Course File On
Traffic Engineering

By
N. Naveen Kumar
Assistant Professor

Civil Engineering Department
KG Reddy College of Engineering and Technology
2019 - 2020

HOD           PRINCIPAL
Civil Engineering      KGRCET
<table>
<thead>
<tr>
<th>COURSE FILE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject Name</td>
</tr>
<tr>
<td>Faculty Name</td>
</tr>
<tr>
<td>Designation</td>
</tr>
<tr>
<td>Regulation /Course Code</td>
</tr>
<tr>
<td>Year / Semester</td>
</tr>
<tr>
<td>Department</td>
</tr>
<tr>
<td>Academic Year</td>
</tr>
</tbody>
</table>
1. VISION, MISSION, PROGRAM EDUCATIONAL OBJECTIVES (PEOs), PROGRAM OUTCOMES (POs) & PROGRAM SPECIFIC OUTCOMES (PSOs)

Vision

To give the world new age civil engineers who can transform the society with their creative vibe for the sustainable development by instilling scientific temper with ethical human outlook.

Mission

- To make the department a centre of excellence in the field of civil engineering and allied research.
- To promote innovative and original thinking in the minds of budding engineers to face the challenges of future.
Program Educational Objectives (PEOs)

<table>
<thead>
<tr>
<th>PEO 1</th>
<th>Graduates will utilize the foundation in Engineering and Science to improve lives and livelihoods through a successful career in civil Engineering or other fields.</th>
</tr>
</thead>
<tbody>
<tr>
<td>PEO 2</td>
<td>Graduates will become effective collaborators and innovators, leading or participating in efforts to address Social, Technical and Business challenges.</td>
</tr>
<tr>
<td>PEO 3</td>
<td>Graduates will engage in Life-Long Learning and professional development through Self-Study, continuing education or graduate and professional studies in engineering &amp; Business.</td>
</tr>
</tbody>
</table>

Program Outcomes (POs)

<table>
<thead>
<tr>
<th>PO1</th>
<th><strong>Fundamental engineering analysis skills:</strong> An ability to apply knowledge of computing, mathematical foundations, algorithmic principles, and civil engineering theory in the modelling and design of civil engineering problems.</th>
</tr>
</thead>
<tbody>
<tr>
<td>PO2</td>
<td><strong>Information retrieval skills:</strong> An ability to design and conduct experiments, as well as to analyze and interpret data.</td>
</tr>
<tr>
<td>PO3</td>
<td><strong>Creative skills:</strong> An ability to design, implement, and evaluate a system, process, component, or program to meet desired needs, within realistic constraints such as economic, environmental, social, political, health and safety, manufacturability, and sustainability. Graduates have design the competence.</td>
</tr>
<tr>
<td>PO4</td>
<td><strong>Teamwork:</strong> An ability to function effectively on multi-disciplinary teams.</td>
</tr>
<tr>
<td>PO5</td>
<td><strong>Engineering problem solving skills:</strong> An ability to analyze a problem, and identify, formulate and use the appropriate computing and engineering requirements for obtaining its solution.</td>
</tr>
<tr>
<td>PO6</td>
<td><strong>Professional integrity:</strong> An understanding of professional, ethical, legal, security and social issues and responsibilities. Graduates must understand the principles of ethical decision making and can interpret the ASCE Code of Ethics. Graduates will understand the proper use of the work of others (e.g., plagiarism, copyrights, and</td>
</tr>
</tbody>
</table>
patents). Graduates will understand the special duty they owe to protect the public's health, safety and welfare by virtue of their professional status as engineers in society.

<table>
<thead>
<tr>
<th>PO7</th>
<th>Speaking / writing skills: An ability to communicate effectively, both in writing and orally. Graduates are able to produce engineering reports using written, oral and graphic methods of communication.</th>
</tr>
</thead>
<tbody>
<tr>
<td>PO8</td>
<td>Engineering impact assessment skills: The broad education necessary to analyze the local and global impact of computing and engineering solutions on individuals, organizations, and society.</td>
</tr>
<tr>
<td>PO9</td>
<td>Social awareness: Knowledge of contemporary issues. Students are aware of emerging technologies and current professional issues.</td>
</tr>
<tr>
<td>PO10</td>
<td>Practical engineering analysis skills: An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.</td>
</tr>
<tr>
<td>PO11</td>
<td>Software hardware interface: An ability to apply design and development principles in the construction of software and hardware systems of varying complexity.</td>
</tr>
<tr>
<td>PO12</td>
<td>Successful career and immediate employment: An ability to recognize the importance of professional development by pursuing postgraduate studies or face competitive examinations that offer challenging and rewarding careers in Civil Engineering</td>
</tr>
</tbody>
</table>
## Program Specific Outcomes (PSOS)

<table>
<thead>
<tr>
<th>PSO</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSO 1</td>
<td>Educating students with fundamental mathematical, scientific, and engineering knowledge to have a significant and positive long-term impact on the field of civil engineering.</td>
</tr>
<tr>
<td>PSO 2</td>
<td>Emphasizing the importance of working in a team effectively and to communicate properly within the team to achieve the desired outcome.</td>
</tr>
<tr>
<td>PSO 3</td>
<td>Motivate students in learning to learn and the ability to keep learning for a lifetime to increase their professionalism, update and deepen their knowledge through the development of the profession.</td>
</tr>
</tbody>
</table>
2. SYLLABUS (University copy)

CE741PE: Traffic Engineering

B.Tech. IV Year I Sem.

UNIT-I
Traffic Studies (Part- I) : Basic principles of Traffic, Volume, Speed and Density; Definitions and their interrelationships; Traffic Volume studies - Objectives, Methods of Volume counts, Presentation of Volume Data; Speed studies- Types of Speeds, Objectives, Methods of speed studies, Statistical Methods for speed data Analysis, Presentation of speed data. Delay Studies; Head ways and Gap Studies - Headway and Gap acceptance, Origin and Destination Studies.

UNIT-II
Traffic Studies (Part-II) : Parking Studies: parameters of parking, definitions, Parking inventory study, Parking survey by Patrolling method; Analysis of Parking Survey data; Accident studies- Causative factors of Road accidents, Accident data collection: Accident analysis and modeling;, Road Safety Auditing, Measures to increase Road safety.

UNIT-III
Capacity and LOS Analysis: Introduction to Traffic capacity, Analysis concepts, Level of Service, Basic definitions, Factors affecting Capacity and LOS, Capacity of Urban/Rural Highway, With or without access control, Basic freeway segments - Service flow rate of LOS, Lane width or Lateral clearance adjustment; Heavy vehicle adjustment; Driver population adjustment.

UNIT-IV

UNIT-V
TEXT BOOKS : Nill

REFERENCES
4. IRC Codes
3. COURSE OBJECTIVES, COURSE OUTCOMES AND TOPIC OUTCOMES

COURSE OBJECTIVES

To provide engineering techniques to achieve the safe and efficient movement of people and goods on roadways.

COURSE OUTCOMES

At the end of the course, the student will be able to:
CO 1: Understand basics principles of Traffic Engineering
CO 2: Analyze parking data and model accidents
CO 3: Determine capacity and LOS.
CO 4: To provide engineering techniques to achieve Safe and efficient movement of people and goods on roadways
<table>
<thead>
<tr>
<th>Lecture no.</th>
<th>Topic to be covered</th>
<th>Topic outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>UNIT-I</strong></td>
<td></td>
</tr>
<tr>
<td>L1</td>
<td>Traffic Studies (Part-I) Introduction</td>
<td>Defining Traffic Studies (Part-I)</td>
</tr>
<tr>
<td>L2</td>
<td>Basic principles of Traffic, Volume, Speed and Density; Definitions and their interrelationships;</td>
<td>Defining Basic principles of Traffic, Volume, Speed and Density; Definitions and their interrelationships;</td>
</tr>
<tr>
<td>L3, L4</td>
<td>Traffic Volume studies – Objectives, Methods of Volume counts, Presentation of Volume Data;</td>
<td>Explaining Traffic Volume studies – Objectives. Explaining Methods of Volume counts, Presentation of Volume Data;</td>
</tr>
<tr>
<td>L8, L9</td>
<td>Delay Studies; Head ways and Gap Studies - Headway and Gap acceptance</td>
<td>Describing Delay Studies; Describing Head ways and Gap Studies - Headway and Gap acceptance</td>
</tr>
<tr>
<td>L10</td>
<td>Origin and Destination Studies.</td>
<td>Defining Origin and Destination Studies.</td>
</tr>
<tr>
<td>L11</td>
<td>Revision class</td>
<td>Revision class</td>
</tr>
<tr>
<td></td>
<td><strong>UNIT-II</strong></td>
<td></td>
</tr>
<tr>
<td>L12</td>
<td>Traffic Studies (Part-II) :</td>
<td>Defining Traffic Studies (Part-II) :</td>
</tr>
<tr>
<td>L13, L14, L15</td>
<td>Parking Studies: parameters of parking, definitions, Parking inventory study, Parking survey by Patrolling method;</td>
<td>Defining Parking Studies: parameters of parking, definitions, Parking inventory study.</td>
</tr>
<tr>
<td></td>
<td>Analysis of Parking Survey data; Explaining Parking survey by Patrolling method; Explaining Analysis of Parking Survey data;</td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>L16, L17, L18</td>
<td>Accident studies- Causative factors of Road accidents. Accident data collection: Accident analysis and modelling; Demonstrating Accident studies- Causative factors of Road accidents. Demonstrating Accident data collection: Describing Accident analysis and modelling;</td>
<td></td>
</tr>
<tr>
<td>L19, L20</td>
<td>Road Safety Auditing. Measures to increase Road safety. Describing Road Safety Auditing. Defining Measures to increase Road safety.</td>
<td></td>
</tr>
<tr>
<td>L21</td>
<td>Revision class Revision class</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>UNIT III</strong></td>
<td></td>
</tr>
<tr>
<td>L25</td>
<td>Capacity and LOS Analysis: Defining Capacity and LOS Analysis:</td>
<td></td>
</tr>
<tr>
<td>L26</td>
<td>Capacity and LOS Analysis: Defining Capacity and LOS Analysis:</td>
<td></td>
</tr>
<tr>
<td>L27</td>
<td>Introduction to Traffic capacity, Analysis concepts Explaining Introduction to Traffic capacity, Analysis concepts</td>
<td></td>
</tr>
<tr>
<td>L28</td>
<td>Introduction to Traffic capacity, Analysis concepts Explaining Introduction to Traffic capacity, Analysis concepts</td>
<td></td>
</tr>
<tr>
<td>L29</td>
<td>Level of Service, Basic definitions Analyzing Level of Service, Basic definitions</td>
<td></td>
</tr>
<tr>
<td>L30</td>
<td>Factors affecting Capacity and LOS Defining Factors affecting Capacity and LOS</td>
<td></td>
</tr>
<tr>
<td>L31</td>
<td>Capacity of Urban/Rural Highway, With or without access control Demonstrating Capacity of Urban/Rural Highway, With or without access control</td>
<td></td>
</tr>
<tr>
<td>L32</td>
<td>Basic freeway segments - Service flow rate of LOS Demonstrating Basic freeway segments - Service flow rate of LOS,</td>
<td></td>
</tr>
<tr>
<td>L33</td>
<td>Basic freeway segments - Service flow rate of LOS Demonstrating Basic freeway segments - Service flow rate of LOS,</td>
<td></td>
</tr>
<tr>
<td>L34</td>
<td>Lane width or Lateral clearance adjustment;</td>
<td>Describing Lane width or Lateral clearance adjustment;</td>
</tr>
<tr>
<td>L35</td>
<td>Heavy vehicle adjustment; Driver population adjustment</td>
<td>Describing Heavy vehicle adjustment; Driver population adjustment</td>
</tr>
<tr>
<td>L36</td>
<td>Revision class</td>
<td>Revision class</td>
</tr>
<tr>
<td><strong>UNIT IV</strong></td>
<td><strong>UNIT IV</strong></td>
<td></td>
</tr>
<tr>
<td>L37</td>
<td>Signal Designing – Fixed Time signals</td>
<td>Defining Signal Designing – Fixed Time signals</td>
</tr>
<tr>
<td>L38</td>
<td>Signal Designing – Fixed Time signals</td>
<td>Defining Signal Designing – Fixed Time signals</td>
</tr>
<tr>
<td>L39</td>
<td>Determination of Optimum Cycle length and Signal setting for Fixed Time signals</td>
<td>Determination of Optimum Cycle length and Signal setting for Fixed Time signals</td>
</tr>
<tr>
<td>L40</td>
<td>Determination of Optimum Cycle length and Signal setting for Fixed Time signals</td>
<td>Determination of Optimum Cycle length and Signal setting for Fixed Time signals</td>
</tr>
<tr>
<td>L41</td>
<td>Warrants for Signals</td>
<td>Explaining Warrants for Signals</td>
</tr>
<tr>
<td>L42</td>
<td>Time Plan Design for Pre-Timed Control</td>
<td>Explaining Time Plan Design for Pre-Timed Control</td>
</tr>
<tr>
<td>L43</td>
<td>Lane group analysis</td>
<td>Analyzing Lane group analysis</td>
</tr>
<tr>
<td>L44</td>
<td>Saturation flow rate, and Adjustment factors</td>
<td>Demonstrating Saturation flow rate, and Adjustment factors</td>
</tr>
<tr>
<td>L45</td>
<td>Uniform and Incremental Delay</td>
<td>Demonstrating Uniform and Incremental Delay</td>
</tr>
<tr>
<td>L46</td>
<td>Vehicle Actuated Signals</td>
<td>Describing Vehicle Actuated Signals,</td>
</tr>
<tr>
<td>L47</td>
<td>Signal Coordination.</td>
<td>Describing Signal Coordination.</td>
</tr>
<tr>
<td>L48</td>
<td>Revision class</td>
<td>Revision class</td>
</tr>
<tr>
<td><strong>UNIT V</strong></td>
<td><strong>UNIT V</strong></td>
<td></td>
</tr>
<tr>
<td>L49</td>
<td>Transportation System Management</td>
<td>Defining Transportation System Management</td>
</tr>
<tr>
<td>-----</td>
<td>----------------------------------</td>
<td>------------------------------------------</td>
</tr>
<tr>
<td>L50</td>
<td>Transportation System Management</td>
<td>Defining Transportation System Management</td>
</tr>
<tr>
<td>L51</td>
<td>Measures for Improving vehicular flow – one way Streets</td>
<td>Explaining Measures for Improving vehicular flow – one way Streets</td>
</tr>
<tr>
<td>L52</td>
<td>Signal Improvement</td>
<td>Explaining Signal Improvement</td>
</tr>
<tr>
<td>L53</td>
<td>Transit Stop Relocation</td>
<td>Analysing Transit Stop Relocation</td>
</tr>
<tr>
<td>L54</td>
<td>Parking Management</td>
<td>Analysing Parking Management</td>
</tr>
<tr>
<td>L55</td>
<td>Reversible lanes</td>
<td>Demonstrating Reversible lanes</td>
</tr>
<tr>
<td>L56</td>
<td>Reducing Peak Period Traffic</td>
<td>Demonstrating Reducing Peak Period Traffic</td>
</tr>
<tr>
<td>L57</td>
<td>Reducing Peak Period Traffic</td>
<td>Demonstrating Reducing Peak Period Traffic</td>
</tr>
<tr>
<td>L58</td>
<td>Strategies for working hours, Congestion Pricing</td>
<td>Describing Strategies for working hours, Congestion Pricing</td>
</tr>
<tr>
<td>L59</td>
<td>Differential Toll Policies</td>
<td>Describing Differential Toll Policies</td>
</tr>
<tr>
<td>L60</td>
<td>Revision class</td>
<td>Revision class</td>
</tr>
</tbody>
</table>

4. COURSE PRE–REQUISITES

1. Highway Engineering
2. Transportation Engineering
5. CO’s, PO’s MAPPING

<table>
<thead>
<tr>
<th></th>
<th>PO1</th>
<th>PO2</th>
<th>PO3</th>
<th>PO4</th>
<th>PO5</th>
<th>PO6</th>
<th>PO7</th>
<th>PO8</th>
<th>PO9</th>
<th>PO10</th>
<th>PO11</th>
<th>PO12</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO1</td>
<td>M</td>
<td>-</td>
<td>H</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>M</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>L</td>
<td>-</td>
</tr>
<tr>
<td>CO2</td>
<td>-</td>
<td>H</td>
<td>-</td>
<td>-</td>
<td>L</td>
<td>-</td>
<td>-</td>
<td>H</td>
<td>M</td>
<td>-</td>
<td>L</td>
<td>-</td>
</tr>
<tr>
<td>CO3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>H</td>
<td>-</td>
<td>M</td>
<td>-</td>
<td>L</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>CO4</td>
<td>-</td>
<td>M</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>L</td>
<td>H</td>
</tr>
</tbody>
</table>

