Lec.No.1

Principles of transport

Lecturer : Hanan Adel

Introduction

Nothing is more important to civilization than transportation and communication, and, nothing is more harmful to the well-being of a society than an irrational transportation system. Trade is essential to economic vitality, and transportation is essential to trade.

Trade is impossible without transportation, and complex trade is impossible without modern, mechanized transportation.

Until the time of railroads, transportation was treated as a "public good" that anyone within the society could use. Even man-made systems, such as roads and canals, were usually publicly or cooperatively owned, and any charges for use were dedicated to offsetting construction and maintenance costs.

Transportation and Ancient Civilization

Prior to mechanized transportation, civilization (that is, village centers and the surrounding farms occurred almost entirely along rivers. The first known civilization was Sumer in lower Mesopotamia. "Sumer" means "land of the civilized lords," and "Mesopotamia" is Greek for "between the rivers." The Sumerians built canals between these rivers, for both irrigation and navigation, and are credited with invention of the wheel. The wheel made it possible for farmers to haul produce short distances over land, which in turn made larger cities possible.
Until the Industrial Revolution, each empire was displaced by a neighboring empire. Although the the established empires fell after the growth of privilege and corruption weakened them as they aged, the newer, more vital neighboring empires were usually those that enjoyed excellent transportation along rivers, seas and oceans. Egyptian kingdoms began on the upper Nile, which at the time was fertile, but the Egyptian empire came to be centered at the Nile Delta, with access to the Mediterranean. Unlike the oceans, the Mediterranean was usually calm enough for safe navigation using early sailing technology.

The Romans also built network of roads throughout its empire, financed through a combination of tolls and taxes. The roads were built by the Roman military and maintained by the local provinces. However, road travel was slow and laborious compared to sea travel. Although each freed society differed in important ways, their cities developed either along rivers or coasts, and the largest cities developed near major harbors, where the advantages of river and sea travel were combined.

**Importance of Transportation**

Being able to move from one point to another is of course important. People seldom live, work, shop and relax in the same place. In order to maintain a functioning economy, people must be able to circulate between the various points that are important to them and do so with ease. In pre-Industrial times, most people got around by foot, horse or boat. Distances were small and trips were few in
number. Today in many locations, fossil fuel availability has dramatically increased the distances one can travel and lifted the overall number of trips made.

But transportation is really much more than the movement of people. The truly vital function that it plays is the movement of goods. Goods movement is often overlooked by transportation planners but it includes the shipment of raw materials, finished products and even wastes. Raw materials such as minerals, energy, food and other resources are obvious candidates for transportation as most occur in limited concentrations away from their eventual points of consumption. Movement of finished goods from manufacturers to their eventual end users also requires a well established transport network. Finally, transportation plays a vital role in removing wastes and preventing their accumulation to dangerous levels.

Likewise, most visualizations of the transportation network commonly are focused on road, rail, marine and air-based systems. While this is accurate, it neglects two other important forms of transport: electrical and pipeline. Both topics are commonly discussed as “infrastructure” in planning documents but really need to be seen as another form of transportation. The electrical transmission system makes it possible to instantaneously move large amounts of energy from one location where it is in overabundance to another where it is in demand. Pipelines play the equally important role of transporting liquids and gasses from one point to another in great, uninterruptible volumes.

Transport infrastructure consists of the fixed installations including roads, railways, airways, waterways, canals and pipelines and terminals such as airports, railway stations, bus stations, refueling depots (including fuel stations) and seaports. Terminals may be used both for interchange of passengers and cargo and for maintenance.

Vehicles traveling on these networks may include automobiles, bicycles, buses, trains, trucks, people, helicopters, watercraft, spacecraft and aircraft. Operations deal with the way the vehicles are operated, and the procedures set for this purpose including financing, legalities and policies. In the transport industry, operations and ownership of infrastructure can be either public or private, depending on the country and mode.

Passenger transport may be public, where operators provide scheduled services, or private. Transport plays an important part in economic growth and globalization, but most types cause air pollution and use large amounts of land. While it is heavily subsidized by governments, good planning of transport is essential to make traffic flow easier and more comfortable.
**Traffic System Components**

- Road users - drivers, pedestrians, and passengers.
- Vehicles - private and commercial
- Streets and highways
- Traffic control devices
- The general environment

**Road Users**

- Physiological – Measurable and Usually Quantifiable
- Psychological – Much more difficult to measure and quantify

**Physiological:**
- Desired speeds
- Desired safety distances

**Psychological:**
- Perception-Reaction time
- Visual factors

\[ \Delta x, \Delta v \]
**Diversity (behaviors)**
- Drivers and other road users have widely varying characteristics.

- Traffic controls could be easily designed if all drivers reacted to them in exactly the same way.

- Safety could be more easily achieved if all vehicles had uniform dimensions, weights, and operating characteristics.

  □ The traffic engineer must deal with elderly drivers as well as 18-year-olds, aggressive drivers and timid drivers, and drivers subject to problems.

**Diversity (behaviors)**
- Most human characteristics follow the normal distribution

  □ A normal distribution defines the proportions of the population expected to fall into these ranges. Because of variation, it is not practical to design a system for “average” characteristics. If a signal is timed, for example, to accommodate the average speed of crossing pedestrians, about half of all pedestrians would walk at a slower rate and be exposed to unacceptable risks.

**Diversity (Vehicles)**
- Highways must be designed to accommodate motorcycles, the full range of automobiles, and a wide range of commercial vehicles, including double and triple-back tractor-trailer combinations.
• Thus, lane widths, for example, must accommodate the largest vehicles expected to use the facility

**Uniformity for Diversity**

• design of roadway systems and traffic controls is in the core of their professional practice.

  □ Roadways of a similar type and function should have a familiar “look” to drivers; traffic control devices should be as uniform as possible. Traffic engineers strive to provide information to drivers in uniform ways.

**Drivers**

• Visual Acuity factors

• Reaction Process

• Hearing

• Physical Strength

• Personality and Psychology

**Visual Acuity factors**

• The most important characteristic of drivers is their ability to see!
Field of Vision

- **Field of Vision**
- **Color Blindness**

Field of Vision

- **Acute or clear vision cone** - 3° to 10° around the line of sight; legend can be read only within this narrow field of vision.

