



# RAILWAY ENGINEERING

(CENG 5242)

## CHAPTER 1

### Basics of railway

# Course Objective

- *To thoroughly introduce the railway system and engineering from civil works perspective .*

The civil engineering sub-course aims to:

- Define the system and distinguish the fixed infrastructure of the system where civil engineers are mainly engaged
- Tell the story of infrastructure development from historic point of view
- Introduce the preliminary design process of railway components
- Introduce and characterize the components of railroad civil works
- Recognize the design considerations and design technical standards
- Inform the **construction process and operation** of railway industry

# Chapter-1 BASICS OF RAILWAY

## Chapter 1. Basics of railway

- Railway Transport system
- Historic development of railway
- Components of railway
- General principle for railway construction and development
- Railway classification and items of Main Technical standards
- Highlight on railway signaling, control, communication and OCS
- Environmental impacts

# 1.1 Railway Transport system

## Definition :

*Rail transport refers to the land transport of people or goods **along guided paths** called railways. A railway consists of two parallel rail tracks at a fixed distance (gauge) apart, usually made of steel and mounted upon cross beams called ties or sleepers”*

**A railroad consists of two steel rails which are held a fixed distance apart on a roadbed. Vehicles, guided and supported by flanged steel wheels and connected into trains, are propelled as a means of transportation.**



# Railway transport system Cont'd

- **Functions:**

- Important infrastructure of a country
- Artery of national economy
- Backbone of traffic and transport system

- **Characteristics:**

- large transport capacity/volume
- Low cost/*energy cost, travel time, power etc./*
- Energy saving and
- Environmentally friendly

# Railway significance 😊

- It has a high level of passenger or cargo utilization over a limited space (*Limited use of space compared to large transport capacity*)
- **Most efficient energy consumer** (1/3 of road transport and 1/7 to 1/5 of air transport)
- Minimum friction and minimum air resistance/guided movement/
- **Environmentally friendly**
  - Mostly electric powered
- **Safest and Reliability mode of land transport** with the lowest accident rate
- **It offers comfortable ride options** such as meal, sleeping and entertainment
- High degree of automation and management

## Drawbacks ☹️

- Huge initial investment and operation costs
- Cannot support severe alignments such as steep slopes and sharp curves
- Low flexibility in terms of network operations
- Severity of accidents is high (but low frequency)
- Security threat as it is prone to attacks

