	140-230km/hr	120km/hr
Rating kW	4,200 (1.5kV DC), 6000 (3kV DC) 6,400 AC	1500-2500
Starting Tractive Effort (kN)	235-450	260-320
Structure Clearance gauge	UIC 505-1	As per operator's loading/structure gauges.
Axle Load	13.5 – 22.5 Tonnes (European)	13.5-20 Tonnes (Asian)

ROLLING STOCK DESIGN

- Varies depending on type of railway services being provided,
- From high speed electric train services to diesel freight services or the metro trams services

AXLE LOAD

- The weight limit applied to trains passing over a line by the railway infra engineer. Axle load refers to the maximum weight permitted on a single axle
- A four-axle vehicle weighing 60 t (metric tonnes) would have an axle load of approximately 15 t depending on how the weight was distributed.
- In the UK the maximum axle load is 20 t on most main lines. The European maximum is 22.5 t.
- Rolling stock designer must design accordingly.

ROLLING STOCK SUB-SYSTEMS

- Running gear (Wheel, axles, bogies and primary suspension)
- Secondary suspension system
- Brake system
- Vehicle body (includes the underframe, monocoque or integrated with underframe, as applicable)
- Air conditioning system (for passenger vehicles and special goods)
- Passenger Information system
- Lighting system
- Communication system

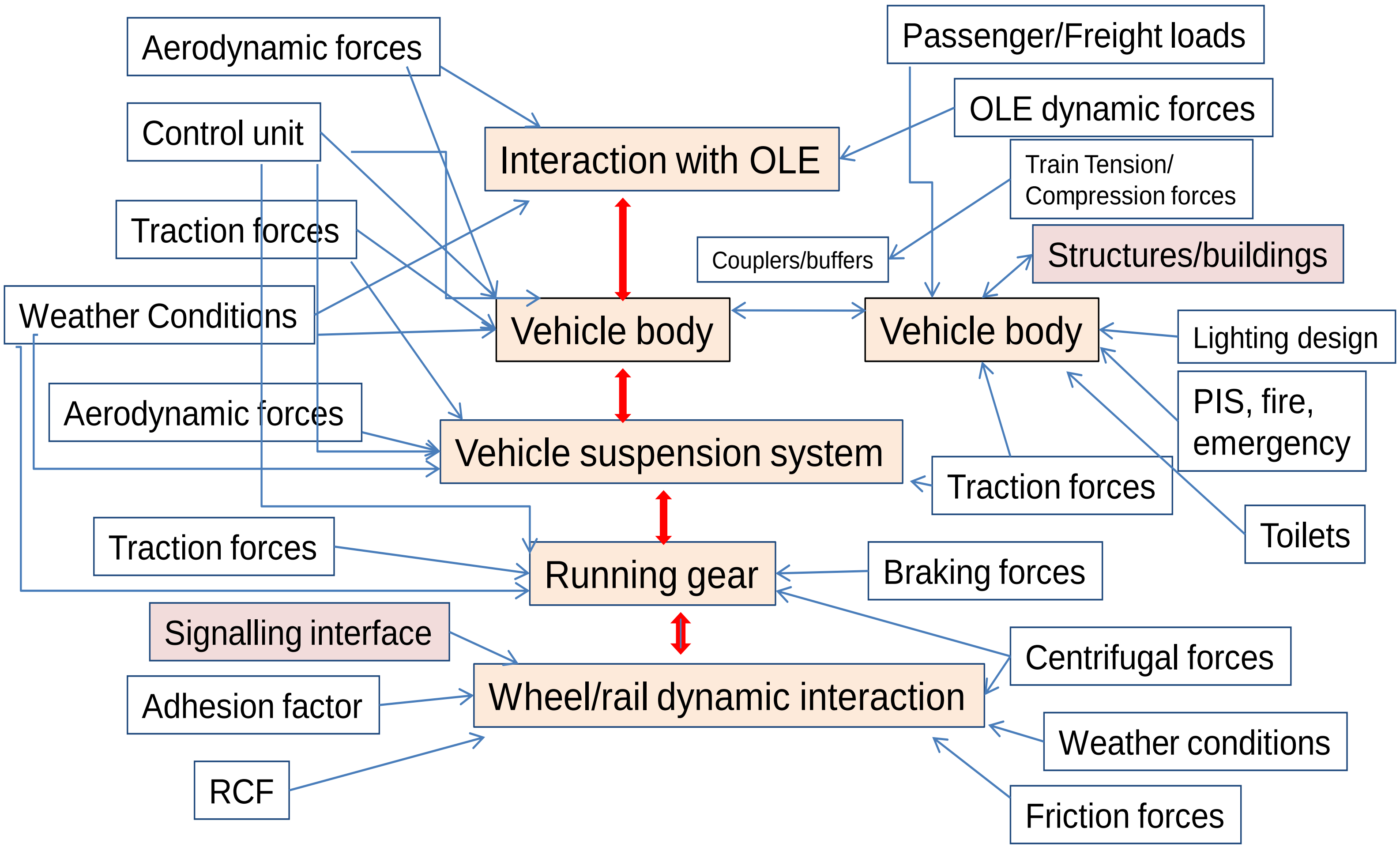
ROLLING STOCK SUB-SYSTEMS

- Couplings and buffers
- Control systems
- Traction system
- Ancillary systems (such as hotel services facilities), and
- Tilting train system
- Rack and Pinion (for steep hill railways)
- Other auxiliary systems (such as specialised equipments for freight, airport vehicles)

ROLLING STOCK RELIABILITY

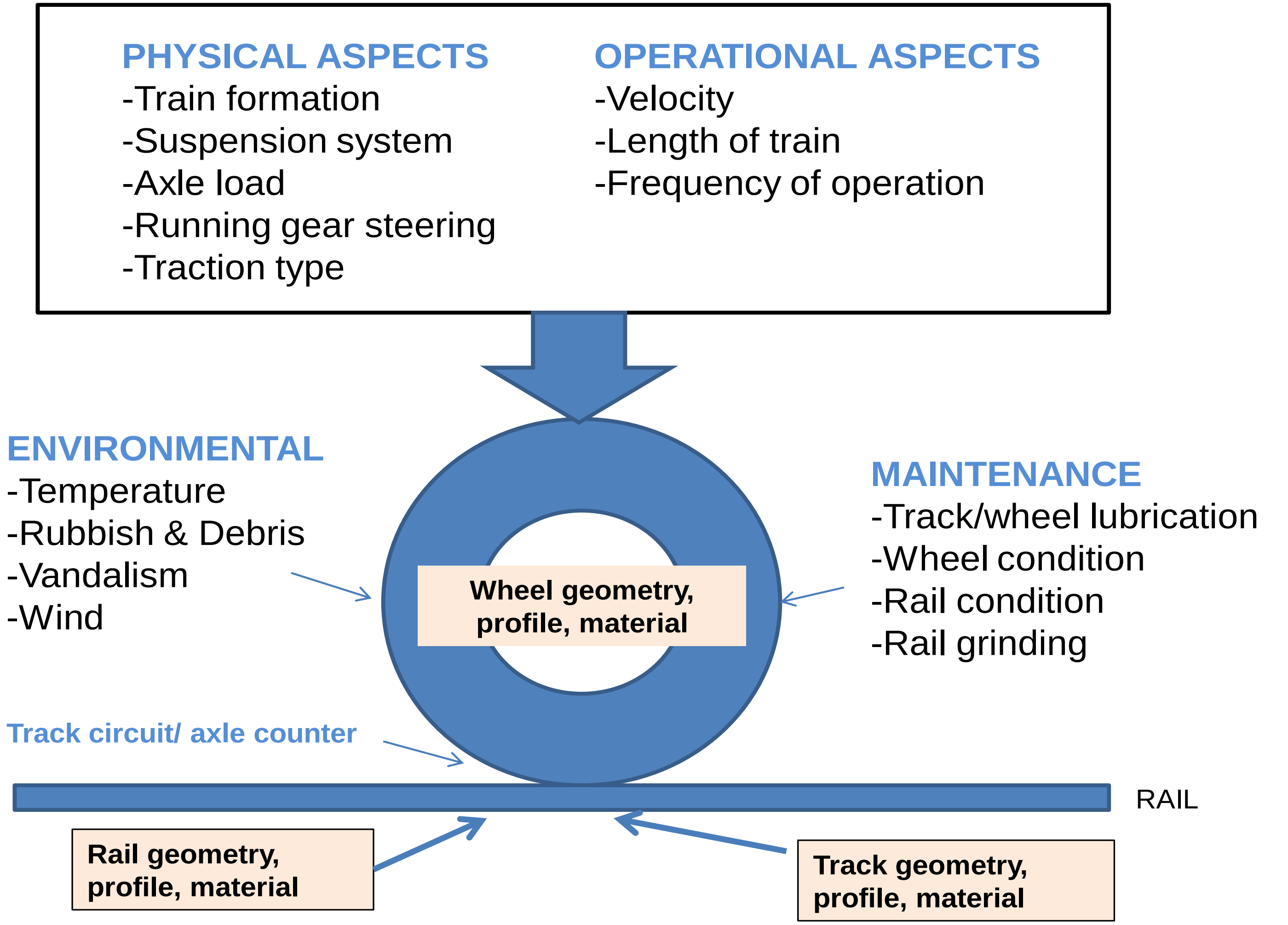
The reliability of the rolling stock system can be defined by the probability that all its component subsystem satisfies their specified behaviour over time and under their given conditions of operation.