NOTES: L – Low, M – Medium, H - High

6. COURSE INFORMATION SHEET (CIS)

a) Course Description

<table>
<thead>
<tr>
<th>Programme</th>
<th>Degree : B. Tech</th>
</tr>
</thead>
<tbody>
<tr>
<td>Course</td>
<td>Traffic Engineering</td>
</tr>
<tr>
<td>Course Code</td>
<td>CE741PE</td>
</tr>
<tr>
<td>Regulation</td>
<td>R16</td>
</tr>
<tr>
<td>Course area / Domain</td>
<td>Theory/ Problematic</td>
</tr>
<tr>
<td>Corresponding Lab Course Code (If Any)</td>
<td>Nil</td>
</tr>
<tr>
<td>Lab Course Name</td>
<td>Nil</td>
</tr>
</tbody>
</table>
b) Syllabus

<table>
<thead>
<tr>
<th>Unit</th>
<th>Details</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Traffic Studies (Part- I) : Basic principles of Traffic, Volume, Speed and Density; Definitions and their interrelationships; Traffic Volume studies - Objectives, Methods of Volume counts, Presentation of Volume Data; Speed studies- Types of Speeds, Objectives, Methods of speed studies, Statistical Methods for speed data Analysis, Presentation of speed data. Delay Studies; Head ways and Gap Studies - Headway and Gap acceptance, Origin and Destination Studies.</td>
<td>12</td>
</tr>
<tr>
<td>II</td>
<td>Traffic Studies (Part-II) : Parking Studies: parameters of parking, definitions, Parking inventory study, Parking survey by Patrolling method; Analysis of Parking Survey data; Accident studies- Causative factors of Road accidents, Accident data collection: Accident analysis and modeling;, Road Safety Auditing, Measures to increase Road safety.</td>
<td>12</td>
</tr>
<tr>
<td>III</td>
<td>Capacity and LOS Analysis: Introduction to Traffic capacity, Analysis concepts, Level of Service, Basic definitions, Factors affecting Capacity and LOS, Capacity of Urban/Rural Highway, With or without access control, Basic freeway segments - Service flow rate of LOS, Lane width or Lateral clearance adjustment; Heavy vehicle adjustment; Driver population adjustment.</td>
<td>12</td>
</tr>
<tr>
<td>IV</td>
<td>Signal Designing – Fixed Time signals, Determination of Optimum Cycle length and Signal setting for Fixed Time signals, Warrants for Signals, Time Plan Design for Pre-Timed Control- Lane group analysis, Saturation flow rate, and Adjustment factors, Uniform and Incremental Delay, Vehicle Actuated Signals, Signal Coordination.</td>
<td>12</td>
</tr>
</tbody>
</table>

**Total No. of classes**: 60

c) Gaps in the Syllabus : Nill

d) Topics beyond Syllabus/ Advanced Topics : Nill
e) Web Source References

<table>
<thead>
<tr>
<th>Sl.</th>
<th>Name of book/ website</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td><a href="https://nptel.ac.in/courses/105101008/11">https://nptel.ac.in/courses/105101008/11</a></td>
</tr>
<tr>
<td>c.</td>
<td><a href="http://www.crridom.gov.in/content/traffic-engineering-and-safety">http://www.crridom.gov.in/content/traffic-engineering-and-safety</a></td>
</tr>
</tbody>
</table>

f) Delivery/Instructional Methodologies

- ☑ CHALK & TALK
- ☑ STUD. ASSIGNMENT
- ☑ WEB RESOURCES

- ☑ LCD/SMART BOARDS
- ☑ STUD. SEMINARS
- ☐ ADD-ON COURSES

g) Assessment Methodologies-Direct

- ☑ ASSIGNMENTS
- ☑ STUD. SEMINARS
- ☑ TESTS/MODEL EXAMS
- ☑ UNIV. EXAMINATION

- ☑ STUD. LAB PRACTICES
- ☑ STUD. VIVA
- ☑ MINI/MAJOR PROJECTS
- ☐ CERTIFICATIONS

- ☐ ADD-ON COURSES
- ☐ OTHERS

h) Assessment Methodologies-Indirect

- ☑ ASSESSMENT OF COURSE OUTCOMES (BY FEEDBACK, ONCE)
- ☑ STUDENT FEEDBACK ON FACULTY (TWICE)

- ☑ ASSESSMENT OF MINI/MAJOR PROJECTS BY EXT. EXPERTS
- ☐ OTHERS
## i) Text/Reference Books

<table>
<thead>
<tr>
<th>T/R</th>
<th>Book Title/Authors/Publication</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Text Book</strong></td>
<td>Nill</td>
</tr>
<tr>
<td><strong>Reference Book</strong></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Traffic Engineering and Transportation Planning – L.R. Kadiyali, Khanna Publishers</td>
</tr>
<tr>
<td>2</td>
<td>Principles of Highways Engineering and Traffic Analysis - Fred Mannering &amp; Walter Kilareski, John Wiley &amp; Sons Publication</td>
</tr>
<tr>
<td>3</td>
<td>Fundamentals of Transportation Engineering - C. S. Papacostas, Prentice Hall India.</td>
</tr>
<tr>
<td>4</td>
<td>IRC Codes</td>
</tr>
<tr>
<td>7</td>
<td>Transportation Engineering - An Introduction - C. Jotin Khisty, Prentice Hall Publication</td>
</tr>
<tr>
<td>8</td>
<td>Fundamentals of Traffic Engineering – McShane &amp; Rogers.</td>
</tr>
</tbody>
</table>
## 7. MICRO LESSON PLAN

<table>
<thead>
<tr>
<th>S.N.</th>
<th>Topic</th>
<th>Schedule data</th>
<th>Actual Date</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>UNIT-I</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Traffic Studies (Part- I)</td>
<td></td>
<td>15/07/19</td>
</tr>
<tr>
<td>2</td>
<td>Basic principles of Traffic, Volume, Speed and Density; Definitions and their interrelationships;</td>
<td></td>
<td>16/07/19</td>
</tr>
<tr>
<td>3</td>
<td>Basic principles of Traffic, Volume, Speed and Density; Definitions and their interrelationships;</td>
<td></td>
<td>17/07/19</td>
</tr>
<tr>
<td>4</td>
<td>Traffic Volume studies - Objectives</td>
<td></td>
<td>18/07/19</td>
</tr>
<tr>
<td>5</td>
<td>Methods of Volume counts, Presentation of Volume Data;</td>
<td></td>
<td>22/07/19</td>
</tr>
<tr>
<td>6</td>
<td>Speed studies- Types of Speeds</td>
<td></td>
<td>23/07/19</td>
</tr>
<tr>
<td>7</td>
<td>Objectives, Methods of speed studies</td>
<td></td>
<td>24/07/19</td>
</tr>
<tr>
<td>8</td>
<td>Statistical Methods for speed data Analysis, Presentation of speed data</td>
<td></td>
<td>25/07/19</td>
</tr>
<tr>
<td>9</td>
<td>Delay Studies;</td>
<td></td>
<td>29/07/19</td>
</tr>
<tr>
<td>10</td>
<td>Head ways and Gap Studies - Headway and Gap acceptance</td>
<td></td>
<td>30/07/19</td>
</tr>
<tr>
<td>11</td>
<td>Origin and Destination Studies.</td>
<td></td>
<td>31/07/19</td>
</tr>
<tr>
<td>12</td>
<td>Revision class</td>
<td></td>
<td>01/08/19</td>
</tr>
<tr>
<td><strong>UNIT-II</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Traffic Studies (Part-II)</td>
<td></td>
<td>05/08/19</td>
</tr>
<tr>
<td>14</td>
<td>Parking Studies: parameters of parking, definitions,</td>
<td></td>
<td>06/08/19</td>
</tr>
<tr>
<td>15</td>
<td>Parking inventory study</td>
<td></td>
<td>07/08/19</td>
</tr>
<tr>
<td>16</td>
<td>Parking survey by Patrolling method;</td>
<td></td>
<td>08/08/19</td>
</tr>
<tr>
<td>17</td>
<td>Analysis of Parking Survey data;</td>
<td></td>
<td>12/08/19</td>
</tr>
<tr>
<td>18</td>
<td>Accident studies- Causative factors of Road accidents</td>
<td></td>
<td>13/08/19</td>
</tr>
<tr>
<td>19</td>
<td>Accident data collection:</td>
<td></td>
<td>14/08/19</td>
</tr>
<tr>
<td>20</td>
<td>Accident analysis and modelling;</td>
<td></td>
<td>16/08/19</td>
</tr>
<tr>
<td>21</td>
<td>Road Safety Auditing</td>
<td></td>
<td>19/08/19</td>
</tr>
<tr>
<td>22</td>
<td>Road Safety Auditing</td>
<td></td>
<td>20/08/19</td>
</tr>
<tr>
<td></td>
<td>Measures to increase Road safety.</td>
<td>21/08/19</td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---------------------------------</td>
<td>----------</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>Revision class</td>
<td>22/08/19</td>
<td></td>
</tr>
</tbody>
</table>

**UNIT III**

<table>
<thead>
<tr>
<th></th>
<th>Capacity and LOS Analysis:</th>
<th>26/08/19</th>
</tr>
</thead>
<tbody>
<tr>
<td>26</td>
<td>Capacity and LOS Analysis:</td>
<td>27/08/19</td>
</tr>
<tr>
<td>27</td>
<td>Introduction to Traffic capacity, Analysis concepts</td>
<td>28/08/19</td>
</tr>
<tr>
<td>28</td>
<td>Introduction to Traffic capacity, Analysis concepts</td>
<td>29/08/19</td>
</tr>
<tr>
<td>29</td>
<td>Level of Service, Basic definitions</td>
<td>02/09/19</td>
</tr>
<tr>
<td>30</td>
<td>Factors affecting Capacity and LOS</td>
<td>03/09/19</td>
</tr>
<tr>
<td>31</td>
<td>Capacity of Urban/Rural Highway, With or without access control</td>
<td>04/09/19</td>
</tr>
<tr>
<td>32</td>
<td>Basic freeway segments - Service flow rate of LOS</td>
<td>05/09/19</td>
</tr>
<tr>
<td>33</td>
<td>Basic freeway segments - Service flow rate of LOS</td>
<td>09/09/19</td>
</tr>
<tr>
<td>34</td>
<td>Lane width or Lateral clearance adjustment;</td>
<td>11/09/19</td>
</tr>
<tr>
<td>35</td>
<td>Heavy vehicle adjustment; Driver population adjustment</td>
<td>16/09/19</td>
</tr>
<tr>
<td>36</td>
<td>Revision class</td>
<td>17/09/19</td>
</tr>
</tbody>
</table>

**UNIT IV**

<table>
<thead>
<tr>
<th></th>
<th>Signal Designing – Fixed Time signals</th>
<th>18/09/19</th>
</tr>
</thead>
<tbody>
<tr>
<td>38</td>
<td>Signal Designing – Fixed Time signals</td>
<td>19/09/19</td>
</tr>
<tr>
<td>39</td>
<td>Determination of Optimum Cycle length and Signal setting for Fixed Time signals</td>
<td>23/09/19</td>
</tr>
<tr>
<td>40</td>
<td>Determination of Optimum Cycle length and Signal setting for Fixed Time signals</td>
<td>24/09/19</td>
</tr>
<tr>
<td>41</td>
<td>Warrants for Signals</td>
<td>25/09/19</td>
</tr>
<tr>
<td>42</td>
<td>Time Plan Design for Pre-Timed Control</td>
<td>26/09/19</td>
</tr>
<tr>
<td>43</td>
<td>Lane group analysis</td>
<td>30/09/19</td>
</tr>
<tr>
<td>44</td>
<td>Saturation flow rate, and Adjustment factors</td>
<td>01/10/19</td>
</tr>
<tr>
<td>45</td>
<td>Uniform and Incremental Delay</td>
<td>02/10/19</td>
</tr>
<tr>
<td>46</td>
<td>Vehicle Actuated Signals</td>
<td>03/10/19</td>
</tr>
<tr>
<td>47</td>
<td>Signal Coordination.</td>
<td>14/10/19</td>
</tr>
<tr>
<td>48</td>
<td>Revision class</td>
<td>15/10/19</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>49</td>
<td>Transportation System Management</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>Transportation System Management</td>
<td></td>
</tr>
<tr>
<td>51</td>
<td>Measures for Improving vehicular flow – one way Streets</td>
<td></td>
</tr>
<tr>
<td>52</td>
<td>Signal Improvement</td>
<td></td>
</tr>
<tr>
<td>53</td>
<td>Transit Stop Relocation</td>
<td></td>
</tr>
<tr>
<td>54</td>
<td>Parking Management</td>
<td></td>
</tr>
<tr>
<td>55</td>
<td>Reversible lanes</td>
<td></td>
</tr>
<tr>
<td>56</td>
<td>Reducing Peak Period Traffic</td>
<td></td>
</tr>
<tr>
<td>57</td>
<td>Reducing Peak Period Traffic</td>
<td></td>
</tr>
<tr>
<td>58</td>
<td>Strategies for working hours, Congestion Pricing</td>
<td></td>
</tr>
<tr>
<td>59</td>
<td>Differential Toll Policies</td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>Revision class</td>
<td></td>
</tr>
</tbody>
</table>

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>16/10/19</td>
</tr>
<tr>
<td></td>
<td>17/10/19</td>
</tr>
<tr>
<td></td>
<td>21/10/19</td>
</tr>
<tr>
<td></td>
<td>22/10/19</td>
</tr>
<tr>
<td></td>
<td>23/10/19</td>
</tr>
<tr>
<td></td>
<td>24/10/19</td>
</tr>
<tr>
<td></td>
<td>28/10/19</td>
</tr>
<tr>
<td></td>
<td>29/10/19</td>
</tr>
<tr>
<td></td>
<td>30/10/19</td>
</tr>
<tr>
<td></td>
<td>31/10/19</td>
</tr>
<tr>
<td></td>
<td>04/11/19</td>
</tr>
<tr>
<td></td>
<td>05/11/19</td>
</tr>
</tbody>
</table>
## 8. TEACHING SCHEDULE

### Traffic Engineering

#### Text Books

<table>
<thead>
<tr>
<th>UNIT</th>
<th>TOPIC</th>
<th>Chapter Nos.</th>
<th>Classes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Traffic Studies (Part- I)</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>Basic principles of Traffic, Volume, Speed and Density; Definitions and their interrelationships;</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>Basic principles of Traffic, Volume, Speed and Density; Definitions and their interrelationships;</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>Traffic Volume studies - Objectives</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>Methods of Volume counts, Presentation of Volume Data;</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>Speed studies- Types of Speeds</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>Objectives, Methods of speed studies</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>Statistical Methods for speed data Analysis, Presentation of speed data</td>
<td>4</td>
<td>1</td>
</tr>
</tbody>
</table>

