Transportation Systems

Areas of Transportation Engineering
- Transportation Planning
- Traffic Operations (signs, signals, ...)
- Roadway Geometric Design
- Pavement Engineering
- Railway Engineering
- Design and Planning of Airports

Three ways we transport on planet earth:
1) Land
   - Railway
   - Highway
   - Pipeline
2) Sea
3) Air

What is Transportation Engineering
- The engineering profession is involved in all aspects of transportation:
  - Aeronautical (aircraft)
  - Chemical (fuels and lubricants)
  - Mechanical (vehicles)
  - Electrical (communications, control system)
  - Civil (development of facilities and manage the demand)
- It is a multi-disciplinary area:
  - Economic
  - Environmental
  - Planning
  - Statistics
  - Law
  - Psychology & human factors
  - Public administration
- One of the major problems of a modern society is the transportation that need to be worked out by competent engineers.

Transportation is the movement of people and goods over time and space.
- Transportation should be...
  - Safe
  - Environmentally friendly
  - And economic as much as possible without sacrificing safety.

Most vehicles are considered as hostile to the environment due to their high emission levels. Ongoing research studies aim to avoid contamination of sea and atmosphere. Contemporary highway hybrid vehicles, however, are quite promising in reducing emission in urban areas.

Some transportation systems may be economic but on safe, while some others can be both safe and economic.

Although pipelines are major means for oil transportation and considered as a transportation system, their design and maintenance are not within the scope of transportation engineers.
Transportation Modes

Motorized
- Automobile
- Transit
- Bus
- Rail
- Rapid Transit (subway)

Non-Motorized
- Biking
- Walking

Transportation systems that are necessary for any one of the above mentioned modes are called as walkways, roads, highways, railways, airlines and marine lines.

Development of Transportation Modes

Ridership

Time

1860 1893 1923 1948

Automobile

Cable car

Horse-drawn omnibus

Evolution of air transportation vehicles

Evolution of land transportation passenger vehicles

Life Cycle of a Transportation Mode

Innovation Period

Ridership

Growth to Maturity

Decline

Nostalgia

Nostalgia

Time

Hybrid Cars

Gasoline power + Electric power

70 miles per gallon

Gasoline power / internal combustion / wasted / applying brake / battery pack / recharge / accelerating / stored energy / fuel consumption

Year: 1804  Speed: 8 km/h

Year: 2008  Speed: ~ 500 km/h

Railways

Locomotives

High speed

Very high speed

Year: 1804  Speed: 8 km/h

Year: 2008  Speed: ~ 500 km/h
Buying a car has become much easier as their production rate and purchasing power of the consumers increased resulting in congested highways. Traffic jams have long been part of our daily life in metropolitan areas. Traffic engineering is therefore an important subdiscipline of civil engineering profession.

One thousand new cars join to Istanbul traffic each day.

Why people like cars?

- We like the cars
- It often (but not always) is the fastest mode, depending on levels of congestion, time of day and the available alternatives
- Privacy
- Automobiles suggest that you are at a higher level of society
- People simply enjoy the sensation of driving

Herby the Love Bug

70s and early 80s are also remembered by movies where cars were the stars!

Some famous car in movies

- 1964 Ford Thunderbird (Sally Field & Nino Cantone) in “Gilligan’s Island”
- 1965 Ford Mustang (Steve McQueen) in “Bullitt”
- 1966 Jaguar XJ (Elizabeth Taylor) in “Who’s Afraid of Virginia Woolf?”
- 1967 Porsche 911 (Steve Martin) in “The Smurfs”
- 1970 Ford Torino (John Belushi) in “Animal House”
- 1972 Lincoln Continental (Jeff Goldblum) in “The Big Chill”
- 1979 El Camino (Chevy Chase & Beverly Johnson) in “Caddyshack”
- 1988 Toyota Land Cruiser (Thomas Haden Church) in “Old School”
- 1991 Toyota Supra (Keanu Reeves) in “The Fast and the Furious”