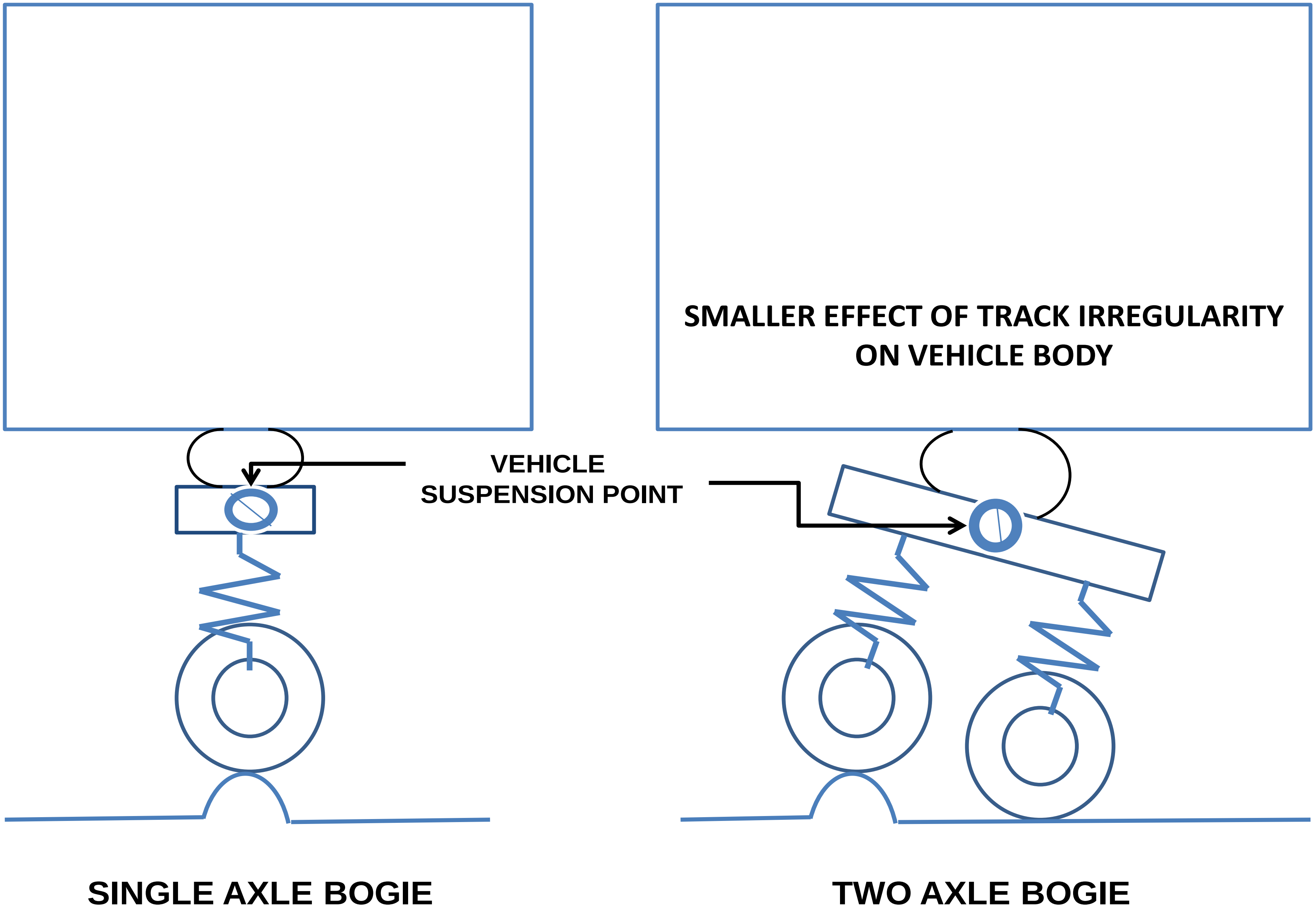
COMPLEXITY OF SUBSYSTEMS ENGINEERING AND INTEGRATION



ROLLING STOCK SUBSYSTEMS COMPLEX INTERFACES

INTERFACING FACTORS





Interaction of bogie and vehicle body (Okamoto, 1998)

THE RUNNING GEAR AND THE SUSPENSION SYSTEM

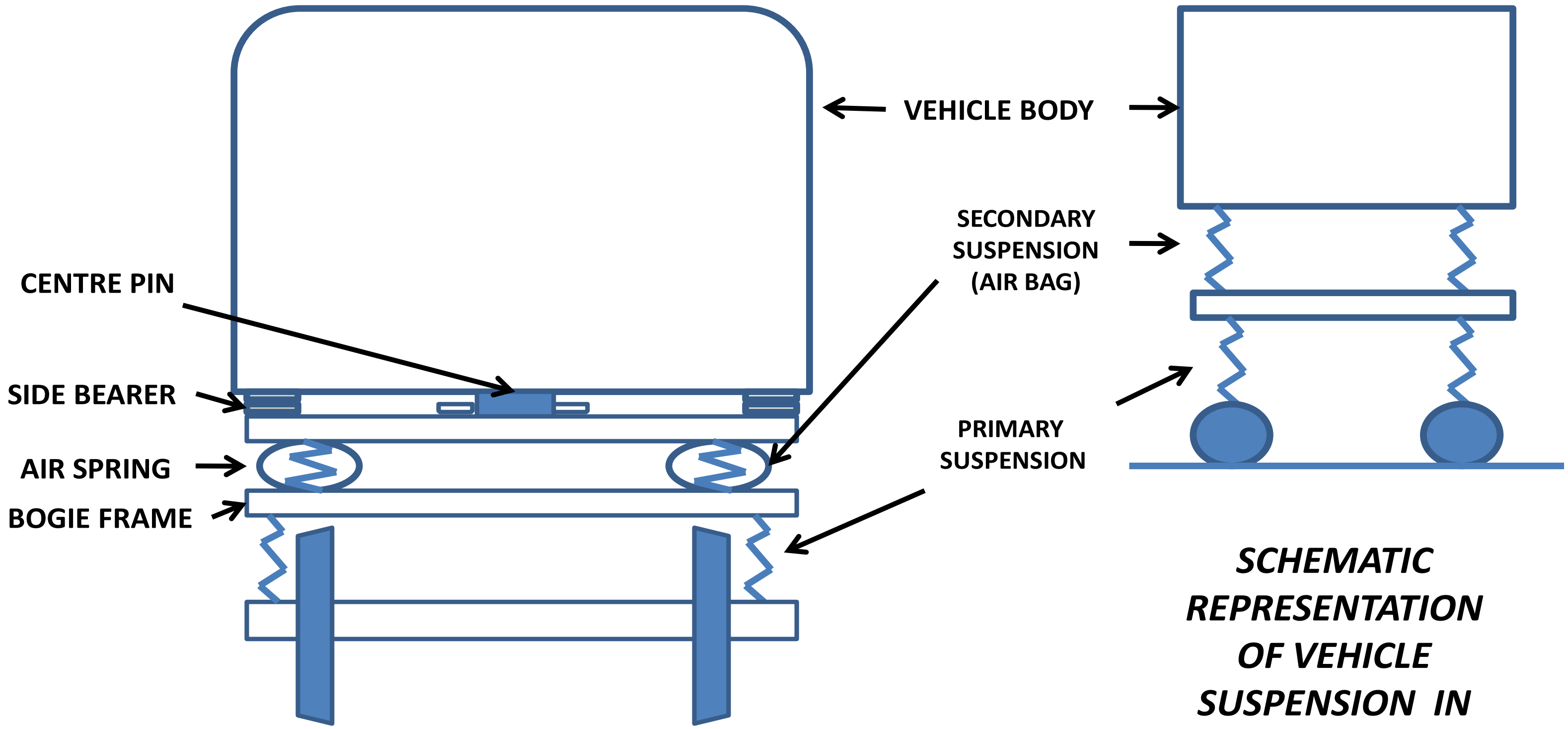
- Comprises the Wheel and Axle, Bogies and Primary Suspension.
  - They serve to provide the steering and guidance to the railway vehicle.

THE RUNNING GEAR AND THE SUSPENSION SYSTEM

Whilst the wheel, axle and bogie system provides the steering and guidance and transmitting the various forces, the primary suspension component of the running gear supports the bogie frame and restrict the axle box movements.

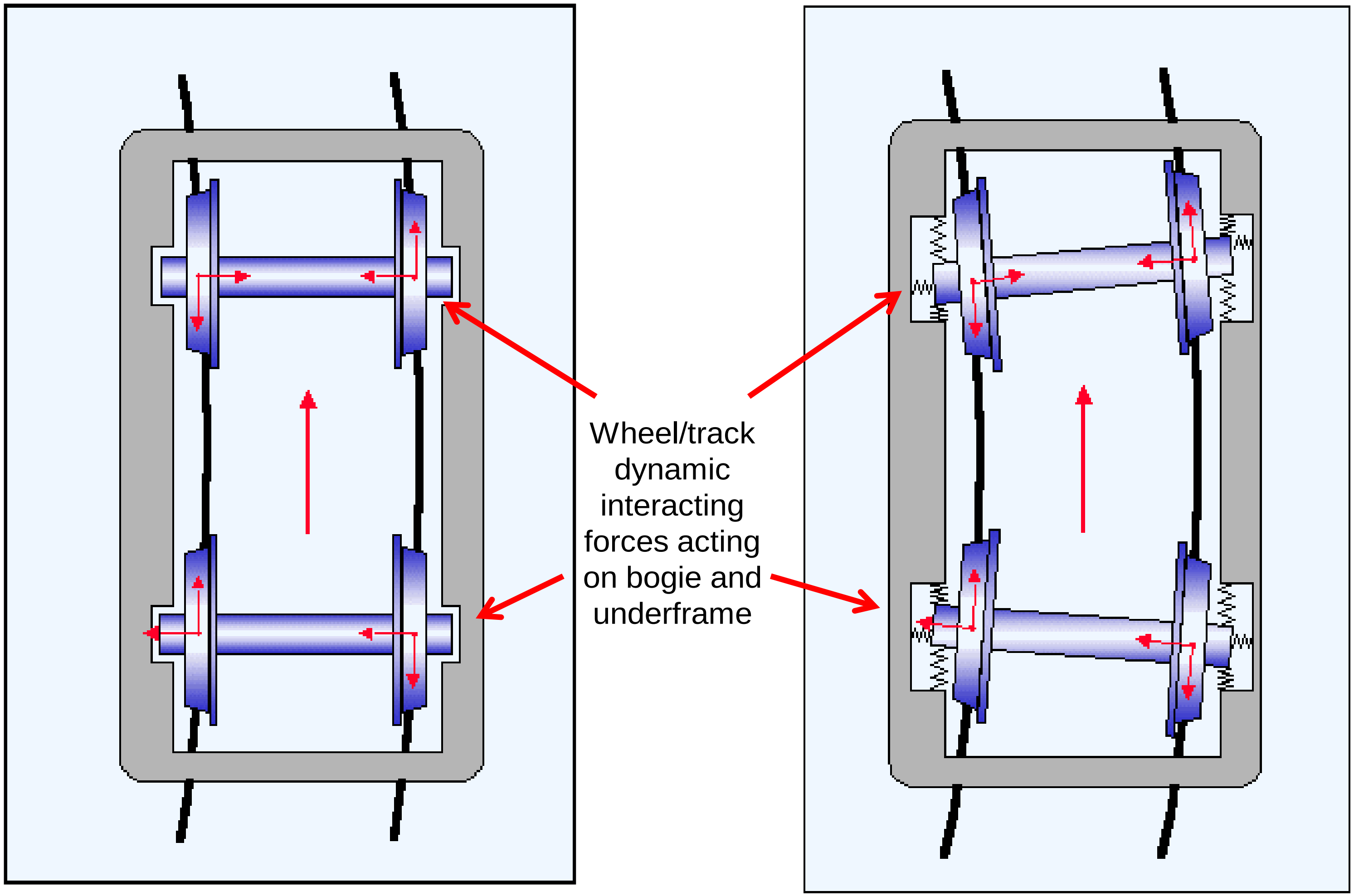
Overall, the running gear system interface with the infrastructure at the wheel/rail interface. It also interfaces with the secondary suspension subsystem.