- **Fairly clear vision cone** - 10° to 12° around the line of sight; color and shape can be identified in this field.

- **Peripheral vision** - This field may extend up to 90° to 60° above and 70° below the line of sight. The right and left of the centerline of the pupil, and up

Stationary objects are generally not seen in the peripheral vision field, but the movement of objects through this field is detected.
Field of Vision

- Objects or other vehicles located in the fairly clear and peripheral vision fields may draw the driver’s attention to an important event occurring in that field, such as the approach of a vehicle on an intersection street or driveway or a child running into the street after a ball. Once noticed, the driver may turn his/her head to examine the details of the situation.

- Traffic Signs: Location, Height, Shapes, Colors

- The peripheral vision field narrows, as speed increases, to as little as $100^\circ$ at 20 mi/h and to $40^\circ$ at 60 mi/h.

Visual Deficits

Unfortunately, one of the most common forms of color blindness involves the inability to discern the difference between red and green.

Perception-Reaction Time

- The second critical driver characteristic is perception-reaction time (PRT).

  - **Detection.** In this phase, an object or condition of concern enters the driver’s field of vision, and the driver becomes consciously aware that something requiring a response is present.

  - **Identification.** In this phase, the driver acquires sufficient information concerning the object or condition to allow the
consideration of an appropriate response.

- **Decision.** Once identification of the object or condition is sufficiently completed, the driver must analyze the information and make a decision about how to respond.

- **Response.** After a decision has been reached, the response is now physically implemented by the driver.

**PRT or PIEV**

- Perception of cue or stimulus
- Interpretation
- Evaluation of appropriate response (i.e., decision)
- Volition or physical response (i.e., reaction)

**Factors Affecting PRT**

- Age
- Fatigue
- Complexity of Reactions
- Presence of Drugs or Alcohol

- AASHTO Recommendations:
  - **For braking reactions on Highways:**
    - Perception and Reaction Time: 2.5 seconds (90th percentile)
  - **For reaction time to traffic signal**
    - Perception and Reaction Time: 1.0 Second (85th percentile)
LEC. NO. 4

Principles of transportation
Lecturer : Hanan Adel

Continuation information to lecture no. 3

• Coefficient of side friction in wet pavements

<table>
<thead>
<tr>
<th>Speed km/h</th>
<th>48</th>
<th>64</th>
<th>80</th>
<th>97</th>
<th>113</th>
</tr>
</thead>
<tbody>
<tr>
<td>$f$</td>
<td>0.16</td>
<td>0.15</td>
<td>0.14</td>
<td>0.12</td>
<td>0.1</td>
</tr>
</tbody>
</table>

The maximum allowable truck sizes and weights on Interstate and other qualifying federal aided highways are at most:

• 80,000 lb gross weight, with axle loads of up to 20,000 lb for single axles and 34,000 lb for tandem (double) axles

• 102 in. width for all trucks

• 48 ft length for semitrailers and trailers

• 28 ft length for each twin trailer
Legal Dimension and Weight Limits for Highway Vehicles
(As per Ohio Revised Code, Sections 5577.04, 5577.05)
Maximum Overall Dimensions
(Including any loads)

<table>
<thead>
<tr>
<th>Width (except municipal bus or traction engine)</th>
<th>8' 5&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Width of municipal bus</td>
<td>8' 3&quot;</td>
</tr>
<tr>
<td>Width of traction engine</td>
<td>11'-6&quot;</td>
</tr>
<tr>
<td>Height (of all vehicles)</td>
<td>13'-6&quot;</td>
</tr>
<tr>
<td>Length of passenger bus operated within a municipal corporation</td>
<td>60'-0&quot;</td>
</tr>
<tr>
<td>Length of other passenger bus type vehicle</td>
<td>40'-0&quot;</td>
</tr>
<tr>
<td>Length of automobile transporter or boat transporter (plus load overhang of 3'-0&quot; in front and 4'-0&quot; in rear)</td>
<td>65'-0&quot;</td>
</tr>
<tr>
<td>Saddlemount vehicle transport</td>
<td>75'-0&quot;</td>
</tr>
<tr>
<td>Length of any stinger-steered automobile transporter or stinger-steered boat transporter (plus load overhang of 3'-0&quot; in front and 4'-4&quot; in rear)</td>
<td>75'-0&quot;</td>
</tr>
<tr>
<td>Length of semi-trailer used in a commercial tractor-semi-trailer combination</td>
<td>53'-0&quot;</td>
</tr>
<tr>
<td>Length of semi-trailer or full trailer used in a commercial tractor-trailer-trailer combination</td>
<td>28'-6&quot;</td>
</tr>
<tr>
<td>Length of all other vehicles</td>
<td>40'-0&quot;</td>
</tr>
<tr>
<td>Length of any other combination</td>
<td>65'-0&quot;</td>
</tr>
</tbody>
</table>

Stopping Sight Distance

<table>
<thead>
<tr>
<th>Design Speed (mph)</th>
<th>Brake reaction distance (ft)</th>
<th>Braking distance on level (ft)</th>
<th>Calculated (ft)</th>
<th>Design (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>55.1</td>
<td>21.6</td>
<td>76.7</td>
<td>80</td>
</tr>
<tr>
<td>20</td>
<td>73.5</td>
<td>38.4</td>
<td>111.9</td>
<td>115</td>
</tr>
<tr>
<td>25</td>
<td>91.9</td>
<td>60.0</td>
<td>151.9</td>
<td>155</td>
</tr>
<tr>
<td>30</td>
<td>110.3</td>
<td>86.4</td>
<td>196.7</td>
<td>200</td>
</tr>
</tbody>
</table>
Traffic Flow

• 2 Classifications of Flow

  – Interrupted - traffic signals/signs impede traffic flow

  – Uninterrupted - no traffic signals/signs

Traffic Stream Parameters
• Volume
• Speed
• Density

Note: brake reaction distance predicated on a time of 2.5s; deceleration rate 11.2 ft/sec²
• Flow Rate (q or v) – No. of vehicles passing a point per unit time (typically hourly representation of No. veh passing a point during a time period of less than one hour) (veh/hr or vph/lane)

• Volume (V) – No. of vehicles passing a point during a specified time interval (veh/hr)

• Density (k or D) – the number of vehicles in a given length of roadway or lane (veh/mi or veh/mi/lane)

**Volume**

• Average annual daily traffic (AADT) – avg. 24-hour volume at a site over a full year

• Average daily traffic (ADT) – avg. 24-hr volume recorded for some period less than a year

• Average weekday traffic (AWT) – avg. daily traffic from 12:01 am on Monday to 12:00 midnight on Friday.

