Why are we here?

Why are we here?

- **Human activities** take place in adapted spaces linked by communications through channels.

- **Town and country planning** is a science that deals with the study of the urban or country "system" covering the interacting activities using adapted spaces linked by communications through channels.

- <u>Transport planning</u> is an important part of overall town and country planning, <u>since</u> it deals with the transport network which is an important channel of a communications.

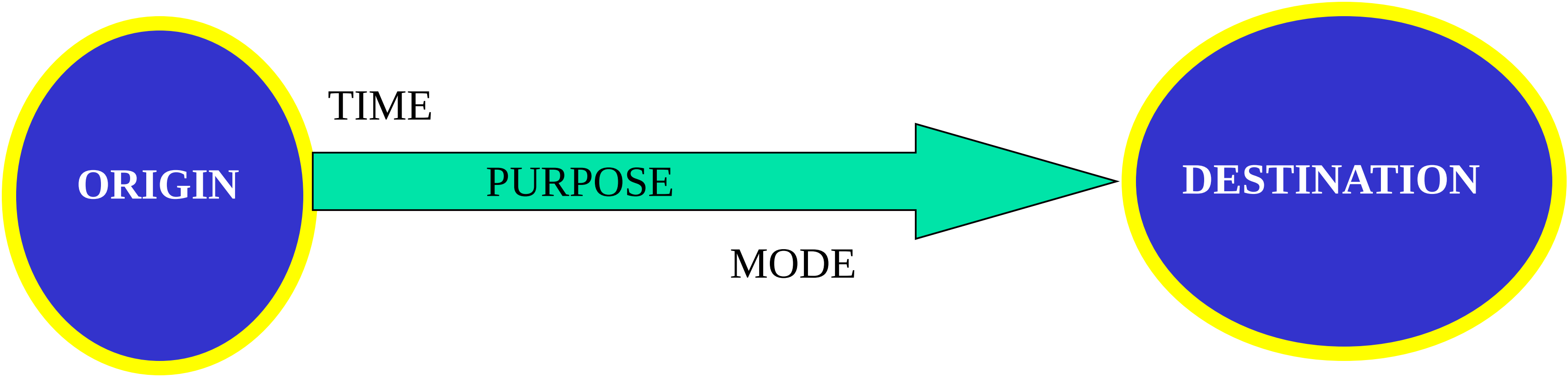
DEFINITION

Transport planning is a science that seeks to study the problems that arise in providing transportation facilities in an urban, regional or national setting and to prepare a systematic basis for planning such facilities

هو العلم الذى يبحث فى دراسة المشكلات التى تواجه عملية توفير تسهيلات ووسائل النقل فى اى مناطق حضرية أو خلوية وكذلك وضع إطار منظم لتخطيط تلك الوسائل

TRIP:

It is the process of moving passengers or goods from origin to a destination within certain time for certain purpose with a certain mode



Transportation & Traffic Engineering

- Transportation engineering: "The application of technological and scientific principles to the planning, functional design, operation and management of facilities for any mode of transportation...."
- Traffic: ".. The actual movement of vehicles or pedestrians on a facility..."

COMPONENTS OF ANY TRANSPORT SYSTEM

1- OBJECT

(PASSANGERS / GOODS)

2- VEHICLE **(SPACE & MOBILITY)**

(CAR/PLANE/TRAIN etc…)

3- PATH

Road networks/airlines/railway lines/ pipelines)

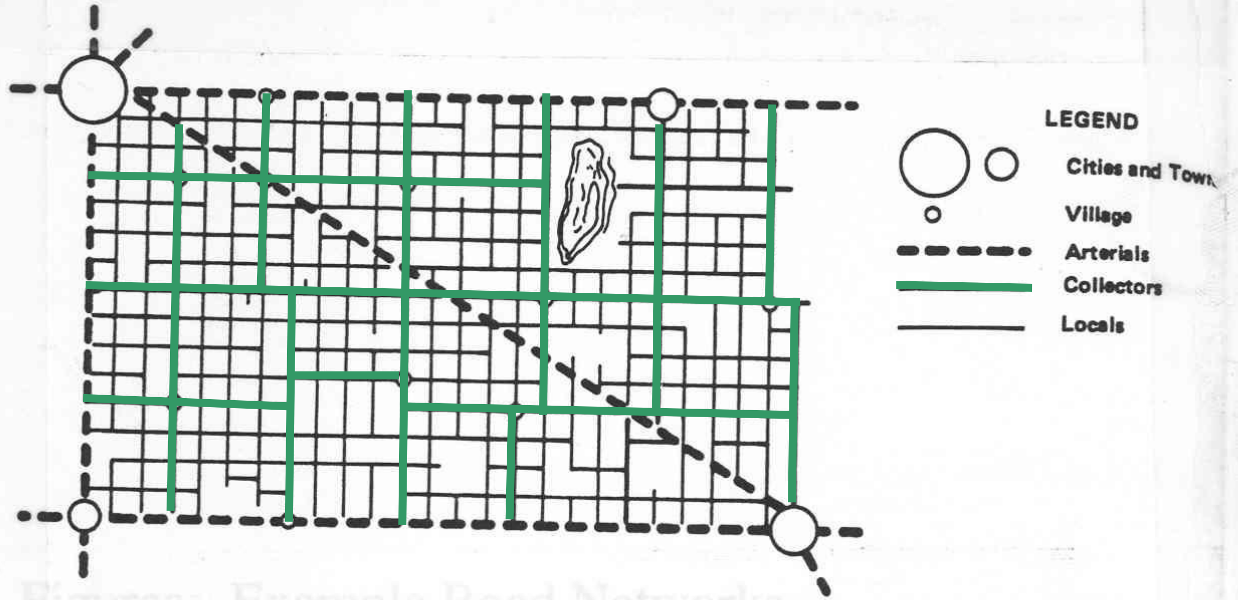
4- TERMINALS

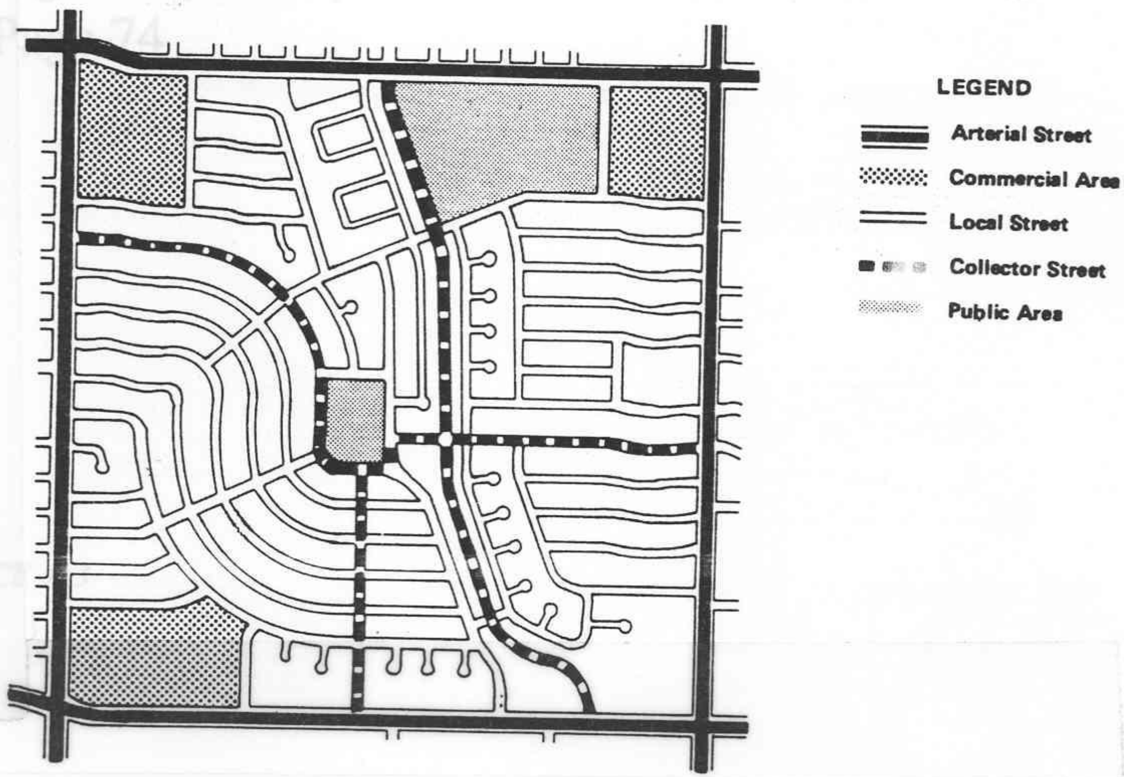
Airports/ Railwya stations etc….)