VEHICLE SUSPENSION SYSTEM



SCHEMATIC REPRESENTATION OF VEHICLE SUSPENSION IN RELATION TO BOGIE FRAME AND VEHICLE BODY

INTERACTING FORCES BETWEEN TRACK, BOGIE AND UNDERFRAME

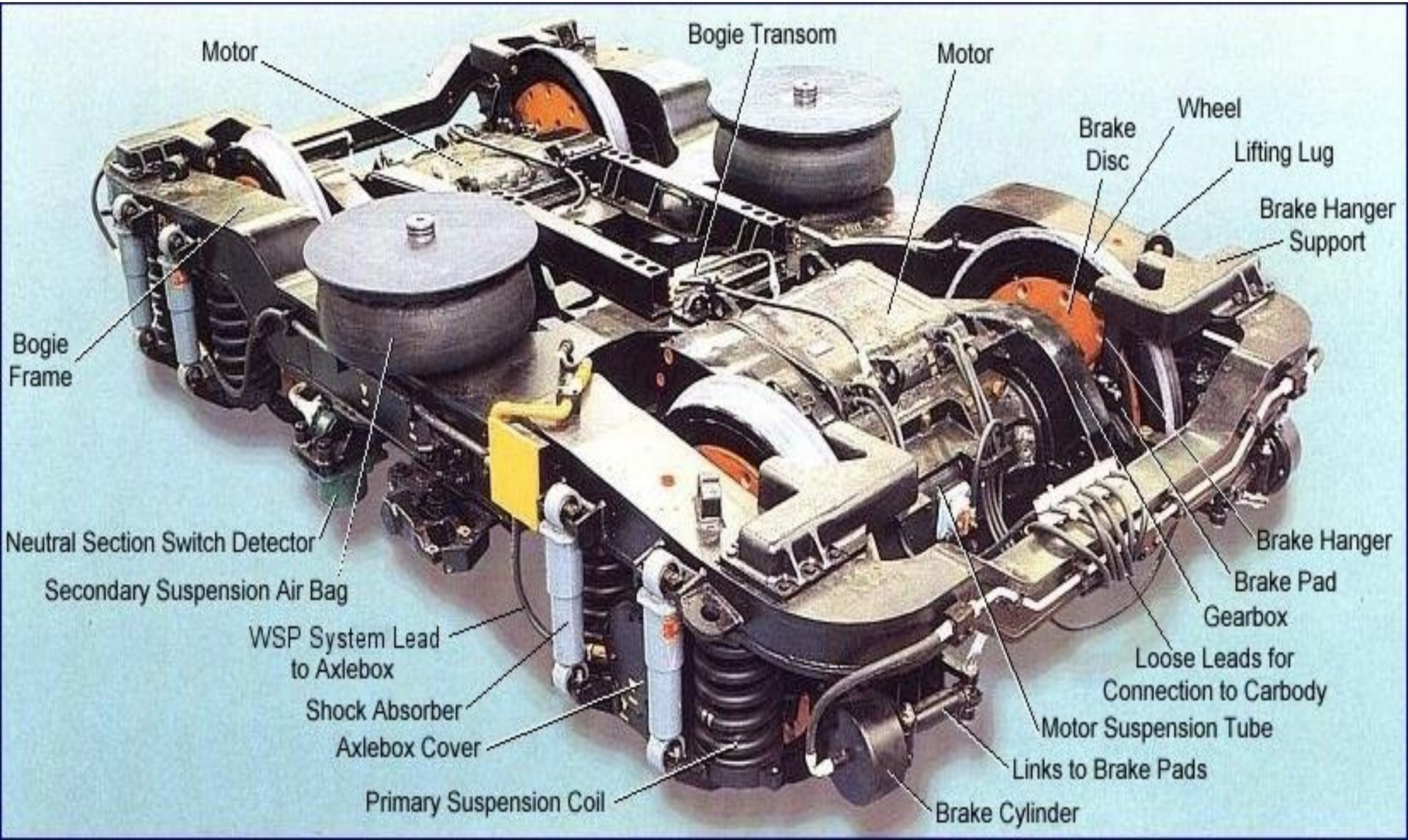


RIGID BOGIE STEERABLE BOGIE

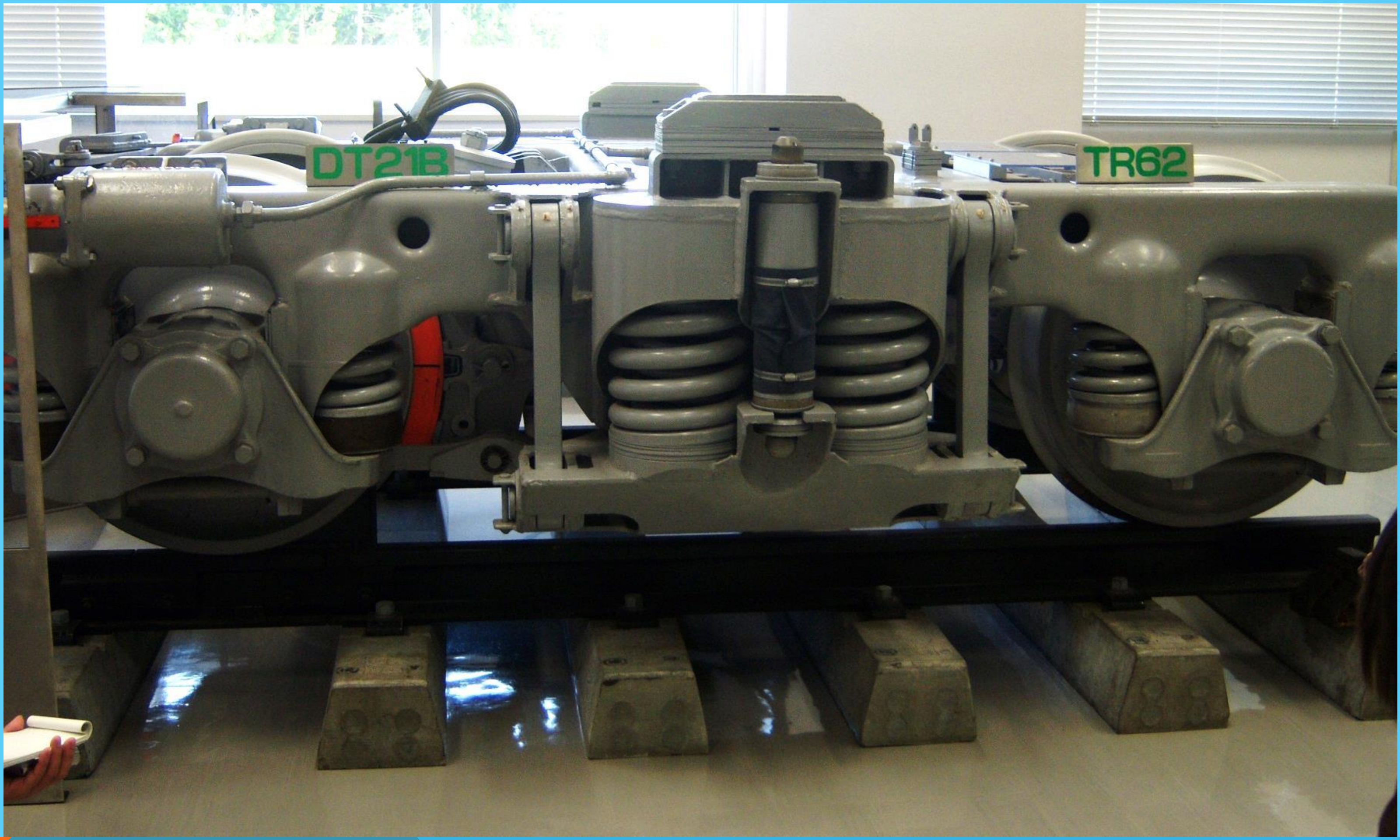
(Picture from http://www.railway-technical.com/whlbog.shtml)

A TYPICAL BOGIE SET

(PHOTOGRAPH FROM HTTP://WWW.RAILWAY-TECHNICAL.COM)