# 1.2 Historic development of Railway

**600 BC- Ship Track way in Ancient Rome and Greek**



**1550's - Hand propelled tubs in Germany**



**1630- Wagon roads for coal mines pulled by horse carts in Beaumont, England**



**1776- First cast iron rails on timber ties laid in tram ways in England**

# The 19<sup>th</sup> century...

**1807- first passenger train ran from Swansea to Mumbles and first railway station**



**1830 - The first railway in the United States opens with mostly hardwood rail topped with iron**



**1857 - Steel rails first used in Britain**



**1863 - First underground railway opened in London**

# 20<sup>th</sup> century and onwards...

**1906- First use of concrete sleepers in Germany**



**1937-41 - Magnetic levitation (maglev) train patents awarded in Germany**

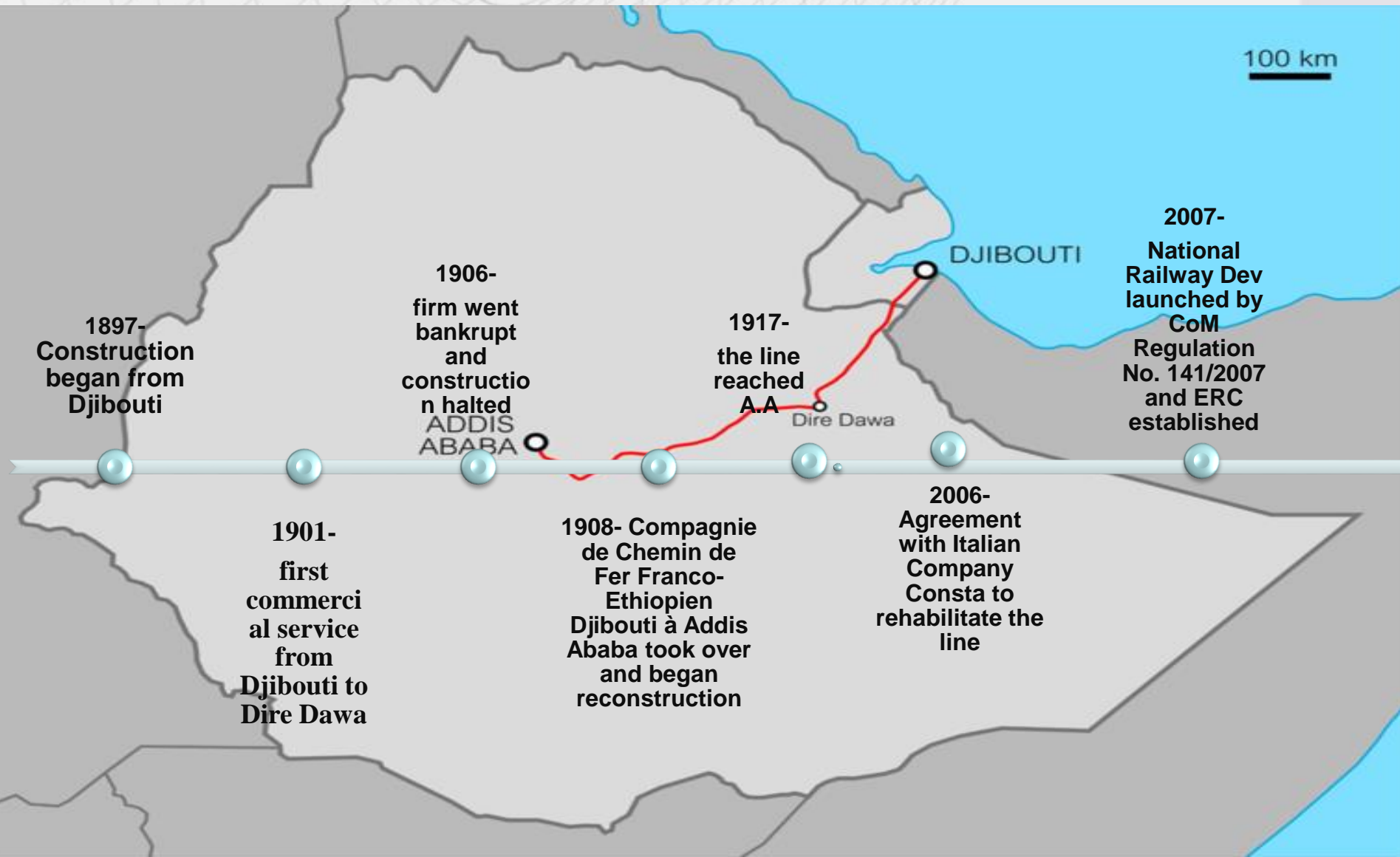


**1959- Construction of the Bullet train in Tokyo, Japan**



**Post WWII- Welded rail, heavier rail-profiles, slab track, innovative elastic fastenings, mechanization of maintenance**

# History of Ethiopian railway



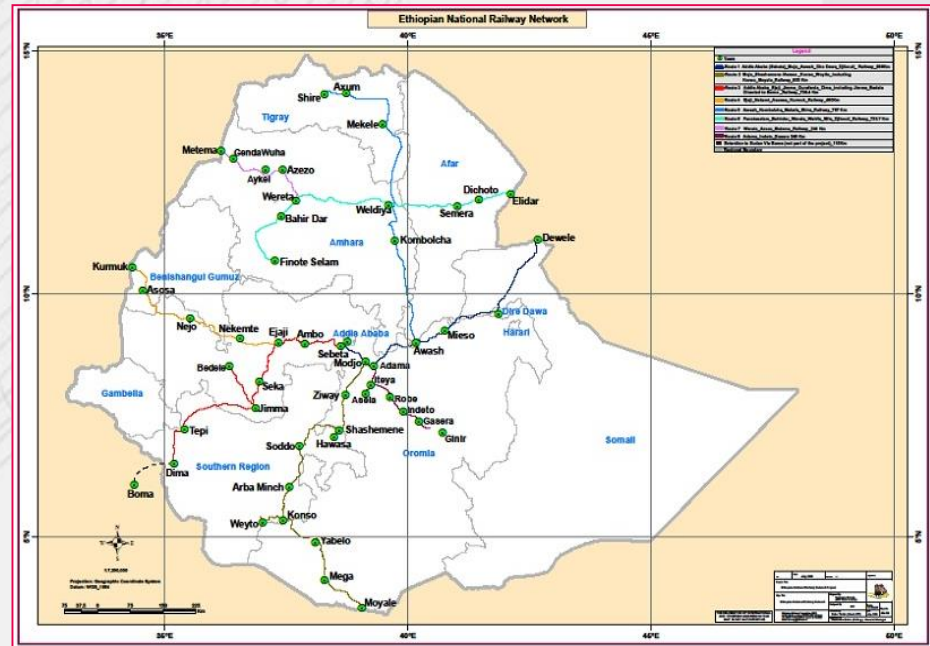
# The legacy railway...

- ❖ 1000 mm gauge and diesel traction
- ❖ Owned and administered by the governments of Djibouti and Ethiopia
- ❖ 781km – 681 in Ethiopia and 100 in Djibouti)
- ❖ Suffers from old-age, lack of spares, high operating cost, worn out track, no Locomotives, very low capacity

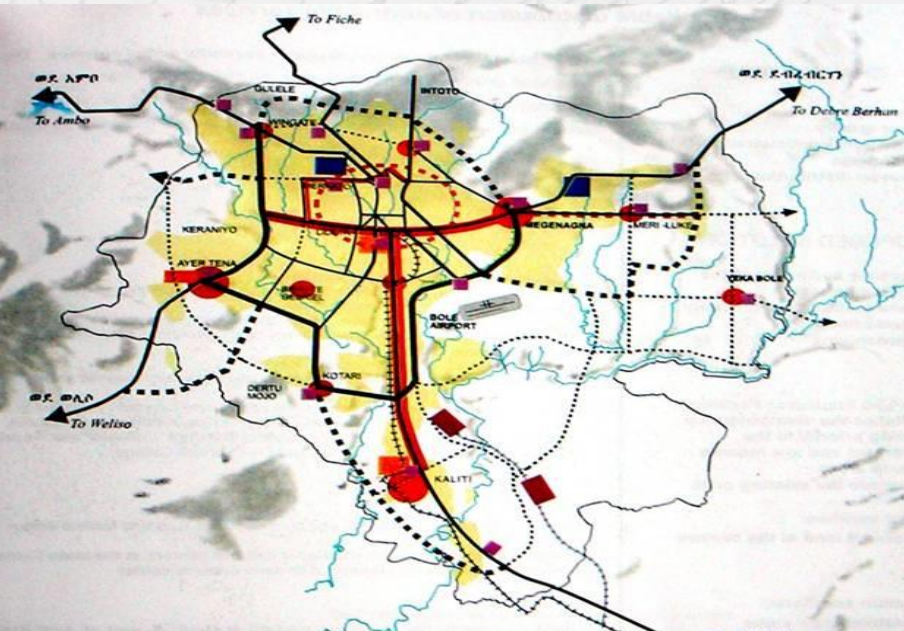


# Ethiopian national railway program[ENRP]

- 5000 km of national railway line
- Standard Gauge (**1435 mm**)
- Electric Traction
- High capacity (25 ton/axle)
- High speed (120 -160 km/hr for passenger and 80 -120 km/hr for freight)
- Concrete sleeper (**160cm X20.5cmX22cm**)



- 34km of Fully electrified LRT for Addis Ababa
- Standard Gauge (1.435 meters) and double track for the whole route
- Capacity: 80,000 PPH (Passenger/hr)
- Headway: 6min with a potential of reducing to 90secs
- Passenger-km based fare system



# Regional integration in Africa...

Railways of Africa "Vision 2025" and its relation to the Planned Ethiopian Railway Network



ADDIS ABABA - MIESO - DIBEDAWA - DEWELE - DJIBOUTI RAILWAY PROJECT  
AS PART OF AFRICAN RAILWAY NETWORK PROJECT (DJIBOUTI - LIBREVILLE)