5- OPERATION PLANS

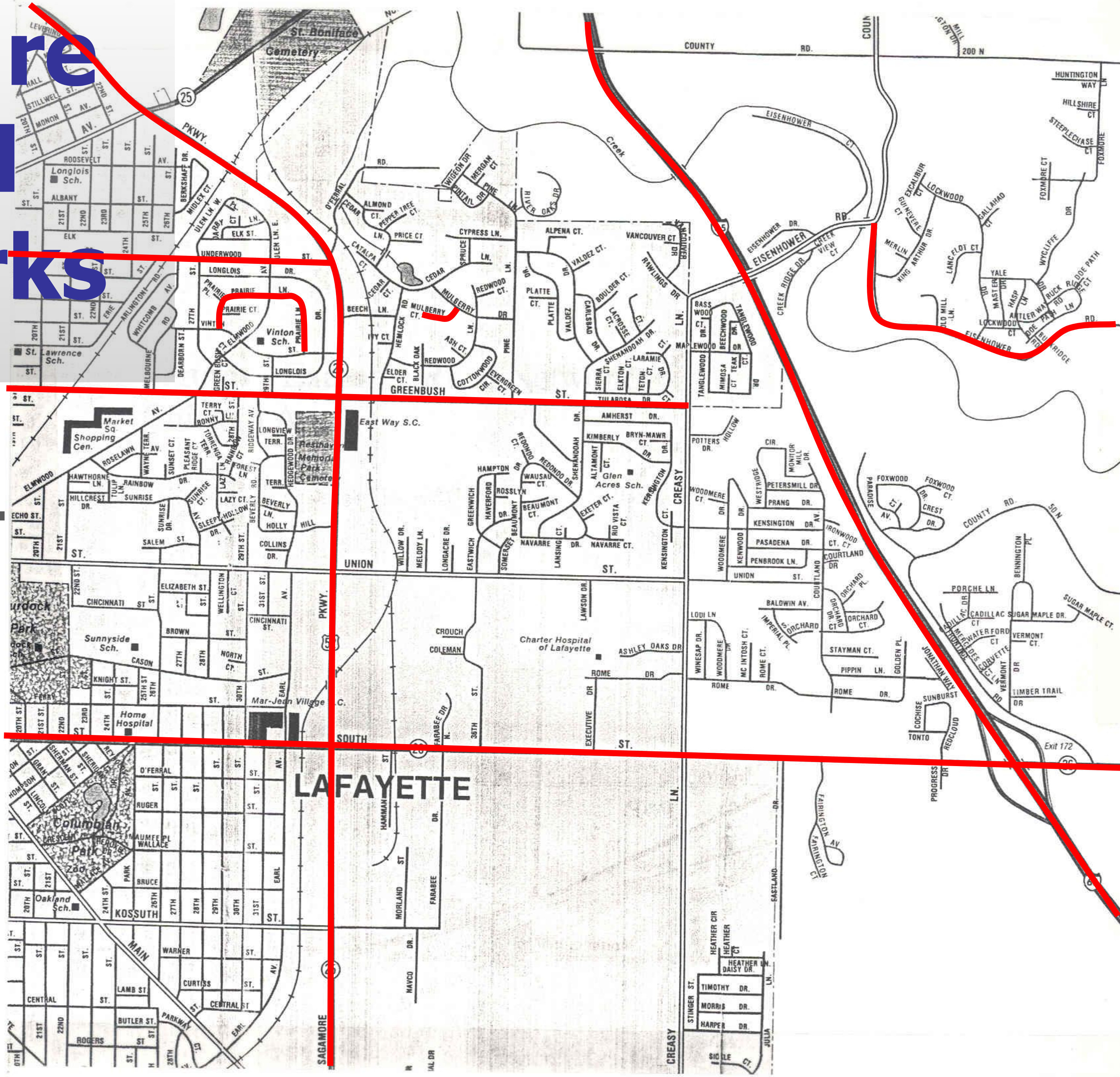
Time schedule/ arrivals/departures/ intervals etc…..

Structure of Road Networks





Structure of Road Networks



Geometric Design

The geometric design of highway facilities deals with the proportioning of the physical elements of highways such as vertical and horizontal curves, lane widths, cross sections and parking bays.

Its main purpose is to provide safe, efficient and economical movement of traffic

Design Controls and Criteria

Geometric design of highways deals with:

Human, Vehicle and environment (physical) characteristics

Human Characteristics

a) Driver personality

(physiology – knowledge – skill and habits – attitudes)

b) Driver Decision/action process

(sensory – perception – analysis – decision – response)

Vehicle Characteristics

a) Size and weight -

b) Dynamic characteristics

(Vehicle in Motion)

It has to overcome the following resistances:

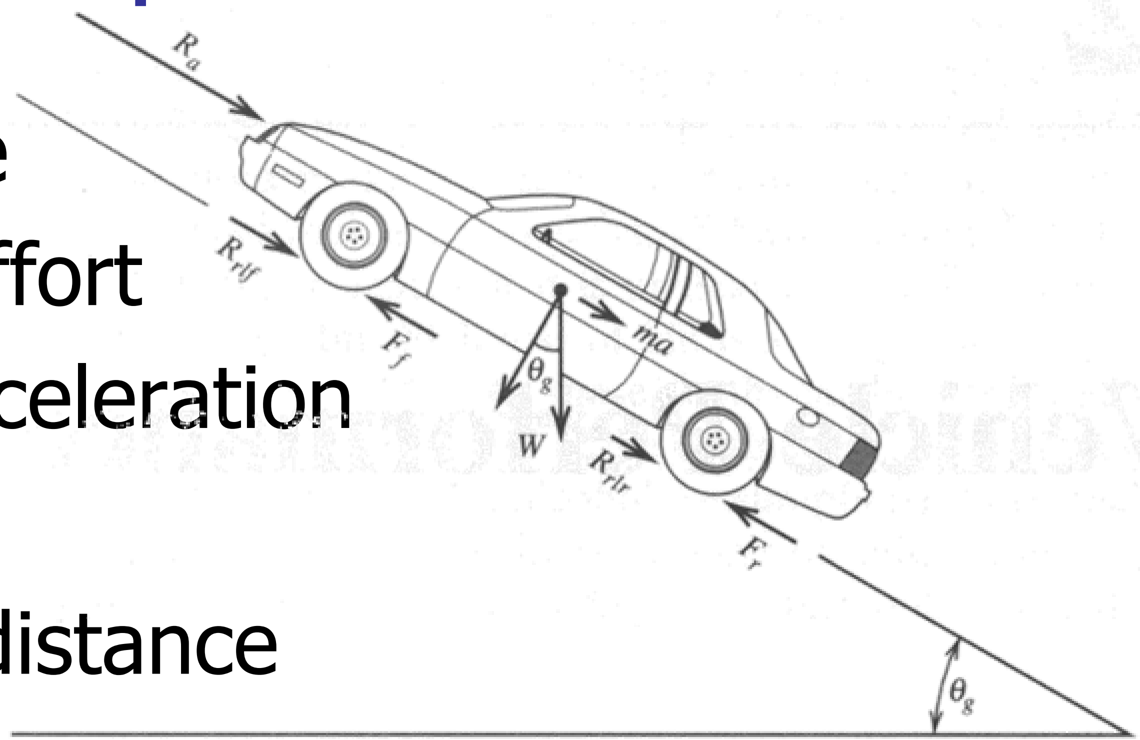
- Air
- Due to rolling
- Due to grdients
- Due to friction

Vehicle Dynamics

1. Resistance
    a. Aerodynamic
    b. Rolling
    c. Grade
2. Tractive Effort
3. Acceleration
4. Braking Force
5. Stopping Sight Distance (SSD)

Main Concepts

- Resistance
- Tractive effort
- Vehicle acceleration
- Braking
- Stopping distance



$$F = ma + R_a + R_{rl} + R_g$$

Resistance

Resistance is defined as the force impeding vehicle motion

1. What is this force?
2. Aerodynamic resistance
3. Rolling resistance
4. Grade resistance

$$\boxed{F = ma + R_a + R_{rl} + R_g}$$

Aerodynamic Resistance R_a

Composed of:

1. Turbulent air flow around vehicle body (85%)
2. Friction of air over vehicle body (12%)
3. Vehicle component resistance, from radiators and air vents (3%)

$$1\ hp = 550\ \frac{ft \cdot lb}{\sec}$$

$$R_a = 0.5\frac{2.15\rho}{2}C_D A_f V^2$$

R a = air resistance force (Ib)

