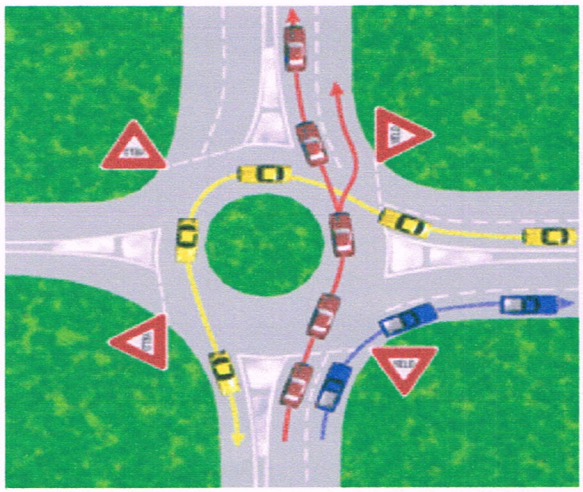
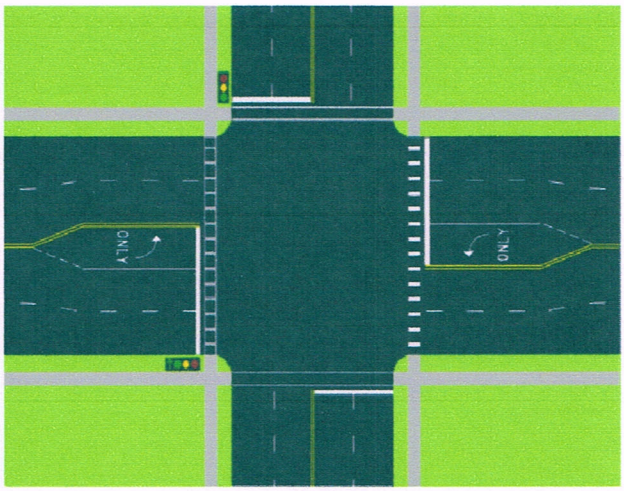
Kurdistan Engineers Union

Suleimanyah Branch

Paper written in support of membership upgrading on

Principles of Highway Capacity





By: Rebaz Hama Ali Hussein

Membership number: 5903

Principles of Highway Capacity

- To provide a general overview of the principles of capacity-operation and safety
- To discuss uninterrupted flow and interrupted flow facilities
- To define Level of Service (LOS) and Measures of Effectiveness (MOE)

Principles of Capacity:

The Capacity of a facility is defined as the maximum hourly rate at which persons or vehicles can reasonably be expected to traverse a point or uniform section of a lane or roadway during a given time period under prevailing roadway, traffic and control conditions.

Level of Service:

- Concepts
  - Uses qualitative measures that characterize operational conditions within a traffic stream and their perception by motorists and passengers
- Factors
  - Speed and travel time
  - Freedom of Maneuver
  - Traffic Interruptions
  - Comfort and Convenience

Measures of Effectiveness

Type of Facility	Measure of Effectiveness
Urban Streets	Average Travel Speed (MPH or KM/H)
Signalized Intersections	Delay (Sec/veh)
Unsignalized Intersections	Delay (Sec/veh)
Pedestrians	Delay (sec/ped) Space (sq. m/p or sq. ft/p)
Bicycles	Frequency of Events (Events/h)
Two Lane Highways	Average Travel Speed (MPH or KM/H) Percent time-spent-following (%)
Multilane Highways	Density (pc/mi/Ln) or (pc/km/Ln)
Basic Freeway Segments	Density (pc/mi/Ln) or (pc/km/Ln)
Freeway Weaving	Density (pc/mi/Ln) or (pc/km/Ln)
Ramps and Ramp Junctions	Density (pc/mi/Ln) or (pc/km/Ln)
Transit	Various

Volume or Rate of Flow

- **Volume**
  - The total number of vehicles that pass over a given point or section of a lane or roadway during a given time interval
- **Rate of Flow**
  - The equivalent hourly rate at which vehicles pass over a given point or section of a lane or roadway during a given time interval less than 1 hour, usually 15 minutes

Peak-Hour Factor

Peak rates of flow are related to hourly volumes using the peak-hour factor (PHF), which is the ratio of total hourly volume to the peak rate of flow within the hour

$$PHF = \frac{\text{Hourly Volume}}{\text{Peak rate of Flow (within the hour)}}$$

For Peak 15-minutes periods are used,

$$PHF = V/(4xV15)$$

Where: PHF= peak-hour factor
V= hourly volume (vph), and
V15= volume during the peak 15 minutes

You are designing not for the peak hour, but rather to the worst 15 minutes. The design volume is the highest 15 minX4