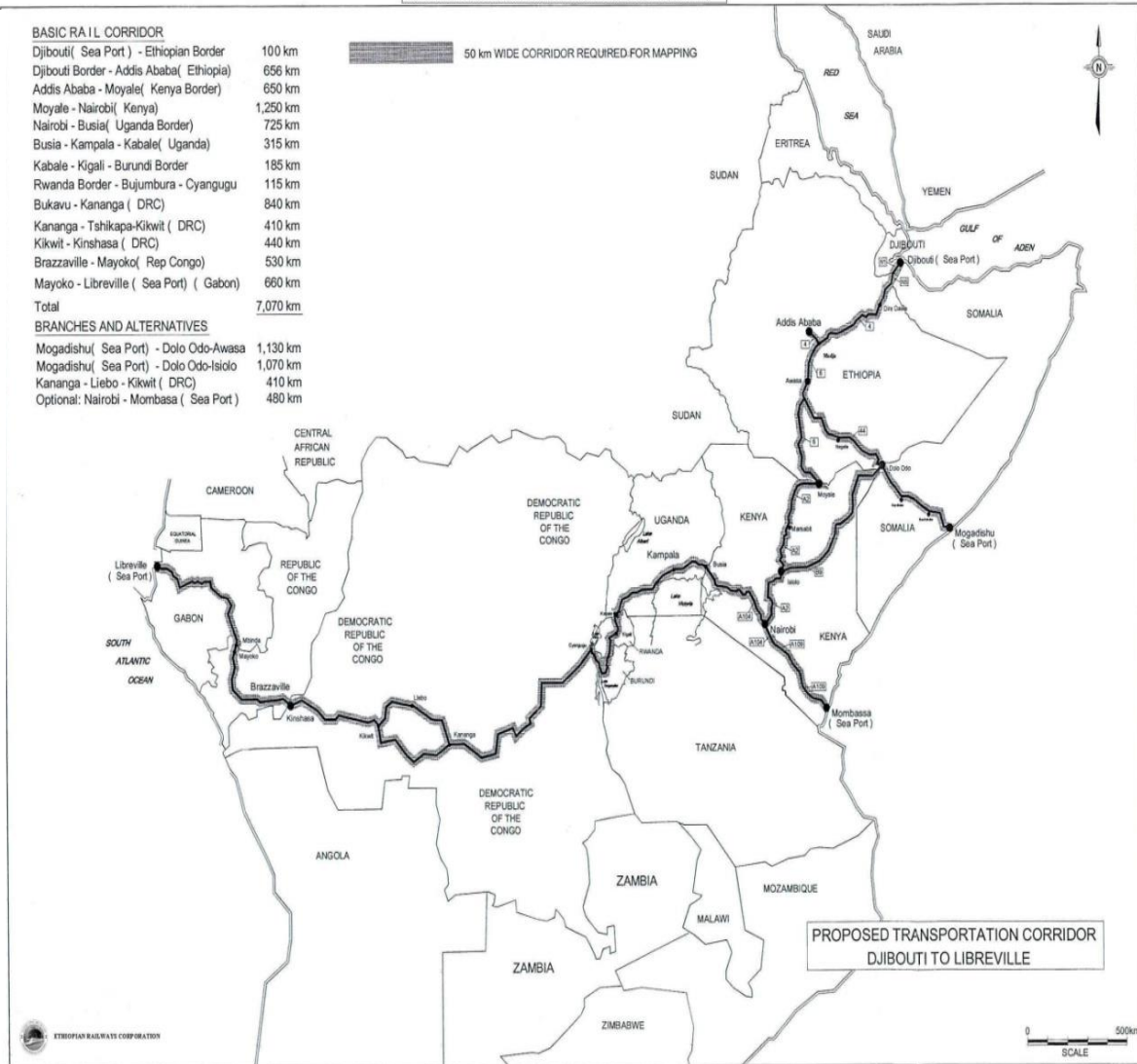
**BASIC RAIL CORRIDOR**

Djibouti( Sea Port) - Ethiopian Border	100 km
Djibouti Border - Addis Ababa( Ethiopia)	656 km
Addis Ababa - Moyale( Kenya Border)	650 km
Moyale - Nairobi( Kenya)	1,250 km
Nairobi - Busia( Uganda Border)	725 km
Busia - Kampala - Kabale( Uganda)	315 km
Kabale - Kigali - Burundi Border	185 km
Rwanda Border - Bujumbura - Cyangugu	115 km
Bukavu - Kananga ( DRC)	840 km
Kananga - Tshikapa-Kikwit ( DRC)	410 km
Kikwit - Kinshasa ( DRC)	440 km
Brazzaville - Mayoko( Rep Congo)	530 km
Mayoko - Libreville ( Sea Port) ( Gabon)	660 km
<b>Total</b>	<b>7,070 km</b>

50 km WIDE CORRIDOR REQUIRED FOR MAPPING

**BRANCHES AND ALTERNATIVES**

Mogadishu( Sea Port) - Dolo Odo-Awasa	1,130 km
Mogadishu( Sea Port) - Dolo Odo-Isiolo	1,070 km
Kananga - Liebo - Kikwit ( DRC)	410 km
Optional: Nairobi - Mombasa ( Sea Port)	480 km



# Progress to date...



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**Ethiopia, China sign**

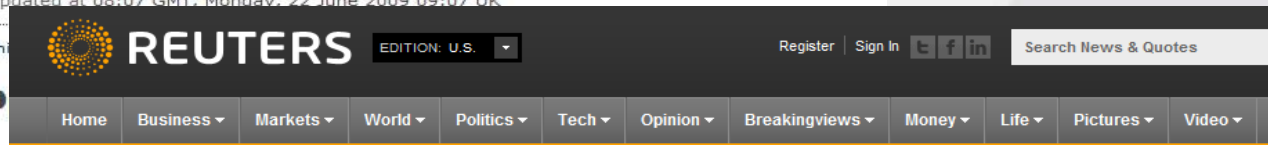
Posted on *Thursday 27 October*  
Solomon Mengist, AfricaNews:  
**Ethiopia and China signed an agreement to build the final section of a railway line that will link its capital Addis Ababa to Djibouti.**



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## Ethiopia signs Djibouti railway deal with China

By Aaron Maasho  
ADDIS ABABA | Sat Dec 17, 2011 11:30am EST

Dec 17 (Reuters) - Ethiopia signed an agreement with a Chinese state-run firm to build the final section of a railway line that will link its capital Addis Ababa to Djibouti.