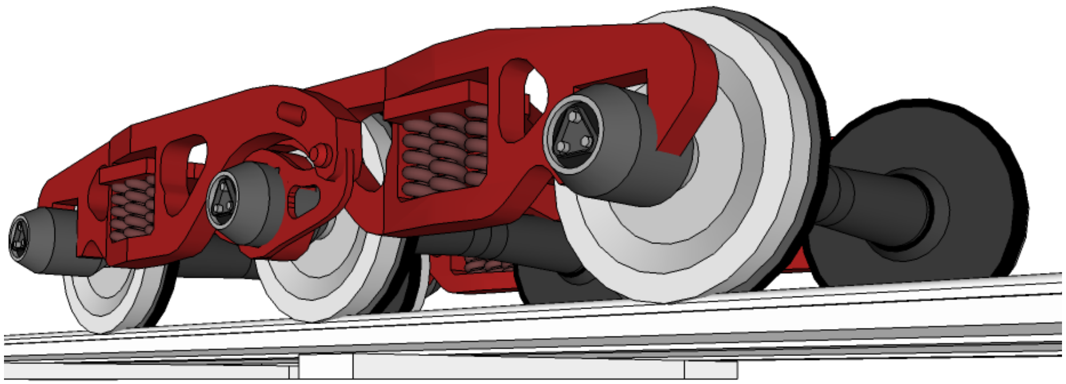


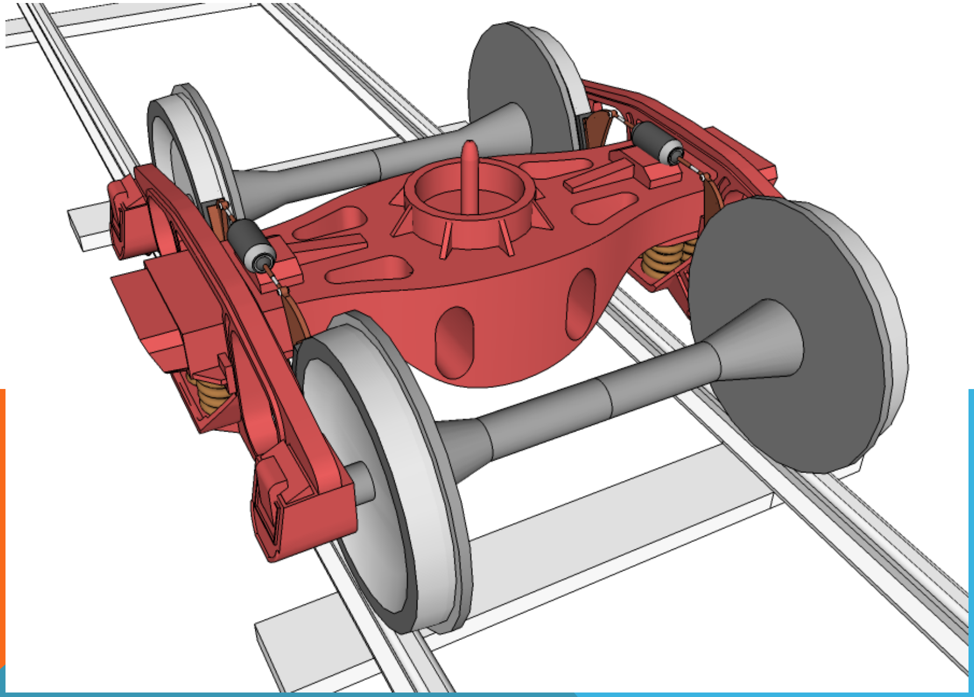
SHINKANSEN BOGIE SET



SELF-STEERING RADIAL BOGIE

- The bogie is a cast steel three-piece bogie, mainly consists of the wheel-sets, rolled bearing, axle-box rubber pad , side-frame, bolster, spring, snubbing device,brake rigging and radial device,etc.
- The bogie have been improved on the base of traditional bogie. With excellent stability and curve negotiation performance, it is more suitable for heavy axle loads.
- Main technical parameters:
  (1) Axle load: 25tons
  (2) Tare weight: 4.85tons
  (3) Max operating speed:120 km/h

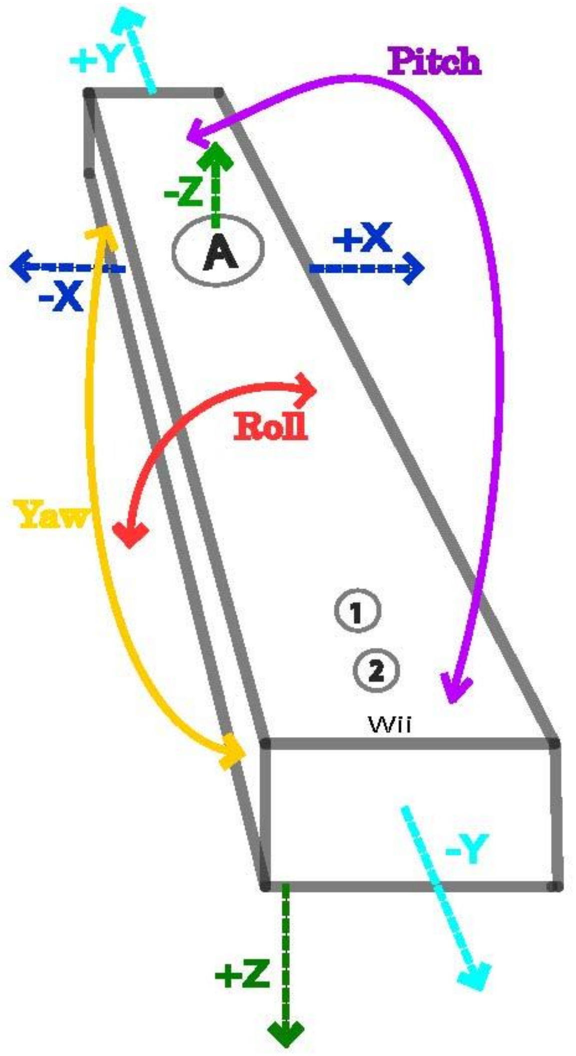




BOGIE DESIGN

Although the train as a whole is restricted to a single degree of freedom, the vehicle undergoes through six modes of motion or vibration:

- longitudinal,
- vertical,
- pitch,
- lower sway,
- upper sway and,
- yaw.



BOGIE DESIGN

Design of bogies must take into account the forces arising from these modes of vibration because the frequency of these vibrations affects vehicle stability.

For these reason, bogie designs incorporate components such as yaw restraint components, shock absorbers and vertical dampers.

BOGIE DESIGN:

PRIMARY & SECONDARY SUSPENSION

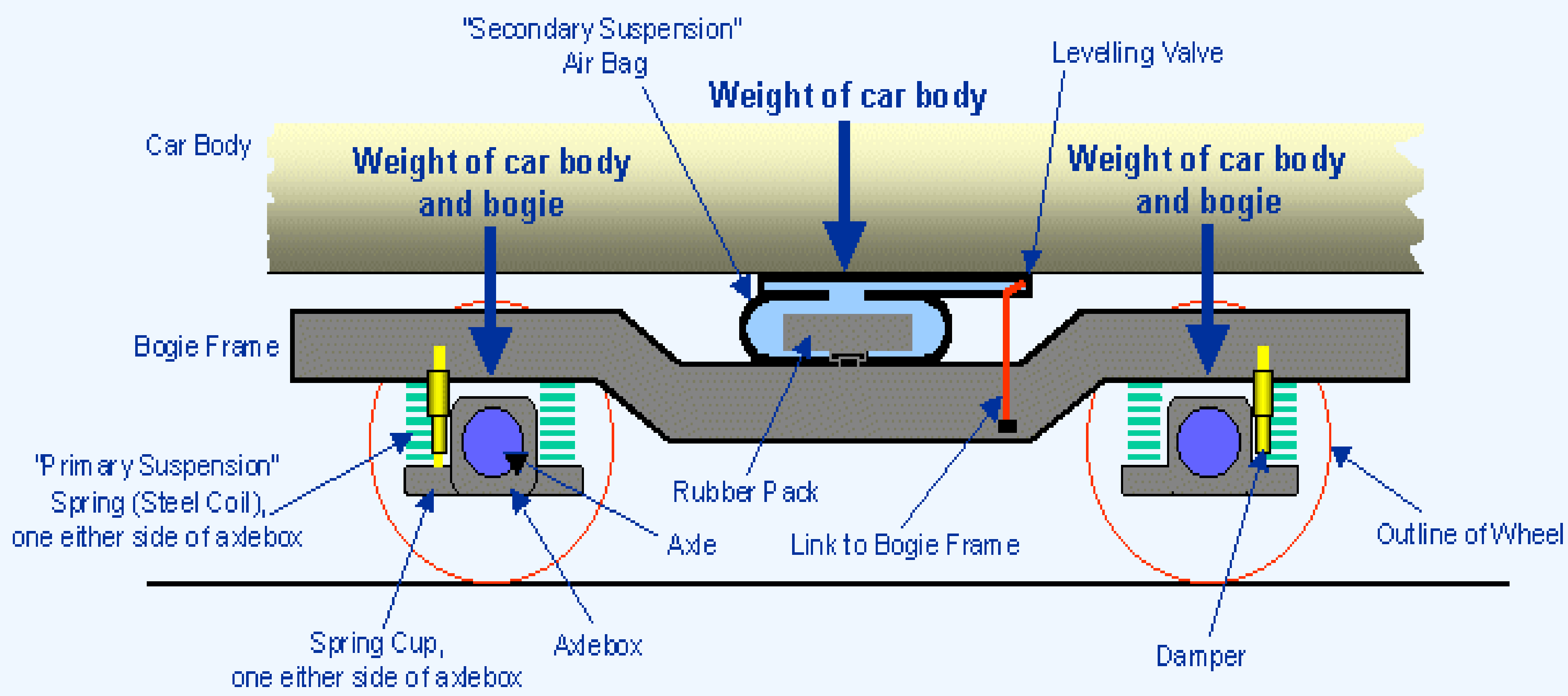


Diagram of bogie with steel primary and air bag secondary suspension

THE BRAKE SYSTEM

- Reduce the speed or stop a train
- A critical safety system
  - During movement, it absorbs and dissipates the kinetic energy of the train
  - During parking, the brake system absorbs the inertial forces from the train load to prevent movement, either on a level or on a gradient track
  - For electric traction, the brake system also function to return energy to the power supply obtained from regenerative braking.