• Design hourly volume (DHV)- one hour volume used as the basis of design or traffic operational decisions.
Volume

- Peak hour volume is used in design

- Peak-hour volume may be estimated from AADT

- DDHV = directional design hourly volume

\[
DDHV = AADT \times K \times D
\]

Where:

- \( K \) = proportion of AADT that occurs during design hour

- \( D \) = proportion of peak hour traffic traveling in the peak direction
Volume

• Typically, K factor represents proportion of AADT occurring during 30th peak hour of the year

• D Factors
  – More variable than K
  – Influenced by development density, radial vs. circumferential route

Table 5.2: General Ranges for $K$ and $D$ Factors

<table>
<thead>
<tr>
<th>Facility Type</th>
<th>Normal Range of Values</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$K$-Factor</td>
</tr>
<tr>
<td>Rural</td>
<td>0.15–0.25</td>
</tr>
<tr>
<td>Suburban</td>
<td>0.12–0.15</td>
</tr>
<tr>
<td>Urban:</td>
<td></td>
</tr>
<tr>
<td>Radial Route</td>
<td>0.07–0.12</td>
</tr>
<tr>
<td>Circumferential Route</td>
<td>0.07–0.12</td>
</tr>
</tbody>
</table>

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Flow Rate vs. Volume

Table 5.3: Illustration of Volumes and Rates of Flow

<table>
<thead>
<tr>
<th>Time Interval</th>
<th>Volume for Time Interval (vehs)</th>
<th>Rate of Flow for Time Interval (vehs/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5:00–5:15 PM</td>
<td>1,000</td>
<td>1,000/0.25 = 4,000</td>
</tr>
<tr>
<td>5:15–5:30 PM</td>
<td>1,100</td>
<td>1,100/0.25 = 4,400</td>
</tr>
<tr>
<td>5:30–5:45 PM</td>
<td>1,200</td>
<td>1,200/0.25 = 4,800</td>
</tr>
<tr>
<td>5:45–6:00 PM</td>
<td>900</td>
<td>900/0.25 = 3,600</td>
</tr>
<tr>
<td>5:00–6:00 PM</td>
<td>Σ = 4,200</td>
<td></td>
</tr>
</tbody>
</table>

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Peak Hour Factor

• 15 minutes is considered to be minimum period of time over which traffic considered statistically to be stable.

• Peak hour factor (PHF) represents the uniformity of flow in the peak hour.

\[ PHF = \frac{V}{4} \times V_{m15} \]

where:
\[ V = \text{hourly volume, vehs/hr} \]
\[ V_{m15} = \text{max15min volume within the hour} \]
**Speed**

- Time mean speed (TMS) – average speed of all vehicles passing a point over a specified time period.

- Space mean speed (SMS) – average speed of all vehicles occupying a given section of roadway over a specific time period.

---

**Table 5.5: Illustrative Computation of TMS and SMS**

<table>
<thead>
<tr>
<th>Vehicle No.</th>
<th>Distance d (ft)</th>
<th>Travel Time t (s)</th>
<th>Speed (ft/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1,000</td>
<td>18.0</td>
<td>1,000/18 = 55.6</td>
</tr>
<tr>
<td>2</td>
<td>1,000</td>
<td>20.0</td>
<td>1,000/20 = 50.0</td>
</tr>
<tr>
<td>3</td>
<td>1,000</td>
<td>22.0</td>
<td>1,000/22 = 45.5</td>
</tr>
<tr>
<td>4</td>
<td>1,000</td>
<td>19.0</td>
<td>1,000/19 = 52.6</td>
</tr>
<tr>
<td>5</td>
<td>1,000</td>
<td>20.0</td>
<td>1,000/20 = 50.0</td>
</tr>
<tr>
<td>6</td>
<td>1,000</td>
<td>20.0</td>
<td>1,000/20 = 50.0</td>
</tr>
<tr>
<td>Total</td>
<td>6,000</td>
<td>119</td>
<td>303.7</td>
</tr>
<tr>
<td>Average</td>
<td>6,000/6 = 1,000</td>
<td>119/6 = 19.8</td>
<td>303.7/6 = 50.6</td>
</tr>
</tbody>
</table>

TMS = 50.6 ft/s  
SMS = 1,000/19.8 = 50.4 ft/s

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Lec. NO.5

Principles of Transportation

Lecturer Hanan Adel

Some Additional Terms and explanations of others

**Spacing**: The spacing is simply the distance between successive vehicles, typically measured from front bumper to front bumper.

**Headway**: Time-headway is the time between the arrival of successive vehicles at a specified point.

Volume is the total number of vehicles that pass a point on a highway during a given time interval. When the time interval is one hour, the unit of volume is vehicle per hour. In some circumstances, volume is also given as the number of passenger cars per hour, with all trucks and buses counted as an equivalent number of passenger cars.

Two measures of traffic volume are of special significance to the engineers –

**Average daily traffic (ADT)**
**and design hourly volume (DHV)**.

ADT is the number of vehicles that pass a particular point on a roadway during a period of 24 consecutive hours averaged over a period of 365 days. ADT values for specified road sections provide the engineer, planner an administrator with essential information needed
for the determination of design standards, the systematic classification of roads as well as for the development of programs for improvement and maintenance.

DHV is a future hourly volume that is used for design. Traffic volumes are much heavier during certain hours of the day or year, and it is for these peak hours that the road is designed. In order to design a road properly, it is necessary to know the capacity that must be provided in order to accommodate the known traffic volume.

On a given roadway, the volume of traffic fluctuates widely with the time. Such variations during a day, week or year tend to be cyclical and to some extent predictable. The nature of the pattern of variation depends on the type of road facility. Urban arterial flow is, for example, characterized by pronounced peaks during the early morning and late afternoon hours, due primarily to commuter traffic.