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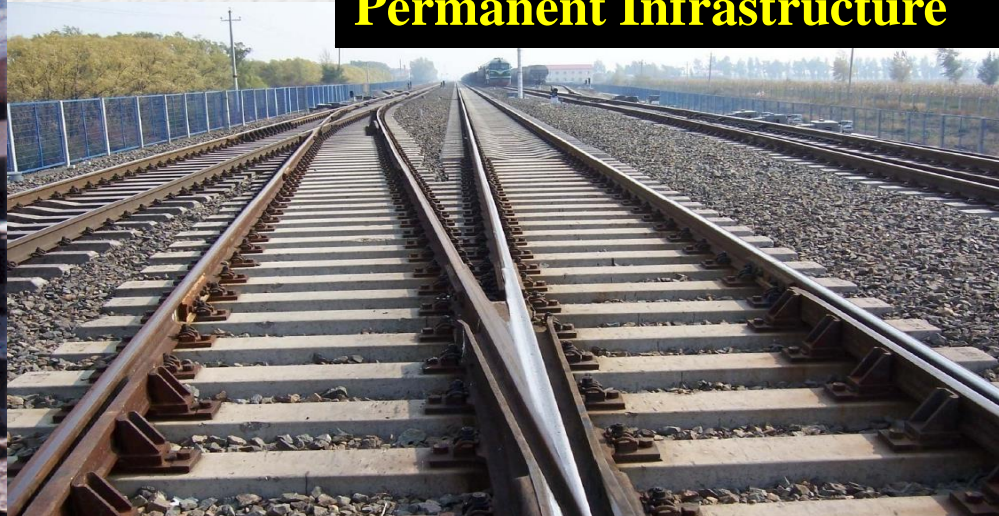
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# 1.3 Components of Railway



**Rolling Stock**



**Permanent Infrastructure**



**Signal and Communication**



**Power Supply**

# Components...

- Railway is a *permanent way* composed of *subway, bridge, culvert, tunnel, track, station, switches etc.*
- In order to provide smooth and stable geometry state, earth structures shall be built by *cutting and filling the ground.*
- For spanning rivers or gorges, *bridges* or culverts shall be built.
- For pass through mountains, mountains shall be excavated to construct *tunnels.*

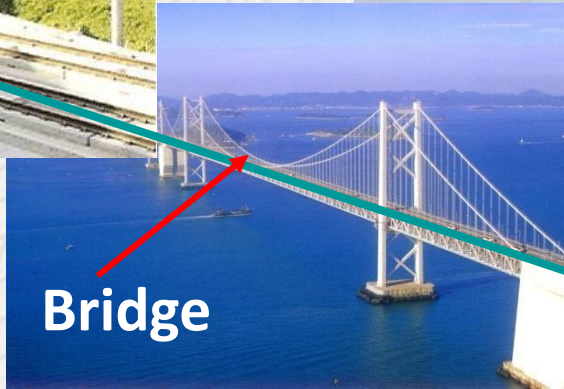
## Cont'd

- For trains *passing and overtaking*, **stations** shall be built. As for unfavorable geologic body which is difficult to detour, engineering *improvement measures* shall be taken in order to ensure operation safety.