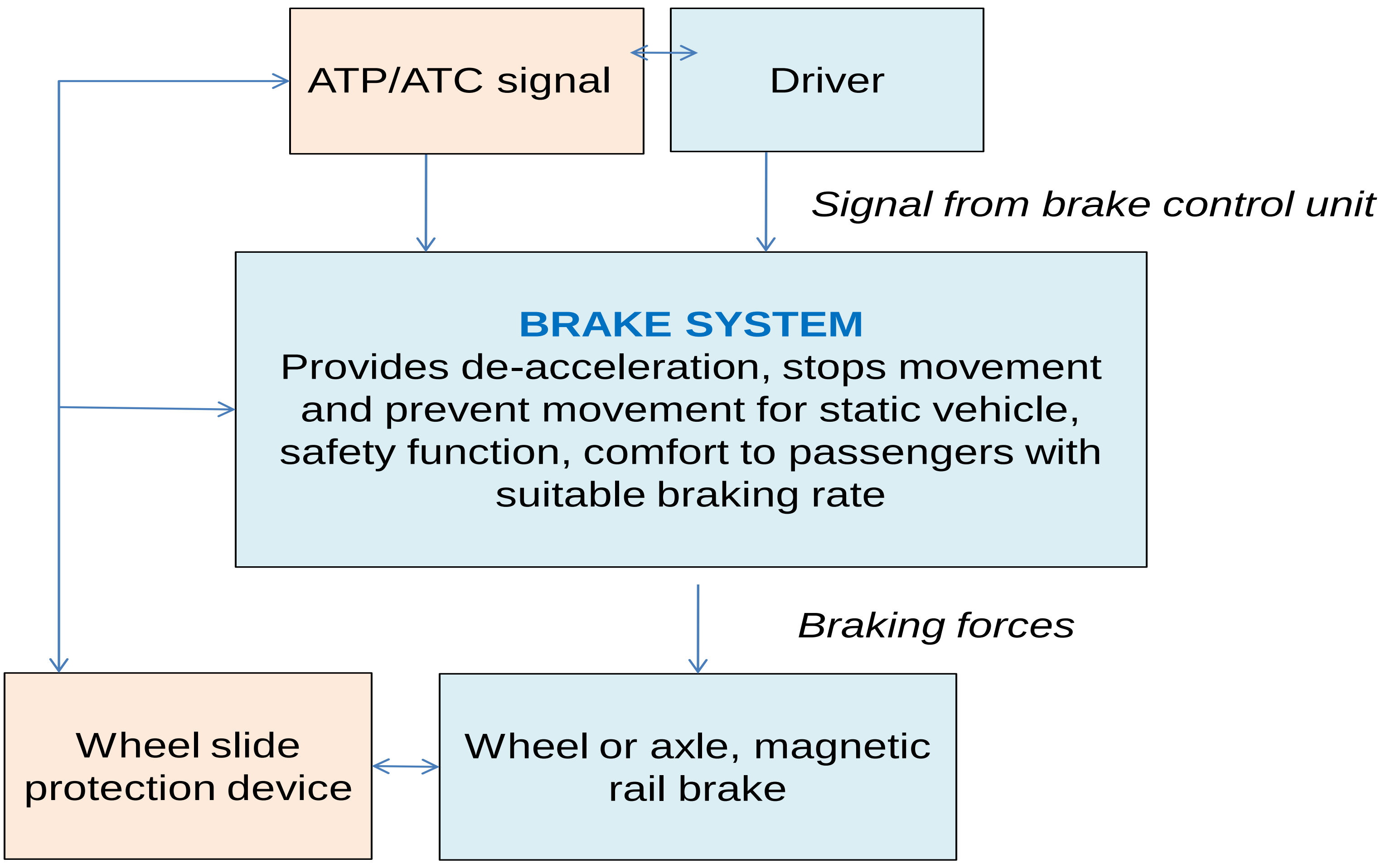
THE BRAKE SUBSYSTEM

Brake control system

Brake actuation system

Brake application system

BRAKE SYSTEM INTERFACE



VEHICLE BODY SYSTEM

Perform the functions of bearing the passenger or freight loads and to ‘protect’ them in transit

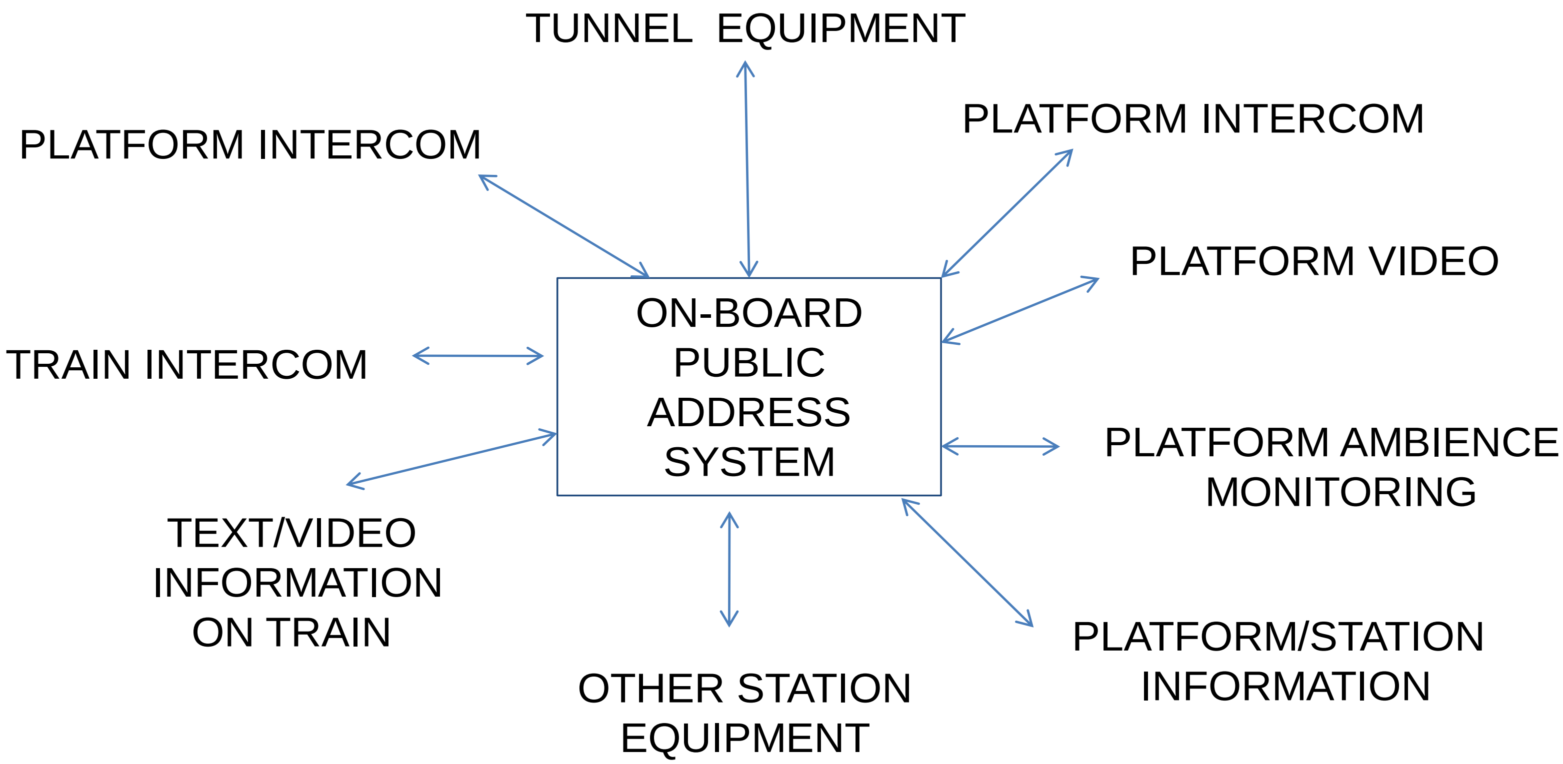
The design of the underframe and vehicle body depends on the type of trains

Need to minimise its weight in order to maximise its load carrying capacity.

VEHICLE BODY SYSTEM DESIGN

- Depends on the type and location of service that the rolling stock is required (eg small size of tunnels in the London Underground system)
- Impact the dimensions of the vehicle underframe and body dimensions
- The length and vehicle floor height will also impact the infrastructure design
- Length of vehicles results in end throws and centre throws at station platforms that are on curves and necessary safety provisions and warnings to passengers
- Dynamic loading gauges interface with structural gauges