#### Reference Books

<p>| Book 1 | Traffic Engineering and Transportation Planning – L.R. Kadiyali, Khanna Publishers |
| Book 2 | Principles of Highways Engineering and Traffic Analysis - Fred Mannering &amp; Walter Kilareski, John Wiley &amp; Sons Publication |
| Book 6 | Transportation Engineering - An Introduction - C. Jotin Khisty, Prentice Hall Publication |
| Book 7 | Fundamentals of Traffic Engineering – McShane &amp; Rogers. |</p>
<table>
<thead>
<tr>
<th></th>
<th>Topic</th>
<th>Chapter</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Delay Studies;</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>Head ways and Gap Studies - Headway and Gap acceptance</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>Origin and Destination Studies.</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>Revision class</td>
<td>3,4,5</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Traffic Studies (Part-II):</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Parking Studies: parameters of parking, definitions</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Parking inventory study</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Parking survey by Patrolling method</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Analysis of Parking Survey data</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Accident studies- Causative factors of Road accidents</td>
<td>18</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Accident data collection:</td>
<td>18</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Accident analysis and modelling;</td>
<td>18</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Road Safety Auditing</td>
<td>18</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Road Safety Auditing</td>
<td>18</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Measures to increase Road safety.</td>
<td>18</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Revision class</td>
<td>6,18</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Capacity and LOS Analysis:</td>
<td>21</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Introduction to Traffic capacity, Analysis concepts</td>
<td>21</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Introduction to Traffic capacity, Analysis concepts</td>
<td>21</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Level of Service, Basic definitions</td>
<td>21</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Factors affecting Capacity and LOS</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Capacity of Urban/Rural Highway, With or without access control</td>
<td>21</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Basic freeway segments - Service flow rate of LOS</td>
<td>21</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Basic freeway segments - Service flow rate of LOS</td>
<td>21</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Lane width or Lateral clearance</td>
<td>21</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>-------</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>3</td>
<td>Heavy vehicle adjustment; Driver population adjustment</td>
<td>21</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Revision class</td>
<td>21</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>Signal Designing – Fixed Time signals</td>
<td>15</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>Signal Designing – Fixed Time signals</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Determination of Optimum Cycle length and Signal setting for Fixed Time signals</td>
<td>15</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>Determination of Optimum Cycle length and Signal setting for Fixed Time signals</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Warrants for Signals</td>
<td>15</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>Time Plan Design for Pre-Timed Control</td>
<td>15</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>Lane group analysis</td>
<td>15</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>Saturation flow rate, and Adjustment factors</td>
<td>15</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>Uniform and Incremental Delay</td>
<td>15</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>Vehicle Actuated Signals</td>
<td>15</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>Signal Coordination.</td>
<td>15</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>Revision class</td>
<td>15</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>Transportation System Management</td>
<td>15</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>Transportation System Management</td>
<td>15</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>Measures for Improving vehicular flow – one way Streets</td>
<td>15</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>Signal Improvement</td>
<td>15</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>Transit Stop Relocation</td>
<td>15</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>Parking Management</td>
<td>15</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>Reversible lanes</td>
<td>15</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>Reducing Peak Period Traffic</td>
<td>15</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>Reducing Peak Period Traffic</td>
<td>15</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>Strategies for working hours, Congestion Pricing</td>
<td>15</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>Differential Toll Policies</td>
<td>15</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>Revision class</td>
<td>15</td>
<td></td>
</tr>
</tbody>
</table>
9. UNIT WISE HAND WRITTEN NOTES
10 OHP/LCD SHEETS /CDS/DVDS/PPT (Soft / Hard copies)
11. UNIVERSITY PREVIOUS QUESTION PAPERS

Code No: RT42012E

R13

Set No. 1

IV B.Tech II Semester Regular/Supplementary Examinations, April/May - 2019
TRAFFIC ENGINEERING
(Civil Engineering)

Max. Marks: 70

Question paper consists of Part-A and Part-B
Answer ALL sub questions from Part-A
Answer any THREE questions from Part-B

PART–A (22 Marks)

1. a) What do you mean by pedestrian? Why pedestrian lane is important? [4]
b) What is time headway? [3]
c) What is meant by signal coordination? [3]
d) How air quality can be measured? [4]
e) What is basic capacity? [4]
f) What is IVHS? Write its applications. [4]

PART–B (3x16 = 48 Marks)

2. a) Explain various human factors governing road user behavior. [8]
b) Explain the classification of highways. [8]

3. a) Discuss about microscopic and macroscopic flow characteristics. [8]
b) What are the various uses of travel time and delay studies? [8]

4. a) Discuss in detail about various kinds of road markings. [8]
b) Explain about analysis of traffic accidents. [8]

5. a) What are the different techniques for controlling traffic noise? [8]
b) Mention the air quality standards. [8]

6. a) What is level of service? What are the factors affecting capacity and level of service? [8]
b) Discuss about capacity and level of service of urban roads. [8]

7. a) Explain the role of IVHS in traffic surveillance and monitoring. [8]
b) Explain various IVHS categories. [8]
PART-A (22 Marks)

1. a) Define spot speed. [3]
    b) Define journey speed.[4]
    c) What is the purpose of warning signs? [4]
    d) How noise levels are predicted? [4]
    e) Define capacity. [3]
    f) What are the categories of IVHS? [4]

PART-B (3x6 = 48 Marks)

2. a) What are the characteristics of road users? [8]
    b) Explain the procedure for conducting floating car method. [8]

3. a) What are the uses of Travel time and delay studies? [8]
    b) Explain about Car-following theories. [8]

4. a) Explain the importance of road safety audit. [8]
    b) A fixed time 2-phase signal is to be provided at an intersection having a North-South and an East-West road where only straight ahead traffic is permitted. The design hour flows from the various arms and the saturation flows for these arms are given in the following table:

     | Design hour flow(q) in PCUs/hour | North | South | East | West |
     |---------------------------------|-------|-------|------|------|
     | Saturation flow(s) in PCUs/hour | 2400  | 2000  | 3000 | 3000 |

     Calculate the optimum cycle time and green times for the minimum overall delay. The inter green time should be the minimum necessary for efficient operation. The time lost per phase due to starting delays can be assumed to be 2 seconds. The value of the amber period is 2 seconds. Sketch the timing diagram for each phase. [8]

5. a) Discuss about various kinds of air pollutants? [8]
    b) What are the various categories in the generation of noise caused by road traffic? [8]

6. a) Explain the operating conditions of different levels of service as per HCM manual. [8]
    b) Discuss about Peak Hour Factor and Service Volume. [8]

7. a) Explain various IVHS categories used in the field of traffic engineering. [8]
    b) What are the various benefits of Intelligent vehicle highway systems? [8]
IV B.Tech II Semester Regular Examinations, April/May - 2017
TRAFFIC ENGINEERING
(Civil Engineering)

Time: 3 hours
Max. Marks: 70

Question paper consists of Part-A and Part-B
Answer ALL sub questions from Part-A
Answer any THREE questions from Part-B

PART-A (22 Marks)

1. a) What is a design vehicle? [3]
b) What is the principle used in the car following theory? [4]
c) Briefly discuss about location files and spot maps. [3]
d) What are the major pollutants emitted from road traffic? [4]
e) Define basic capacity. [4]
f) Define IVHS. [4]

PART-B (3x16 = 48 Marks)

2. a) What are the characteristics of road users? [8]
b) Explain various methods for determining the spot speed. [8]

3. a) Explain various microscopic and macroscopic flow characteristics. [8]
b) Discuss about density measurement techniques. [8]

4. a) Classify the different types of traffic signs and mention the general objective of each type of sign. Explain them with neat sketches. [8]
b) What are the advantages and disadvantages of traffic signals? [8]

5. a) What are the detrimental effects of traffic noise on environment? [8]
b) What are the measures for controlling air pollution from road traffic? [8]

6. a) Explain the capacity of freeways and express ways in rural areas. [8]

b) What are the benefits of IVHS? [8]
### 12. MID EXAM DESCRIPTIVE QUESTION PAPER WITH KEY

#### MID EXAM – I

<table>
<thead>
<tr>
<th>K. G. Reddy College of Engineering &amp; Technology</th>
<th>College Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Approved by AICTE, Affiliated to JNTUH)</td>
<td>QM</td>
</tr>
<tr>
<td>Chilkur (Vil), Moinabad (Mdl), RR District</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Name of the Exam:</th>
<th>I Mid Examinations</th>
<th>Marks: 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year-Sem &amp; Branch:</td>
<td>IV – I SEM</td>
<td>Duration: 60 Min</td>
</tr>
<tr>
<td>Subject:</td>
<td>Traffic Engineering</td>
<td>Date &amp; Session</td>
</tr>
</tbody>
</table>

**Answer ANY TWO of the following Questions**

1. Explain about analysis of road accidents?
2. What is meant by signal coordination?
3. What are the uses of travel time and delay studies?
4. Explain about car flowing theories.

#### MID EXAM – II

<table>
<thead>
<tr>
<th>K. G. Reddy College of Engineering &amp; Technology</th>
<th>College Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Approved by AICTE, Affiliated to JNTUH)</td>
<td>QM</td>
</tr>
<tr>
<td>Chilkur (Vil), Moinabad (Mdl), RR District</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Name of the Exam:</th>
<th>II Mid Examinations</th>
<th>Marks: 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year-Sem &amp; Branch:</td>
<td>IV – I SEM</td>
<td>Duration: 60 Min</td>
</tr>
<tr>
<td>Subject:</td>
<td>Traffic Engineering</td>
<td>Date &amp; Session</td>
</tr>
</tbody>
</table>

**Answer ANY TWO of the following Questions**

1. What is level of service and what are the factors affecting level of service.
2. Discuss about capacity and level of service on urban roads.
3. Explain the operating conditions of different as per HCM Manual
4. What are various benefits of intelligent highway systems?
Q1. The basic objective of traffic engineering is to achieve
a) Efficient, free and rapid flow of traffic with least priority given to accidents
b) Efficient, free and rapid flow of traffic with fewer accidents
c) Efficient and rapid flow of traffic
d) Rapid flow of traffic

Q2: The study of traffic engineering is divided into how many major categories?
a) Five  
b) Six  
c) Seven  
d) Eight

Q3: The first objective of the traffic volume studies is
a) To decide priority for improvement of roads  
b) For geometric design  
c) For computing roadway capacity  
d) To plan traffic operation

Q4: Which of the following method is more accurate for traffic analysis?
a) Manual count
b) Automatic count
b) Average of manual and automatic
d) Past records

5. The weaving manoeuvres is a type of
a) Merging
b) Diverging
c) Intersection
d) Crossing

6. Which of the following does not affect traffic flow?
a) Vehicles travelling at speed
b) Length of the vehicle
b) Weather conditions
d) Geometric design

7. To reduce the conflict points which method is preferable?
a) Restricting the entry in one side
b) Widening of the roads
c) Use of traffic signals
d) Diverting the traffic
8. One of the disadvantages of traffic signals is
   a) Provide orderly moment at intersection
   b) The quality of the traffic flow improves
   c) Traffic handling capacity increases
   d) The rear end collision increases

9. The first stage of parking lot is
   a) Entrance
   b) Acceptance
   c) Storage
   d) Delivery

10. Which of the following relationship is correct?
   a) Travel speed= running speed
   b) Travel speed< running speed
   c) Travel speed>running speed
   d) Travel speed=1.5 times of running speed

1. The traffic stream includes a combination of driver and vehicle behavior.
2. Speed is considered as a quality measurement of travel.
3. Parking Policy has a direct impact on vehicular ownership and road space use.
4. The manoeuvres associated with parking and unparking are known to cause road accidents.
5. Land use, transportation and road network plans are Inter linked.
6. The main cause of accidents in urban areas is Improper planning.
7. The time-space diagram is simply the plot of signal indications as a function of time for two or more signals.
8. A one-way street system has a number of advantages, not the least of which is traffic elimination of left turns against opposing traffic.
9. Reversible lanes are well suited for bridges and within tunnels because at these areas it is desirable to maintain adequate capacity within the restricted right-of-ways of work zones.
10. Shared Parking means that a parking facility serves multiple users or destinations.
UNIT-WISE LECTURE NOTES

UNIT-I

1. Traffic data collection

Overview

Unlike many other disciplines of the engineering, the situations that are interesting to a traffic engineer cannot be reproduced in a laboratory. Even if road and vehicles could be set up in large laboratories, it is impossible to simulate the behavior of drivers in the laboratory. Therefore, traffic stream characteristics need to be collected only from the field. There are several methods of data collection depending on the need of the study and some important ones are described in this chapter.

Data requirements

The most important traffic characteristics to be collected from the field includes speed, travel time, flow and density. Some cases, spacing and headway are directly measured. In addition, the occupancy, i.e. percentage of time a point on the road is occupied by vehicles is also of interest. The measurement procedures can be classified based on the geographical extent of the survey into five categories: (a) measurement at point on the road, (b) measurement over a short section of the road (less than 500 metres) (c) measurement over a length of the road (more than about 500 metres) (d) wide area samples obtained from number of locations, and (e) the use of an observer moving in the traffic stream. In each category, numerous data collection are there. However, important and basic methods will be discussed.

2. Measurements at a point

The most important point measurement is the vehicle volume count. Data can be collected manually or automatically. In manual method, the observer will stand at the point of interest and count the vehicles with the help of hand tallies. Normally, data will be collected for short interval of 5 minutes or 15 minutes etc. and for each types of vehicles like cars, two wheelers, three wheelers, LCV, HCV, multi axle trucks, nonmotorised traffic like bullock cart, hand cart etc. From the flow data, flow and headway can be derived.

Modern methods include the use of inductive loop detector, video camera, and many other technologies. These methods helps to collect accurate information for long duration. In video cameras, data is collected from the field and is then analyzed in the lab for obtaining results. Radars and microwave detectors are used to obtain the speed of a vehicle at a point. Since no length is involved, density cannot be obtained by measuring at a point.
3. **Measurements over short section**

The main objective of this study is to find the spot speed of vehicles. Manual methods include the use of enoscope. In this method a base length of about 30-90 metres is marked on the road. Enoscope is placed at one end and observer will stand at the other end. He could see the vehicle passing the farther end through enoscope and starts the stop watch. Then he stops the stop watch when the vehicle passes in front of him. The working of the enoscope is shown in figure 32:1.

An alternative method is to use pressure contact tube which gives a pressure signal when vehicle moves at either end. Another most widely used method is inductive loop detector which works on the principle of magnetic inductance. Road will be cut and a small magnetic loop is placed. When the metallic content in the vehicle passes over it, a signal will be generated and the count of the vehicle can be found automatically. The advantage of this detector is that the counts can be obtained throughout the life time of the road. However, chances of errors are possible because noise signals may be generated due to heavy vehicle passing adjacent lanes. When dual loops are used and if the spacing between them is known then speed also can be calculated in addition to the vehicle cost.

4. **Measurements over long section**

This is normally used to obtain variations in speed over a stretch of road. Usually the stretch will be having a length more than 500 metres. We can also get density. Most traditional method uses aerial photography. From a single frame, density can be measured, but not speed or volumes. In time lapse photography, several frames are available. If several frames are obtained over short time intervals, speeds can be measured from the distance covered between the two frames and time interval between them.

5. **Moving observer method for stream measurement**

Determination of any of the two parameters of the traffic flow will provide the third one by the equation \( q = u.k \). Moving observer method is the most commonly used method to get the relationship between the fundamental stream characteristics. In this method, the observer moves in the traffic stream unlike all other previous methods.

Consider a stream of vehicles moving in the north bound direction. Two different cases of motion can be considered. The first case considers the traffic stream to be moving and the observer to be stationary. If \( n_o \) is the number of vehicles overtaking the observer during a period, \( t \), then flow \( q \) is \( n_0 \), or

\[
\text{n}_0 = q \times t
\]  

(32.1)

The second case assumes that the stream is stationary and the observer moves with speed \( v_o \). If \( n_p \) is the number of vehicles overtaken by observer over a length \( d \), then by definition, density \( k \) is \( n_p \), or
\[ n_p = k \times l \quad (32.2) \]

or

\[ n_p = k \cdot v_o \cdot t \quad (32.3) \]

where \( v_0 \) is the speed of the observer and \( t \) is the time taken for the observer to cover the road stretch. Now consider the case when the observer is moving within the stream. In that case \( m_o \) vehicles will overtake the observer and \( m_p \) vehicles will be overtaken by the observer in the test vehicle. Let the difference \( m \) is given by \( m_o - m_p \), then from equation 32.5 and equation 32.7,

\[ m = q \cdot t - k \cdot v_o \cdot t \quad (32.4) \]

This equation is the basic equation of moving observer method, which relates \( q, k \) to the counts \( m, t \) and \( v_o \) that can be obtained from the test. However, we have two unknowns, \( q \) and \( k \), but only one equation. For generating another equation, the test vehicle is run twice once with the traffic stream and another one against traffic stream, i.e.

\[ m_w = q \cdot t_w + k \cdot v_w \]

\[ = q \cdot t_w + k \cdot l \cdot m_a = q \cdot t_w - k \cdot v_a \cdot t_a = q \cdot t_a - k \cdot l \]

where, \( a, w \) denotes against and with traffic flow. It may be noted that the sign of equation 32.5 is negative, because test vehicle moving in the opposite direction can be considered as a case when the test vehicle is moving in the stream with negative velocity. Further, in this case, all the vehicles will be overtaking, since it is moving with negative speed. In other words, when the test vehicle moves in the opposite direction, the observer simply counts the number of vehicles in the opposite direction. Adding equation 32.5 and 32.5, we will get the first parameter of the stream, namely the flow\((q)\) as:

\[ q = \frac{m_w + m_a}{t_w + t_a} \quad (32.5) \]

Now calculating space mean speed from equation 32.5,

\[ \frac{m_w}{t_w} = q - k \cdot v_w \cdot t \]

\[ = q - \frac{q}{v} \sum_{l} l \sum_{w} \]

\[ = q - \frac{q}{v} t_w \]

\[ = q(1 \quad l \quad 1) \]

\[ - v \times t_w \]
$$= q (1 - \frac{t_{avg}}{t_w})$$

If $v_s$ is the mean stream speed, then average travel time is given by $t_{avg} = \frac{l}{v_s}$. Therefore,

$$\frac{m_w}{q} = t_w \left(1 - \frac{t_{avg}}{l/m_w}\right) = -t_{avg}$$

$$t_{avg} = t_w \frac{m_w}{q} = \frac{l}{v_s}$$

Rewriting the above equation, we get the second parameter of the traffic flow, namely the mean speed $v_s$ and can be written as,
\[ v_s = \frac{m_w}{m_{w} + m_{v}} w - q^{32.6} \]

Thus two parameters of the stream can be determined. Knowing the two parameters the third parameter of traffic flow density \( (k) \) can be found out as

\[ k = \frac{q}{v_s} \]  \hspace{1cm} (32.7)

For increase accuracy and reliability, the test is performed a number of times and the average results are to be taken.