ρ **= density of air (0.002385 Ib/ft3) at sea level**

C D = aerodynamic drag coefficient (0.15 -0.5) ====(0.4 as an average)

A =frontal cross sectional area (ft^2)

V = VEHICLE SPEED (mph)

g =acceleration due to gravity (ft/sec^2)

Rolling Resistance R_{rl}

Composed primarily of

1. Resistance from tire deformation (~90%)
2. Tire penetration and surface compression (~ 4%)
3. Tire slippage and air circulation around wheel (~ 6%)
4. Wide range of factors affect total rolling resistance
5. Simplifying approximation:

$$P_{Rrl} = f_{rl} W$$

$$f_{rl} = 0.01\left(1 + \frac{V}{147}\right)$$

R $_{rl}$ = rolling resistance force (Ib)
W = GROSS VEHICLE WEIGHT (Ib)
V = VEHICLE SPEED (mph)

Grade Resistance R_g

Composed of

- Gravitational force acting on the vehicle

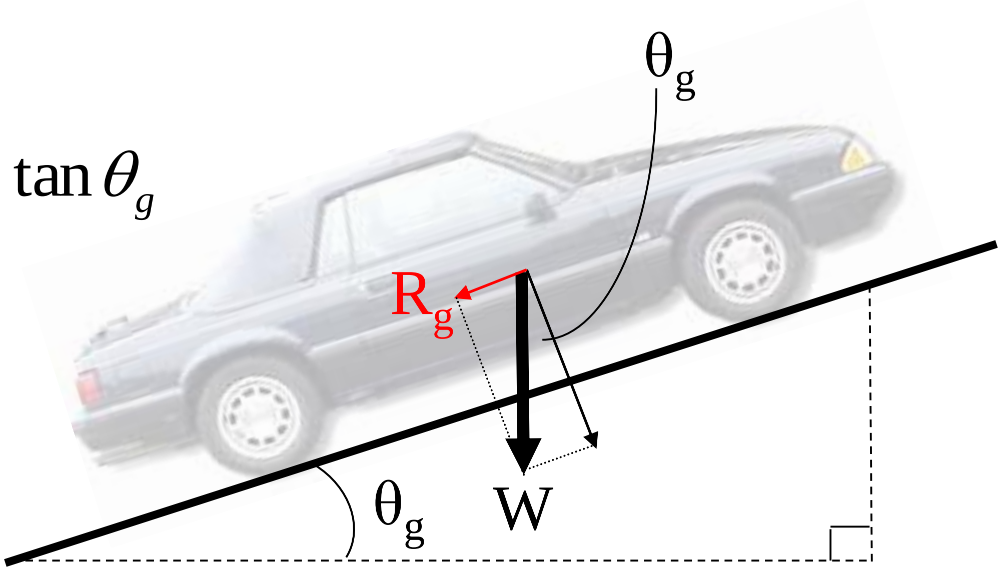
$$R_g = W \sin \theta_g$$

For small angles, $\sin \theta_g \approx \tan \theta_g$

$$R_g = W \tan \theta_g$$

$$\tan \theta_g = G$$

$$R_g = WG$$



Available Tractive Effort

The minimum of:

1. Force generated by the engine, F_e
2. Maximum value that is a function of the vehicle's weight distribution and road-tire interaction, F_{max}

$$\text{Available tractive effort} = \min\left(F_e, F_{\max}\right)$$

Engine-Generated Tractive Effort

- Force

$$F_e = \frac{M_e \varepsilon_0 \eta_d}{r}$$

F_e = Engine generated tractive effort reaching wheels (lb)

M_e = Engine torque (ft-lb)

ε_0 = Gear reduction ratio

η_d = Driveline efficiency

r = Wheel radius (ft)

- Power

$$\mathrm{hp}\left(550\frac{\mathrm{ft}\cdot\mathrm{lb}}{\mathrm{sec}}\right) = \frac{\mathrm{torque}\left(\mathrm{ft}\cdot\mathrm{lb}\right)}{550} \times \frac{\mathrm{engine\ rpm}}{60\left(\frac{\mathrm{sec}}{\mathrm{min}}\right)} \times 2\pi$$

Vehicle Speed vs. Engine Speed

$$V = \frac{2\pi r n_e (1 - i)}{\varepsilon_0}$$

V = velocity (ft/s)

r = wheel radius (ft)

n_e = crankshaft rps

i = driveline slippage

ε_0 = gear reduction ratio

Maximum Tractive Effort

- Front Wheel Drive Vehicle

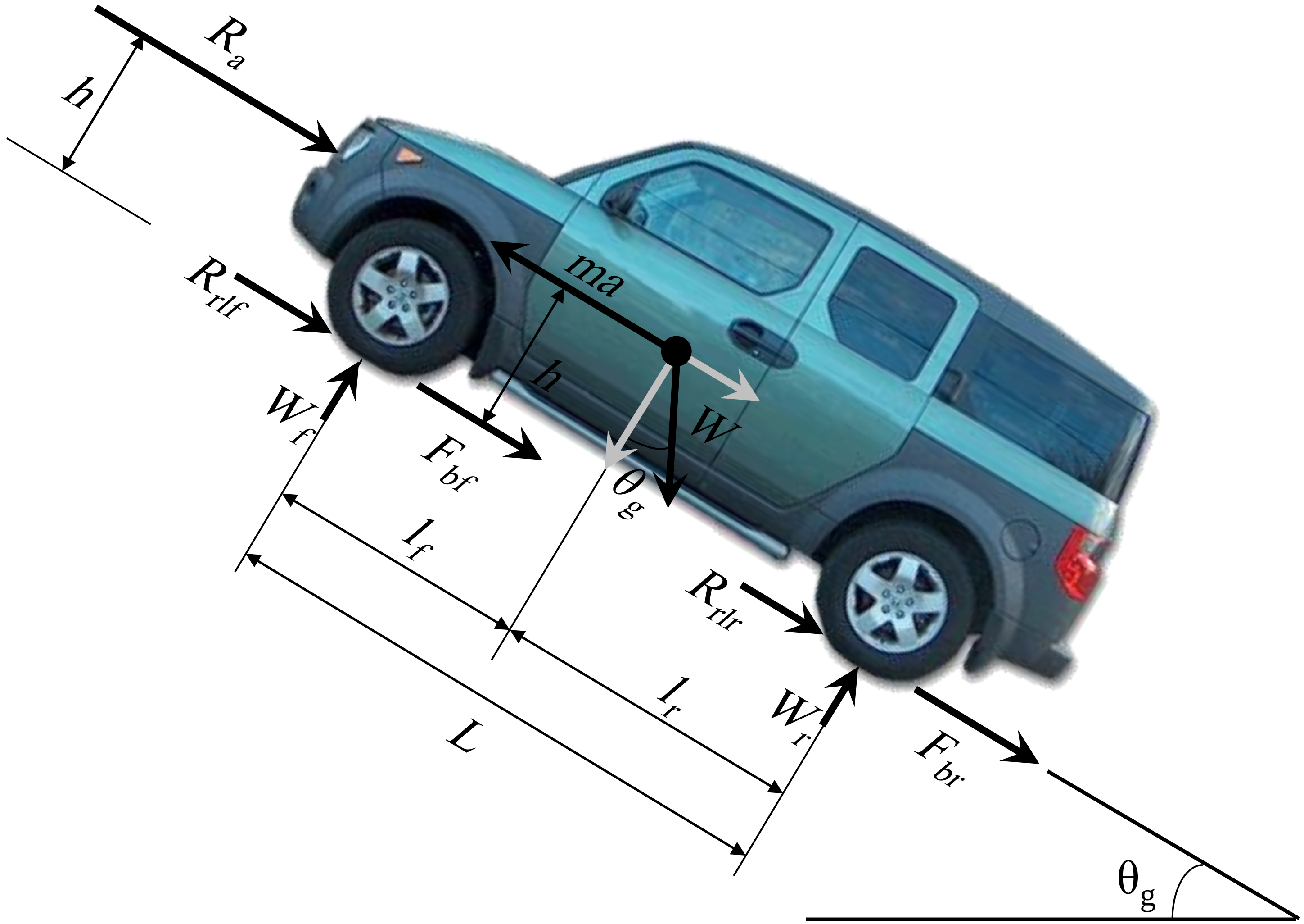
$$F_{\max} = \frac{\mu W \dfrac{(l_r + f_{rl} h)}{L}}{1 + \dfrac{\mu h}{L}}$$

- Rear Wheel Drive Vehicle

$$F_{\max} = \frac{\mu W \dfrac{(l_f - f_{rl} h)}{L}}{1 - \dfrac{\mu h}{L}}$$

- What about 4WD?

