Principles of Traffic Engineering

**Traffic Engineering:** A branch of transportation engineering is described as "that phase of transportation engineering which deals with planning, geometric design, and traffic operation of roads, streets, and highways, their networks, terminals, and relationships with other modes of transportation".

Traffic stream elements:
1. **Speed of vehicles**
2. **Volume of traffic**
3. **Traffic density**

1- **Speed (V):** Is the rate of travel usually expressed in distance per unit time (km/hr.) or (mile/hr.).

Types of speed:
A- **Spot speed:** Is the instantaneous speed of vehicles at any specified point.
B- **Running speed:** Is the average speed maintained over a particular section of the road while the vehicle is moving.
C- **Journey speed:** Is the overall speed of the vehicle on a journey between two points.

Methods used to measure spot speed
a- **Manual method**
b- **Radar meter**
c- **Photographic technique**

2- **Volume of traffic (Q):** Is the number of vehicles that pass a certain point on a road during a period of time (veh./hr.) (veh./min.).

Types of measurement units:
* **AADT:** Annual Average Daily Traffic (veh./day)
* **ADT:** Average Daily Traffic (veh./day).
* **HV:** Hourly Volume (veh./hr.)

<table>
<thead>
<tr>
<th>Running speed</th>
<th>Journey speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance / running time</td>
<td>Distance / total time</td>
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</table>

* أعلاً قراءة لعدد المركبات التي تسجل على الطريق لفترة ساعة واحدة على طول السنة (مركبة/ساعة).
3- **Density (D):** Is defined as the number of vehicles occupying a given length of a lane or roadway (veh./mile-vpm) (veh./km-vpkm).

\[ Q = V* D \quad D = Q/V \quad V = Q/D \]

Traffic stream characteristics are affected by:

1- Width and other geometrical design features of the roadway.
2- Condition of the road surface
3- Width, number, and separation of lanes
4- Gradients
5- Sight distance
6- Frequency and form of intersections
7- Drainage structures
8- Signs, signals, markings, ... etc.

Traffic lane: Is a strip of roadway intended to accommodate a single stream of moving vehicles. It is the basic unit of width in measuring traffic stream characteristics.

Standard lane width = 12 feet. Minimum lane width = 10 feet.

Types of traffic stream:

1- Single-lane-one way (no overtaking).
2- Two-lane (one-way or two-way).
3- Three-lane.
4- Four-lane.

Capacity: Is the maximum number of vehicles which has a reasonable expectation of passing over a given section of a lane or a roadway in one direction (or in both directions for a two-lane or a three-lane highway) during a given time period under prevailing roadway and traffic conditions.

Service volume: Is the number of vehicles that can pass over a given section of a lane or a roadway during a specified time period while operating conditions are maintained corresponding to the selected or specified level of service (LOS).

Factors involved in evaluating level of service:

1- Speed and travel time (i.e. operating speed and overall travel time).
2- Traffic interruption or restriction (i.e. no. of stops per km = delay).
3- Freedom to maneuver (i.e. to maintain desired speed).
4- Safety and accidents.
5- Driving comfortable and convenience.
6- Economy (i.e. vehicle operating cost).

**Speed, Volume and Density relationships:**

Free flow speed ($V_f$): Is the theoretical speed of traffic as density approaches zero.
Jam density ($D_j$): Is the maximum value of density when the flow must be equal to zero.
LOS (A) = Free flow.
LOS (B) = Stable flow.
LOS (C) = Still stable flow.
LOS (D) = approximate unstable.
LOS (E) = Unstable flow.
LOS (F) = Congested or forced flow.
Example: The relationship between speed (V) and density (D) on a given highway was found to be:
\[ V = 50 - \frac{D}{3} \]
1- Calculate the jam density of this highway.
2- The free flow speed on this highway.
Solution:
1- The jam density occurs when the speed equal to zero:
\[ 0 = 50 - \left( \frac{D_j}{3} \right) \quad 50 = \frac{D_j}{3} \quad D_j = 50 \times 3 = 150 \text{ veh./km} \]
2- Free-flow speed = 50 – (0/3) = 50 km/hr.