Example 1

The length of a road stretch used for conducting the moving observer test is 0.5 km and the speed with which the test vehicle moved is 20 km/hr. Given that the number of vehicles encountered in the stream while the test vehicle was moving against the traffic stream is 107, number of vehicles that had overtaken the test vehicle is 10, and the number of vehicles overtaken by the test vehicle is 74, find the flow, density and average speed of the stream.

<table>
<thead>
<tr>
<th>Sample no.</th>
<th>( h )</th>
<th>( r_w )</th>
<th>( m )</th>
<th>( m_{w} )</th>
<th>( m_{v} )</th>
<th>( q )</th>
<th>( q )</th>
<th>( q )</th>
<th>( q )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>107</td>
<td>1</td>
<td>74</td>
<td>-64</td>
<td>0.025</td>
<td>0.025</td>
<td>860</td>
<td>5.03</td>
<td>171</td>
</tr>
<tr>
<td>2</td>
<td>30</td>
<td>5</td>
<td>10</td>
<td>0.025</td>
<td>0.025</td>
<td>0.025</td>
<td>800</td>
<td>4</td>
<td>20</td>
</tr>
<tr>
<td>3</td>
<td>5</td>
<td>9</td>
<td>0</td>
<td>0.025</td>
<td>0.025</td>
<td>1760</td>
<td>25.14</td>
<td>70</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>79</td>
<td>1</td>
<td>9</td>
<td>800</td>
<td>400</td>
<td>1760</td>
<td>25.14</td>
<td>70</td>
<td></td>
</tr>
</tbody>
</table>

Solution: Time taken by the test vehicle to reach the other end of the stream while it is moving along with the traffic is \( t_w = 0.5 = 0.025 \) hr. Time taken by the observer to reach the other end of the stream while it is moving against the traffic is \( t_a = 0.025 \) hr. Flow is given by equation, \( q = \frac{107\times 10 - 74}{t_a + t_w} = 860 \) veh/hr. Stream density can be found out from equation as

\[ 0.025 = \frac{5}{0.025 - 0.74} \]

<table>
<thead>
<tr>
<th>Column 1</th>
<th>Column 2</th>
<th>Column 3</th>
<th>Column 4</th>
<th>Column 5</th>
<th>Column 6</th>
<th>Column 7</th>
<th>Column 8</th>
<th>Column 9</th>
<th>Column 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample no.</td>
<td>( h )</td>
<td>( r_w )</td>
<td>( m )</td>
<td>( m_{w} )</td>
<td>( m_{v} )</td>
<td>( q )</td>
<td>( q )</td>
<td>( q )</td>
<td>( q )</td>
</tr>
<tr>
<td>1</td>
<td>107</td>
<td>1</td>
<td>74</td>
<td>-64</td>
<td>0.025</td>
<td>0.025</td>
<td>860</td>
<td>5.03</td>
<td>171</td>
</tr>
<tr>
<td>2</td>
<td>30</td>
<td>5</td>
<td>10</td>
<td>0.025</td>
<td>0.025</td>
<td>0.025</td>
<td>800</td>
<td>4</td>
<td>20</td>
</tr>
<tr>
<td>3</td>
<td>5</td>
<td>9</td>
<td>0</td>
<td>0.025</td>
<td>0.025</td>
<td>1760</td>
<td>25.14</td>
<td>70</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>79</td>
<td>1</td>
<td>9</td>
<td>800</td>
<td>400</td>
<td>1760</td>
<td>25.14</td>
<td>70</td>
<td></td>
</tr>
</tbody>
</table>

\[ v_s = \frac{m_w}{m_{w} + m_{v}} w - q^{32.6} \]
\[ k = \frac{860}{5} = 172 \text{veh/km} \]

Example 2

The data from four moving observer test methods are shown in the table. Column 1 gives the sample number, column 2 gives the number of vehicles moving against the stream, column 3 gives the number of vehicles that had overtaken the test vehicle, and last column gives the number of vehicles overtaken by the test vehicle. Find the three fundamental stream parameters for each set of data. Also plot the fundamental diagrams of traffic flow.

Traffic engineering studies differ from other studies in the fact that they require extensive data from the field which cannot be exactly created in any laboratory. Speed data are collected from measurements at a point or over a short section or over an area. Traffic flow data are collected at a point. Moving observer method is one in which both speed and traffic flow data are obtained by a single experiment.
UNIT 2

Overview

Parking is one of the major problems that is created by the increasing road traffic. It is an impact of transport development. The availability of less space in urban areas has increased the demand for parking space especially in areas like Central business district. This affects the mode choice also. This has a great economical impact.

Parking studies

Before taking any measures for the betterment of conditions, data regarding availability of parking space, extent of its usage and parking demand is essential. It is also required to estimate the parking fares also. Parking surveys are intended to provide all these information. Since the duration of parking varies with different vehicles, several statistics are used to access the parking need.

Parking statistics

Parking accumulation: It is defined as the number of vehicles parked at a given instant of time. Normally this is expressed by accumulation curve. Accumulation curve is the graph obtained by plotting the number of bays occupied with respect to time.

Parking volume: Parking volume is the total number of vehicles parked at a given duration of time. This does not account for repetition of vehicles. The actual volume of vehicles entered in the area is recorded.

Parking load: Parking load gives the area under the accumulation curve. It can also be obtained by simply multiplying the number of vehicles occupying the parking area at each time interval with the time interval. It is expressed as vehicle hours.

Average parking duration: It is the ratio of total vehicle hours to the number of vehicles parked.

Parking turnover: It is the ratio of number of vehicles parked in a duration to the number of parking bays available.
Parking index: Parking index is also called occupancy or efficiency. It is defined as the ratio of number of bays occupied in a time duration to the total space available. Illustrate the various measures, consider a small example in figure 38:1, which shows the duration for which each of the bays are occupied (shaded portion). Now the accumulation graph can be plotted by simply noting the number of bays occupied at time interval of 15, 30, 45 etc.

Parking surveys

Parking surveys are conducted to collect the above said parking statistics. The most common parking surveys conducted are in-out survey, fixed period sampling and license plate method of survey.

1. In-out survey: In this survey, the occupancy count in the selected parking lot is taken at the beginning. Then the number of vehicles that enter the parking lot for a particular time interval is counted. The number of vehicles that leave the parking lot is also taken. The final occupancy in the parking lot is also taken. Here the labor required is very less. Only one person may be enough. But we wont get any data regarding the time duration for which a particular vehicle used that parking lot. Parking duration and turn over is not obtained. Hence we cannot estimate the parking fare from this survey.

2. Fixed period sampling: This is almost similar to in-out survey. All vehicles are counted at the beginning of the survey. Then after a fixed time interval that may vary between 15 minutes to 1 hour, the count is again taken. Here there are chances of missing the number of vehicles that were parked for a short duration.

3. License plate method of survey: This results in the most accurate and realistic data. In this case of survey, every parking stall is monitored at a continuous interval of 15 minutes or so and the license plate number is noted down. This will give the data regarding the duration for which a particular vehicle was using the parking bay. This will help in calculating the fare because fare is estimated based on the duration for which the vehicle was parked. If the time interval is shorter, then there are less chances of missing short-term parkers. But this method is very labor intensive.
**Ill effects of parking**

Parking has some ill-effects like congestion, accidents, pollution, obstruction to firefighting operations etc.

**Congestion:** Parking takes considerable street space leading to the lowering of the road capacity. Hence, speed will be reduced, journey time and delay will also subsequently increase. The operational cost of the vehicle increases leading to great economical loss to the community.

**Accidents:** Careless maneuvering of parking and unparking leads to accidents which are referred to as parking accidents. Common type of parking accidents occur while driving out a car from the parking area, careless opening of the doors of parked cars, and while bringing in the vehicle to the parking lot for parking.

**Environmental pollution:** They also cause pollution to the environment because stopping and starting of vehicles while parking and unparking results in noise and fumes. They also affect the aesthetic beauty of the buildings because cars parked at every available space creates a feeling that building rises from a plinth of cars.

**Obstruction to firefighting operations:** Parked vehicles may obstruct the movement of firefighting vehicles. Sometimes they block access to hydrants and access to buildings.

**Parking requirements**

There are some minimum parking requirements for different types of building. For residential plot area less than 300 sq.m require only community parking space. For residential plot area from 500 to 1000 sq.m, minimum one-fourth of the open area should be reserved for parking. Offices may require at least one space for every 70 sq.m as parking area. One parking space is enough for 10 seats in a restaurant whereas theatres and cinema halls need to keep only 1 parking space for 20 seats. Thus, the parking requirements are different for different land use zones.

**On street parking**

On street parking means the vehicles are parked on the sides of the street itself. This will be usually controlled by government agencies itself. Common types of on-street parking are as listed below. This classification is based on the angle in which the
vehicles are parked with respect to the road alignment. As per IRC the standard dimensions of a car is taken as 5× 2.5 metres and that for a truck is 3.75× 7.5 metres.

Parallel parking: The vehicles are parked along the length of the road. Here there is no backward movement involved while parking or unparking the vehicle. Hence, it is the most safest parking from the accident perspective. However, it consumes the maximum curb length and therefore only a minimum number of vehicles can be parked for a given kerb length. This method of parking produces least obstruction to the on-going traffic on the road since least road width is used. Parallel parking of cars is shown in figure 38:2. The length available to park \( N \) number of vehicles, \( L = \frac{N}{5} \).

30° parking: In thirty degree parking, the vehicles are parked at 30° with respect to the road alignment. In this case, more vehicles can be parked compared to parallel parking. Also there is better maneuver- ability. Delay caused to the traffic is also minimum in this type of parking.

45° parking: As the angle of parking increases, more number of vehicles can be parked ____________
Hence compared to parallel parking and thirty degree parking, more number of vehicles can be accommodated in this type of parking. From figure 38:4, length of parking space available for parking $N$ number of vehicles in a given kerb is $L = 3.54 \, N + 1.77$

60° parking: The vehicles are parked at 60° to the direction of road. More number of vehicles can be accommodated in this parking type. From the figure 38:5, length available for parking $N$ vehicles = $2.89N + 2.16$.

![Figure 38:4: Illustration of 45° parking](image)

![Figure 38:5: Illustration of 60° parking](image)

Right angle parking: In right angle parking or 90° parking, the vehicles are parked perpendicular to the direction of the road. Although it consumes maximum width kerb length required is very little. In this type of parking, the vehicles need complex maneuvering and this may cause severe accidents. This arrangement causes obstruction to the road traffic particularly if the road width is less. However, it can accommodate maximum number of vehicles for a given kerb length. An example is shown in figure 38:6. Length available for parking $N$ number of vehicles is $L = 2.5N$.

**Off street parking**

In many urban centres, some areas are exclusively allotted for parking which will be at some distance away from the main stream of traffic. Such a parking is referred to as off-street parking. They may be operated by either public agencies or private
Example 1
From an in-out survey conducted for a parking area consisting of 40 bays, the initial count was found to be 25. Table gives the result of the survey. The number of vehicles coming in and out of the parking lot for a time interval of 5 minutes.

Accumulation can be found out as initial count plus number of vehicles that entered the parking lot till that time minus the number of vehicles that just exited for that particular time interval. For the first time interval of 5 minutes, accumulation can be found out as $25+3-2 = 26$. It is being tabulated in column 4.

Example 2
The parking survey data collected from a parking lot by license plate method is shown in the table 38:3 below. Find the average occupancy, average turn over, parking load, parking capacity and efficiency of the parking lot.
Solution See the following table for solution 38:4. Columns 1 to 5 is the input data. The parking status in every bay is coded first. If a vehicle occupies that bay for that time interval, then it has a code 1. This is shown in columns 6, 7, 8 and 9 of the table corresponding to the time intervals 15, 30, 45 and 60 seconds.

Turn over is computed as the number of vehicles present in that bay for that particular hour. For the first bay, it is counted as 3. Similarly, for the second bay, one vehicle is present throughout that hour and hence turnout is 1 itself. This is being tabulated in column 10 of the table. Average turn over =

Accumulation for a time interval is the total of number of vehicles in the bays 1 to 12 for that time interval. Accumulation for first time interval of 15 minutes = 1+1+1+1+0+0+1+1+1+1+1+1 = 10

Parking volume = Sum of the turn over in all the bays = 27 vehicles

Average duration is the average time for which the parking lot was used by the vehicles. It can be calculated as sum of the accumulation for each time interval × time interval divided by the parking volume = (10+11+9+11)×15 = 22.78 minutes/vehicle.

Occupancy for that time interval is accumulation in that particular interval divided by total number of bays. For first time interval of 15 minutes, occupancy = (10×100)/12 = 83% Average occupancy is found out as the average of total number of vehicles occupying the bay for each time interval.

Summary

Providing suitable parking spaces is a challenge for traffic engineers and planners in the scenario of ever increasing vehicle population. It is essential to conduct traffic surveys in order to design the facilities or plan the fares.
UNIT 3

Capacity and Level of service

Overview

Capacity and Level of service are two related terms. Capacity analysis tries to give a clear understanding of how much traffic a given transportation facility can accommodate. Level of service tries to answer how good is the present traffic situation on a given facility. Thus it gives a qualitative measure of traffic, whereas capacity analysis gives a quantitative measure of a facility. Capacity and level of service varies with the type of facility, prevailing traffic and road conditions etc. These concepts are discussed in this chapter.

Capacity

Capacity is defined as the maximum number of vehicles, passengers, or the like, per unit time, which can be accommodated under given conditions with a reasonable expectation of occurrence. Some of the observations that are found from this definition can be now discussed. Capacity is independent of the demand. It speaks about the physical amount of vehicles and passengers a road can afford. It does not depend on the total number of vehicles demanding service. On the other hand, it depends on traffic conditions, geometric design of the road etc. For example, a curved road has lesser capacity compared to a straight road. Capacity is expressed in terms of units of some specific thing (car, people, etc.), so it also does depend on the traffic composition. In addition, the capacity analysis depends on the environmental conditions too. Capacity is a probabilistic measure and it varies with respect to time and position. Hence it is not always possible to completely derive analytically the capacity. In most cases it is obtained, through field observations.

Level of service

A term closely related to capacity and often confused with it is service volume. When capacity gives a quantitative measure of traffic, level of service or LOS tries to give a qualitative measure. A service volume is the maximum number of vehicles, passengers, or the like, which can be accommodated by a given facility or system under given conditions at a given level of service.

For a given road or facility, capacity could be constant. But actual flow will be different for different days and different times in a day itself. The intention of LOS is to relate the traffic service quality to a given flow rate of traffic. It is a term that designates a range of operating conditions on a particular type of facility. Highway capacity manual (HCM) developed by the transportation research board of USA provides some procedure to determine level of service. It divides the quality of traffic into six levels ranging from level A to level F. Level
A represents the best quality of traffic where the driver has the freedom to drive with free flow speed and level F represents the worst quality of traffic. Level of service is defined based on the measure of effectiveness or (MOE). Typically three parameters are used under this and they are speed and travel time, density, and delay. One of the important measures of service quality is the amount of time spent in travel. Therefore, speed and travel time are considered to be more effective in defining LOS of a facility. Density gives the proximity of other vehicles in the stream. Since it affects the ability of drivers to maneuver in the traffic stream, it is also used to describe LOS. Delay is a term that describes excess or unexpected time spent in travel. Many specific delay measures are defined and used as MOE’s in the highway capacity manual.