Diagram



Vehicle Acceleration

- Governing Equation

$$F - \sum R = \gamma_m ma$$

- Mass Factor

  (accounts for inertia of vehicle’s rotating parts)

$$\gamma_m = 1.04 + 0.0025\varepsilon_0^2$$

Braking Force

- Front axle

$$F_{bf\ \max} = \frac{\mu W\left[l_r + h\left(\mu + f_{rl}\right)\right]}{L}$$

- Rear axle

$$F_{br\ \max} = \frac{\mu W\left[l_f - h\left(\mu + f_{rl}\right)\right]}{L}$$

Braking Distance

- Theoretical
  - ignoring air resistance

$$S = \frac{\gamma_b \left(V_1^2 - V_2^2\right)}{2g\left(\eta_b \mu + f_{rl} \pm \sin\theta_g\right)}$$

- Practical

$$d = \frac{V_1^2 - V_2^2}{2g\left(\frac{a}{g} \pm G\right)}$$

<u>For grade = 0</u>

$$d = \frac{V_1^2 - V_2^2}{2a}$$

$$d_p = V_1 t_p$$

- Perception

$$d_s = d + d_p$$

Factors influencing highway design

1- Functional classification of the highway

2- Expected traffic volume and vehicle mix

3- Design Speed

4-Topography of the area in which the highway will be located

5- Level of service to be provided

6- Available Funds

7- safety

8- Social and environmental factors

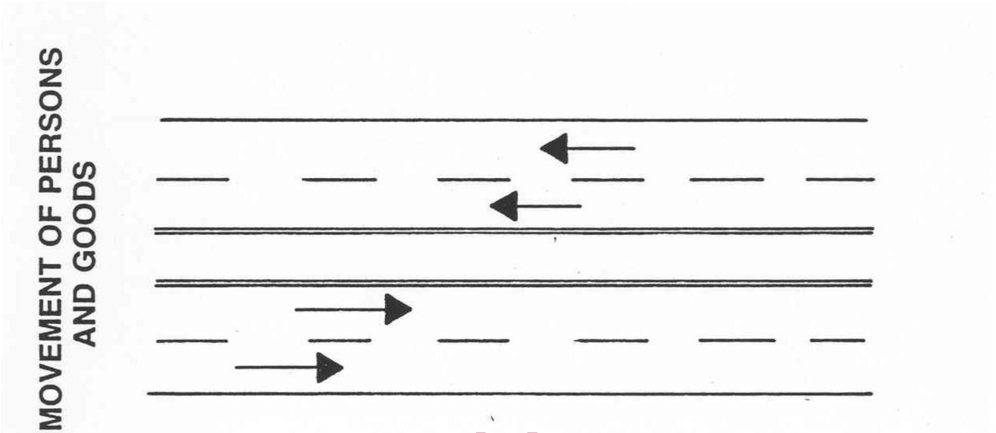
1-Functional classification of roads

- Road functions
- structure of road networks

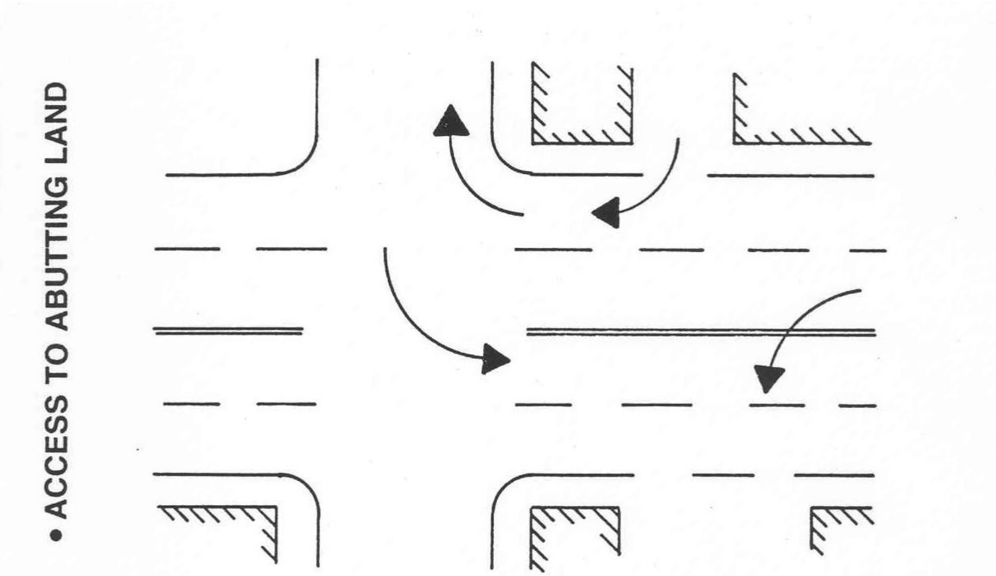
Highway components

- Cross-sections
- Highway plan and profile
- Interchanges
- Rural and urban intersections