Rural roads tend to experience less pronounced daily peaks, but they may accommodate heaviest traffic flow on weekends and holidays because of recreational travel. As might be expected, the seasonal fluctuations are most pronounced for rural recreation routes.

The term rate of flow accounts for the variability or the peaking that may occur during periods of less than one hour. The term is used to express an equivalent hourly rate of vehicles passing a point along a roadway or for traffic during an interval less than one hour.

**Speed**

a) Spot speed
b) Overall speed
c) Running speed

All speeds vary with time; location, environmental and traffic vary also with the quality of traffic services, being generally higher along motorways and expressways as well as during times when traffic congestions are not a factor. For example during the petroleum crises in 1970s and 1980s the average speed decreased.
Today the most important factor impacting speed is traffic density and problem of traffic congestions.

At a given time and location, speeds are widely dispersed and the range of speeds decreases with increase in traffic volume.

**Spot speed**: is the instantaneous speed of a vehicle as it passes a specified point along a road. Spot speeds may be determined by manually measuring (with use of electronic or electromechanical devices like pneumatic tube detectors or radars) the time required for a vehicle to traverse a relatively short specified distance.

Two common ways of computing the average, or mean, speed. The average of a series of measures of spot speeds can be expressed as time-mean speed or space mean-speed.

**The time mean speed**: is the arithmetic mean of spot speeds of all vehicles passing a point during a specified interval of time.

**Space-mean speed**: is the average of vehicle speeds weighted according to how long they remain on the section of road.

**Overall speed and running speed**
These speeds are measured over a relatively long section of a road between an origin and a destination.

These measures are used in travel time studies to compare the quality of service between alternative routes.

Overall speed is defined as the total distance traveled divided by the total time required, including traffic delays.

Running speed is defined as the total distance traveled divided by the running time. The running time is the time the vehicle is in motion. Both speeds are normally measured by means of a test vehicle that is
driven over the test section of a roadway at the average speed of the traffic stream. A passenger uses a stopwatch to record time of travel to various previously chosen points along the course.

Free-flow speed- Speed at which vehicles would travel if totally unimpeded by other vehicles.

Jam density – the density which occurs when traffic becomes so congested that it completely stops moving.

The relationships between speed –flow and density
There are several points to be noticed about these relationships:

1. When the density on the highway is zero, the flow is also zero as there are no vehicles on the highway.

2. As the density increases, the flow also increases.

3. However, when the density reaches its maximum, generally referred to as the jam density (kj), the flow must be zero.

4. It follows, therefore, that as density increases from zero, the flow will also initially increases from zero to a maximum value. Further continuous increase in density, however, will result in continuous reduction of the flow, which will eventually be zero when the density is the jam density.
Sample Linear Speed-Density Relationship

\[ S = 65.0 \left( 1 - \frac{D}{110} \right) \]

The two curves below show:

Flow-Density and Speed-Flow Curves Resulting from a Linear Speed-Density Relationship
The capacity of a road is measured by its ability to accommodate traffic and is usually expressed as the number of vehicles that can pass a given point in a certain period of time at a given speed.

Factors affecting capacity, service flow rate and level of service
Since prevailing conditions are seldom ideal, computation of capacity, service flow rate, or level of service must be adjusted to account for departures from the ideal. Prevailing conditions may be grouped into three categories:

Roadway factors.
a) The type of facility and its environment.
b) Lane width.
c) Shoulder widths and/or lateral clearances.
d) Design speed.
e) Horizontal and vertical alignments

Traffic conditions refer to the types of vehicles using the facility and how the traffic flow is distributed by lane use and direction. It is well known that larger and heavier vehicles have an adverse effect on traffic flow in a number of ways. In addition to the distribution of vehicle types, the effects of two other traffic characteristic on capacity, service flow rates and level of service must be considered. Directional distribution has a significant impact on the directional split of two-lane rural highways. Capacity generally declines as the directional split becomes unbalanced. For multilane motorways and expressways, capacity analysis
procedures focus on a single direction, that of the peak rate of flow. Lane distribution must also be considered for multilane facilities.

**Control conditions.** For interrupted flow facilities, the control of the time available for movement of each traffic flow is of utmost importance in determining capacity, service flow rates and level of service. Of greatest importance is the control of such facilities by the traffic signal. Signalized operations are affected by the type of signal in use, the phasing, the allocation of green time and the length of cycle.
Lec. NO.7

Principles of Transportation

Lecturer Hanan Adel

Example about Peak Hour Volume, PHF

It is commonly known in your area that the heaviest traffic flow rates occur between 4:00 PM and 6:30 PM. Your assignment for the day is to find the peak hour volume, peak hour factor (PHF), and the actual or design flow rate for an existing one-lane approach. To do this, you obtain a click-counter and position yourself at the intersection. For each fifteen-minute interval, you record the numbers of right-turns, left-turns, straight-through trucks, and straight-through passenger cars. Your tabulated values are as shown below.

<table>
<thead>
<tr>
<th>Time Interval</th>
<th>Left Turns</th>
<th>Right Turns</th>
<th>ST Trucks</th>
<th>ST Cars</th>
</tr>
</thead>
<tbody>
<tr>
<td>4:00-4:15</td>
<td>5</td>
<td>10</td>
<td>6</td>
<td>30</td>
</tr>
<tr>
<td>4:15-4:30</td>
<td>6</td>
<td>15</td>
<td>8</td>
<td>26</td>
</tr>
<tr>
<td>4:30-4:45</td>
<td>4</td>
<td>7</td>
<td>10</td>
<td>35</td>
</tr>
<tr>
<td>4:45-5:00</td>
<td>7</td>
<td>16</td>
<td>8</td>
<td>40</td>
</tr>
<tr>
<td>5:00-5:15</td>
<td>10</td>
<td>13</td>
<td>6</td>
<td>49</td>
</tr>
<tr>
<td>5:15-5:30</td>
<td>9</td>
<td>12</td>
<td>12</td>
<td>55</td>
</tr>
<tr>
<td>5:30-5:45</td>
<td>14</td>
<td>15</td>
<td>8</td>
<td>65</td>
</tr>
<tr>
<td>5:45-6:00</td>
<td>12</td>
<td>12</td>
<td>10</td>
<td>50</td>
</tr>
<tr>
<td>6:00-6:15</td>
<td>10</td>
<td>9</td>
<td>8</td>
<td>39</td>
</tr>
<tr>
<td>6:15-6:30</td>
<td>9</td>
<td>12</td>
<td>4</td>
<td>30</td>
</tr>
</tbody>
</table>

If a truck is equal to 1.5 passenger cars and a right-turn is as well, and if a left-turn is equal to 2.5 passenger cars, then calculate the peak hour volume and peak hour factor (PHF).