Types of facilities

Most important classification of transportation facilities from the engineering perspective is based on the continuity of flow, that is uninterrupted flow and interrupted flow. Uninterrupted flow is the flow of traffic in which there is no obstructions to the movement of vehicles along the road. Freeway is one example for this type of facility. In a freeway, when a vehicle enters a freeway, there is no need for the vehicle to stop anywhere till it leaves the freeway. There are three sections in a freeway - basic unit, weaving section and ramps(on/off). Vehicles will be entering the freeway through ramps. Ramps used for entering the freeway is called on-ramps and those used for exiting the freeway are called off-ramps. Freeways generally have 4, 6, or 8 lane alignments. Multi lanes also provide uninterrupted flow. HCM defines the levels of service of freeway sections based on density, as described in tables 35:1 and 35:2.

Table 35:1: LOS for a basic freeway segment

<table>
<thead>
<tr>
<th>LOS</th>
<th>K</th>
<th>FFS</th>
<th>v/c</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(veh/km/lane)</td>
<td>(Km/hr)</td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>0-7</td>
<td>120</td>
<td>0.35</td>
</tr>
<tr>
<td>B</td>
<td>7-11</td>
<td>120</td>
<td>0.55</td>
</tr>
<tr>
<td>C</td>
<td>11-16</td>
<td>114</td>
<td>0.77</td>
</tr>
<tr>
<td>D</td>
<td>16-22</td>
<td>99</td>
<td>0.92</td>
</tr>
<tr>
<td>E</td>
<td>22-28</td>
<td>85</td>
<td>1.0</td>
</tr>
<tr>
<td>F</td>
<td>&gt;28</td>
<td>&lt;85</td>
<td>&gt;1.0</td>
</tr>
</tbody>
</table>

In many roads, there will be signalized as well as unsignalized intersections. Uninterrupted flow is possible in sections of rural and suburban multilane highways between signalized intersections where signal spacing is sufficient to allow for uninterrupted flow. Two lane highways also provide uninterrupted flow facilities.

Interrupted flow refers to the condition when the traffic flow on the road is obstructed due to some
reasons. This is experienced in signalized intersections, unsignalized intersections, arterials etc. At signalized intersections, there will be some kind of active control and the vehicle will have to stop or sometimes to reduce its speed and the flow of traffic is interrupted. Thus the capacity is defined in terms of control delay i.e. sec/veh. Arterials are roads of long stretches with many intersections in between and obviously there will be interruption to the flow of traffic. Here, the capacity is expressed in terms of average travel speed. Some other facilities are facilities for pedestrians, bicycles, bus-transit, rail-transit etc. Example for pedestrian facility is a provision of subway exclusively for the use of pedestrians. Here, the capacity may be expressed in terms of number of passengers. In bus transit system, the buses has to stop at the bus bays and also it has to share the road with the other vehicles. Hence the capacity will be affected by the control characteristics and the traffic conditions prevailing in the road. Since trains have exclusive right of way, the capacity is strictly governed by the control characteristics. It has two types of capacities - line capacity and station capacity. Line capacity is based on the number of tracks available between two stations. Station capacity refers to the facilities available in the platform of the station, and other facilities.

For uninterrupted flow of traffic, measure of effectiveness (MOE) is density in freeways. Speed also becomes important in two-lane highways and multilane highways. In the case of interrupted flow, MOE is delay. The delay of travel time becomes an important factor in calculating the capacity.

**Highway capacity**

Highway capacity is defined by the Highway Capacity Manual as the maximum hourly rate at which persons or vehicles can be reasonably expected to traverse a point or a uniform segment of a lane or roadway during a given time period under prevailing roadway, traffic and control conditions. The highway capacity depends on certain conditions as listed below;

1. **Traffic conditions:** It refers to the traffic composition in the road such as the mix of cars, trucks, buses etc in the stream. It also include peaking characteristics, proportions of turning movements at intersections and the like.

<table>
<thead>
<tr>
<th>LOS</th>
<th>Control Delay sec/veh(signalised)</th>
<th>Delay sec/veh(unsignalised)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>≤ 10</td>
<td>≤ 10</td>
</tr>
<tr>
<td>B</td>
<td>10-20</td>
<td>10-15</td>
</tr>
<tr>
<td>C</td>
<td>20-35</td>
<td>15-25</td>
</tr>
<tr>
<td>D</td>
<td>35-55</td>
<td>25-35</td>
</tr>
<tr>
<td>E</td>
<td>55-80</td>
<td>35-60</td>
</tr>
<tr>
<td>F</td>
<td>&gt; 80</td>
<td>&gt; 50</td>
</tr>
</tbody>
</table>
2. Roadway characteristics: This points out to the geometric characteristics of the road. These include lane width, shoulder width, lane configuration, horizontal alignment and vertical alignment.

3. Control conditions: This primarily applies to surface facilities and often refer to the signals at intersections etc.

Again capacity can be defined for a point or uniform section. Capacity is estimated for segments having uniform conditions. Points where these conditions change represent the boundaries where separate analysis may be required. Capacity is the maximum flow rate that a facility can afford. This maximum flow rate is taken for the worst 15 minutes of the peak hours while finding out the capacity. Capacity is measured as a reasonably expected value and not the maximum flow rate ever observed in the facility. This is because the measured capacity at a single location will show significant variation from day to day. Further, local driving habits also produce variations in the observed capacity.

**Factors affecting level of service**

The level of service can be derived from a road under different operating characteristics and traffic volumes. The factors affecting level of service (LOS) can be listed as follows:

4. Speed and travel time
5. Traffic interruptions/restrictions

6. Freedom to travel with desired speed

7. Driver comfort and convenience

8. Operating cost.

Highway Capacity Manual (HCM) used travel speed and volume by capacity ratio (v/c ratio) to distinguish between various levels of service. The value of v/c ratio can vary between 0 and 1. Depending upon the travel speed and v/c ratio, HCM has defined six levels of service, level A to level F based on a graph between operating speed and v/c ratio as shown in the figure 35:1. Level of service A represents the zone of free flow. Here the traffic volume will be less, traffic will be experiencing free flow also. The drivers will be having the complete freedom to choose their desired speed. Even at maximum density, for this LOS the average spacing between vehicles is 167 m. Lane changes within the traffic stream, as well as merging and diverging movements, are made relatively easy. The effect of minor incidents and point breakdowns are easily aborted at this level.

Level of service B represents zone of reasonably free flow. Free flow speeds are still maintained at this level of service. The drivers freedom to choose their desired speed is only slightly restricted. The lowest average spacing between vehicles is about 100 m. The effects of small incidents and point breakdowns are still easily contained.

At level of service C, the presence of other vehicles begins to restrict the maneuverability within the traffic stream. Average speeds remain at or near the free flow speed level, but significant increase in driver vigilance is required at this level. Minimum average spacing between the vehicles is in the range of 67 m. Queues may be expected to form behind any significant blockage. At level of service D, the average speeds begin to decline with increasing flows. Freedom to maneuver within the traffic stream is noticeably restricted. At this level, density deteriorates more quickly with flow. The spacing between the vehicles is about 50 m. As the traffic stream has little space to absorb disruptions, minor incidents can lead to queuing of vehicles. Level of service E define operation at capacity. At this level, the stream reaches it’s maximum density limit. There will be no usable gaps in the stream and even slight disruptions will cause a breakdown, with queues forming rapidly behind the disruption. Maneuvering within the traffic stream becomes extremely difficult. Level of service F describes conditions in a queue that has formed behind a point of breakdown or disruption. As vehicles shuffle through the queue, there may be periods when they move quickly, and others when they are stopped completely. Thus this level of service is used to describe the point of breakdown as well, eventhough operations downstream of such a breakdown may appear good. Level of service F represents the region of forced flow, having low speed, and complete breakdown of the system.
Summary

Capacity and level of service are two important terms applied to traffic operation and are given suitable definitions by highway capacity manual. Capacity represents the ability of the system to handle traffic whereas level of service looks at the system from the drivers perspective. The fundamental diagrams of traffic flow can be used in the representation of level of service. Level of service ranges from level A to F, representing the free flow conditions and F representing the worst traffic conditions like less speed, high density etc.
UNIT 4

Traffic Signal Design - I

The conflicts arising from movements of traffic in different directions is solved by time sharing of the principle. The advantages of traffic signal include an orderly movement of traffic, an increased capacity of the intersection and requires only simple geometric design. However the disadvantages of the signalized intersection are it affects larger stopped delays, and the design requires complex considerations. Although the overall delay may be lesser than a rotary for a high volume, a user is more concerned about the stopped delay.

Definitions and Notations

A number of definitions and notations need to be understood in signal design. They are discussed below:

- Cycle: A signal cycle is one complete rotation through all of the indications provided.

- Cycle length: Cycle length is the time in seconds that it takes a signal to complete one full cycle of indications. It indicates the time interval between the starting of green for one approach till the next time the green starts. It is denoted by $C$.

- Interval: Thus it indicates the change from one stage to another. There are two types of intervals - change interval and clearance interval. Change interval is also called the yellow time indicates the interval between the green and red signal indications for an approach. Clearance interval is also called all red is included after each yellow interval indicating a period during which all signal faces show red and is used for clearing off the vehicles in the intersection.

- Green interval: It is the green indication for a particular movement or set of movements and is denoted by $tt_i$. This is the actual duration the green light of a traffic signal is turned on.

- Red interval: It is the red indication for a particular movement or set of movements and is denoted by $R_i$. This is the actual duration the red light of a traffic signal is turned on.

- Phase: A phase is the green interval plus the change and clearance intervals that follow it. Thus, during green interval, non conflicting movements are assigned into each phase. It allows a set of movements to flow and safely halt the flow before the phase of another set of movements start.

- Lost time: It indicates the time during which the intersection is not effectively utilized for any movement. For example, when the signal for an approach turns from red to green, the driver of the vehicle which is
in the front of the queue, will take some time to perceive the signal (usually called as reaction time) and some time will be lost here before he moves.

**Phase design**

The signal design procedure involves six major steps. They include the (1) phase design, (2) determination of amber time and clearance time, (3) determination of cycle length, (4) apportioning of green time, (5) pedestrian crossing requirements, and (6) the performance evaluation of the above design. The objective of phase design is to separate the conflicting movements in an intersection into various phases, so that movements in a phase should have no conflicts. If all the movements are to be separated with no conflicts, then a large number of phases are required. In such a situation, the objective is to design phases with minimum conflicts or with less severe conflicts.

There is no precise methodology for the design of phases. This is often guided by the geometry of the intersection, flow pattern especially the turning movements, the relative magnitudes of flow. Therefore, a trial and error procedure is often adopted. However, phase design is very important because it affects the further design steps. Further, it is easier to change the cycle time and green time when flow pattern changes, where as a drastic change in the flow pattern may cause considerable confusion to the drivers. To illustrate various phase plan options, consider a four legged intersection with through traffic and right turns. Left turn is ignored. See figure 41:1. The first issue is to decide how many phases are required. It is possible to have two, three, four or even more number of phases.
Two phase signals

Two phase system is usually adopted if through traffic is significant compared to the turning movements. For example in figure 41:2, non-conflicting through traffic 3 and 4 are grouped in a single phase and non-conflicting through traffic 1 and 2 are grouped in the second phase. However, in the first phase flow 7 and 8 offer some conflicts and are called permitted right turns. Needless to say that such phasing is possible only if the turning movements are relatively low. On the other hand, if the turning movements are significant, then a four phase system is usually adopted.

Phase 1 (P1)  Phase 1 (P2)

Figure 41:2: Two phase signal

Phase 2 (P3)  Phase 2 (P4)

Figure 41:3: One way of providing four phase signals

Four phase signals

There are at least three possible phasing options. For example, figure 41:3 shows the most simple and trivial phase plan, where, flow from each approach is put into a single phase avoiding all conflicts. This type of phase plan is ideally suited in urban areas
where the turning movements are comparable with through movements and when through traffic and turning traffic need to share same lane. This phase plan could be very inefficient when turning movements are relatively low.

Figure 41:4 shows a second possible phase plan option where opposing through traffic are put into same phase. The non-conflicting right turn flows 7 and 8 are grouped into a third phase. Similarly flows 5 and 6 are grouped into fourth phase. This type of phasing is very efficient when the intersection geometry permits to have at least one lane for each movement, and the through traffic volume is significantly high. Figure 41:5 shows yet another phase plan. However, this is rarely used in practice.

There are five phase signals, six phase signals etc. They are normally provided if the intersection control is adaptive, that is, the signal phases and timing adapt to the real time traffic conditions.

Figure 41:4: Second possible way of providing a four phase signal

Figure 41:5: Third possible way of providing a four-phase signal
Interval design

There are two intervals, namely the change interval and clearance interval, normally provided in a traffic signal. The change interval or yellow time is provided after green time for movement. The purpose is to warn a driver approaching the intersection during the end of a green time about the coming of a red signal. They normally have a value of 3 to 6 seconds.

The design consideration is that a driver approaching the intersection with design speed should be able to stop at the stop line of the intersection before the start of red time. Institute of transportation engineers (ITE) has recommended a methodology for computing the appropriate length of change interval which is as follows:

\[ y = t + \frac{v_{85}}{2a} + 19.6g \]
where $y$ is the length of yellow interval in seconds, $t$ is the reaction time of the driver, $v_{85}$ is the $85^{th}$ percentile speed of approaching vehicles in m/s, $a$ is the deceleration rate of vehicles in m/s$^2$, $g$ is the grade of approach expressed as a decimal. Change interval can also be approximately computed as $y = \frac{SSD}{v}$, where SSD is the stopping sight distance and $v$ is the speed of the vehicle. The clearance interval is provided after yellow interval and as mentioned earlier, it is used to clear off the vehicles in the intersection. Clearance interval is optional in a signal design. It depends on the geometry of the intersection. If the intersection is small, then there is no need of clearance interval whereas for very large intersections, it may be provided.

**Cycle time**

Cycle time is the time taken by a signal to complete one full cycle of iterations. i.e. one complete rotation through all signal indications. It is denoted by $C$. The way in which the vehicles depart from an intersection when the green signal is initiated will be discussed now. Figure 41:6 illustrates a group of $N$ vehicles at a signalized intersection, waiting for the green signal. As the signal is initiated, the time interval between two vehicles, referred as headway, crossing the curb line is noted. The first headway is the time interval between the initiation of the green signal and the instant vehicle crossing the curb line. The second headway is the time interval between the first and the second vehicle crossing the curb line. Successive headways are then plotted as in figure 41:7. The first headway will be relatively longer since it includes the reaction time of the driver and the time necessary to accelerate. The second headway will be comparatively lower because the second driver can overlap his/her reaction time with that of the first driver’s. After few vehicles, the headway will become constant. This constant headway which characterizes all headways beginning with the fourth or fifth vehicle, is defined as the saturation headway, and is denoted as $h$. This is the headway that can be achieved by a stable

![Figure 41:7: Headways departing signal](image)

moving platoon of vehicles passing through a green indication. If every vehicles require
$h$ seconds of green time, and if the signal were always green, then $s$ vehicles/per hour would pass the intersection. Therefore,

$$s = \frac{3600}{h} \quad (41.2)$$

where $s$ is the saturation flow rate in vehicles per hour of green time per lane, $h$ is the saturation headway in seconds. vehicles per hour of green time per lane. As noted earlier, the headway will be more than $h$ particularly for the first few vehicles. The difference between the actual headway and $h$ for the $i^{th}$ vehicle and is denoted as $e_i$ shown in figure 41:7. These differences for the first few vehicles can be added to get start up lost time, $l_1$ which is given by,

$$l_1 = \frac{n}{e_i} \quad (41.3)$$

i=1

The green time required to clear N vehicles can be found out as,

$$T = l_1 + h.N \quad (41.4)$$

where $T$ is the time required to clear N vehicles through signal, $l_1$ is the start-up lost time, and $h$ is the saturation headway in seconds.

**Effective green time**

Effective green time is the actual time available for the vehicles to cross the intersection. It is the sum of actual green time ($tt_i$) plus the yellow minus the applicable lost times. This lost time is the sum of start-up lost time ($l_1$) and clearance lost time ($l_2$) denoted as $t_L$. Thus effective green time can be written as,

$$g_i = tt_i + Y_i - t_L \quad (41.5)$$

**Lane capacity**

The ratio of effective green time to the cycle length ($\frac{g_i}{C}$) is defined as green ratio. We know that saturation flow rate is the number of vehicles that can be moved in one lane in one hour assuming the signal to be green always.