Road Functions

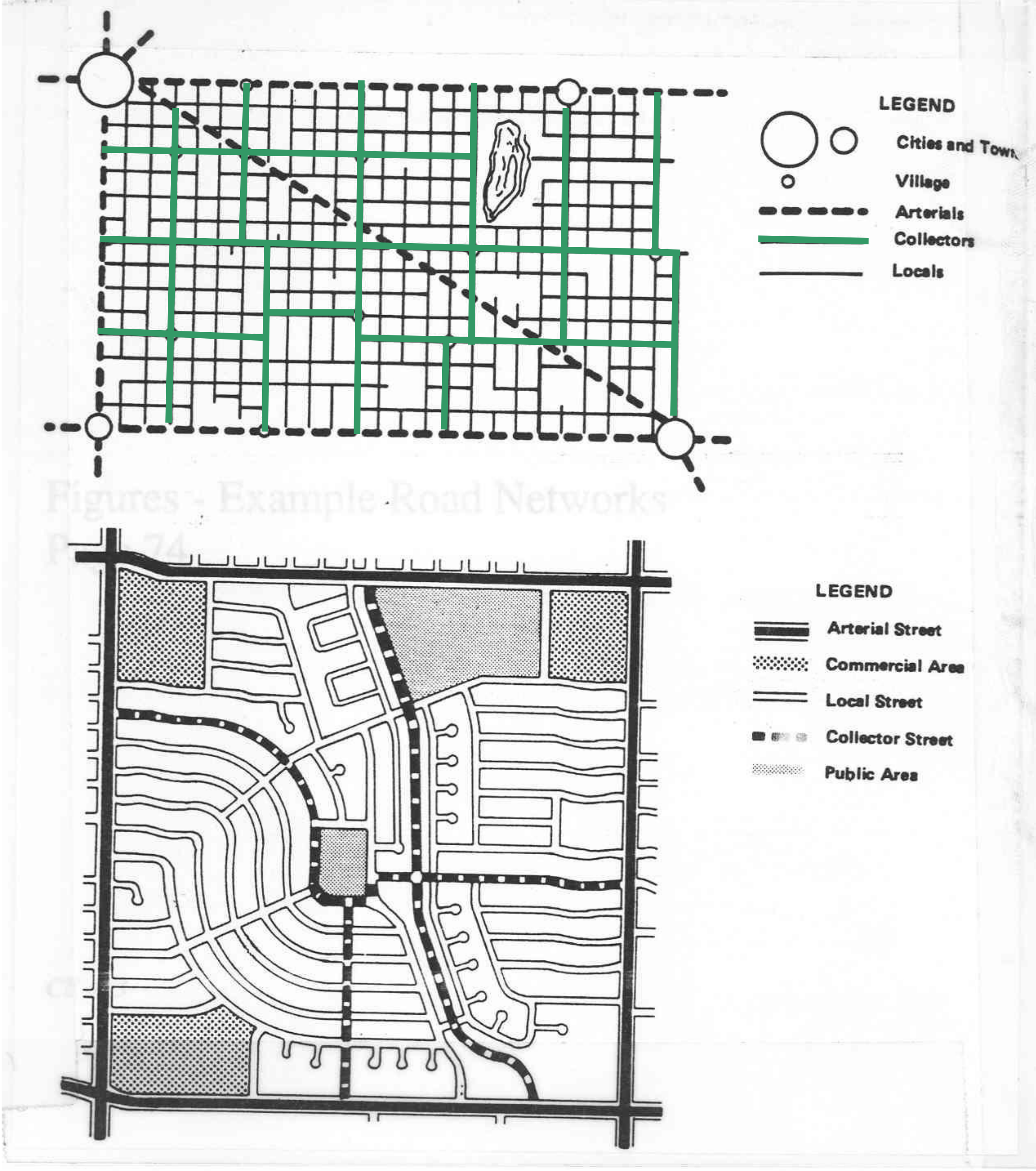


Mobility

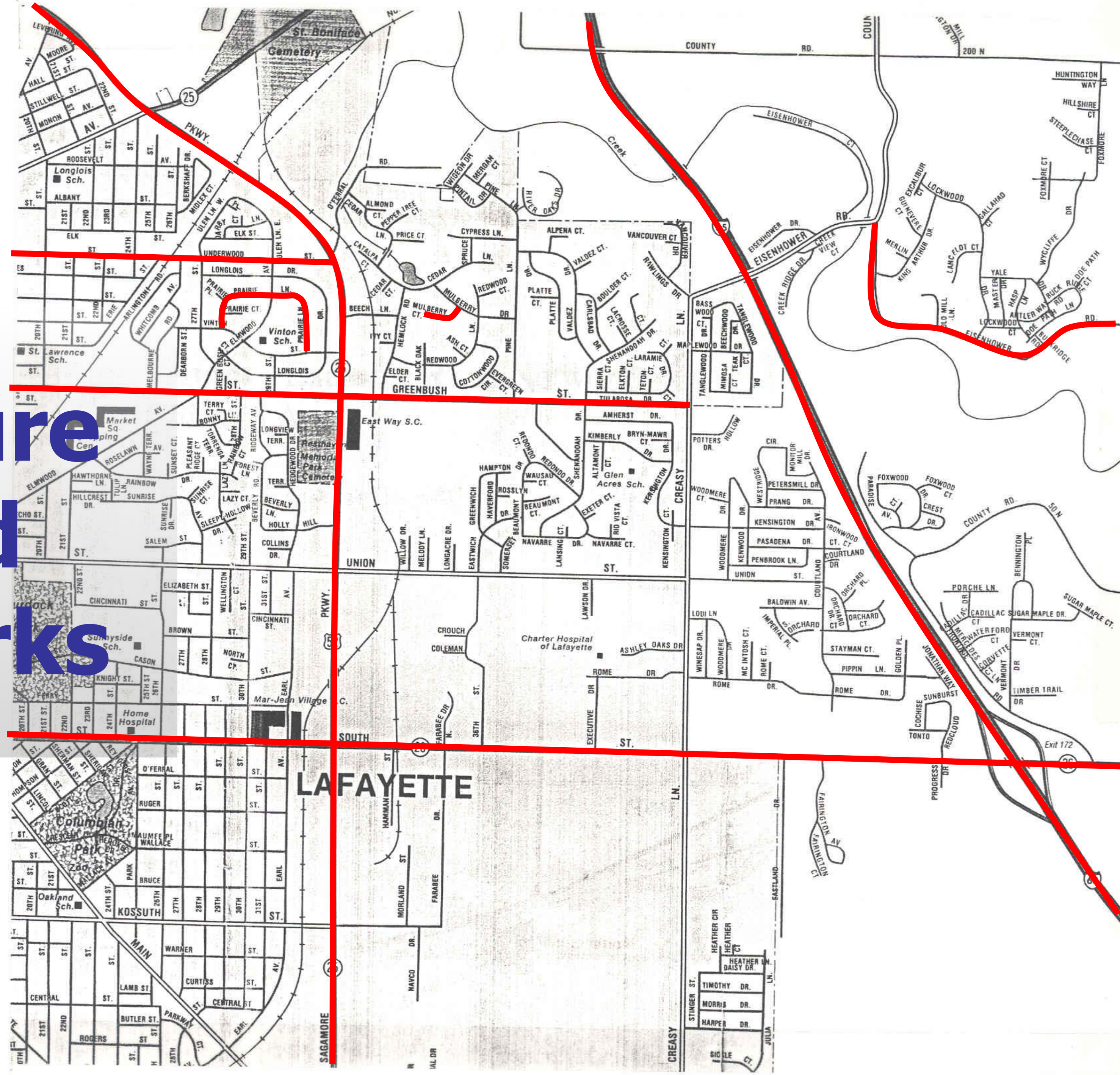


Accessibility

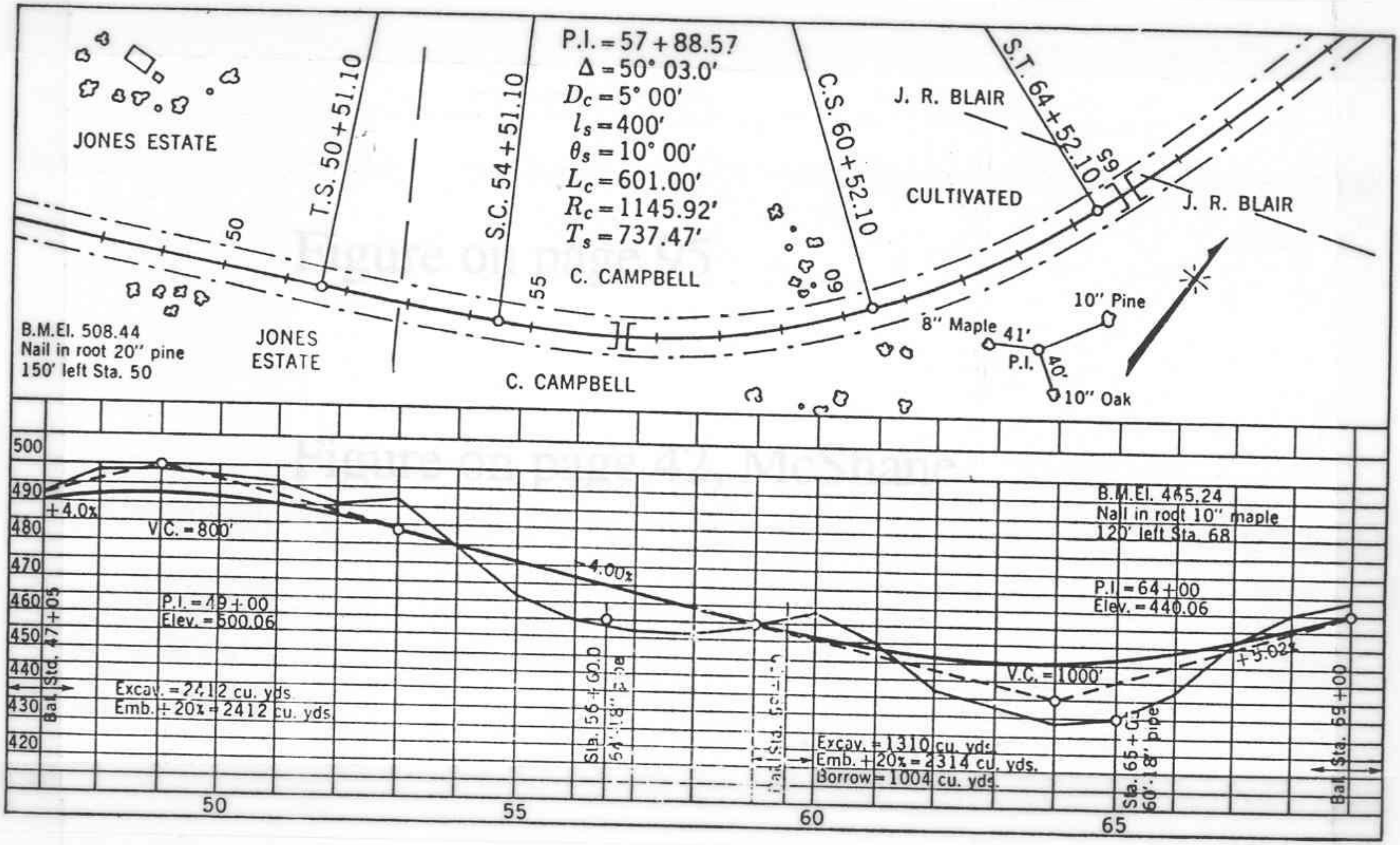
Structure of Road Networks



Structure of Road Networks



Highway Components
Highway plan and profile

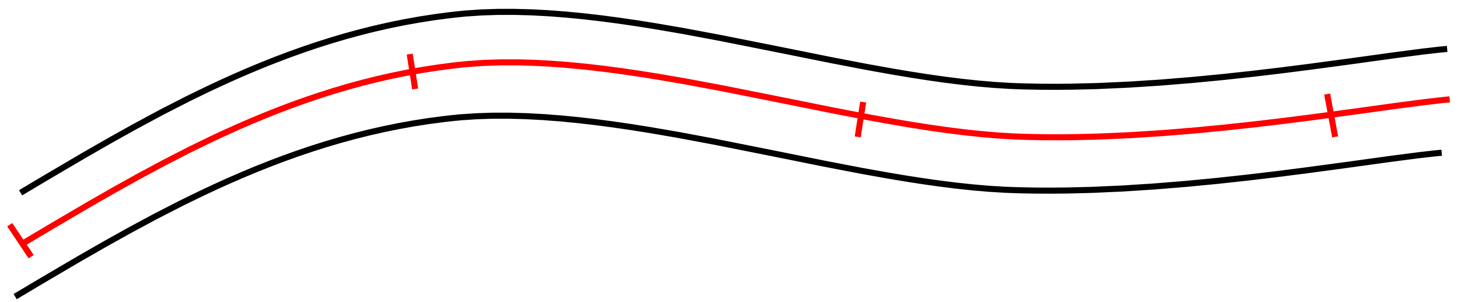


Concepts

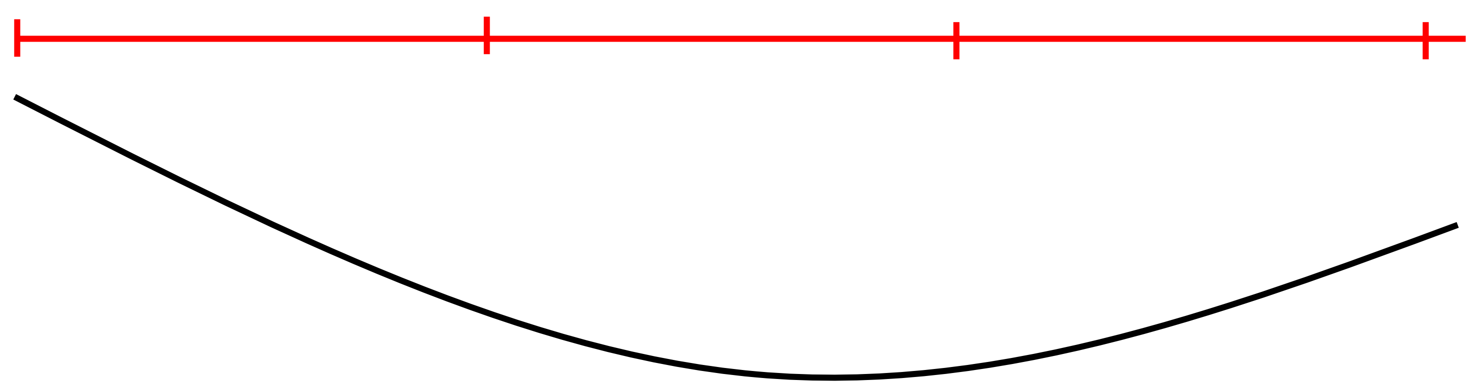