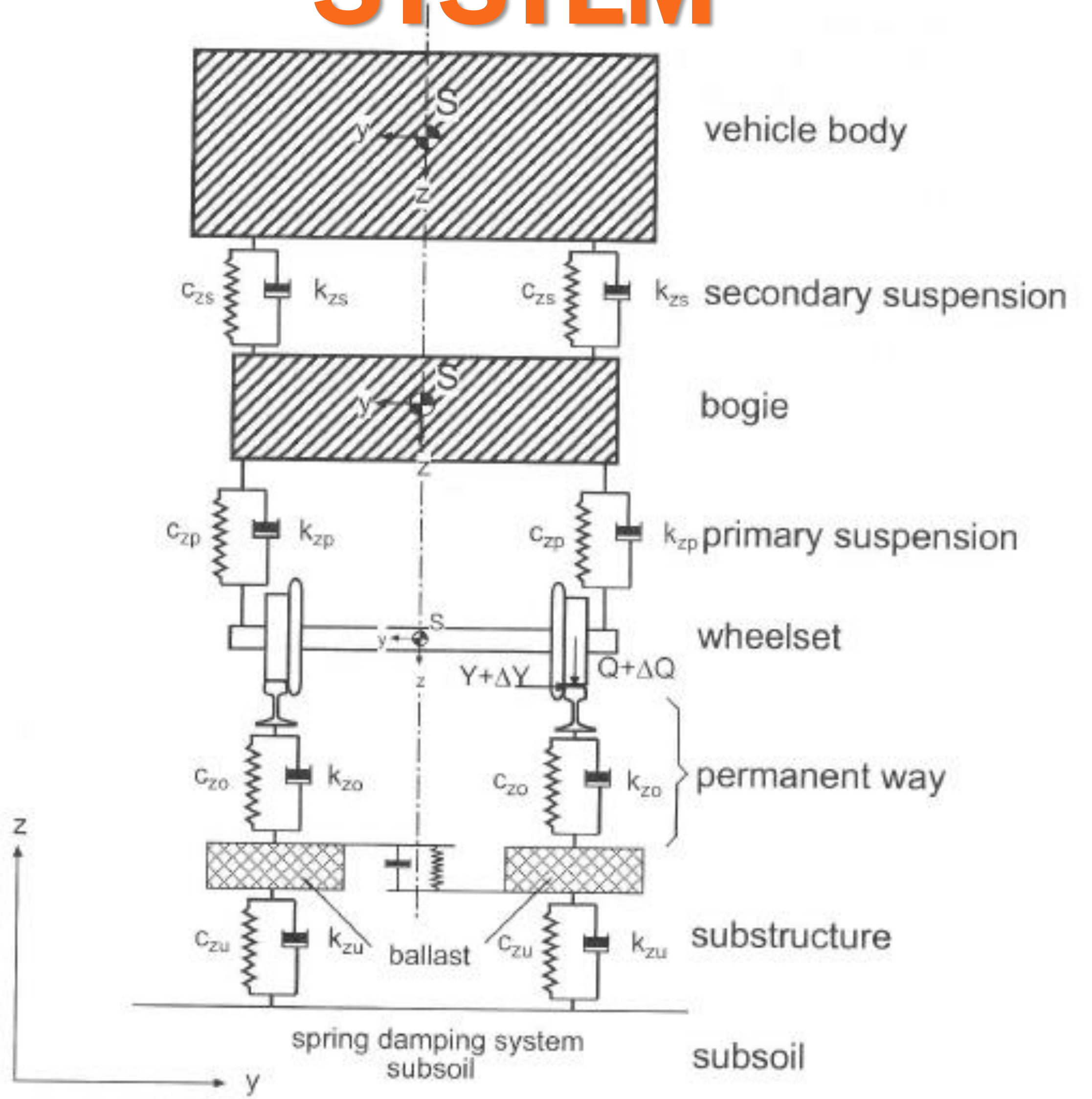
VEHICLE PA SYSTEM



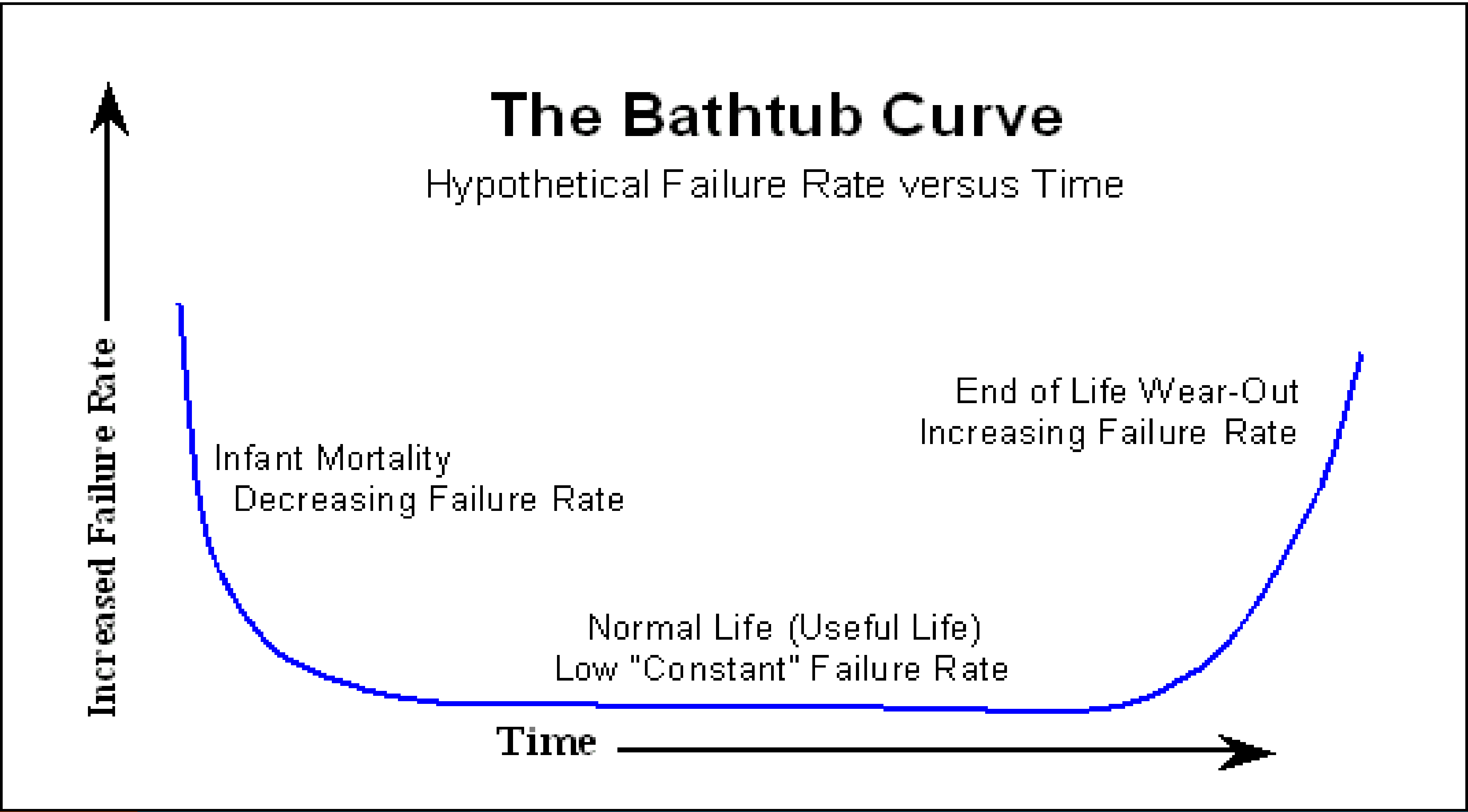
VEHICLE BODY INTERFACE WITH COUPLING AND BUFFERS

- Connect vehicles to form the train.
- Absorb and transfer the traction and longitudinal forces between vehicle, and,
- Connect the air and electrical systems
- Critical subsytem *(eg. couplings are broken and results in run-away vehicles)*
- A means of protection between vehicles

VEHICLE/TRACK SYSTEM



MAINTENANCE ASPECT



GENERAL SPECIFICATIONS KTMB ETS

Car body construction	Aluminium
Train length	138.6 m
Car length	23.7 m (End cars) 22.8 m (Intermediate cars)
Width	2,750 mm (2.750 m)
Height	3,905 mm (3.905 m)
Floor height	1,100 mm (1.100 m)
Doors	3 double-leaf doors per side
Articulated sections	none
Maximum speed	140 km/h (Design) 120 km/h (Service)
Weight	238 t
Traction System:	Siemens Traction Unit

KTMB SPECIFICATIONS

Rolling Stock Standardization

- Technical Overview
  - Coupler Type
    - Specification :

1) Type of Coupler	:	Alliance coupler (Locomotive) Alliance controlled slack coupler (Coach) Automatic coupler alliance (Wagon)
1) Coupler Height	:	850 (+10;-0) mm from top of rail
2) Knuckle Height	:	279.5 mm
3) Type of Shank	:	127 mm (5”) x 127 mm (5”)
4) Negotiation curve at main line	:	160 m radius (Max. speed 110 km/hour)
6) Negotiation curve at points and siding	:	80 m radius (Max. speed 20 km/hour)

KTMB SPECIFICATIONS

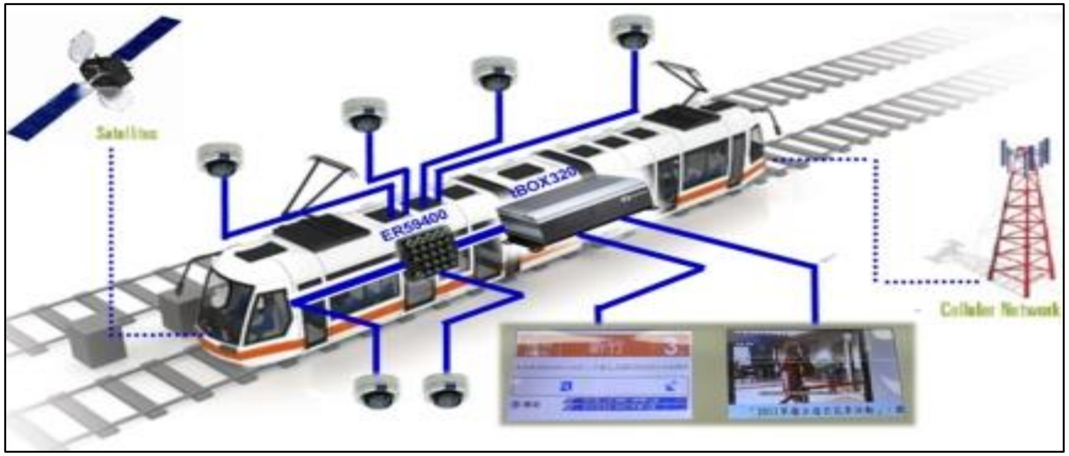
System Infrastructure Standardization

- Technical Overview
  - Electrified Track
    - Specification

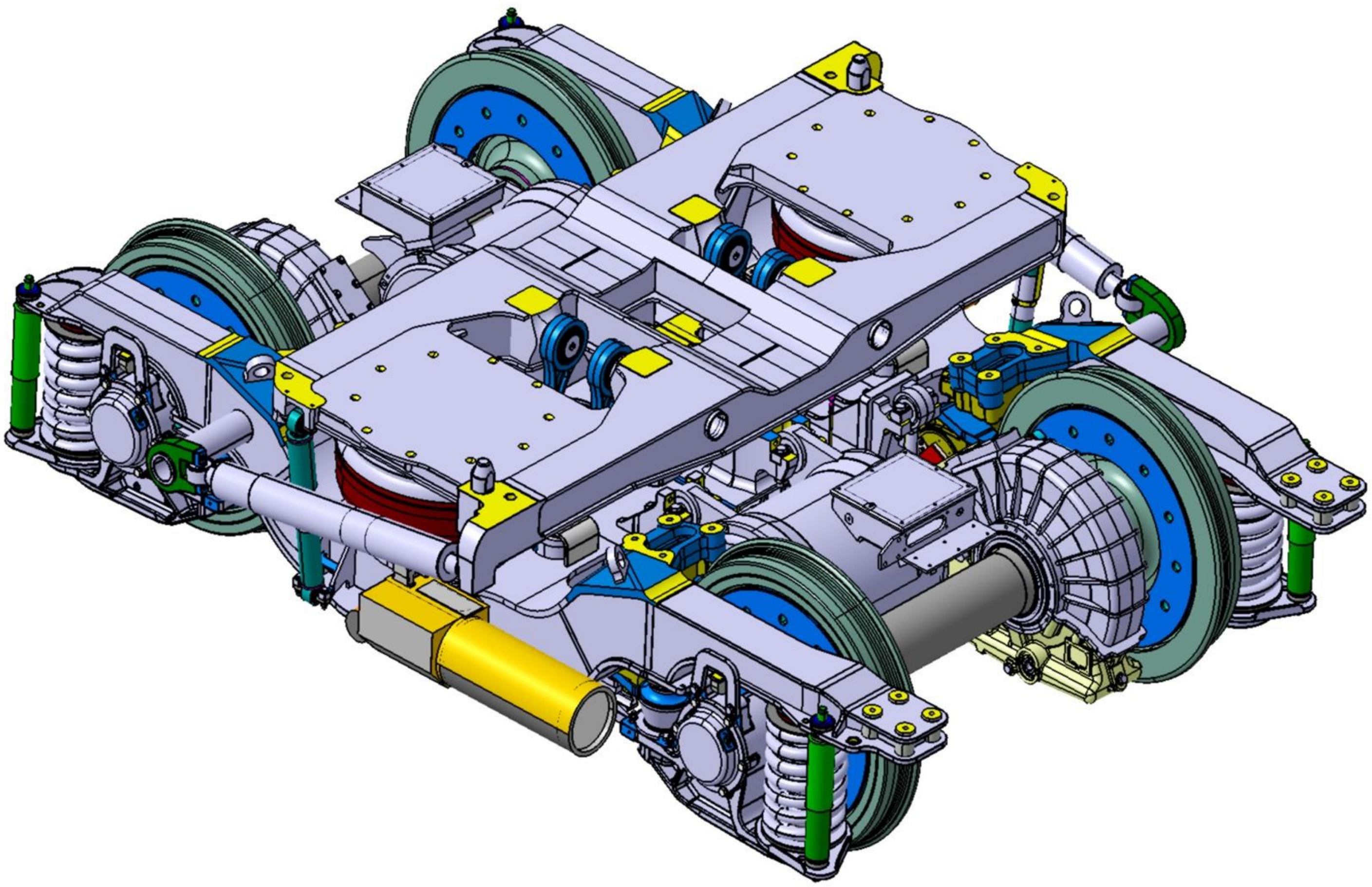
1) 25 KV A.C electrification :

i.	Vehicle height	: 3950 mm
ii.	Track tolerance	: 25 mm
iii.	Vehicle bounce	: 25 mm
iv.	Passing Clearance	: 200 mm
v.	Wire Tolerance	: 75 mm
vi.	Tension Tolerance	: 50 mm
vii.	Nominal Contact wire height (Mid-Span)	: 4325 mm
viii.	Pre-sag	: 75 mm