Then the capacity of a lane can be computed as,

$$\frac{c_{gi}}{i} = \frac{s}{h} \quad (41.6)$$
where $c_i$ is the capacity of lane in vehicle per hour, $s_i$ is the saturation flow rate in vehicle per hour per lane, $C$ is the cycle time in seconds.

**Problem**

Let the cycle time of an intersection is 60 seconds, the green time for a phase is 27 seconds, and the corresponding yellow time is 4 seconds. If the saturation headway is 2.4 seconds/vehicle, the start-up lost time is 2 seconds/phase, and the clearance lost time is 1 second/phase, find the capacity of the movement per lane?

**Solution**

Total lost time, $t_L = 2 + 1 = 3$ seconds. From equation effective green time, $g_i = 27 + 4 - 3 = 28$ seconds. From equation saturation flow rate, $s_i = \frac{3600}{28} = 150$ veh/hr. Capacity of the given phase can be found out from equation, $C_i = 500 \times \frac{28}{2.4} = 700$ veh/hr/lane.

**Critical lane**

During any green signal phase, several lanes on one or more approaches are permitted to move. One of these will have the most intense traffic. Thus it requires more time than any other lane moving at the same time. If sufficient time is allocated for this lane, then all other lanes will also be well accommodated. There will be one and only one critical lane in each signal phase. The volume of this critical lane is called critical lane volume.

**Determination of cycle length**

The cycle length or cycle time is the time taken for complete indication of signals in a cycle. Fixing the cycle length is one of the crucial steps involved in signal design.

If $t_{Li}$ is the start-up lost time for a phase $i$, then the total start-up lost time per cycle, $L = \sum_{i=1}^{N} t_{Li}$, where $N$ is the number of phases. If start-up lost time is same for all phases, then the total start-up lost time is $L = N t_{L}$. If $C$ is the cycle length in seconds, then the number of cycles per hour = $\frac{3600}{C}$. The total lost time per hour is the number of cycles per hour times the lost time per cycle and is = $\frac{3600}{C} \cdot L$. Substituting as $L = N t_{L}$, Let the total number of critical lane volume that can be accommodated per hour given by $V_c$, then $V_c = Tg$ Substituting for $T_g$, from equation 41.9 and $s_i$ from the maximum sum of critical lane volumes that can be accommodated within the hour is given by,
The expression for $C$ can be obtained by rewriting the above equation. The above
equation is based on the assumption that there will be uniform flow of traffic in an
hour. To account for the variation of volume in an hour, a factor called peak hour
factor, (PHF) which is the ratio of hourly volume to the maximum flow rate, is
introduced. Another ratio called v/c ratio indicating the quality of service is also
included in the equation. Incorporating these two factors in the equation for cycle
length, the final expression will be,

Highway capacity manual (HCM) has given an equation for determining the cycle length
which is a slight modification of the above equation. Accordingly, cycle time $C$ is given
by

$$C = \frac{N.L.X_C}{X_C - \Sigma (\frac{1}{v_c})_i}$$  \hspace{1cm} (41.16)
where \( N \) is the number of phases, \( L \) is the lost time per phase, \( \frac{V}{X} \), is the ratio of volume to saturation flow for phase \( i \), \( X_C \) is the quality factor called critical \( V \) ratio where \( V \) is the volume and \( C \) is the capacity.

**Problem**

The traffic flow in an intersection is shown in the figure 41:8. Given start-up lost time is 3 seconds, saturation head way is 2.3 seconds, compute the cycle length for that intersection. Assume a two-phase signal.

**Solution**

- If we assign two phases as shown below figure 41:9, then the critical volume for the first phase which is the maximum of the flows in that phase = 1150 vph. Similarly critical volume for the second phase = 1800 vph. Therefore, total critical volume for the two signal phases = 1150+1800 = 2950 vph. This means, that the intersection can handle only 1565.2 vph. However, the critical volume is 2950 vph. Hence the critical lane volume should be reduced and one simple option is to split the major traffic into two lanes. So the resulting phase plan is as shown in figure (41:10).

- Here we are dividing the lanes in East-West direction into two, the critical volume in the first phase is 1150 vph and in the second phase it is 900 vph.
The total critical volume for the signal phases is 2050 vph which is again greater than the saturation flow rate and hence we have to again reduce the critical lane volumes.

- Assigning three lanes in East-West direction, as shown in figure 41:11, the critical volume in the first phase is 575 vph and that of the second phase is 600 vph, so that the total critical lane volume = 575+600 = 1175 vph which is lesser than 1565.2 vph.

= 24 seconds.

**Summary**

Traffic signal is an aid to control traffic at intersections where other control measures fail. The signals operate by providing right of way to a certain set of movements in a cyclic order. Depending on the requirements they can be either fixed or vehicle actuated and two or multivalued. The design procedure discussed in this chapter include interval design, determination of cycle time, and computation of saturation flow making use of HCM guidelines.

Traffic signal design-II

**Overview**

In the previous chapter, a simple design of cycle time was discussed. Here we will discuss how the cycle time is divided in a phase. The performance evaluation of a signal is also discussed.

**Green splitting**

Green splitting or apportioning of green time is the proportioning of effective green time in each of the signal phase. The green splitting is given by,

\[ t_{L} = \frac{C}{n} \]

where \( C \) is the cycle time in seconds, \( n \) is the number of phases, and \( t_{L} \) is the
lost time per phase. If lost time is different for different phases, then cycle time can be computed as follows.

\[ T_g = C - \sum_{i=1}^{n} t_{Li} \]  \hspace{1cm} (42.3)

where \( t_{Li} \) is the lost time for phase \( i \), \( n \) is the number of phases and \( C \) is the lost time in seconds. Actual green time can be now found out as,

\[ t_{ti} = g_i - y_i + t_{Li} \]  \hspace{1cm} (42.4)

where \( t_{ti} \) is the actual green time, \( g_i \) is the effective green time available, \( y_i \) is the amber time, and \( L_i \) is the lost time for phase \( i \).

Problem

The phase diagram with flow values of an intersection with two phases is shown in figure 42:1. The lost time and yellow time for the first phase is 2.5 and 3 seconds respectively. For the second phase the lost time and yellow time are 3.5 and 4 seconds respectively. If the cycle time is 120 seconds, find the green time allocated for the two phases.

Figure 42:1: Phase diagram for an intersection

Figure 42:2: Timing diagram

Solution
• Critical lane volume for the first phase, \( V_{C1} = 1000 \) vph.
• Critical lane volume for the second phase, \( V_{C2} = 600 \) vph.
• The sum of the critical lane volumes, \( V_C = V_{C1} + V_{C2} = 1000 + 600 = 1600 \) vph.
• Effective green time can be found out from equation \( T_g = 120 - (2.5 - 3.5) = 114 \) seconds.
• Green time for the first phase, \( g_1 \) can be found out from equation \( g_1 = \frac{1000 \times 114}{1600} = 71.25 \) seconds.
• Green time for the second phase, \( g_2 \) can be found out from equation \( g_2 = \frac{600 \times 114}{1600} = 42.75 \) seconds.
• Actual green time can be found out from equation Thus actual green time for the first phase, \( t_{t1} = 71.25 - 3 + 2.5 = 70.75 \) seconds.
• Actual green time for the second phase, \( t_{t2} = 42.75 - 3 + 2.5 = 42.25 \) seconds.
• The phase diagram is as shown in figure 42:2.

**Pedestrian crossing requirements**

Pedestrian crossing requirements can be taken care by two ways; by suitable phase design or by providing an exclusive pedestrian phase. It is possible in some cases to allocate time for the pedestrians without providing an exclusive phase for them. For example, consider an intersection in which the traffic moves from north to south and also from east to west. If we are providing a phase which allows the traffic to flow only in north-south direction, then the pedestrians can cross in east-west direction and vice-versa. However in some cases, it may

\[
D_1 = \text{Stopped time delay} \\
D_2 = \text{Approach delay} \\
D_3 = \text{Travel time delay}
\]
be necessary to provide an exclusive pedestrian phase. In such cases, the procedure involves computation of time duration of allocation of pedestrian phase. Green time for pedestrian crossing $t_{tp}$ can be found out by,

$$ (42.5) $$

where $t_{tp}$ is the minimum safe time required for the pedestrians to cross, often referred to as the “pedestrian green time”, $t_s$ is the start-up lost time, $dx$ is the crossing distance in metres, and $u_p$ is the walking speed of pedestrians which is about 15th percentile speed. The start-up lost time $t_s$ can be assumed as 4.7 seconds and the walking speed can be assumed to be 1.2 m/s.

**Performance measures**

Performance measures are parameters used to evaluate the effectiveness of the design. There are many parameters involved to evaluate the effectiveness of the design and most common of these include delay, queuing, and stops. Delay is a measure that most directly relates the driver’s experience. It describes the amount of time that is consumed while traversing the intersection. The figure 42:3 shows a plot of distance versus time for the progress of one vehicle. The desired path of the vehicle as well as the actual progress of the vehicle is shown. There are three types of delay as shown in the figure. They are stopped delay, approach delay and control delay. *Stopped time delay* includes only the time at which the vehicle is actually stopped waiting at the red signal. It starts when the vehicle reaches a full stop, and ends when the vehicle begins to accelerate. *Approach delay* includes the stopped time as well as the time lost due to acceleration and deceleration. It is measured as the time differential between the actual path of the vehicle, and path had there been green signal. *Control delay* is measured as the difference between the time taken for crossing the intersection and time taken to traverse the same section, had been no intersection. For a signalized intersection, it is measured at the stop-line as the vehicle enters the intersection. Among various types of delays, stopped delay is easy to derive and often used as a performance indicator and will be discussed.

Vehicles are not uniformly coming to an intersection. i.e., they are not approaching the intersection at constant time intervals. They come in a random manner. This makes the modeling of signalized intersection delay complex. Most simple of the delay models is Webster’s delay model. It assumes that the vehicles are
arriving at a uniform rate. Plotting a graph with time along the x-axis and cumulative vehicles along the y-axis we get a graph as shown in figure 42:4. The delay per cycle is shown as the area of the hatched portion in the figure. Webster derived an expression for delay per cycle based on this, which is as follows.

\[
d_i = \frac{C [1 - \frac{i}{V_i S}]^2}{2 \frac{C}{1 - \frac{1}{V_i S}}} = \frac{C}{2} \left( 1 - \frac{1}{V_i S} \right)^2
\]  

(42.6)
where \( g_i \) is the effective green time, \( C \) is the cycle length, \( V_i \) is the critical flow for that phase, and \( S \) is the saturation flow.

Delay is the most frequently used parameter of effectiveness for intersections. Other measures like length of queue at any given time \( (Q_T) \) and number of stops are also useful. Length of queue is used to determine when a given intersection will impede the discharge from an adjacent upstream intersection. The number of stops made is an important input parameter in air quality models.

**Problem**

The traffic flow for a four-legged intersection is as shown in figure 42:5. Given that the lost time per phase is 2.4 seconds, saturation headway is 2.2 seconds, amber time is 3 seconds per phase, find the cycle length, green time and performance measure(delay per cycle). Assume critical \( v/c \) ratio as 0.9.
• The effective green time can be found out as $tt_i = V_i \times (C - L) = 80 - (4 \times 2.4) = 70.4$ seconds, where $L$ is the lost time for that phase = $4 \times 2.4$.

• Green splitting for the phase 1 can be found out as $g_1 = 70.4 \times \left[\frac{483}{1298}\right] = 22.88$ seconds.

• Similarly green splitting for the phase 2, $g_2 = 70.4 \times \left[\frac{417}{1298}\right] = 22.02$ seconds.

• Similarly green splitting for the phase 3, $g_3 = 70.4 \times \left[\frac{233}{1298}\right] = 12.04$ seconds.

• Similarly green splitting for the phase 4, $g_4 = 70.4 \times \left[\frac{215}{1298}\right] = 11.66$ seconds.

• The actual green time for phase 1 from equation as $tt_1 = 22.88 - 3 + 2.4 \approx 23$ seconds.

• Similarly actual green time for phase 2, $tt_2 = 22.02 - 3 + 2.4 \approx 23$ seconds.

• Similarly actual green time for phase 3, $tt_3 = 12.04 - 3 + 2.4 \approx 13$ seconds.

• Similarly actual green time for phase 4, $tt_4 = 11.66 - 3 + 2.4 \approx 12$ seconds.

• Pedestrian time can be found out from as $tt_p = 4 + 6 \times 3.5 = 21.5$ seconds. The phase diagram is shown in figure 42:7. The actual cycle time will be the sum of actual green time plus amber time plus actual red time for any phase. Therefore, for phase 1, actual cycle time = $23 + 3 + 78.5 = 104.5$ seconds.
Green splitting is done by proportioning the green time among various phases according to the critical volume of the phase. Pedestrian phases are provided by considering the walking speed and start-up lost time. Like other facilities, signals are also assessed for performance, delay being the important parameter used.

**Problems**

1. Table shows the traffic flow for a four-legged intersection. The lost time per phase is 2.4 seconds, saturation headway is 2.2 seconds, amber time is 3 seconds per phase. Find the cycle length, green time and performance measure. Assume critical volume to capacity ratio as 0.85. Draw the phasing and timing diagrams.

<table>
<thead>
<tr>
<th>From</th>
<th>To</th>
<th>Flow(veh/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>North</td>
<td>South</td>
<td>750</td>
</tr>
<tr>
<td>East</td>
<td>West</td>
<td>500</td>
</tr>
<tr>
<td></td>
<td></td>
<td>650</td>
</tr>
<tr>
<td></td>
<td></td>
<td>450</td>
</tr>
<tr>
<td></td>
<td></td>
<td>500</td>
</tr>
<tr>
<td></td>
<td></td>
<td>650</td>
</tr>
</tbody>
</table>

Figure 42:8: Phase diagram

Figure 42:9: Phase diagram
Solution

- Given, saturation headway is 2.2 seconds, total lost time per phase \((t_L)\) is 2.4 seconds, saturation flow \(= \frac{3600}{2.2} = 1636.36\) veh/hr. Phasing diagram can be assumed as in figure 42:9.

- Cycle time \(C\) can be found from equation as negative.

\[
C = \frac{-750+650}{1636.36}
\]

- Hence the traffic flowing from north to south can be allowed to flow into two lanes.

- Now cycle time can be find out as

\[
\frac{-450+650}{1636.36} = 22.95 \text{ or } 23 \text{ seconds}
\]

- The effective green time, \(t_g = C - (N \times t_L) = 23 - (2 \times 2.4) = 18.2\) seconds.

- This green time can be split into two phases as, For phase 1, \(g_1 = \frac{450 \times 18.2}{18.2} = 7.45\) seconds. For phase 2, \(g_2 = \frac{650 \times 18.2}{18.2} = 10.75\) seconds. Now actual green time, \(tt_1 = g_1\) minus amber time plus lost time.

Therefore, \(tt_1 = 7.45 - 3 + 2.4 = 6.85\) seconds.

\(tt_2 = 10.75 - 3 + 2.4 = 10.15\) seconds.
UNIT 5

Transportation Systems Management

This chapter describes Transportation System Management (TSM) techniques, which are generally low-cost and designed to maximize the efficiency of the existing transportation system, reduce travel demand and dependence on single occupant vehicles, improve air quality, and reduce or eliminate the need for new and expensive transportation infrastructure.

TRANSPORTATION SYSTEM MANAGEMENT (TSM)

Finding creative solutions to deal with growth in population, traffic congestion, and achieving federal air quality standards, is an ongoing effort. One element of this effort that remains constant is finding ways to make our existing transportation system as efficient as possible. This is the role of Transportation System Management (TSM).

Transportation Systems Management (TSM) is often used interchangeably with Transportation Control Measures (TCMs) and Travel Demand Management (TDM) to describe a series of techniques designed to maximize the efficiency of the existing transportation system by reducing dependence on single occupant vehicles. The common goals of TSM, TCMs, and TDM are to reduce traffic congestion, improve air quality, and reduce or eliminate the need for new and expensive transportation infrastructure. Techniques are generally low-cost measures to reduce travel demand or improve the utilization of existing transportation facilities.