# Major components...



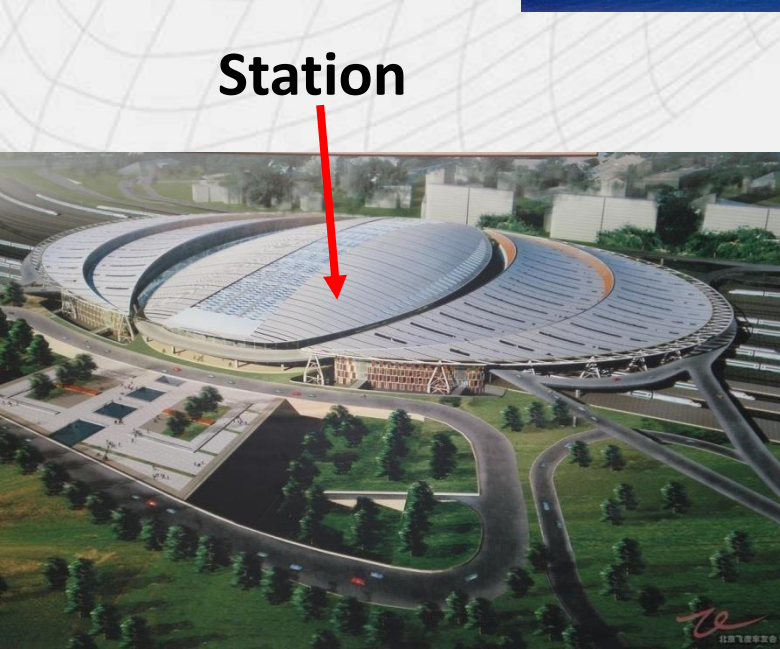
**Tunnel**



**Bridge**



**Track  
Alignment**



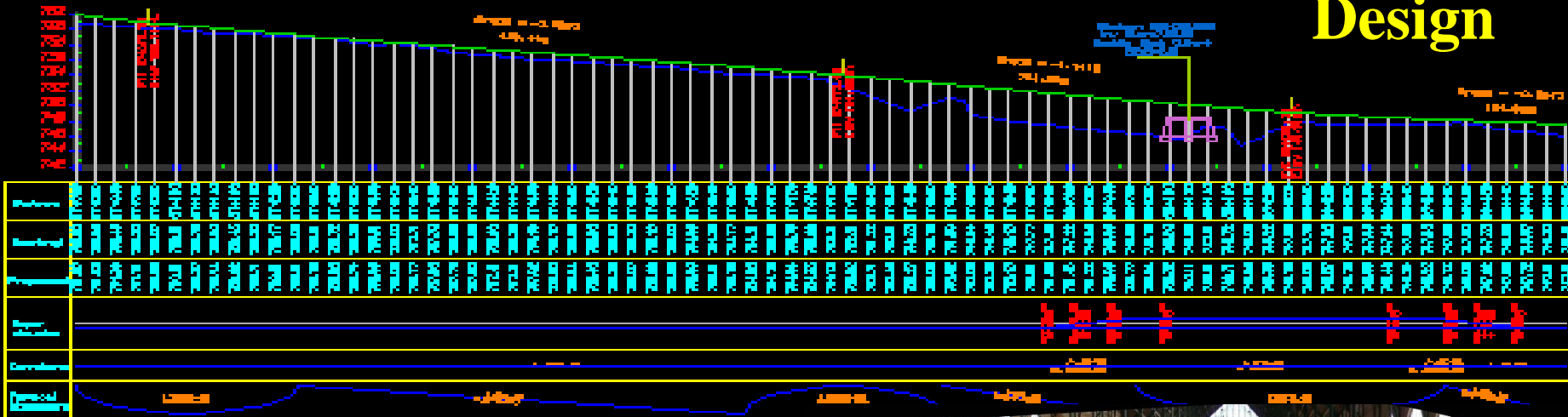
**Station**

**Earth Work**



# What types of Civil Works?

**Design**



**Construction**



**Operation and maintenance**

## *1.4 General principle for railway construction and development*

- Based on the strategies of national economy and social development and the demands of territorial development,
- *national defense*
- *transport market*
- highlighting key points and strengthening weak links,
- coordinated development with other traffic and transport modes and relevant industries such as energy industry.

# General principles...

- Directed by national development strategies
- Oriented by market, centered with benefit and on the premise of transport safety
- Actively adopting mature, advanced, economic, practical & reliable technologies and emphasizing comprehensive integration of technologies
- Insisting on the principle of using optimized system to maximize comprehensive benefit

# Design year of railway construction

- **Short term:** The tenth year after delivery for operation
- **Long term:** The twentieth year after delivery for operation

**N.B:-** Traffic volumes in short term and long term are both forecasted.

# 1.5 Railway Classification & Main Technical Standards

## 1.5.1 Railway Classification:

- is the class grade of a railway classified according to its role in railway network, properties, volume of passenger traffic, goods traffic volume, maximum allowable axle load, design speed, etc.
- is the basic standard of a railway system, which is the basis to determine the technical standards and equipment types.

## Classification...cont'd

- When railway is designed, railway classification should be determined
- Due to the reasons of
  - ✓ vast territory,
  - ✓ complicated topography,
  - ✓ unbalanced population and resources distribution and
  - ✓ the different economic conditions

# Classification...cont'd

- railway's role in network, properties, volume of passenger & goods traffic, maximum allowable axle load and speed are different. Hence, railways should be classed in to different grades

# Basis of railway classification

- Bases for railway classification include
  - axle load of rolling stock,
  - maximum running speed,
  - volume of passenger and goods traffic,
  - designed speed, and
  - significance of railway construction.

# Basis of railway classification

## 1. *Axle load of rolling stock*

- Axle load is one of major basis to determine the design load standard.
- Axle load of locomotives affect the power of locomotive, and car's axle load affect the train's load per meter. The bridge load and track type is controlled by car's axle loads.

# Basis of railway classification

## 2. *maximum speed*

- The maximum speed is one of the most important marker of railway transportation quality.
- It affects the travelling time of passenger and freight trains, traffic capacity and the using condition of rolling stock.
- It also affect construction cost, expenditure for buying rolling stock, locomotive energy consumption, transportation cost, etc.

# Basis of railway classification

The running speed is limited by the power of locomotive, the standards of alignment and track, level of signal facilities, method of traffic control, traffic organization, etc.

The Maximum speed is the major technical parameter to determine the

- ✓ radius of horizontal & vertical curves
- ✓ length of transition curve
- ✓ the type of track.

# Basis of railway classification

## 3. *Annual Volume of Passenger and Goods traffic*

- it is the main base for
  - designing transport capacity
  - evaluation of economic effectiveness
  - determination of route alternatives
- The annual volume of passenger and goods traffic affect the track-train interaction, track deformation, residual life of structures.

# Cont'd

- In general, railway investment cost, cost of railway traffic and traffic revenue shall be decided by annual volume of passenger and goods traffic.
- For these reasons, under the same service life, equipment with high standards should be used in the railway with heavy traffic volume.

# Basis of Classification...cont'd

- Example:- In china, railways are classified in to three categories based on the annual volume of passenger and fright traffic, role they played in railways network, and maximum design speed. These are:
  1. Railway line for passenger traffic
  2. Railway line for mixed passenger and freight traffic
  3. Line for goods traffic

# Cont'd

- These further classified in to seven grades:
  - ✓ High speed line
  - ✓ Rapid speed line
  - ✓ Classes I ~IV
  - ✓ Heavy haul railway

# 1. Railway line for passenger traffic

- Mainly responsible for transportation of passenger with design speed of passenger car not less than 200km/h. Further classified as:

## 1) High-speed railway :

- Railways for passenger with maximum design speed of 250km/h and over and play trunk parts in railway network
- Generally built in a developing region where is densely populated and has a heavy volume of passenger traffic.

## Cont'd

- It links political center and economic center, or economic center and economic center.
- On high-speed line, passenger trains could operate with speed of 250km/h or over in main section, the seating capacity could be up to 1600 persons per train, the maximum traffic-carrying capacity could be  $2 * 32000$  person or over.

# Cont'd

## 2) Rapid -speed railway

- Railways are classified as rapid-speed railways which play a linking and auxiliary part in railway network for passenger traffic, with designed speed of 250km/h or lower.
- In China, rapid-speed line also classified as rapid-speed trunk line for passenger traffic or inter-city line in terms of the role in rapid railway passenger transport network, transport demand, and service area.

## 2. Railway line for mixed passenger and freight traffic

- These railway lines are responsible for passenger and freight transportation, with design speed of 160km/h or lower (passenger train) and 120km/h (freight train).
- Railways for mixed passenger and freight traffic can be classified as 4 grades,  
Class I , Class II , Class III, and ClassIV.