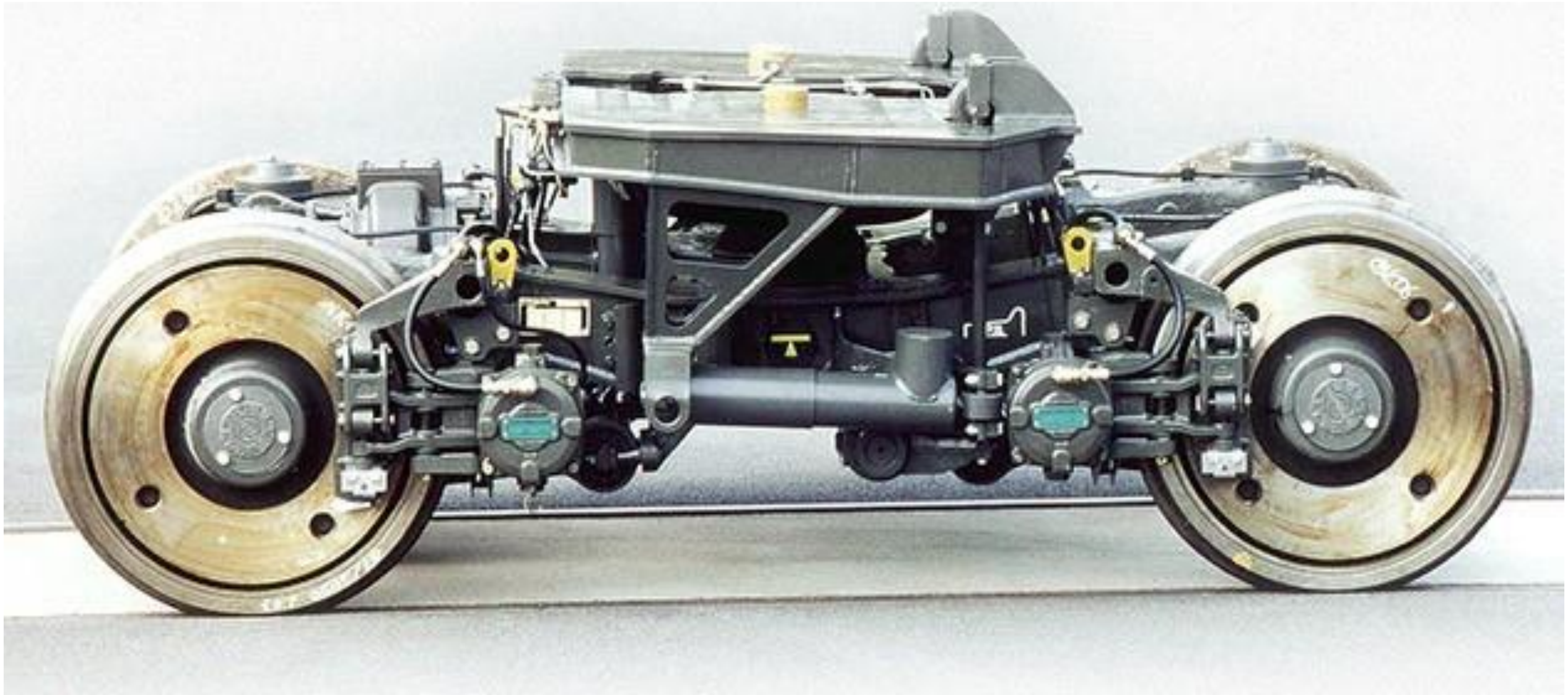
TRAIN INFORMATION SYSTEM



BOMBARDIER FLEXX BOGIE

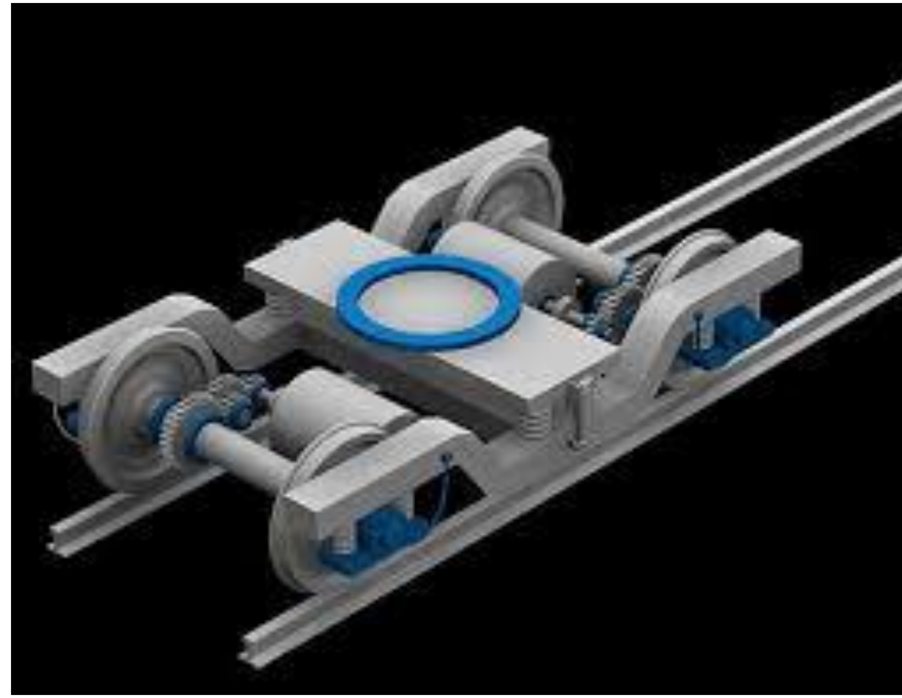


BOMBARDIER FLEXX BOGIE



- Lighter
- Track Friendly
- Savings in energy and maintenance costs

ARTICULATED BOGIE – JACOBS BOGIE



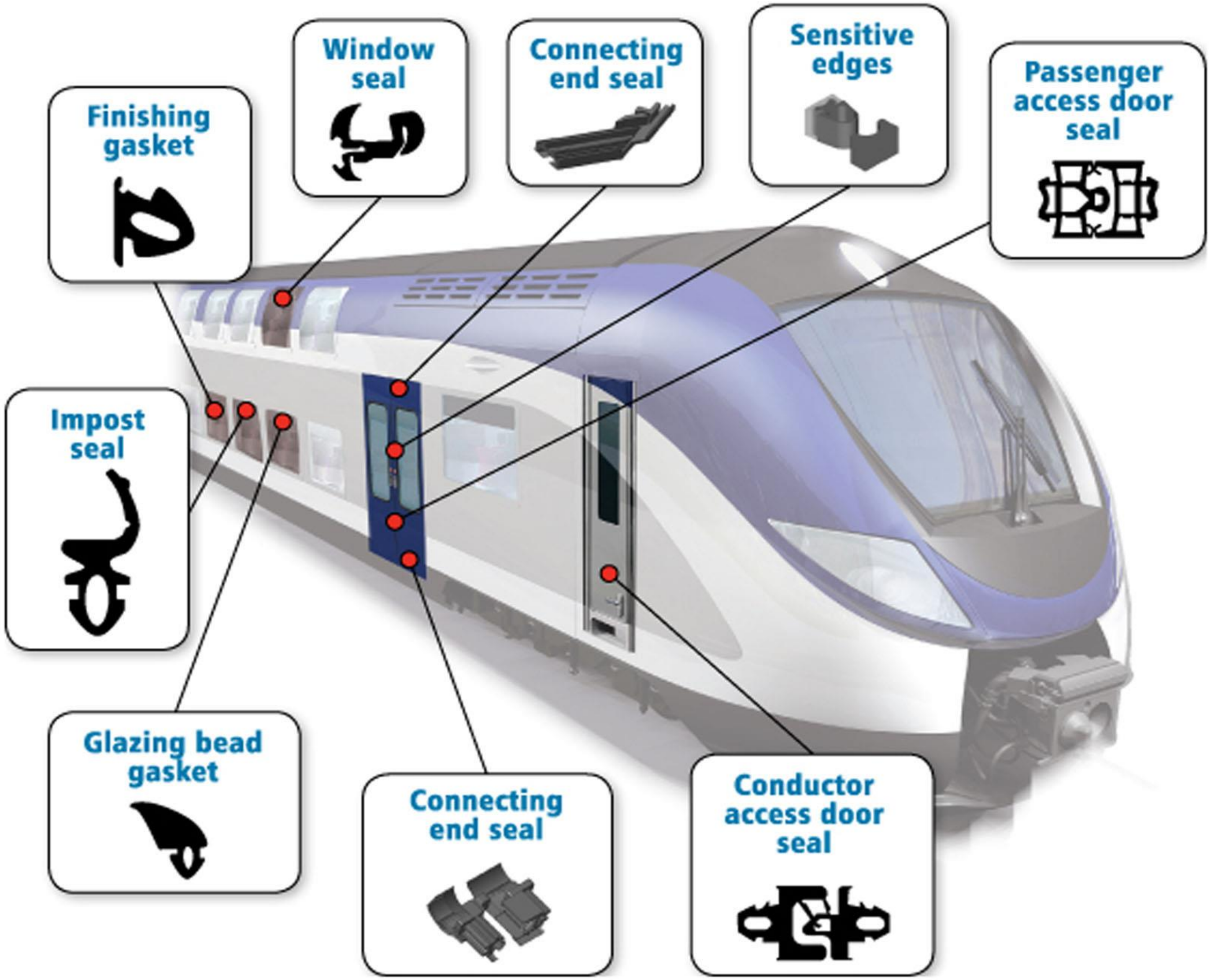
TYPICAL WORKSHOP

LIFTING JACK

MAINTENANCE BAY

KTMB AUTOMATIC WASHING PLANT

(SOURCE: N. ABU BAKAR)