The differences between the three concepts are subtle. Each contains alternative transportation measures, such as carpooling, transit, bicycling, walking, vanpooling, compressed work weeks, and telecommuting. Transportation Systems Management (TSM) places emphasis on reducing traffic congestion by increasing the person-trip capacity of existing transportation systems. TSM techniques also include restriping roadways for channelization, ramp metering, establishment of freeway auxiliary lanes, and freeway service patrol. Travel Demand Management (TDM) strategies are designed to influence an individual’s travel behavior by reducing the demand for single occupant vehicle travel, especially during peak commute periods. TDM strategies include techniques such as preferential parking for carpoolers, teleconferencing and advanced communication technology. Transportation Control Measures (TCMs) are geared towards reducing air pollution through techniques such as alternative fuel vehicles.

Since 1981, the Federal Highway Administration (FHWA) and the Federal Transit Administration (FTA) have required that Transportation Systems Management (TSM) be part of the regional transportation planning and programming process. Specifically, the Regional Transportation Plan must have a TSM element which describes how the region intends to deal with the movement of people and goods by improving the efficiency and effectiveness of the total transportation system.

SACOG’s MTP 2035 identifies a goal to reduce regional trips anticipated in the MTP by 10 percent. Land uses defined by Blueprint principals provide the framework for the future reduction in trips and VMT. TSM and TDM programs are a complementary component toward achieving the 10 percent trip reduction goal. Work-based trips account for about 20 percent of all
daily trips in the region. To contribute to the goals set forth in the MTP 2035, TSM and TDM programs will need to expand services to target the other 80 percent of regional trips. This chapter outlines various TSM and TDM strategies currently implemented in Placer County that will contribute toward achieving the regional goal.

According to 2005 Urban Mobility Report prepared by the Texas Transportation Institute, using 2002 data for Sacramento, about 48 percent of daily travel occurs in congested conditions, resulting in 40 hours of delay per traveler per year at a total congestion cost of $739 per traveler per year.

TSM STRATEGIES

Traffic Flow Improvements

Roadway restriping, spot widening, channelization, ramp metering, auxiliary lanes, elimination of on-street parking, and computerized signalization are techniques currently used to improve the flow of traffic without new road construction.

- Roadway restriping seeks to increase the number of lanes by reducing lane width, thus increasing traffic capacity.
- Channelization, which is often done in conjunction with restriping, adds turn lanes to busy roadways to eliminate traffic backups behind cars trying to make turns.
- Auxiliary lanes are often added to ease merging of traffic onto and off of freeways, such as Interstate 80.
- Elimination of on-street parking is done to add lanes, and thus capacity, to heavily traveled roadways. In addition, traffic backups caused by vehicles entering or exiting on-street parking spaces is eliminated.
- Computerized signalization seeks to coordinate signal timing to smooth traffic flow.

Freeway Service Patrol (FSP)

Approximately half of the delay experienced by travelers in the United States is due to causes other than simple high volumes of traffic. Much of this nonrecurring congestion occurs as a result of traffic accidents and stalled vehicles. Quickly identifying and removing vehicle incidents reduces traveler delay by returning traffic capacity to normal levels. Freeway service patrol (FSP) programs are designed to reduce the traffic congestion during peak commute periods on area freeways by removing traffic impediments, such as cars with mechanical problems or that have been involved in accidents, as well as assisting the motoring public.
In 2003, PCTPA received grant funding from the Placer County Air Pollution Control District (APCD) to implement a Freeway Service Patrol in the congested areas of I-80 in south Placer County. This service operates weekdays during peak commute periods.

In 2005 and 2008, the Freeway Patrol Service was augmented by State funding, allowing the program to expand to SR 65 and adding hours of operation. A service truck which provides non-tow related service was added in 2009 to complement the existing weekday tow service and on Sundays in 2010 to assist recreational traffic occurring in the late afternoon / early evening. Table 6.7-1 summarizes recent assist data for the PCTPA administered program.

Table 6.7-1
Freeway Service Program Assist Comparison By Problem Type & Vehicle Location

<table>
<thead>
<tr>
<th>Problem Type</th>
<th>2007 / 2008</th>
<th>2008 / 2009</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SR65</td>
<td>I-80</td>
</tr>
<tr>
<td>Abandoned</td>
<td>137</td>
<td>132</td>
</tr>
<tr>
<td>Accidents</td>
<td>204</td>
<td>179</td>
</tr>
<tr>
<td>Debris</td>
<td>37</td>
<td>30</td>
</tr>
<tr>
<td>Electrical</td>
<td>28</td>
<td>14</td>
</tr>
<tr>
<td>Flat Tire</td>
<td>175</td>
<td>183</td>
</tr>
<tr>
<td>Mechanical</td>
<td>142</td>
<td>147</td>
</tr>
<tr>
<td>Other</td>
<td>109</td>
<td>152</td>
</tr>
<tr>
<td>Out of Gas</td>
<td>168</td>
<td>100</td>
</tr>
<tr>
<td>Overheat</td>
<td>74</td>
<td>39</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1074</strong></td>
<td><strong>976</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>SR65</td>
<td>I-80</td>
</tr>
<tr>
<td>FWY Lanes</td>
<td>85</td>
<td>46</td>
</tr>
<tr>
<td>On Ramp</td>
<td>27</td>
<td>63</td>
</tr>
<tr>
<td>Left Shoulder</td>
<td>59</td>
<td>93</td>
</tr>
<tr>
<td>Right Shoulder</td>
<td>887</td>
<td>710</td>
</tr>
<tr>
<td>Other</td>
<td>12</td>
<td>19</td>
</tr>
<tr>
<td>Unable to Locate</td>
<td>4</td>
<td>45</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1074</strong></td>
<td><strong>976</strong></td>
</tr>
</tbody>
</table>

Note: Service Truck implemented in January 2009 (reflects only 6 months of assists).
Public Transit

Public transit service is the most widely used TSM measure in Placer County serving residents who depend on transit for commuting to work and school and for shopping, medical, and leisure trips. For a more comprehensive overview of the public transit and passenger rail services operating in Placer County see the Public Transit and Passenger Rail sections of the Action Element.

Public transit service is provided by the Placer County Department of Public Works, the City of Roseville, the City of Auburn, the City of Lincoln, and the Western Placer Consolidated Transportation Services Agency (CTSA). Both Roseville and Placer County provide commuter bus services to downtown Sacramento. In addition, Placer County subsidizes ten commuter vanpools that provide an alternative to driving alone. The Capitol Corridor Joint Powers Authority (CCJPA) provides intercity passenger rail service between Auburn and San Jose with stops in Rocklin and Roseville in Placer County.

Ridesharing

There are several coordinated ridesharing programs that serve Placer County. The Sacramento Area Council of Governments (SACOG) manages the Regional Rideshare program covering Placer, El Dorado, Sacramento, Yolo, Yuba, and Sutter counties. It is part of a statewide network of rideshare agencies. The purpose of the Regional Rideshare program is to encourage the use of carpooling and other alternative transportation modes for traveling to work, school, personal trips, and recreation. The Regional Rideshare program includes a toll-free, easy to remember number (511) to call for information, a database of commuters interested in ridesharing (carpools and vanpools), and an extensive outreach program through employers.

Another regional program focused on encouraging ridesharing is Spare-the-Air managed by the Sacramento Metropolitan Air Quality Management District (SMAQMD) and supported by the air districts of the Sacramento region (including the Placer County Air Pollution Control District). Spare-the-Air is a regional driving curtailment and health notification program that operates in the Sacramento ozone non-attainment area (which includes Placer County with the exception of the Tahoe Basin) during the summer smog season of June through September. Drivers are alerted to reduce driving on days when ozone formation is expected to be high, and the public is advised of ozone levels and health effects through a variety of media. In addition, all of the public transit providers in Placer County offer free rides on Spare the Air days.

PCTPA and the City of Roseville implement the Congestion Management Program (CMP) for Placer County. Their efforts are closely coordinated with the Regional Rideshare program and Spare-the-Air. The CMP provides marketing, seasonal incentive, educational and outreach efforts to the public and employers throughout Placer County about the benefits of using alternative modes of transportation, with the goal of reducing drive-alone auto commute trips and VMT. The CMP also offers an emergency guaranteed ride home program for employees, and includes educating school age children about the benefits of using alternative transportation, with the objective of positively impacting their view of alternative transportation before driving habits are established. A component of the CMP also includes implementation of the Western Placer Marketing Study, completed in 2003. The purpose of this Study is to facilitate the marketing of
transit services as an integrated system, focused on increasing awareness of public transit through specific marketing strategies.

Finally, PCTPA has received a grant, from the Placer County Air Pollution Control District that funds a coordinated transit marketing program geared specifically to raise awareness of public transit options in Placer County. The coordinated transit marketing effort complements the CMP and includes the cooperation of the public transit operators who provide direction on marketing campaigns. As part of the program, public transit operators offer a summer youth pass good for unlimited rides on all fixed route transit in Placer County during summer months.

**Pedestrian and Bikeway Facilities**

By making these methods safer and more convenient, pedestrian and bikeway facilities make bicycling and walking more attractive as alternatives to the automobile. To further support biking as a viable alternative to driving alone, Placer County bike maps are available to the public. For a discussion of plans for pedestrian and bikeway facilities within Placer County, see the Non-motorized Transportation section of the Action Element.

**Park-and-Ride Lots**

The purpose of park-and-ride lots is to provide a central meeting place adjacent to major travel routes where commuters can congregate and form carpools or catch buses for the remainder of the commute trip. Non-commuters can use these facilities for recreational purposes, such as trail access for bicycling, hiking, and equestrian usage.

Caltrans operates numerous park-and-ride lots in Placer County, located along Interstate 80. Placer County also operates several lots, which are located convenient to I-80 as well. Many lots include bicycle lockers and are all paved areas for parking cars. Table 6.7-2 identifies Placer County park-and-ride lot locations and their service characteristics.

<table>
<thead>
<tr>
<th>Jurisdiction</th>
<th>Location</th>
<th>Owner</th>
<th>Spaces</th>
<th>Transit Service</th>
<th>Bike Locker</th>
<th>Bike Lockers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auburn</td>
<td>West of SR 49 at Atwood Rd</td>
<td>State</td>
<td>42</td>
<td>No</td>
<td>No</td>
<td>0</td>
</tr>
<tr>
<td>Auburn</td>
<td>Auburn Amtrak Rail Station - Nevada Street and Fulweiler Avenue</td>
<td>City</td>
<td>50</td>
<td>Amtrak</td>
<td>No</td>
<td>0</td>
</tr>
<tr>
<td>Placer Uninc.</td>
<td>Bell Rd and Bowman Rd NW side of 80</td>
<td>State / County</td>
<td>33</td>
<td>No</td>
<td>No</td>
<td>0</td>
</tr>
<tr>
<td>Placer Uninc.</td>
<td>Bowman - East side of Lincoln Way</td>
<td>County</td>
<td>21</td>
<td>No</td>
<td>Yes</td>
<td>4</td>
</tr>
<tr>
<td>Location</td>
<td>Description</td>
<td>Type</td>
<td>Number</td>
<td>Trans. Access</td>
<td>Access</td>
<td></td>
</tr>
<tr>
<td>------------------------</td>
<td>-----------------------------------------------------------------------------</td>
<td>----------</td>
<td>--------</td>
<td>---------------</td>
<td>---------</td>
<td></td>
</tr>
<tr>
<td>Meadow Vista</td>
<td>Interchange of I-80 Clipper Gap Rd - South side SR 80 on Placer Hills Road</td>
<td>County</td>
<td>53</td>
<td>Placer Transit</td>
<td>No 0</td>
<td></td>
</tr>
<tr>
<td>Newcastle</td>
<td>Newcastle - SE side of Newcastle Rd Interchange</td>
<td>State/County</td>
<td>39</td>
<td>No</td>
<td>No 0</td>
<td></td>
</tr>
<tr>
<td>Newcastle</td>
<td>Indian Hills Rd and Newcastle Rd</td>
<td>State</td>
<td>27</td>
<td>No</td>
<td>No 0</td>
<td></td>
</tr>
<tr>
<td>Ophir</td>
<td>Lincoln / Ophir SR 193 on North West side of I-80</td>
<td>County</td>
<td>37</td>
<td>No</td>
<td>No 0</td>
<td></td>
</tr>
<tr>
<td>Penryn</td>
<td>Penryn Rd Interchange on NW of I-80 on Boyington Rd</td>
<td>County</td>
<td>39</td>
<td>Placer Transit</td>
<td>No 0</td>
<td></td>
</tr>
<tr>
<td>Weimar</td>
<td>Weimar Cross Rd - SW side of SR 80 at Weimar Cross Roads</td>
<td>County</td>
<td>12</td>
<td>No</td>
<td>No 0</td>
<td></td>
</tr>
<tr>
<td>Colfax</td>
<td>Dingus McGees Colfax (former) - Approx 1 mile south of Colfax/west side of SR 80</td>
<td>Private</td>
<td>50</td>
<td>No</td>
<td>No 0</td>
<td></td>
</tr>
<tr>
<td>Colfax</td>
<td>Colfax Amtrak Railroad Street</td>
<td>City</td>
<td>10</td>
<td>Amtrak and Placer Transit</td>
<td>No 0</td>
<td></td>
</tr>
<tr>
<td>Lincoln</td>
<td>Sierra College Blvd - SW corner of SR 193 and Sierra College Blvd</td>
<td>State</td>
<td>24</td>
<td>No</td>
<td>No 0</td>
<td></td>
</tr>
<tr>
<td>Location</td>
<td>Name</td>
<td>Type</td>
<td>County</td>
<td>Service Type</td>
<td>No.</td>
<td>Notes</td>
</tr>
<tr>
<td>-------------------</td>
<td>-----------------------------------------------------------</td>
<td>-------------</td>
<td>--------</td>
<td>-----------------------</td>
<td>-----</td>
<td>-------</td>
</tr>
<tr>
<td>Loomis</td>
<td>Horseshoe Bar Rd Interchange South side of SR 80</td>
<td>County</td>
<td>24</td>
<td>No, No</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Loomis</td>
<td>Loomis Train Station, Horseshoe Bar Road</td>
<td>City</td>
<td>71</td>
<td>Placer County Transit</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Rocklin</td>
<td>Sierra College Blvd - SE I-80 at Sierra College Blvd</td>
<td>County</td>
<td>24</td>
<td>No, No</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Rocklin</td>
<td>Rocklin Amtrak Station - Rocklin Road and Railroad Avenue</td>
<td>City</td>
<td>50</td>
<td>Amtrak and Placer County Transit</td>
<td>No</td>
<td>0</td>
</tr>
<tr>
<td>Roseville</td>
<td>Roseville Amtrak Station - Church Street and North Grant Street</td>
<td>City</td>
<td>78</td>
<td>Amtrak and Roseville Transit</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Roseville</td>
<td>Church at Cirby Way and Orlando Av</td>
<td>Private</td>
<td>172</td>
<td>Roseville Transit</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Roseville</td>
<td>Creekside Town Center - Creekside Ridge Court</td>
<td>Private</td>
<td>50</td>
<td>Roseville Transit</td>
<td>No</td>
<td>0</td>
</tr>
<tr>
<td>Roseville</td>
<td>Foothills Blvd / Junction Blvd</td>
<td>Private</td>
<td>25</td>
<td>Roseville Transit</td>
<td>No</td>
<td>0</td>
</tr>
<tr>
<td>Roseville</td>
<td>Mahany Park - Pleasant Grove Blvd / Woodcreek Oaks</td>
<td>Private</td>
<td>42</td>
<td>Roseville Transit</td>
<td>Yes</td>
<td>0</td>
</tr>
<tr>
<td>Location</td>
<td>Description</td>
<td>Type</td>
<td>Capacity</td>
<td>Transit Access</td>
<td>Parking Access</td>
<td>Comments</td>
</tr>
<tr>
<td>--------------------------</td>
<td>-----------------------------------------------------------------------------</td>
<td>---------</td>
<td>----------</td>
<td>----------------</td>
<td>----------------</td>
<td>----------</td>
</tr>
<tr>
<td>Roseville</td>
<td>Maidu Park - East of I-80 at Rocky Ridge Drive and Johnson Ranch Drive</td>
<td>City</td>
<td>50</td>
<td>Roseville Transit</td>
<td>No</td>
<td>0</td>
</tr>
<tr>
<td>Roseville</td>
<td>Highland Reserve Marketplace - Pleasant Grove Boulevard and Fairway Drive</td>
<td>Private</td>
<td>25</td>
<td>Roseville Transit</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Roseville</td>
<td>Roseville Galleria Blvd / East Roseville Parkway</td>
<td>Private</td>
<td>50</td>
<td>Placer County Transit and Roseville Transit</td>
<td>No</td>
<td>0</td>
</tr>
<tr>
<td>Roseville</td>
<td>Saugstad Park - NE of I-80 at Douglas Blvd and Buljan Street</td>
<td>State / County</td>
<td>91</td>
<td>Roseville Transit</td>
<td>Yes</td>
<td>6</td>
</tr>
<tr>
<td>Roseville</td>
<td>Roseville Costco - Stanford Ranch Road / Five Star Blvd</td>
<td>Private</td>
<td>35</td>
<td>Placer County Transit</td>
<td>No</td>
<td>0</td>
</tr>
<tr>
<td>Roseville</td>
<td>Taylor Road &amp; Eureka Road</td>
<td>State</td>
<td>150</td>
<td>Placer County Transit and Roseville Transit</td>
<td>Yes</td>
<td>16</td>
</tr>
</tbody>
</table>

Source: Guide to Regional Park and Ride Lot, Sacramento Region 511 / SACOG, October 2006.