Example: The relationship between volume (Q) and density (D) on a given highway was found to be: 
\[ Q = 71.4D - 0.94D^2 \]
while the relationship between volume (Q) and speed (V) on the same highway was found to be: 
\[ Q = 35.4V - 0.65V^2 \]
What is the expected relationship between speed (V) and density (D) on this highway? (assume a linear relationship).
Solution:
Let Q = zero:
\[ 0 = 71.4D - 0.94D^2 \quad \text{either } D = \text{zero or } D_j = 76 \text{ veh.km} \]
\[ 0 = 35.4V - 0.65V^2 \quad \text{either } V = \text{zero or } V_f = 54.5 \text{ km/hr} \]
Therefore: \[ V = 54.5 - (54.5/76.0) \quad V = 54.5 - 0.717D \]

Sight Distance:
There are mainly three types of sight distance:
1- Stopping sight distance (S.S.D.):
2- Passing sight distance (P.S.D.):
3- Intersection sight distance (I.S.D.):

1- Stopping sight distance (S.S.D.): It contains two elements:
a) The distance traveled after the obstruction comes view but before the driver applies the brakes. During this, the vehicle travels at its initial velocity.
\[ d_1 = 0.278Vt \]
where: \( d_1 = \text{distance in meter}, V = \text{speed in km/hr}., t = \text{perception-reaction time in sec.} \)

<table>
<thead>
<tr>
<th>Time (sec.)</th>
<th>Urban</th>
<th>Rural</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perception</td>
<td>0.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Reaction</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Total</td>
<td>1.5</td>
<td>2.5</td>
</tr>
</tbody>
</table>

b) The second distance is consumed while the driver brakes the vehicle to stop (after brake application) = braking distance (d2).
\[ d_2 = \frac{V^2}{254\left( \frac{a}{9.81} \right) + g} \]
where: \( d_2 \) = braking distance (m), \( V \) = Design speed (km/hr.), \( a \) = acceleration rate (m/sec\(^2\)), \( g \) = percent grade divided by 100.

\[
S.S.D. = 0.278(V)^2 + \frac{V^2}{254} + \frac{a}{9.81} + g
\]

2- **Passing sight distance (P.S.D.):** It is the minimum distance required on two-way two-lane highway to give the opportunity to pass slow moving vehicles and it must be provided at intervals otherwise capacity decrease and accident may occur.

\[
d_1 = 0.278 \times t_1 (V - m + \frac{a \times t_1}{2})
\]

where:
- \( d_1 \) = initial maneuver distance, (m),
- \( V \) = average speed of passing vehicle, (km/hr.),
- \( t_1 \) = time of initial maneuver, (sec.),
- \( a \) = average acceleration rate, (km/hr./sec.),
- \( m \) = difference in speed of passed vehicle and passing vehicle, (km/hr.).

\[
d_2 = 0.278 (V)^2 (t_2)
\]

where:
- \( d_2 \) = Distance while vehicle occupies left lane, (m),
- \( V \) = average speed of passing vehicle, (km/hr.),
- \( t_2 \) = time passing vehicle occupies the left lane, (sec.).

\[
d_3 = \text{Clearance (safety) length, (30-75) meters.}
\]
\[ d_4 = \frac{2}{3} d_2 \] (distance traversed by an opposing vehicle in the opposite lane), (m).

\[ P.S.D. = d_1 + d_2 + d_3 + d_4 \]

Example (Stopping sight distance):
A driver is traveling at an average speed of (40 kph) when a person is crossing the road. Assuming that perception time of the driver is (2.0 sec.) and the acceleration rate is (5m/sec^2) calculate:

a) The safe S.S.D. on a level road (g = 0%).

b) The safe S.S.D. on a 3% uphill road.

c) The safe S.S.D. on a 2% downhill road.

Solution:

\[ S.S.D. = 0.278(V) \times (t) + \frac{V^2}{\frac{a}{9.81} + g} \]

\[ d_1 = 0.278 \times t(V - m + \frac{a \times t_1}{2}) = d_1 = 0.278 \times 3.6(56 - 16 + \frac{2 \times 3.6}{2}) = 43.6 \text{ m}. \]

\[ d_2 = 0.278 \times (V) \times (t_2) = 0.278 \times 56 \times (9.3) = 144.8 \text{ m}. \]

\[ d_3 = 30 \text{ m}. \]

\[ d_4 = \frac{2}{3} (d_2) = \frac{2}{3} (144.8) = 96.5 \text{ m}. \]

P.S.D. = 43.6 + 144.8 + 30.0 + 96.5 = 314.9 m.

Example (Passing sight distance):
A driver traveling at a speed of (56 km/hr.) is trying to overtake the vehicle in front of him. The speed of the overtaken vehicle is (40 km/hr.). The acceleration rate of the overtaking vehicle is (2.0 km/hr./sec.) and the vehicle spent (3.6 sec.) to move to the opposing lane and (9.3 sec.) traveling on it. The speed of the opposing vehicle is (45 kph). Assume a safety distance of 30 meters. Calculate the required passing sight distance.

Solution:

\[ P.S.D. = d_1 + d_2 + d_3 + d_4 \]

\[ d_1 = 0.278 \times t(V - m + \frac{a \times t_1}{2}) = d_1 = 0.278 \times 3.6(56 - 16 + \frac{2 \times 3.6}{2}) = 43.6 \text{ m}. \]

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