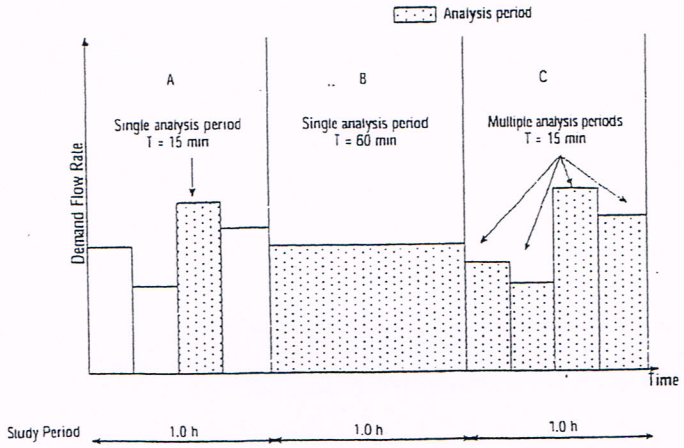
Peak Hour Factor

Time Period	Volume (veh)	Rate of Flow (veh)
5:00- 5:15	1,000	4,000
5:15- 5:30	1,200	4,800
5:30-5:45	1,100	4,400
5:45-6:00	1,000	4,000
5:00-6:00	4,300	

PHF = 4300/4 x 1200
=4300/4800= 0.90

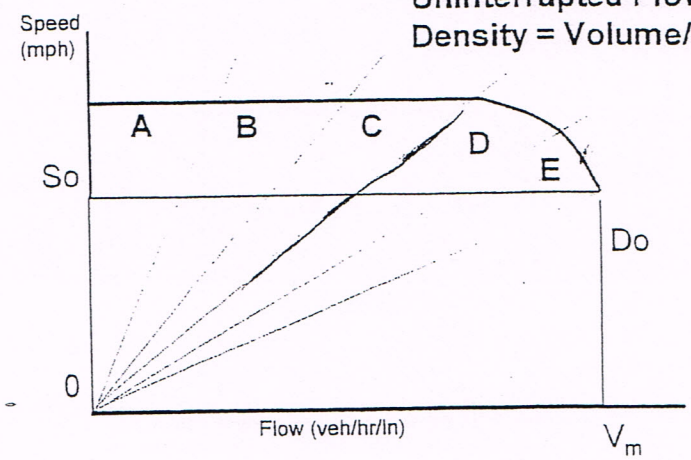
Analysis Period

EXHIBIT 16-6. THREE ALTERNATIVE STUDY APPROACHES



Speed Flow Relationship

Uninterrupted Flow
Density = Volume/Speed



Density

- Density is defined as the number of vehicles occupying a given length of a lane or roadway at a particular instance
- Density can be observed or computed:

$$D = v/S$$

Where:

v= rate of flow (pcph)
S= average travel speed (mph or km/h)
D= Density (pc/mi/ln) or pc/km/ln)

Interrupted Flow

- More Complex due to time dimension involved in the allocation of space to conflicting traffic streams.
- Measures- operational defined as:
  - Volume and/ or rate of flow
  - Saturation flow and/ or departure headways (1900 vph for Intersections, and 2500 vph for Freeways)
  - Variables parameters of stop or signal control
  - Gaps available in the conflicting traffic streams (Critical Gap time (4.5-7 sec) is the time needed to cross an intersection
  - Delay in average seconds per vehicle

Saturation Flow Rate

- Saturation Flow Rate is defined as the flow rate per lane at which vehicles can pass through a signalized intersection in such a stable moving queue

- Formula is: $s = 3{,}600/h$

Where: s= saturation flow rate (vphgpl)
h=saturation headway (sec)
3,600= number of seconds per hour

Headway is the distance between the fronts of cars. The longer the headway is the less the capacity. Headway depends on:

- Number of Trucks
- Grades
- Lane widths (for every extra foot of lane than 12 feet, you gain 3% more capacity)

- Right turns curve radius (the more the radius, the more capacity you gain for turns)
- Left turns- Unprotected (if you use protected left turns and right turns, then you will loose only 1%)
- Bicycles and Pedestrians

Lost time

- Lost time is experienced each time a movement is started and stopped due to the signal timing
- For example, a 60-second cycle length will have twice the start and stop time as a 120 second cycle
  - 60-second cycle length start and stop= [60 (I1+I2)]
  - 120-second cycle length start and stop= [30 (I1+I2)]

Where: I1= total start-up lost time (sec)
I2= clearance lost time (sec)

- Amount of lost time affects capacity and delay

Delay

- A critical performance measure on interrupted flow facilities is delay
- HCM (Highway Capacity Manual) uses the average control delay in second per vehicle as the primary measure of effectiveness in evaluating level of service at signalized intersections and unsignalized intersections