- Alignment is a 3D problem broken down into two 2D problems
  - Horizontal Alignment (plan view)
  - Vertical Alignment (profile view)
- Stationing
  - Along horizontal alignment
  - 12+00 = 1,200 ft.

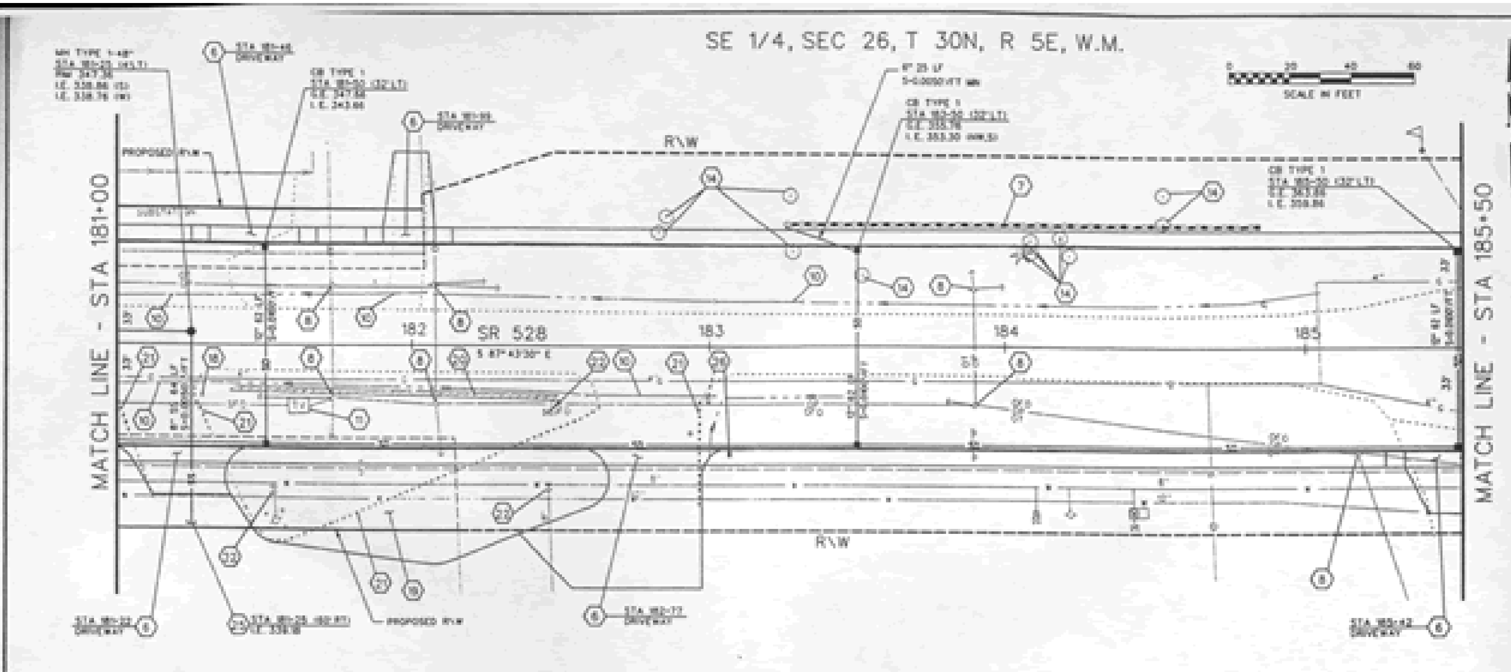
Stationing

Horizontal Alignment



Vertical Alignment



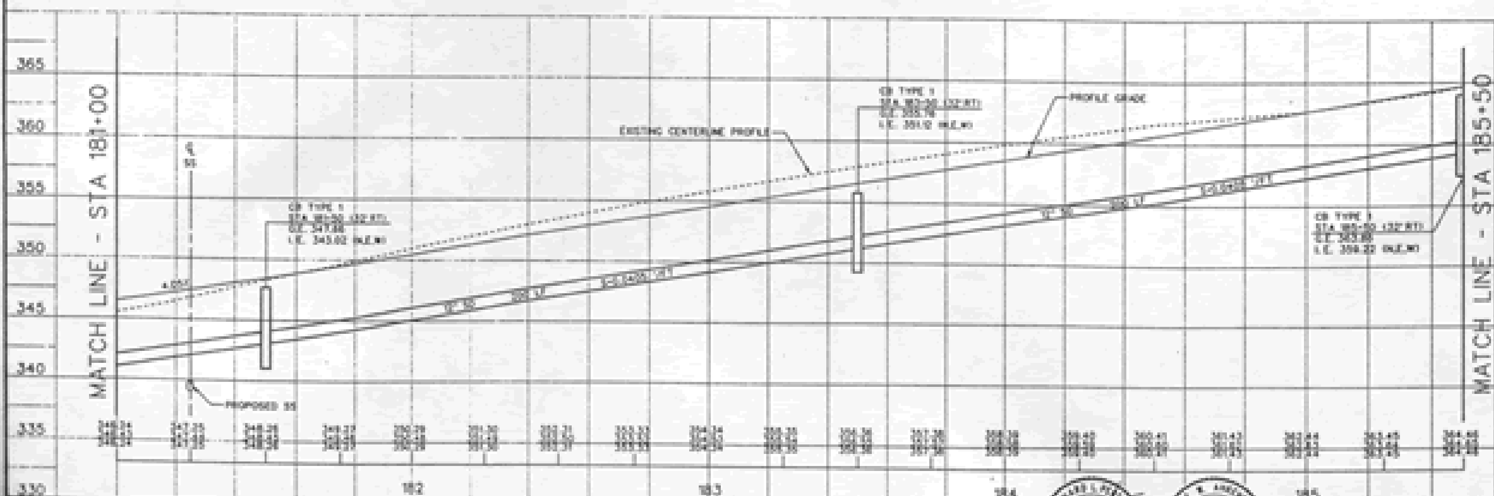


GENERAL CONSTRUCTION NOTES:

1. ADJUST EXISTING MONUMENT CASE AND COVER TO GRADE
2. ADJUST MANHOLE TO GRADE.
3. ADJUST CATCH BASIN FRAME AND LID TO GRADE.
4. REMOVE EXISTING SIDEWALK.
5. REMOVE EXISTING CONCRETE CURB AND GUTTER.
6. CONSTRUCT CEMENT CONCRETE APPROACH AND ASPHALT DRIVEWAY. SEE DRIVEWAY PROFILE SHEET
7. CONSTRUCT ROCKERY. SEE WALL SHEETS 32-37 FOR PROFILE.
8. EXISTING UTILITY POLE TO BE RELOCATED BY OTHERS
9. REMOVE EXISTING FENCE WITHIN R/W.
10. REMOVE EXISTING CULVERT.
11. UTILITY VAULT TO BE RELOCATED BY OTHERS.
12. SAWCUT.
13. REMOVE EXISTING STORM DRAINAGE PIPE.
14. REMOVE EXISTING TREE.
15. CONSTRUCT CURB RAMP. SEE WSDOT STD. PLAN F-3.
16. CONSTRUCT CURB RAMP ALTERNATE. SEE WSDOT STD. PLAN F-3.
17. PLANE EXISTING PAVEMENT. SEE DETAIL, SHEET 5.

CONSTRUCTION NOTES:

18. REMOVE BOLLARD.
19. CONSTRUCT ISLAND. SEE ISLAND DETAIL, SHEET 47.
20. REMOVE WOOD CEDAR EDGING.
21. REMOVE EXISTING CONCRETE CURB.
22. ADJUST VALVE TO GRADE.
23. CONSTRUCT RETAINING WALL. SEE SHEETS 30-37 FOR PROFILE.
24. CONNECT UNDER WALL DRAIN TO CB.
25. END SANITARY SEWER WITH CAP.
26. RELOCATE MAILBOX.



NOTE: ALL METAL FRAMES AND GRATES FOR CATCH BASINS AND INLETS SHALL BE PER WSDOT STD. PLAN B-2a UNLESS OTHERWISE SPECIFIED.

N.A.V.D. 1988

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City of Marysville
SR 528 (64TH ST. NE)
STA 181+00 to STA 185+50
PLAN & PROFILE

SHEET 21 of 67

2- Design Speed and Design Traffic Concepts

- Posted speed = speed limit
- Operating speed = free flow (spot speed)
- Running speed = length of highway section ÷ running time
- Design speed = selected speed used to determine geometric design features

Design Speed

- Design speed is defined by the AASHTO Green Book as: ***...the maximum safe speed that can be maintained over a specified section of highway when conditions are so favorable that the design features of the highway govern.***
- Design Speed should: 1) "...be consistent with the speed the driver is likely to **expect**." and 2) ". . .fit the travel desires and habits of nearly all drivers."
- Not posted speed and not operating speed (but ALWAYS higher than both)
- See first part of: http://www.fhwa.dot.gov/environment/flex/ch04.htm (Chapter 4 from FHWA's Flexibility in Highway Design)

Design Speed Considerations

- Functional classification of the highway
- Character of the terrain
- Density and character of adjacent land uses
- Traffic volumes expected to use the highway
- Economic and environmental considerations

Design Speed in Green Book

(suggested minimum design speed)

Rural Local Roads

Type of terrain	Metric: Design speed (km/h) for specified design volume (veh/day)						US Customary: Design speed (mph) for specified design volume (veh/day)					
	under 50	50 to 250	250 to 400	400 to 1500	1500 to 2000	2000 and over	under 50	50 to 250	250 to 400	400 to 1500	1500 to 2000	2000 and over
Level	50	50	60	80	80	80	30	30	40	50	50	50
Rolling	30	50	50	60	60	60	20	30	30	40	40	40
Mountainous	30	30	30	50	50	50	20	20	20	30	30	30

Exhibit 5-1. Minimum Design Speeds for Local Rural Roads

Source: *A Policy on Geometric Design of Highways and Streets* (The Green Book). Washington, DC. American Association of State Highway and Transportation Officials, 2001 4th Ed.

Design Speed in Green Book
(suggested minimum design speed)

Rural Collectors

Type of terrain	Metric: Design speed (km/h) for specified design volume (veh/day)			US Customary: Design speed (mph) for specified design volume (veh/day)		
	0 to 400	400 to 2000	over 2000	0 to 400	400 to 2000	over 2000
Level	60	80	100	40	50	60
Rolling	50	60	80	30	40	50
Mountainous	30	50	60	20	30	40

Note: Where practical, design speeds higher than those shown should be considered.

Exhibit 6-1. Minimum Design Speeds for Rural Collectors

Source: *A Policy on Geometric Design of Highways and Streets* (The Green Book). Washington, DC. American Association of State Highway and Transportation Officials, 2001 4th Ed.

Design Speed in Green Book
(suggested minimum design speed)

Rural Arterials

- 60 – 120 kph (40-75 mph)
- Depends on …
  - Terrain
  - Driver expectancy
  - Alignment (reconstruction)

Design Speed in Green Book
(suggested minimum design speed)

Urban

- Locals 20-30 mph
- Collectors 30 mph+
- Arterials 30-60 mph

Freeways	Design Speeds	
Terrain	**Rural**	**Urban**
Flat	70-80	70
Rolling	60-70	60-70
Mountainous	50-60	50-60
Arterial Highways		
Terrain	**Rural**	**Urban**
Flat	60-70	30-60
Rolling	40-60	30-50
Mountainous	30-50	30-50
Collector and Local Roads		
Terrain	**Rural**	**Urban**
Flat	30-50	30-40
Rolling	20-40	20-40
Mountainous	20-30	20-30

Source: Traffic *Engineering Handbook (Fourth Edition)*, Institute of Transportation Engineers, Washington, DC, 1992, p. 156. Note: 1 mile/hr = 1.613 km/hr

Values represent the minimum acceptable design speeds for the various conditions of terrain and traffic volumes associated with new or reconstructed highway facilities

Design Traffic

Traffic Definitions

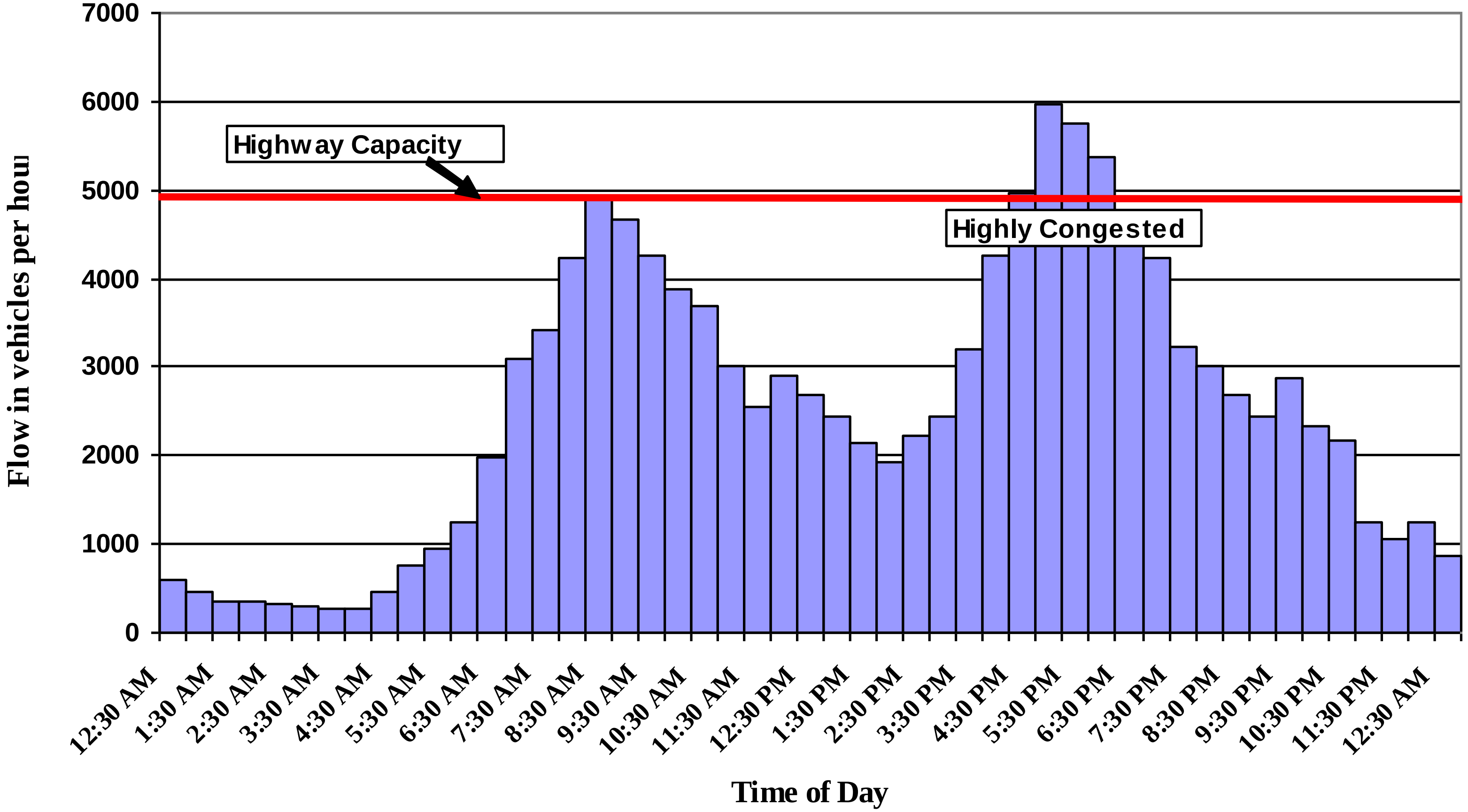
- **Volume:**
  - number of vehicles, pedestrians, etc. passing a point during a specific period of time
  - for vehicles, usually expressed as veh/hour (vph) or veh/hour/lane (vphpl)