# Cont'd

- The class of a new line or reconstructed railway should be determined in terms of
- the role in railway network
- Properties
- Design speed of passenger train and
- volume of passenger and freight traffic

And Should meet the following requirements

## Cont'd

- **Class I Railway:** Play a trunk part in railway network, and the volume of short-term traffic is no less than 20 million tons.
- **Class II Railway:** Play a linking and auxiliary part in railway network, and the volume of short-term traffic is less than 20 million tons.
- **Class III Railway:** Give service to a local zone, and the volume of short-term traffic is less than 20 million tons and larger than 5 million tons.

## Cnt'd

- **Class IV Railway:** Give service to a local zone, and the volume of short-term traffic is less than 5 million tons.

## 1.5.2 Items of Main technical standards

- Main technical standards includes the *basic standards and types of railway facilities*, which shall give obvious influence on the traffic capacity, construction cost, operation quality, and the selection of other equipment standards.

# Main technical Standards...cont'd

- The design of railway of mixed service shall include main technical standards of the following:
  - **ruling grade**
  - minimum radius of curvature**
  - available length of arrival & departure**
  - kind of energy supply**
  - types of locomotives**
  - tonnage rating**
  - locomotive routing and**
  - type of blocking.**

# Cont'd

Main technical standards for railway of passenger traffic include:

- ◆ designed speed
- ◆ distance between centers of main line tracks
- ◆ minimum plane curve radius
- ◆ maximum gradient
- ◆ available length of arrival and departure line
- ◆ EMU type
- ◆ train operation control mode
- ◆ train operation command mode
- ◆ minimum head

# 1. 6 Railway Signals, Communication and control



# 1.5.1 Railway communication

- From the method of transmission:  
Cable and wireless communication.
- From the service area: toll communication; area communication, section communication, station communication.
- From the service nature: public communication, private communication and data transmission.

# Cont'd

Railway private communication system consists of:

## **1. Train dispatching telephone**

- The train dispatching phone is a kind of wired phone, which is used to communicate between dispatchers and station attendants.

# Cont'd

## **2. train dispatching radio phone**

- The train dispatching radio phone can be used as the communication tool between train dispatchers, locomotive dispatchers, station attendants or others and the driver.

# Cont'd



**Wireless dispatching telephone in a station**



**train dispatching radio phone**

## Cont'd

### **3. Wireless dispatching telephone in a station**

- The wireless dispatching telephone in a station is used by dispatchers, hump attendants or other commanders to communicate to the shunting locomotive driver.

# Cont'd

## **4. Other railway private communication equipments**

- Private telecom system
- Railway local telephone
- Long distance telephone and telegraph within railway administration and mail lines
- Train out report telegraph and telephone
- Railway station communication system

# 1.5.2 Railway signaling & control system

Signaling consists of the systems, devices and means by which trains are operated efficiently and tracks are used to maximum extent, maintaining the safety of passengers, the staff and the rolling stock.

It includes the use and working of signals, points, block instruments and other equipments

Signals have **aspects** and **indication**

- Aspect is the visual appearance of the signal
- Indication is the meaning

# Objectives of signaling

The various objectives of providing & operating signals are:

- ✓ To provide facilities for the efficient movement of trains
- ✓ To ensure safety between two or more trains
- ✓ To provide facilities for the maximum utility of track
- ✓ To provide facilities for safe and efficient shunting operations
- ✓ To guide the trains movement during maintenance and repair of tracks

# Cont'd

- Signals can be placed:
  - At the start of a section of track
  - On the approach to a movable item of infrastructure, such as switches or a swing bridge
  - In advance of other signals
  - On the approach to a level crossing
  - Ahead of platforms or other places that trains are likely to be stopped

# Signal equipments introduction

- Railway signal equipments are the key facilities to organize and command train operation, ensure safety, enhance the transport efficiency, transfer information, improve working conditions of driving personnel .
- The foundation of railway signal equipment includes **signal machine, switch machine, track circuit, signal relays**, etc.

# Signal machine

- Signal and signal reapter say a signal that used to command train operation and shunting homework.



Signal reapter

# Switch machine

The switch machine plays an important role on train operation, which is used to complete the conversion and locking of switch.

ZD6 series are used for the existing line

S700K are used for **speeding track line**



# Track circuit

- The track circuit is used to monitor the occupancy of the train and transfer the traffic information.



# Signal relay












- Signal relay is not only the key component of various relay control system but also the interface unit of electronic or computer control system



# The basic color of the visual signal

- Red - stop。
- Yellow - Noting and reducing speed
- Green- driving at the required speed
- Bluish-white calling-on signal or permitting shunting signal
- Blue - permissive signal or prohibiting shunting signal

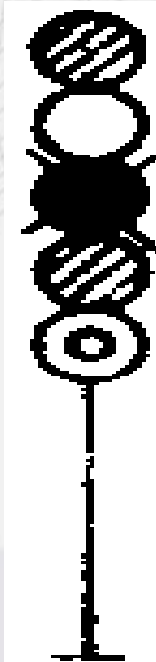
# Cont'd

number	symbol	description
1		Green
2		yellow
3		red
4		blue
5		Bluish-white
6		white
7		empty
8		stable
9		flash
10		Pairs of semi-yellow
11		Half yellow half red


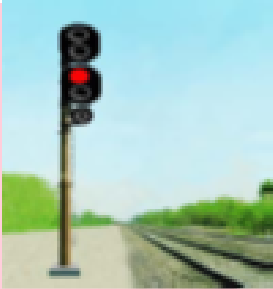




# Home signal

**Function:** Protecting stations, indicating the train operating conditions to ensure the receiving route safe and reliable.