Solution

The first step in this solution is to find the total traffic volume for each 15 minute period in terms of passenger car units. This is done by multiplying the number of trucks by 1.5, the number of right turns by 1.5, and the number of left turns by 2.5. We then add these three numbers and the volume of straight-through cars.
together to get the total volume of traffic serviced in each interval. Once we have this, we can locate the hour with the highest volume and the 15 minute interval with the highest volume. The peak hour is shown in blue below with the peak 15 minute period shown in a darker shade of blue.

<table>
<thead>
<tr>
<th>Time Interval</th>
<th>Interval Volume (pcu)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4:00-4:15</td>
<td>67</td>
</tr>
<tr>
<td>4:15-4:30</td>
<td>76</td>
</tr>
<tr>
<td>4:30-4:45</td>
<td>71</td>
</tr>
<tr>
<td>4:45-5:00</td>
<td>94</td>
</tr>
<tr>
<td>5:00-5:15</td>
<td>103</td>
</tr>
<tr>
<td>5:15-5:30</td>
<td>114</td>
</tr>
<tr>
<td>5:30-5:45</td>
<td>135</td>
</tr>
<tr>
<td>5:45-6:00</td>
<td>113</td>
</tr>
<tr>
<td>6:00-6:15</td>
<td>90</td>
</tr>
<tr>
<td>6:15-6:30</td>
<td>77</td>
</tr>
</tbody>
</table>

The peak hour volume is just the sum of the volumes of the four 15 minute intervals within the peak hour (464 pcu). The peak 15 minute volume is 135 pcu in this case. The peak hour factor (PHF) is found by dividing the peak hour volume by four times the peak 15 minute volume.

\[
\text{PHF} = \frac{464}{4 \times 135} = 0.86
\]

H.W. For a two-way highway with information shown below determine future ADT and DHV. a design 20 years & construction on period of 5 years, current ADT is 5500 vpd, annual growth rate of traffic is 4.5% per year

**Geometric Design**

**Highway Functional Classification**

- Freeways
  - Long trips
  - High speed
  - Full control of access
  - High L.O.S. (level of service)

- Arterials
  - Moderate length trips
Moderate speed
· Minimum interference to through traffic

Collectors
· Collect traffic from local streets industrial or commercial areas and convey it to arterials.
· Shorter trips than those on arterials
· Intermediate speed

Local streets
· Serve trips of relatively short distances
· Low speed
· Provide access to abutting land and connection to collectors

The geometric design of highways includes the visible elements of highway or street. It deals with the grade line or profile, horizontal alignment, the several components of the cross section, sight distances, & intersections.

When designing a new highway or the redesign of an old one, the highway engineer must pay attention to these points:

1. The design must be adequate for the estimated future traffic volume, both average daily traffic & design peak hour, for the character of vehicles, and for the design speed.

2. The design must be safe for driving and should still confidence for the majority of drivers.

3. The design must be consistent, and must avoid surprise changes in alignment, grade, or sight distance.

4. The design must be complete. It must include the necessary roadside treatment & provide essential traffic control devices, such as markings & signs, and proper lighting.

5. The design must be as economical as possible relative to initial costs and maintenance costs.
**Design Elements**

I- Clear Sight
Sight distance: length of highway visible ahead.

1- *Stopping Sight Distance (SSD)*: Minimum distance required for stopping a vehicle traveling at the design speed, after seeing an object in the vehicle’s path without hitting that object.

\[ SSD = d1 + d2 \]

2. *Passing Sight Distance (PSD)*
Minimum distance required to give the opportunity to pass slow moving vehicles, it must be provided at intervals, otherwise capacity decreases and accidents may occur.

\[ PSD = d1 + d2 + d3 + d4 \]

- **d1**: distance traveled during perception and acceleration time (initial maneuver distance).
  \[ d1 = 0.278 t1 \left[ V + \left( a.t1 \right)/2 \right] \]
  Where:
  - **V**: average speed of overtaking vehicle (Km/hr)
  - **t1**: preliminary delay me (3.5-4.5) sec
  - **a**: acceleration rate ¾ - 2 Km/hr/sec for trucks
    3-8 Km/hr/sec for ordinary car
\[ d_2 = 0.278 \cdot V_2 \cdot t_2 \]

Where:
- \( d_2 \) = overtaking distance (m)
- \( V_2 \) = average speed of overtaking vehicle (Km/hr)
- \( t_2 \) = me of occupying opposing lane (9.5-11.5) sec

\[ d_3 = 100 \text{m} \]

\[ d_4 = \frac{2}{3} \cdot d_2 \]

- \( d_4 \): distance traveled by opposing vehicle in the opposing lane (m)

**Highway Cross-Section Elements**

The highway cross section is made up of design elements which can be classified into three broad groups:

1. The traveled way: pavement surface, lane widths, normal cross slopes.
2. Road margins: shoulders, sidewalks, curbs, guard rails, road side slope.
3. Traffic separation: the median.

**Pavement surfaces:**
- For heavy traffic volumes the pavement surface should be smooth, and may be designed with minimum cross slope.
- Low - type rough surfaces must be crowded enough to drain well.

**Lane widths**
- 12´ lane widths are standard.
- Lane width < 12´ can adversely affect capacity & safety.
- Lane width of 13´ & 14´ have been used on some high-speed, rural, two lane roads.
**Normal cross slopes:**
Pavements on straight sections of two-lane & multi-lane highways without medians are sloped from the middle downward to both sides of the highway.