Importance of Transportation

- Necessary for economic growth, but not sufficient
  - The speed, cost, and capabilities of available transportation have a significant economic impact on an area.
  - Countries with better/advanced transportation networks and services are leaders in industry and commerce.
- Determines the location and character of cities and regions by interacting with land use (e.g. silk road).
- National security

Infrastructure of Ancient Roads

- The initiation of roads goes back to the invention of the wheel (5000 BC).
- However, the pavements that we use today is first seen commonly in Roman Empire.
- Roman roads were made of gravel, broken stones, cement, and pavement stones.
- The surface drainage of the roads were provided by the mild curves towards the slopes at the edges of the roads.
- The main drainage was provided by the ditches at both sides of the roads.

The oldest road in Turkey is the Babil - Bapsekus road built by Assyrians and Babylonians at the Euphrates river bed in 2000 BC.

After the foundation of Turkish Republic, in 1946 General Directorate of Highways was established.
Components of the Transportation System

- Infrastructure (supply):
  - Physical facilities: highways, railroads, ports
  - Transfer points: parking areas, driveways
  - Supporting elements: signals, signs, safety hardware, etc.

- Vehicles (demand): Planes, trains, autos, buses, ships, trucks

- Operators/users: Drivers, pilots, freight, passengers

A regular day in a parking lot

Some safety hardware

facility / transfer point / parking area / parking lot / driveway / sign / safety hardware
driver / passenger / freight / commuter spot

Development of a Transportation Network

- Development of a transportation network consists of planning, design and construction stages.

  In the planning stage the following activities are pursued:

  1. Identify problems, gather and analyze data
  2. Forecast future traffic demands and estimate the environmental and social impacts
  3. Evaluate alternatives and determine the alternative that meet the requirements and constraints of the problem at the lowest cost

The four step transport planning process

Step 1: Trip Generation
Step 2: Trip Distribution
Step 3: Mode Choice
Step 4: Trip Traffic Assignment

OUTPUT
- Estimated trips
- Estimated modal shares
- Estimated travel speeds
- Estimated travel delays
Trip Generation

- Decision to travel for a specific purpose (e.g., eat lunch)
- How much do people use the transport system?
- Why do people use the transport system?
- Where can different types of activities be satisfied?

Mode Choice

- How do people use the transport system?
  - What modes do they choose (transit, walk, carpool, drive alone,...)?
  - How do they react to varying transport service quality?

Trip / Traffic Assignment

- How do people use the transport system?
  - Given a mode, which route do they choose (e.g., E-S-...)?
  - Which parts of the transport system do they use?

Demographic Data

- Household size
- Income level
- Autos per household

Network Data

- Highway network
- Transit network

Capacity Restraint for Highways

- A qualitative measure describing operational conditions within a traffic stream and their perception by drivers and/or passengers is necessary in system planning.
  - The measure shall be different for different facilities (freeway, multilane, 2-lane rural, signals).

Ideal Capacity for a road may be stated as follows:

- Freeways: Capacity (Free-Flow Speed)
  - Freeways: Capacity (Free-Flow Speed)
    - 2,400 pcphpl (70 mph)
    - 2,350 pcphpl (65 mph)
    - 2,300 pcphpl (60 mph)
    - 2,250 pcphpl (55 mph)

- Multilane Suburban/Rural
  - 2,200 pcphpl (60 mph)
  - 2,100 (55 mph)
  - 2,000 (50 mph)
  - 1,900 (45 mph)

- 2-lane rural – 2,800 pcph
  - Signal – 1,900 pcphpl
Level of Service (LOS)

- Chief measure of “quality of service”
- Describes operational conditions within a traffic stream
- Does not include safety
- Different measures for different facilities
- There are 6 measures that vary from A through F.

Free-Flow Speed (FFS)

- The mean speed of passenger cars that can be accommodated under low to moderate flow rates on a uniform freeway segment under prevailing roadway and traffic conditions is called as FFS.