The entrance of the station must be fitted with home signal



# Cont'd

indication	Meanings	picture
	Banning train through the signal	
	Allowing train through the signal at the limited speed , Being prepared to stop on the main track by switch normal position	
	Allowing train through the signal at the limited speed , Being prepared to stop on the siding track by switch reverse position	

# Cont'd

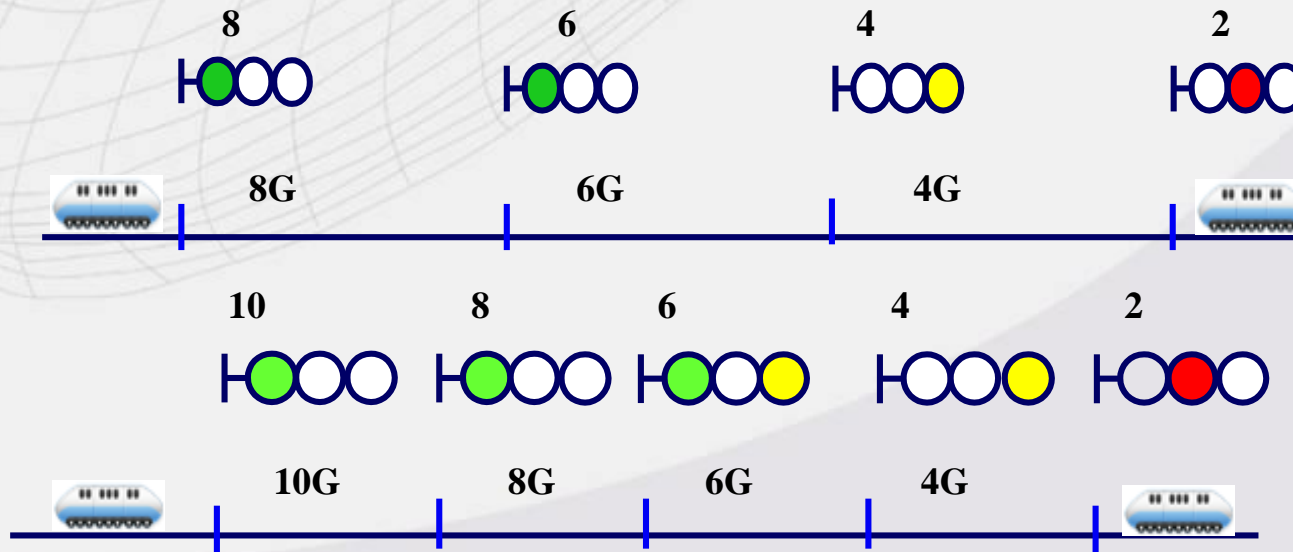
indication	meanings	picture
	allowing train entering or through the station according to the speed required by the switch normal position , which means there are at least three block sections idle in front of the train	
	allowing train entering the station according to the speed required by the switch normal position , which means the next signal has been cleared at yellow light	
	Calling-on signal, entering station at no more than 20 km/h speed and being ready to stop.	

# Through signal

Function : **protecting block section**, Indicating the train can enter the next block section.

Three-aspect automatic block

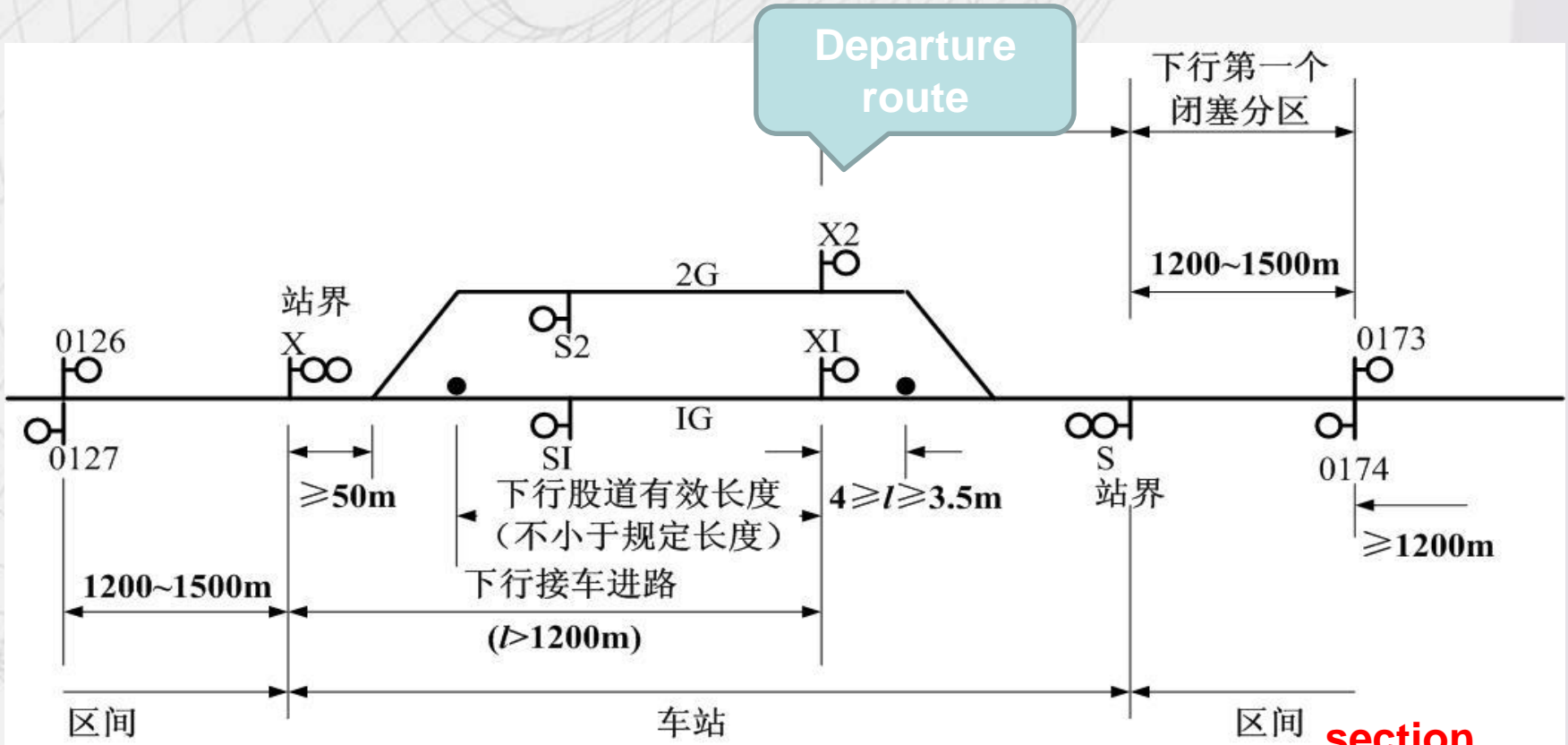
Four-aspect automatic bloc



# Departure signal

- **Function :** indicating the train can enter the section or not, and the parking place





section

station

section

⊙ — 出站 (SI、S2、XI、X2) 或通过 (0126、0127、0175、0174) 信号机;