Recommended rates of cross slopes are 1.5% to 2% for high type pavements & 1.5% to 3% for intermediate-type pavement.

**Shoulders:**
Adjacent to the traveled way shoulders are provided for the accommodation of stopped vehicles, for emergency use, .

Full width usable shoulders (8 to 12 feet) should be provided on highways where the DHV exceeds 100 vehicles per hour.

**Sidewalks:**
Generally sidewalks should be provided when pedestrian traffic is high along main or high-speed roads in either rural or urban areas. Sidewalks have a minimum clear width of 4´ to8´ in commercial areas.

**Curbs and Gutters:**
- Curbs are raised structures used mainly on urban highways. They are used to delineate pavement edges & control drainage .

- Gutters: usually located on the pavement side of a curb to provide principal drainage facility for the highways.

**Guard rails**
- Guard rails are longitudinal barriers placed on the outside of sharp curves and at sections with high fills. Their main function is to prevent vehicles from leaving the road.

**Side slopes:**
- Side slopes are provided on embankments & fill to provide stability for earthworks. They also serve as a safety feature by providing recovery area for out of control vehicles. Slopes of 3 to1 or flatter are generally used for high embankments.
**Median:**
- Median is the section of a divided highway that separates the lanes in opposing direction.

Main functions of a median:-
1- Providing a recovery area for out-of control vehicles.
2- Separating opposing traffic.
3- Providing refuge for pedestrians.

Medians range in width from a minimum of 4 feet to 60 feet or more.

![Diagram of highway with median]

- $W$ – total width of highway
- $W_1, W_2$ – overall highway width in one direction
- $a$ – width of traffic lane
- $c$ – width of paved shoulder
- $e$ – width of unpaved shoulder
- $d$ – width of median
- $v_1$ – width of outer marginal strip
- $v_2$ – width of inner marginal strip
Lec. NO.9

Principles of Transportation

Lecturer Hanan Adel

Basics of horizontal and vertical alignment

The center line layout or position on the ground surface is called Alignment. There are two types of Alignments horizontal Alignment and Vertical Alignment. Horizontal Alignment includes the straight path, curves or deviation in horizontal direction. Vertical Alignment includes vertical curves and gradient on the ground. But it is difficult to change the alignment once the road is constructed, so care has to be taken in finalizing the alignment.

Basic Requirement of an Ideal Alignment

1. It should have a shortest path.
2. The alignment must be easy to construct and maintain and also it should be easy for vehicle operation.
3. It should be safe in case of designing the horizontal and vertical curves.
4. The alignment should be selected in such a way that it is economical during construction.

Vertical Alignment

• Specifies the elevations of points along a roadway.
• Elevations are determined by need to provide proper drainage and driver safety.
• A primary concern of vertical alignment is to establish a transition between two roadway grades by means of a vertical curve.

Types of Vertical Alignment

• Two types of Vertical Curves:

1. Crest Vertical Curves.

2. Sag Vertical Curves.
Vertical Curve Properties
• The initial road grade is called G1 the final road grade is called G2 and is typically given in percent.
• PVC is the point of the vertical curve.
• The point of intersection of the initial tangent grade and the final tangent grade is the point of vertical intersection (PVI).
• The point of intersection of the vertical curve with the final tangent grade is called the PVT.
• The length (L) of the vertical curve is the horizontal distance between PVC and PVT.
• Equal Tangent, if PVC to PVI is L/2.

Vertical Curve Design
• Vertical Curves maximum grades depend on:
  – Design Speed
  – Type of Terrain
  – Length of Grade

• Grades also affect:
  – fuel consumption
  – speed
  – accidents (speed differential)
This equation is used to determine the elevation of any point within the vertical curve.

\[
x_{t} = -\frac{G_{1}}{r} \quad r = \frac{G_{2} - G_{1}}{L}
\]

(lowest point or highest point)

\[
Ep = Epvc + G_{1}x + \frac{r}{2}(x^2)
\]

This equation is used to determine the elevation of any point within the vertical curve.
Problem:

A 600-feet “equal-tangent” sag vertical curve, with PVC elevation 1250 ft. The initial grade is -3% and the final grade is +5%. Determine the position and elevation of the lowest point on the curve.

Solution:

\[ x_o = -\frac{G_1}{r} \quad r = G_2 - G_1/L \quad \text{notice that } L = 6 \text{ stations} \]

\[ x_o = 2.25 \text{ station} = 225 \text{ ft} \]

\[ E_p = E_{pvc} + G_1x + \frac{r}{2}(x^2) \]

\[ E(x_o) = 1250 - 3(2.25) + \left(\frac{1.33}{2}\right)(2.25)^2 \]

\[ E(x_o) = 1246.625 \text{ ft} \]

**Horizontal Curves**

**Elements of curve design**

- Curve radius
- Super elevation
- Side friction
- Assumed vehicle speed
Example
A horizontal curve is designed with a 2000-ft radius. The curve has a tangent length of 400 ft and the PI is at station 103. Determine length of curve and stationing of the PT.
The point-mass formula is used to define vehicular operation around a curve. Where the curve is expressed using its radius, the basic equation for a simple curve is:

\[ T = R \tan \frac{\Delta}{2} \]

\[ 400 = 2000 \tan \frac{\Delta}{2} \]

\[ \Delta = 22.62^\circ \]

So, from Eq. 3.39, the length of the curve is

\[ L = \frac{\pi R \Delta}{180} \]

\[ L = \frac{3.1416 \times 2000(22.62)}{180} = 789.58 \text{ ft} \]

Given that the tangent length is 400 ft,

stationing \( PC = 103 + 00 \) minus 4 + 00 = 99 + 00

Since horizontal curve stationing is measured along the alignment of the road,

stationing \( PT = \) stationing \( PC + L \)

\[ = 99 + 00 \text{ plus } 7 + 89.58 = 106 + 89.58 \]

The point-mass formula is used to define vehicular operation around a curve. Where the curve is expressed using its radius, the basic equation for a simple curve is:

\[ R = \frac{V^2}{15(e + f)} \]

where:

\( R = \) radius of curve, ft
\( e = \) super elevation rate, decimal
\( f = \) side-friction factor, decimal
\[ V = \text{vehicular speed, mph} \]

\[ R = \frac{V^2}{127(e + f)} \]

Metric

where:

\[ R = \text{radius of curve, m} \]
\[ V = \text{vehicular speed, km/hr} \]

**H.W.**

A horizontal alignment with radius 100m, design speed 50 km/hr, coefficient of friction is 0.15

Find:

1) Superelevation.