- **Demand:**
  - number of vehicles, pedestrians, etc. that desire to travel between locations during a specific period
  - Frequently higher than volume during certain peak times
  - Trips are diverted or not made when there are constraints in the system
  - difficult to measure actual demand because capacity constrains the demand
- **Capacity:**
  - maximum number of vehicles that can pass a point during a specific period
  - A characteristic of the roadway or facility

Characteristics of Traffic Flow

- Highly variable
  - Time of day
  - Day of week
  - Season
  - Road characteristics
  - Direction

Traffic Typically Peaks twice per day



Source: www.ecn.purdue.edu/~darcy

Volume Studies

- AADT: Annual average daily traffic (counted for 365 days)
- ADT: average daily traffic (counted for > 1 day and < 365)
- PHV: peak hour volume
- Classification counts: fleet mix

Estimating AADT

- Annual Average Daily Traffic
- Use count station information
- Extrapolate to non-count locations
- Used to adjust ADT for
  - Seasons
  - Daily variation

AADT Data Help to:

- Estimate highway revenues
- Establish overall volume trends
- Establish annual accident rates
- Analyze benefits of road improvements

Design Volume

- Usually hourly volume
- Which hour?
  - Average hourly volume – inadequate design
  - Maximum peak hour – not economical
  - Hourly volume used for design should not be exceeded very often or by very much
  - Usually use 30th highest hourly volume of the year
  - On rural roads 30 HHV is ~ 15% of ADT
  - Tends to be constant year to year

Design Hourly Volume

DHV is a representation of peak hour traffic, usually for the future, or horizon year

K-factor represents proportion of AADT that occurs in the 30th HHV

$$\text{K-factor} = \frac{\text{DHV}}{\text{AADT}} \times 100$$

K = 8 to 12% urban, 12 to 18% rural

Design Hourly Volume (Example)

If AADT is 3500 vpd and the 30th highest hourly volume for the year is 420 vph what is the K-factor for that facility?

$$\text{K-factor} = \frac{\text{DHV}}{\text{AADT}} \times 100$$

$$\text{K-factor} = \frac{420}{3500} \times 100 = \underline{12}$$

Question: What's the impact of choosing different K factor for design?

If AADT is 3500 vpd, how will the design volume differ for K-factor = 8% vs. 12%?

$$DHV = \frac{\text{K-factor x AADT}}{100}$$

$$DHV_{k=8\%} = \frac{8 \times 3500}{100} = 280 \text{ vph}$$

$$DHV_{k=12\%} = \frac{12 \times 3500}{100} = 420 \text{ vph}$$ (diff of 140 veh)

Traffic Demand (cont.)

- D = directional distribution = one way volume in peak direction (expressed as a percentage of two-way traffic) Rural 55 to 80%
- Can also adjust for how traffic is distributed between lanes (e.g., 3 lanes, highest/outside lane may be 40% of total directional flow)

Peak Hour Factor (PHF)

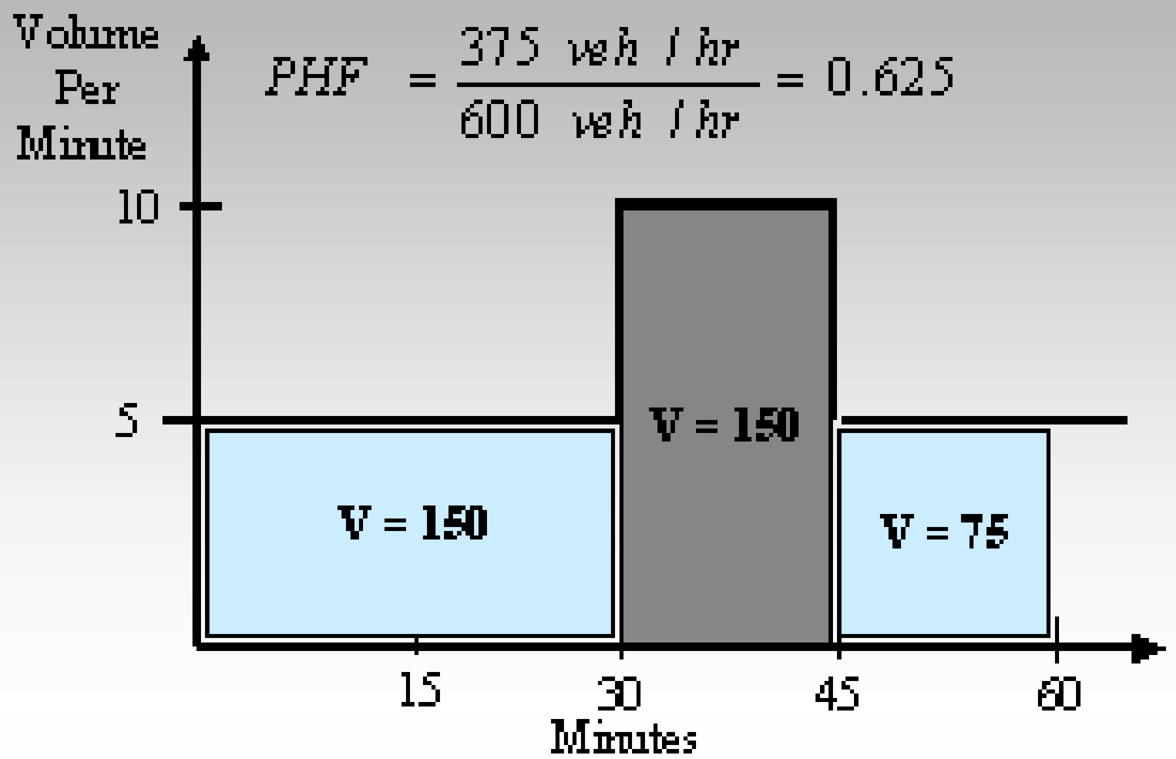
$$PHF = \frac{\text{peak-hour volume}}{4(\text{peak 15-min volume})}$$

- Flow is not uniform throughout an hour
- HCM considers operating conditions during most congested 15-minute period of the hour to determine service level for the hour as a whole

Peak Hour Factor

$$PHF = \frac{\textit{hourly volume}}{\textit{peak 15 min flow rate}}$$

$$PHF = \frac{375 \ veh/hr}{600 \ veh/hr} = 0.625$$



$$DHV = \frac{\text{Peak-Hour Volume}}{PHF}$$

Example

Peak hour volume from previous = 375 vph

PHF = 0.625

$$DHV = \frac{375}{0.625} = \mathbf{600\ vph}$$

Note: the traffic you design for is the busiest 15 minutes during the peak hour … another way to think of it is 150 vehicles per 15 minutes = 600 vehicles per 60 minutes

Geometric design deals with

1- Cross section elements

2- sight distance considerations

3- Horizontal alignment details

4- Vertical alignment details

5- Intersection elements