LOS A
- Free flow conditions
- Vehicles are unimpeded in their ability to maneuver within the traffic stream.

LOS B
- Flow is reasonably free.
- Ability to maneuver is slightly restricted.
- General level of physical and psychological comfort provided to drivers is high.

LOS C
- Flow is at or near FFS.
- Freedom to maneuver is noticeably restricted.
- Lane changes are more difficult.
- Queues may form behind significant blockage.

LOS D
- Speeds begin to decline with increasing flow.
- Freedom to maneuver is noticeably limited.
- Drivers experience physical and psychological discomfort.
- Even minor incidents cause queuing.

LOS E
- Highway reaches its capacity.
- Vehicles are closely spaced.
- Disruptions such as lane changes can cause a disruption wave that propagates throughout the upstream traffic flow.

LOS F
- This is a breakdown or forced flow situation.
- Occurs when:
  - Traffic incidents cause a temporary reduction in capacity
  - At points of recurring congestion, such as merge or weaving segments
  - In forecast situations, projected flow (demand) exceeds estimated capacity

Design Level of Service
- This is the desired quality of traffic conditions from a driver’s perspective (used to determine number of lanes):
  - Design LOS is higher for rural areas.
  - LOS is higher for level/rolling than mountainous terrain.
  - Other factors include adjacent land use type and development intensity, environmental factors, and aesthetic as well as historic values.

Design Decision

What can we change in a design to provide an acceptable LOS? 
- Lateral clearance: Distance to fixed objects
  - Assumes
    - >= 1.8 m from right edge of travel lanes to obstruction
    - >= 1.8 m from left edge of travel lane to object in median
  - Lane width
  - Number of lanes

Highway Design

- Problem Statement
- Objective and Constraints
- Horizontal Alignment
- Vertical Alignment
- Mass Diagram
- Final Report - Blueprint for construction

- The direction that a road follows on the ground is called route of the road.
- A road is composed of straight and curved portions.
- The straight portions of a road is called tangent (has an infinite radius) and the curved portions (with a definite radius) are horizontal curves.
- Plan is the projection of the road over a horizontal surface.
- Profile is the vertical cross section of the road.
Red line: The line showing the axis of the road on the profile after the construction is completed.

Black line: The line showing the natural ground level.

- The structure that carries the traffic loads and converts these loads to the soil beneath is called the superstructure.
- It may be flexible or rigid.

Constraints
- Environmental
  - Wetland, ponds and creeks.
- Geometric
  - 90° flat grade for starting and ending points.
  - Simple horizontal and vertical curve
- Safety
  - Maximum grade
  - Minimum radius
  - Enough stopping sight distance
- Budget
  - Maximum cut-and-fill depth
  - Mass balance

Alignment
- Alignment is a 3D problem broken down into two 2D problems
- Horizontal Alignment (plan view)
- Vertical Alignment (profile view)

Vertical Alignment
- Objective:
  - Determine elevation to ensure
  - Proper drainage
  - Acceptable level of safety
- Primary challenge
  - Transition between two grades
  - Vertical curves

A crossfall is the slope on the highway in two directions departing from the axis in order the rainfall can drain as soon as possible.
- In Asphalt roads: 1% - 2%
- In Gravelly roads: 3% - 4%
- In Soil roads: 4% - 6%
- In Concrete roads: 1.5%

A superelevation is the slope in one direction on a horizontal curve of a highway in order to resist centrifugal force.
Horizontal Alignment

- Objective:
  - Geometry of directional transition to ensure:
    - Safety
    - Comfort
- Primary challenge
  - Transition between two directions
  - Horizontal curves
- Fundamentals
  - Circular curves
  - Superelevation

During horizontal alignment, mass balance is always sought.

Mass Diagram

- Indicate grade points
- Indicate points where \( \sum \) fills = \( \sum \) cuts

Profile

Elevation

Ground

Grade

Mass diagram

Profile

Elevation

Ground

Grade

Cut areas

Fill areas

Volume