2) If there is no superelevation find coefficient of friction.
LEC. NO. 11

Principles of transportation

Lecturer : Hanan Adel

The **track** on a railway or railroad, also known as the **permanent way**, is the structure consisting of the rails, **railroad ties** (sleepers) and **ballast**, plus the underlying **subgrade**.

**Structure**

**Traditional track structure**[1]

Section through railway track and foundation showing the ballast and formation layers. The layers are slightly sloped to help drainage.

The **track ballast** is customarily crushed stone, and the purpose of this is to support the ties and allow some adjustment of their position, while allowing free drainage.
A disadvantage of traditional track structures is the heavy demand for maintenance, particularly surfacing (tamping) and lining to restore the desired track and smoothness of vehicle running. Weakness of the subgrade and drainage deficiencies also lead to heavy maintenance costs. This can be overcome by using ballastless track. In its simplest form this consists of a continuous slab of concrete (like a highway structure) with the rails supported directly on its upper surface (using a resilient pad).

**Rail**

Cross-sections of flat-bottomed rail, which can rest directly on the sleepers.

Modern track typically uses Hot rolled steel with a profile of an asymmetrical rounded I-beam. Unlike some other uses of iron and steel, railway rails are subject to very high stresses and have to be made of very high-quality steel alloy. It took many decades to improve the quality of the materials, including the change from iron to steel. The heavier the rails and the rest of the trackwork, the heavier and faster the trains the track can carry.
Rail support (sleeper/tie)

A railroad tie (a railway sleeper) is a rectangular object on which the rails are supported and fixed. The tie has two main roles: to transfer the loads from the rails to the track ballast and the ground underneath, and to hold the rails to the correct width apart (to maintain the rail gauge). They are generally laid transverse (perpendicular) to the rails.

**Railway Sleepers - Types of Sleepers - Longitudinal, Transvers**

Depending upon the position in a railway track, sleepers may be classified as:
1. Longitudinal Sleepers
2. Transverse Sleepers

sleepers may be classified as:
- Timber/wooden sleepers
- Steel sleepers
- Cast Iron Sleepers
- Concrete Sleepers

**Timber/Wooden Sleepers**
The timber sleepers nearly fulfilled all the requirements of ideal sleepers.

**The most important advantages of Timber Sleepers**
- They are much useful for heavy loads and high speeds
- They have long life of 10-12 years depending upon the climate, condition, rain, intensity, nature of traffic, quality of wood etc
- They are able to accommodate any gauge
- Can be used with any section of rail
- Can be handled and placed easily
- Cheaper than any other types of sleepers

**Disadvantages of Timber Sleepers**
- Liable to be attacked by vermin so, they must be properly treated before use
- Liable to catch fire
- They do not resist creep
- They are affected by dry and wet rot
- Become expensive day by day
- Life is shorter compare to others
Steel Sleepers

Advantages of Steel Sleepers
· Have a useful life of 20-25 years.
· Free from decay and are not attacked by vermins.
· Connection between rail and sleeper is stronger.
· Connection between rail and sleeper is simple.
· More attention is not required after laying.
· Having better lateral rigidity.
· Good scrap value.
· Suitable for high speeds and load.
· Good resistance against creep.

Disadvantages of Steel Sleepers
· Liable to corrosion by moisture.
· Cannot be used for all sections of rails and gauges.
· Very costly.
· The rail seat is weaker.

Cast Iron Sleepers

The relative advantages and disadvantages are given below.

Advantages of Cast Iron Sleepers
· Long life upto 50-60 years.
· High scrap value as they can be remolded.
· Prevent and check creep of rail.
· They are not attacked by vermin.

Disadvantages Cast Iron Sleepers
· They are prone to corrosion and cannot be used in salty formations.
· Not suitable for track circuited portions of railways.
· Difficult to maintain the gauge.
· Require a large number of fastening materials.
· Difficult to handle and may be easily damaged.
· Lack of good shock absorber.
· They are expensive.
Concrete sleepers

R.C.C and pre-stressed concrete sleepers are now replacing all other types of sleepers except to some special circumstances such as crossing bridges etc here timber sleepers are first of all used in France round about in 1914 but are common since 1950.

They may be a twin block sleepers joined by an angle iron. It may be a single block pre-stressed type.

Advantages Concrete Sleepers

- Durable with life range from 40-50 years
- They can be produced on large quantities by installing a plant
- Heavier than all other types thus giving better lateral stability to the track
- Good insulators and thus suitable for use in track circuited lines
- Efficient in controlling creep
- They are not attacked by corrosion
- Free from attacks of vermin and decay, suitable for all types of soils
- Prevent buckling more efficiently
- Initial cost is high but proves to be economical in long run
- Effectively and strongly hold the track to gauge
- Inflammable and fire resistant

Disadvantages Concrete Sleepers

- Difficult to be handled
- Difficult to be manufactured in different sizes thus cannot be used in bridges and crossing
- Can be damaged easily while loading and unloading

Gauge

Measuring rail gauge
During the early days of rail, there was considerable variation in the gauge used by different systems. Today, 60% of the world's railways use a gauge of (4 ft 8 ½ in), known as standard or international gauge. Gauges wider than standard gauge are called broad gauge; narrower, narrow gauge.

**Foundation**

Railway tracks are generally laid on a bed of stone track ballast, in turn is supported by prepared earthworks known as the track formation. The formation comprises the subgrade and a layer of sand or stone dust. The sub-grade layers are slightly sloped to one side to help drainage of water.
**Lec. NO.8**

**Principles of Transportation**

**Lecturer Hanan Adel**

**Intersections**

An intersection is the junction at grade (that is to say, on the same level) of two or more roads either meeting or crossing. An intersection may be three-way (a \textit{T junction} or \textit{Y junction}), four-way, or have five or more arms. Busy intersections are often controlled by traffic lights.