Technology

- Intelligent Transportation Systems (ITS) are being developed to enhance safety and efficiency of roadway systems
- ITS includes any technology that allows real-time information to be gathered and used by drivers and traffic control system operations to provide better vehicle navigation, roadway system control, or both

ITS Impacts

- Freeways- New vehicle guidance systems can offer the driver an increase in level of comfort for existing headway time or even reduce headway times ⇨ increasing capacity
- Signalized Intersections- More efficient allocation of phasing and green times ⇨ increasing capacity
- Unsignalized Intersections- Assisting drivers in judging gaps can ⇨ increasing capacity

Summary

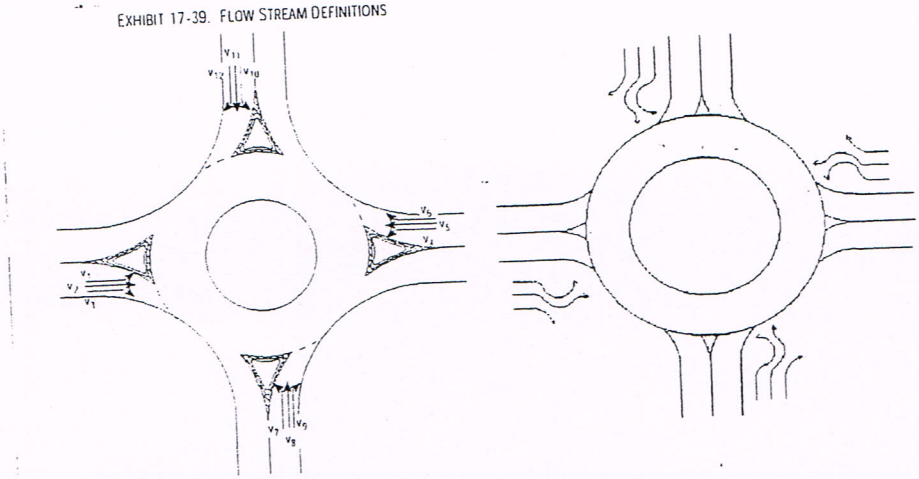
- Capacity Principles
- Level of Service (LOS)
- Measure of Effectiveness (MOE)
- Volume and Rate of Flow
- Peak-Hour Factor (PHF)
- Uninterrupted flow
    - Speed
    - Density
- Interrupted Flow
    - Lost time
    - Delay
- Intelligent Transportation Systems (ITS)
    - ITS effects

Introduction to Roundabouts

- Characteristics
  - Central Island
  - Splitter Islands
  - Circulating Flows
- Capacity
  - Upper Bound Solution
  - Lower Bound Solution

- Roundabout Flows

EXHIBIT 17-39. FLOW STREAM DEFINITIONS



- Difference between Traffic Circles and Roundabouts

Traffic Circles	Roundabouts
Vehicles in Circle must yield	Vehicles entering must yield
Negotiated speed is 30-35mph (higher speed)	Negotiated speed is 15-25mph (Slower speed)
Larger inscribed diameter	Smaller inscribed diameter
Can be Signalized	Has splitter Islands-No signals

- The key in Roundabouts is the slower speed that makes it the safest Traffic Engineering controls for unsignalized Intersections.
- Single lane Roundabouts are much safer than signals, two-way or Four-way Stops Intersections, and are much safer for pedestrians than signals if designed properly for pedestrians manuver {The safe location for pedestrian cross walks can be placed 3 Car spacings into the circle (1-3 car lengths into the splitter)}.

- Effective locations to design Roundabouts:
  - High speed local roads with high rate of fatality.
  - Traffic Calming for neighbourhoods

- Signalized Intersections with high capacity and delay problems

- Roundabout Variables
  - ca = approach capacity (veh/hr)
  - tc = critical gap, minimum length time interval that allows intersection entry to one minor stream vehicle (sec)
  - tf = follow-up time, time span between departure of one vehicle from minor street and departure of next vehicle, using same major-stream gap during periods of continuous queue on minor traffic stream (sec)
  - va = approach flow rate (veh/hr)
  - vc = circulation flow rate (veh/hr)

- Roundabout adjustments

EXHIBIT 17-37. CRITICAL GAP AND FOLLOW-UP TIMES FOR ROUNDABOUTS

	Critical Gap (s)	Follow-Up Time (s)
Upper bound	4.1	2.6
Lower bound	4.6	3.1

- Roundabout Capacity

$$ca = \frac{vc\ e^{(-vc\ tc/3600)}}{1-\ E^{(-vc\ tf/3600)}}$$

Where:

ca = approach capacity
vc = conflicting circulation traffic flow rate
tc = critical gap
tf = follow-up time

EXHIBIT 17-38. ROUNDABOUT APPROACH CAPACITY