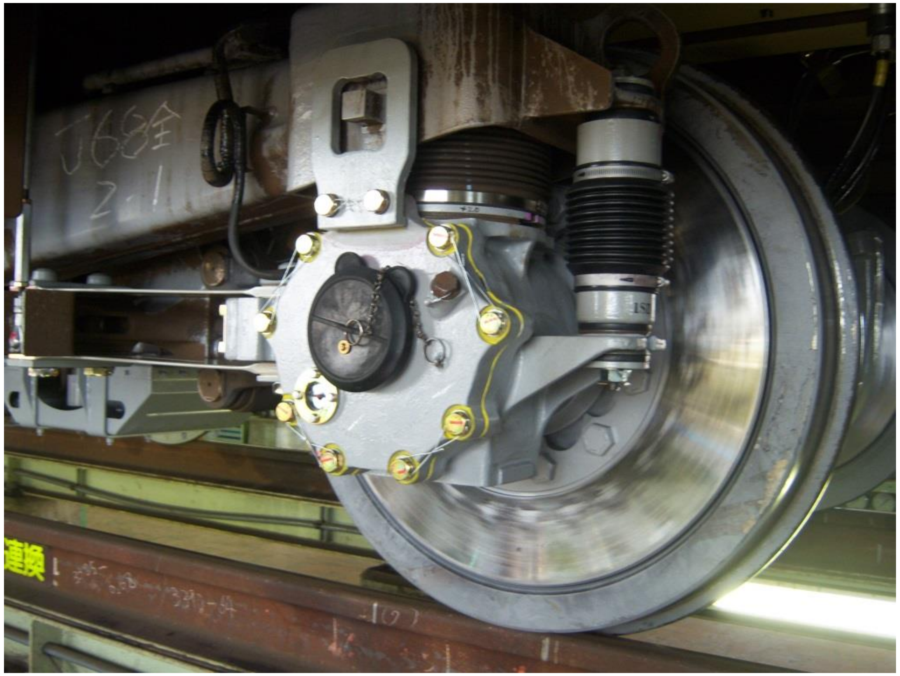
Window seal
Connecting end seal
Sensitive edges
Passenger access door seal
Finishing gasket
Impost seal
Glazing bead gasket
Connecting end seal
Conductor access door seal

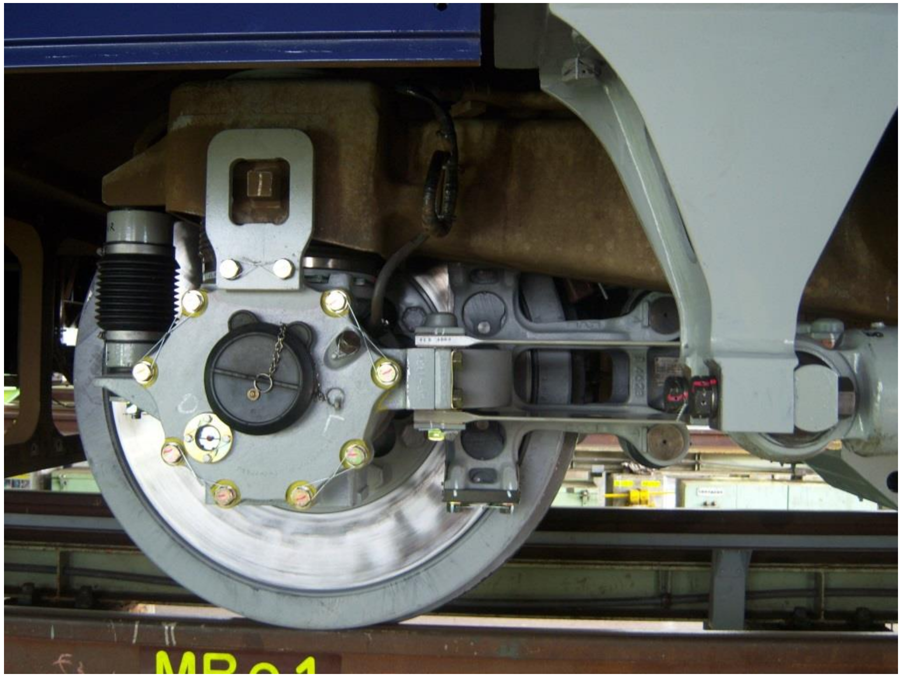
SHINKANSEN NOSE

TRACTION MOTOR

16 x 420 kW (560Hp) AC Traction Motors, Power Output 6.72 MW

WHEEL AND UNDERCARRIAGE





WHEEL AND UNDERCARRIAGE

TRAIN SIMULATOR

TESTING PROCESS

Unlike most trains, which have a single engine car in the front or back, the AGV has a series of distributed motors underneath the passenger carriages, which saves space and allows the train to carry 20% more passengers. (Notice in the photo below how little space there is from the nose of the train to the first passenger seats.)

The AGV is being tested over 12 nights this month on the Eastern high-speed line, between the Champagne-Ardenne and Lorraine stations, at its ideal speed of 224 mph.

The test train is outfitted with 4,000 sensors that will look at both the train's overall mechanical capabilities, as well as the interior passenger compartment. Although significant testing has already been done with computer models and on closed course test tracks, it is impossible to perfectly replicate the environment a train will face on live tracks.

TESTING PROCESS

Some of the features being tested at high speeds include the train's acoustics, vibration levels, wheel-to-rail dynamics, and forces exerted upon passengers. Additionally, safety features, such as the emergency braking mechanism is being tested through the activation of the brakes on tracks made slippery with soapy water. This is intended to simulate extreme conditions, such as when leaves may be covering the rails.

Additionally, electromagnetic interference will be measured by using aerial sensors hung above the tracks. This is to ensure that the train does not interfere with local radio and TV reception, as well as to make sure its own communications systems will work.

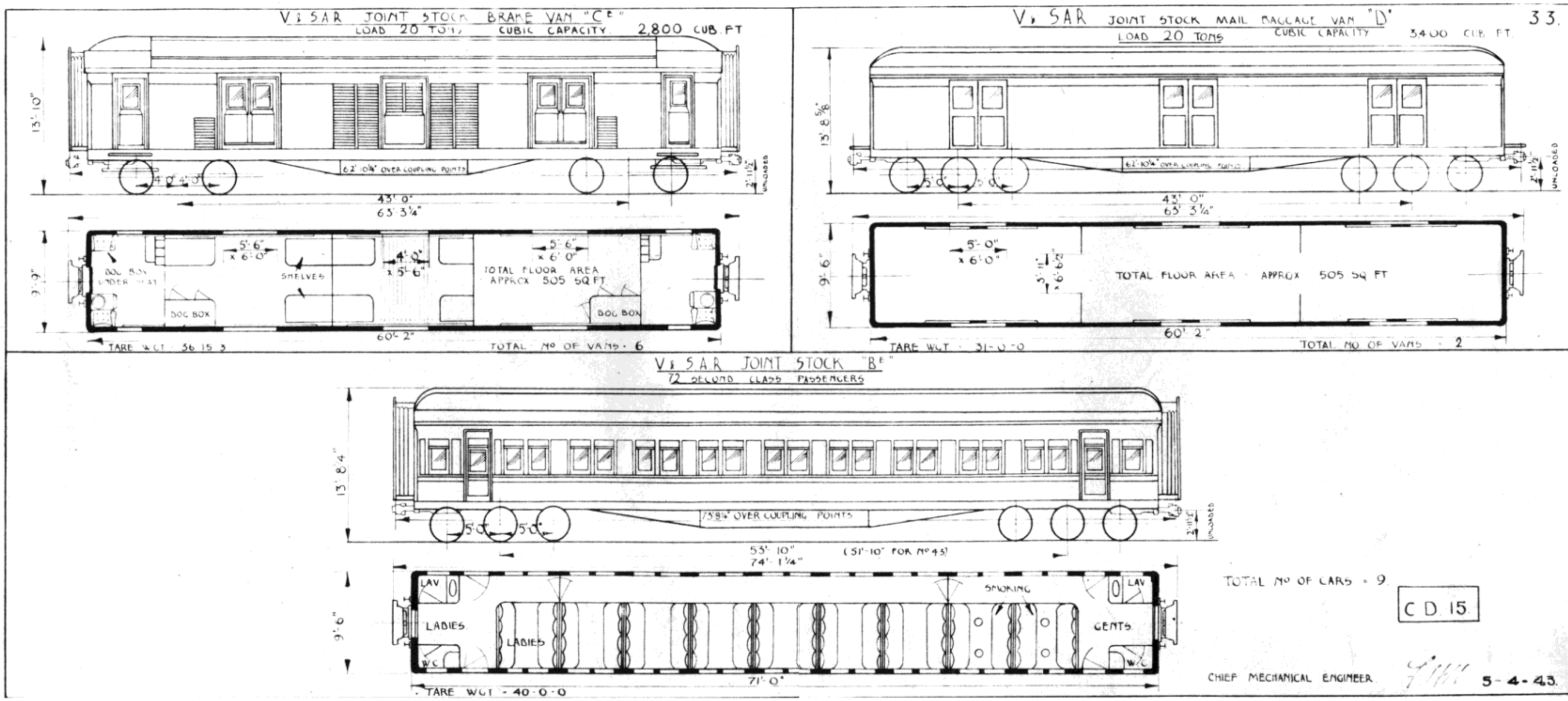
Alstom, which also builds the TGV and Eurostar trains, hopes that if the AGV passes these live tests it will receive final European certification by next year so that it can begin delivering production models by 2010

SUMMARY:

- Vehicle dynamics arising from interaction of the bogie and suspension system to the track is crucial for the safe operation of trains.
- The demand placed on the rolling stock system to carry heavier loads, to travel at higher speeds with higher level of comfort has increased over the years
- With global environmental concerns, its environmental effects (such as noise) need to be mitigated and minimised.

SUMMARY:

- Designing for maintainability and for dependability;
- Better understanding on the complexity of the system & standardised interfaces;
- More usage of new technology, eg. lighter bogies, better spring and damping characteristics & advanced composite materials.
- Usage of condition monitoring system



V & S.A.R JOINT STOCK BRAKE VAN "CE"
LOAD 20 TONS CUBIC CAPACITY 2,800 CUB. FT
TOTAL FLOOR AREA APPROX 505 SQ FT
DOG BOX
SHELVES
TARE WGT 36 15 3
TOTAL NO OF VANS - 6
V & SAR JOINT STOCK MAIL BAGGAGE VAN "D"
LOAD 20 TONS CUBIC CAPACITY 3400 CUB. FT.
33.
TOTAL FLOOR AREA APPROX 505 SQ FT
TARE WGT 31-0-0
TOTAL NO OF VANS 2
V & S.A.R JOINT STOCK "BE"
72 SECOND CLASS PASSENGERS
73' 8¼" OVER COUPLING POINTS
53' 10" (51'-10" FOR No 43)
74' 1¼"
LAV
LADIES
SMOKING
GENTS
71' 0"
TARE WGT - 40-0-0
TOTAL No OF CARS = 9
C.D. 15
CHIEF MECHANICAL ENGINEER
5-4-43.

Thank You