The intersections encompassed by a roundabout are considered as safe intersections. The efficiency of an intersection is determined on the basis of how well an intersection accommodates the demands of all road users. The performance of a signalized intersection is judged on the basis of its signal timings.

One way to classify intersections is by the number of road segments (arms) that are involved.

- **3-way intersection** – A junction between three road segments (arms) is a \textit{T junction} or a \textit{Y junction}.

- **4-way intersections** usually involve a crossing over of two streets or roads, the crossing streets or roads are \textit{perpendicular} to each other. However, two roads may cross at a different angle.

- **5-way & 6-way intersections** are less common but still exist.
Another way of classifying intersections is by traffic control technology:

- **Uncontrolled intersections**, without signs or signals (or sometimes with a warning sign). Priority (right-of-way) rules may vary by country: on a 4-way intersection traffic from the right often has priority.

- **Yield-controlled intersections** may or may not have specific "YIELD" signs (known as "GIVE WAY" signs in some countries).

- **Stop-controlled intersections** have one or more "STOP" signs. Two-way stops are common, while some countries also employ four-way stops.

- **Signal-controlled intersections** depend on traffic signals, usually electric, which indicate which traffic is allowed to proceed at any particular time.

**INTERSECTION DESIGN ELEMENTS Geometric Design**

Geometric design of a signalized intersection involves the functional layout of travel lanes, curb ramps, crosswalks, bike lanes, and transit stops in both the horizontal and vertical dimensions. Geometric design has a profound influence on roadway safety; it shapes road user expectations and defines how to proceed through an intersection where many conflicts exist.

The needs of all possible road users must be considered to achieve optimal safety and operational levels at an intersection. At times, design objectives may conflict between road user groups.

Elements of geometric design of an intersection include:

- Sight distance.
- Channelization.
- Number of intersection approaches.
- Pedestrian facilities.
- Bicycle facilities.
- Intersection angle.
- Horizontal and vertical alignment.
- Corner radius.
Sight Distance

A driver’s ability to see the road ahead and other intersection users is critical to safe and efficient use of all roadway facilities, especially signalized intersections. Stopping sight distance, decision sight distance, and intersection sight distance are particularly important at signalized intersections.

Stopping Sight Distance

Stopping sight distance should be provided throughout the intersection and on each entering and exiting approach.

Decision Sight Distance

Decision sight distance is “the distance needed for a driver to detect an unexpected or otherwise difficult-to-perceive information source or condition in a roadway environment that may be visually cluttered, recognize the condition or its potential threat, select an appropriate speed and path, and initiate and complete the maneuver safely and efficiently. Decision sight distance at intersections is applicable for situations where vehicles must maneuver into a particular lane in advance of the intersection.

Decision sight distance varies depending on whether the driver is to come to a complete stop or make some kind of speed, path, or direction change. Decision sight distance also varies depending on the environment—urban, suburban, or rural.

Intersection Sight Distance

Intersection sight distance is the distance required for a driver without the right of way to perceive and react to the presence of conflicting vehicles and pedestrians.

Intersection sight distance is traditionally measured through the determination of a sight triangle. This triangle is bounded by a length of roadway defining a limit away from the intersection on each of the two
conflicting approaches and by a line connecting those two limits. Intersection sight distance should be measured using an assumed height of driver’s eye of 1,080 mm (3.5 ft) and an assumed height of object of 1,080 mm (3.5 ft). The area within the triangle is referred to as the clear zone and should remain free from obstacles.

Intersection sight distance at signalized intersections is generally simpler than for stop-controlled intersections. The following criteria should be met:

- The first vehicle stopped on an approach should be visible to the first driver stopped on each of the other approaches.
- Vehicles making permissive movements (e.g., permissive left turns, right turns on red, etc.) should have sufficient sight distance to select gaps in oncoming traffic.
- Permissive left turns & right turns on red should be treated carefully.

**Channelization**

A primary goal of intersection design is to limit or reduce the severity of potential road user conflicts.

**Discourage undesirable movements.** Designers can utilize corner radii, raised medians, or traffic islands to prevent undesirable or wrong-way movements.

Figure below shows how a raised median can be used to restrict undesirable turn movements within the influence of signalized intersections.
The fig. shows a raised median that restricts left-turn egress movements from a driveway located between two signalized intersections.

. Define desirable paths for vehicles. The approach alignment to an intersection as well as the intersection itself should present the roadway user with a clear definition of the proper vehicle path. This is especially important at locations with “unusual” geometry or traffic patterns such as highly skewed intersections, multileg intersections, offset-t intersections and intersections with very high turn volumes. Clear definition of vehicle paths can minimize lane changing and avoid “trapping” vehicles in the incorrect lane. Avoiding these undesirable effects can improve both the safety and capacity at an intersection. Figure below shows how pavement markings can be applied to delineate travel paths.
Pavement markings can be used to delineate travel lanes within wide intersections as shown.

**Encourage safe speeds through design.** An effective intersection design promotes desirable speeds to optimize intersection safety. The appropriate speed will vary based on the use, type, and location of the intersection. On high-speed roadways with no pedestrians, it may be desirable to promote higher speeds for turning vehicles to remove turning vehicles from the through traffic stream as quickly and safely as possible. This can be accomplished with longer, smooth tapers and larger curb radii. On low-speed roadways or in areas with pedestrians, promotion of lower turning speeds is appropriate. This can be accomplished with smaller turning radii, narrower lanes, and/or channelization features.

**Separate points of conflict where possible.** Separation of conflict points can ease the driving task while improving both the capacity and safety at an intersection. The use of exclusive turn lanes, channelized right turns, and raised medians as part of an access control strategy are all effective ways to separate vehicle conflicts.
**Pedestrian Facilities**

Pedestrian facilities should be provided at all intersections in urban and suburban areas. In general, design of the pedestrian facilities of an intersection with the most challenged users in mind—pedestrians with mobility or visual impairments should be done. The resulting design will serve all pedestrians well.

**Bicycle Facilities**

Some intersections have on-street bicycle lanes or off-street bicycle paths entering the intersection. When this occurs, intersection design should accommodate the needs of cyclists in safely navigating such a large and often complicated intersection.