⊕ — 进站 (X、S) 信号机

● — 警冲标。Fouling point

# Shunting signal

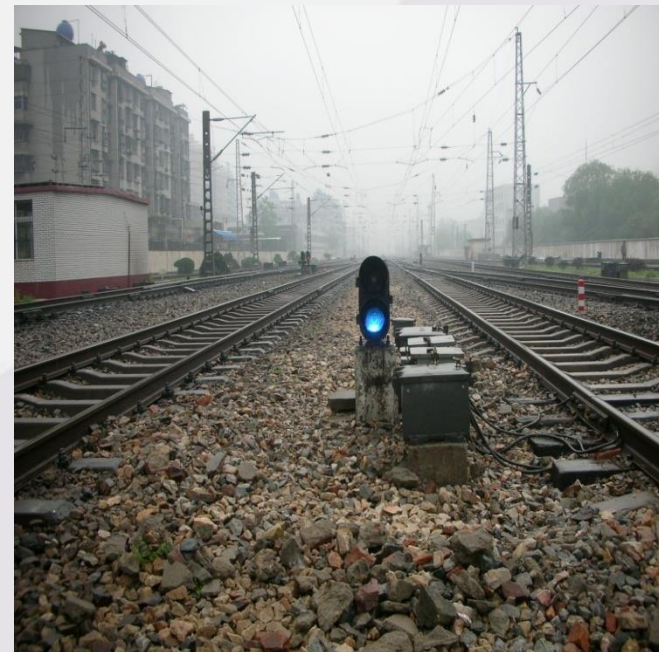
**function:** Indicates the various shunting operation, be Installed in interlocking yard with shunting operation

A:single shunting signal

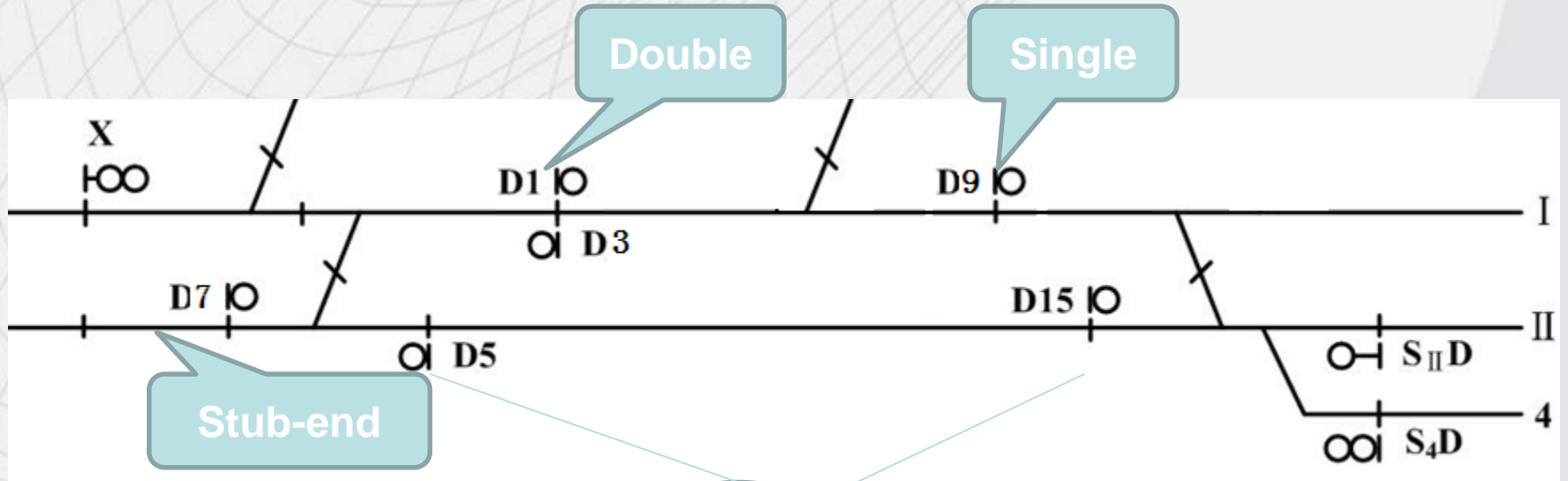
B:double shunting signal

C: difference shunting signal

D:stub-end shunting signal



# Cont'd



difference

# Cab signal

Cab signal	description		
	Four-aspect automatic block	Three-aspect automatic block	Semi automatic block
L	run at the required speed		
LU	pay attention to run at the required limit speed	run at the required speed	
U	slow to under the speed level required	pay attention to run	
UU	run at the required limit speed , which means that the signal train approach is at clear and switch is in the reverse		

# Cont'd

U2	means that train slows to the required level of speed though the closing ground signal. and indicates the next ground signal showing two yellow lamps	Means train pay attention to run and indicates the next ground signal showing two yellow lamps
USU	Run at required limit speed, which means that the signal train is approaching is at clear and the larger switch is in the station of reversion	

# Cont'd

HU	Request to take measures to stop
HSU	Home signal which train is approaching opens calling-on signal
H	Train has been over the red signal
B	Not Repeat the ground signal, train runs according to the ground signal showing
null	Cab signal Stops working

# Control of movement of trains

- One of the basic objectives of signaling is to control the movement of trains with a view to ensure safety by preventing accidents
- To achieve this goal, a particular system of working should be adopted keeping in view three important aspects i.e **safety**, **speed** and **traffic density of operation**

# System types...

- The Various systems of controlling the movement of trains are:
  - 1) one –engine only system
  - 2)Following train/time interval system
  - 3)Pilot guard system
  - 4)Train staff & ticket system
  - 5)Absolute block system
  - 6)Automatic block system
  - 7)C.T.C system
  - 8)A.T.C system



**Thank You**