**Mobility Rest Areas**

Mobility rest areas are provided to increase driver safety and satisfaction. They offer motorists and commercial drivers regular stopping opportunities to rest, receive pertinent traveler information, and access to restroom facilities. There are currently two rest areas in Placer County, located along I-80 at Gold Run and Donner Summit, and one additional facility on SR20 just west of I-80 in Nevada County. One new rest area has been identified by Caltrans for I-80 east of Truckee, although no funding has been identified for its implementation.
**Potential TSM Strategies**

In Placer County, most every applicable TSM strategy is already being used in some form. Some strategies, such as transit, are well-established, while others, such as use of alternative fuels, are just beginning to expand their applicability. In addition, there are several Intelligent Transportation Systems (ITS) studies recently completed or underway in the Sacramento region, in the foothill counties (Placer, El Dorado, Nevada, Sierra), and in the Tahoe Basin (refer to Chapter 6.9). The result of these studies will be recommendations for implementation of technology improvements that can improve the flow and timeliness of information available to the traveler in order to avoid and/or reduce traffic congestion and delays due to traffic.

**Telecommuting, Compressed Work Weeks, and Flexible Work Hours**

Telecommuting, compressed work weeks, and flexible work hours are employment based techniques to reduce the number of work trips per week, or to transfer trips to reduce peak hour congestion. Telecommuting, or alternative work location, allows workers to perform job duties at home or another location, communicating with the main work center by modem, fax, or telephone as necessary. This alternative is especially attractive for workers in rural areas or those commuting long distances, and studies have shown telecommuters are up to 20% more productive.

Compressed work weeks increase the number of hours worked each day to squeeze a regular work week into fewer work days. A typical schedule could be four 10-hour work days each week (4/10 schedule) or eight 9-hour days and one 8 hour day in two weeks (9/80 schedule).

Flexible work hours do not reduce the number of work trips per week, but seek to reduce traffic congestion by shifting some trips out of the peak period. Employers using flexible hours may allow workers to vary time of arrival and departure daily, or may require workers to choose a specific schedule to meet the needs of the employer and employee.

**Teleconferencing**

Teleconferencing is generally defined as meetings held by telephone or via video hookup to replace the need for traveling to meet in person. Many employers in Placer County utilize teleconferencing as a cost-effective way to conduct meetings and seminars while avoiding travel on roadways.
TDM Examples

There are many examples of TDM promotions and marketing campaigns currently being implemented in Placer County. The venues outlined below provide an opportunity for promoting alternative transportation modes through both on-going and seasonal campaigns, with an emphasis on congestion management and improved air quality.

Examples of ongoing TDM promotions and marketing campaigns implemented in Placer County include:

- Coordination with SACOG, regional air districts, and jurisdictions on alternative transportation efforts
- Transportation fair participation
- Sacramento Region 511 Rideshare marketing and match listing services
- Sacramento Region Commuter Club
- Vanpool promotion
- Emergency Guaranteed Ride Home services
- Transit information services for the general public
- TDM outreach for major capital projects
- Media releases, including Public Service Announcements, cable, radio and newspaper advertisements and articles
- Outreach to jurisdictions, employers and schools
- Quarterly employer TSM meetings, including training seminars for Employee Transportation Coordinators
- New employee outreach, including information packets with alternative transportation information
- Speaking engagements

Examples of seasonal TDM promotions and marketing campaigns implemented in Placer County include:

- Spare the Air, including free fare and incentive campaigns
- Summer Youth Bus Pass
- Bucks for Bikes
- May is Bike Month bike to work day events
- Earth Days
- Capitol Corridor holiday shopper program and kids ride free on weekends
- Way to Go-Walk to School days

**TDM Partnerships**

Partnering occurs with other on-going and seasonal campaigns with similar messages. This helps leverage resources for greater impact. PCTPA is an active partner in SACOG’s Transportation Demand Management Working Group. This group coordinates and develops alternative transportation marketing strategies that are promoted by member organizations. Examples of recent regional efforts include the Commuter Club and Bike Month. PCTPA has a strong working partnership with the City of Roseville and their large employer based network of businesses. PCTPA also works with the Capitol Corridor to promote passenger rail transportation as an alternative for placer County residents traveling to downtown Sacramento, Davis and to the Bay Area both for commute and recreational purposes. All of Placer County jurisdictions are members in the Transit Operators Working Group (TOWG), which serves as an advisory group for implementing the recommendations of the Western Placer County Transit Marketing Study.

**TDM Program Impacts**

With a number of commuters using ridesharing arrangements and public transit, and an increasing percentages traveling outside peak periods, it is increasingly important to understand the effects traveler choices relate to external influences and public policy choices. Currently, the Sacramento region does not have a monitoring and measurement system in place to assess progress or long-term effectiveness of existing TDM programs. At one time, placement surveys were used to assess whether persons registering for ridesharing were placed into alternate modes of commuting. These surveys were, however, discontinued several years ago by SACOG. The current means of assessing program effectiveness is to use the results of the decennial Census Household Travel Survey. SACOG has recently assembled a Regional Transportation Monitoring Report documenting transportation data and trends in the Sacramento region from 2002 to 2009. The Monitoring Report provides a useful understanding of how the transportation system in the region is being used; and what changes and trends are in evidence. SACOG anticipates the Regional Transportation Monitoring Report will be updated every two years. The report will provide a resource to track and monitor the progress of transportation system performance.
TSM ACTION PLAN

Short and Long Range

1. Work cooperatively with neighboring jurisdictions to implement ITS improvements that would support TSM efforts in the region. (PCTPA, SACOG, TRPA, NCTC, EDCTC, Sierra County, Caltrans)

2. Continue to work cooperatively with SACOG, SMAQMD, and the City of Roseville on implementation and enhancement of regional rideshare programs that encourage the use of alternative modes of transportation. (SACOG, SMAQMD, PCTPA, City of Roseville, local employers)

3. Continue to work cooperatively with area school districts on outreach to children in educating them about the benefits realized through the use of alternative transportation. (PCTPA, school districts, transit operators)

4. Promote alternative modes of transportation to help meet the transportation needs of rural agricultural workers in Placer County. (PCTPA, transit operators, agricultural industry, Placer County Farm Bureau, Placer County Agricultural Commissioner, Placer County Agriculture Department, Caltrans, SACOG)

5. Implement traffic flow improvements on regionally significant roadways. (PCTPA, jurisdictions, Caltrans)

6. Improve and expand public transportation systems (bus and rail) as feasible, to maintain existing and increase new ridership. (PCTPA, CCJPA, transit operators)

7. Develop and expand facilities to support the use of alternative transportation such as pedestrian and bicycle facilities, park-and-ride lots, and intermodal transfer stations. (PCTPA, CCJPA, jurisdictions, Caltrans)

8. Increase the awareness to media, employers and the general public of alternative transportation options in Placer County through outreach, educational and incentive programs. (PCTPA, jurisdictions, transit operators)

9. Encourage SACOG to develop a periodic regional survey of traveler choices, which would monitor trends in traveler choices related to external influences and the impact of public policy programs. (SACOG, jurisdictions, transit operators, PCTPA, Caltrans)

10. Promote a transportation system which minimizes the dependency of long-distance, single-occupant vehicle trips and vehicle miles traveled in Placer County toward achieving SACOG’s 10 percent regional trip reduction goal. (SACOG, jurisdictions, transit operators, PCTPA, Caltrans)
14. ASSIGNMENT TOPICS WITH MATERIALS
UNIT-I

Topic 1: Traffic Stream Parameters
The traffic stream includes a combination of driver and vehicle behavior. The driver or human behavior being non-uniform, traffic stream is also non-uniform in nature. It is influenced not only by the individual characteristics of both vehicle and human but also by the way a group of such units interacts with each other. Thus a flow of traffic through a street of defined characteristics will vary both by location and time corresponding to the changes in the human behavior.
The traffic engineer, but for the purpose of planning and design, assumes that these changes are within certain ranges which can be predicted. For example, if the maximum permissible speed of a highway is 60 kmph, the whole traffic stream can be assumed to move on an average speed of 40 kmph rather than 100 or 20 kmph.

Topic 2: Speed
Speed is considered as a quality measurement of travel as the drivers and passengers will be concerned more about the speed of the journey than the design aspects of the traffic. It is defined as the rate of motion in distance per unit of time. Mathematically speed or velocity \( v \) is given by, \( v = \frac{d}{t} \)
where, \( v \) is the speed of the vehicle in m/s, \( d \) is distance traveled in m in time \( t \) seconds. Speed of different vehicles will vary with respect to time and space. To represent these variations, several types of speed can be defined. Important among them are spot speed, running speed, journey speed, time mean speed and space mean speed.

Topic 3: Time mean speed and space mean speed
Time mean speed is defined as the average speed of all the vehicles passing a point on a highway over some specified time period. Space mean speed is defined as the average speed of all the vehicles occupying a given section of a highway over some specified time period. Both mean speeds will always be different from each other except in the unlikely event that all vehicles are traveling at the same speed. Time mean speed is a point measurement while space mean speed is a measure relating to length of highway or lane, i.e. the mean speed of vehicles over a period of time at a point in space is time mean speed and the mean speed over a space at a given instant is the space mean speed.

Topic 4: Variations of Volume
The variation of volume with time, i.e. month to month, day to day, hour to hour and within a hour is also as important as volume calculation. Volume variations can also be observed from season to season. Volume will be above average in a pleasant motoring month of summer, but will be more pronounced in rural than in urban
area. But this is the most consistent of all the variations and affects the traffic stream characteristics the least. Weekdays, Saturdays and Sundays will also face difference in pattern. But comparing day with day, patterns for routes of a similar nature often show a marked similarity, which is useful in enabling predictions to be made. The most significant variation is from hour to hour. The peak hour observed during mornings and evenings of weekdays, which is usually 8 to 10 per cent of total daily flow or 2 to 3 times the average hourly volume. These trips are mainly the work trips, which are relatively stable with time and more or less constant from day to day

**Topic 5: Density**

Density is defined as the number of vehicles occupying a given length of highway or lane and is generally expressed as vehicles per km. One can photograph a length of road x, count the number of vehicles, nx, in one lane of the road at that point of time and Density is also equally important as flow but from a different angle as it is the measure most directly related to traffic demand. Again it measures the proximity of vehicles in the stream which in turn affects the freedom to maneuver and comfortable driving.
UNIT 2

**Topic 1:** license plate survey, assume that each patrolling observer can check about four spaces per minute. The first observer will be slower, because all the license plate numbers will have to be recorded, but subsequent observers will be able to work much faster. The form shown below can be used for a license plate survey.

**Topic 2: Parking management Strategies**
Parking Management includes a variety of strategies that encourage more efficient use of existing parking facilities, improve the quality of service provided to parking facility users and improve parking facility design. Parking Management can help address a wide range of transportation problems, and help achieve a variety of transportation, land use development, economic, environmental objectives. The various strategies are (Donald Shoup – 1999, TDM Encyclopaedia 2008):

- Establishing a parking plan
- Limit parking supply
- Prioritize use
- Regulate the parking facilities for efficiency
- Impose parking prices
- Tax parking facilities or their use
- Shared parking
- More accurate parking requirements
- Address spill over problems
- Parking maximums
- Allowing “in-lieu” fees as an alternative to onsite parking

**Topic 3: Objectives of Parking Policy**

- Demand Management Revenue generation
- Reducing congestion
- Reducing pollution

Support of economic development

- Support of mode shift to public transport

Factors Considered during the parking Policy

- Area
  - Characteristics of the area
  - Use of mode
  - Land use and density
  - Characteristics of retail and employment
**Topic 4: Accident Investigation**
The accident data collection involves extensive investigation which involves the following procedure:

1. **Reporting:** It involves basic data collection in form of two methods:
   (a) **Motorist accident report** - It is filed by the involved motorist involved in all accidents fatal or injurious.
   (b) **Police accident report** - It is filed by the attendant police officer for all accidents at which an officer is present. This generally includes fatal accidents or mostly accidents involving serious injury required emergency or hospital treatment or which have incurred heavy property damage.

2. **At Scene Investigation:** It involves obtaining information at scene such as measurement of skid marks, examination of damage of vehicles, photograph of final position of vehicles, examination of condition and functioning of traffic control devices and other road equipments.

3. **Technical Preparation:** This data collection step is needed for organization and interpretation of the study made. In this step measurement of grades, sight distance, preparing drawing of after accident situation, determination of critical and design speed for curves is done.

**Topic 5: Causes of Road Accidents**

**Ans:** The various causes of road accidents are:

1. **Road Users** - Excessive speed and rash driving, violation of traffic rules, failure to perceive traffic situation or sign or signal in adequate time, carelessness, fatigue, alcohol, sleep etc.

2. **Vehicle** - Defects such as failure of brakes, steering system, tyre burst, lighting system.

3. **Road Condition** - Skidding road surface, pot holes, ruts.

4. **Road design** - Defective geometric design like inadequate sight distance, inadequate width of shoulders, improper curve design, improper traffic control devices and improper lighting.
UNIT 3

Topic 1: Level of service
Ans: A term closely related to capacity and often confused with it is service volume. When capacity gives a quantitative measure of track, level of service or LOS tries to give a qualitative measure. A service volume is the maximum number of vehicles, passengers, or the like, which can be accommodated by a given facility or system under given conditions at a given level of service.

Topic 2: Highway capacity
Ans: Highway capacity is defined by the Highway Capacity Manual as the maximum hourly rate at which persons or vehicles can be reasonably expected to traverse a point or a uniform segment of a lane or roadway during a given time period under prevailing roadway, traffic and control conditions.

Topic 3: Factors affecting level of service
Ans: The level of service can be derived from a road under different operating characteristics and traffic volumes. The factors affecting level of service (LOS) can be listed as follows:
1. Speed and travel time
2. Traffic interruptions/restrictions
3. Freedom to travel with desired speed
4. Driver comfort and convenience
5. Operating cost.

Topic 4: Saturation flow rate
Ans: A saturation flow rate for each lane group is computed according to above equation. The saturation flow rate is the flow in vehicles per hour that can be accommodated by the lane group assuming that the green phase were displayed 100 percent of the time (i.e., g/C = 1.0).

\[
S = SO \times NfwfHV \times fgpfbbfafLUfLT \times fRT \times fLpbfRpb (37.5)
\]

where,
- \( S \) = saturation flow rate for subject lane group, expressed as a total for all lanes in lane group (veh/h);
- \( SO \) = base saturation flow rate per lane (pc/h/ln);
- \( N \) = number of lanes in lane group;
- \( fw \) = adjustment factor for lane width;
- \( fHV \) = adjustment factor for heavy vehicles in traffic stream;
- \( fg \) = adjustment factor for approach grade;
- \( fp \) = adjustment factor for existence of a parking lane and parking activity adjacent to lane group;
- \( fbb \) = adjustment factor for blocking effect of local buses that stop within intersection area;
- \( fa \) = adjustment factor for area type;
- \( fLU \) = adjustment factor for lane utilization;
- \( fLT \) = adjustment factor for left turns in lane group;
- \( fRT \) = adjustment factor for right turns in lane group;
- \( fLpb \) = pedestrian adjustment factor for left-turn movements; and
fRpb = pedestrian-bicycle adjustment factor for right-turn Movements.

**Topic 5: Explain about Level of Service**

Ans: The level-of-service concept was introduced in the 1965 HCM as a convenient way to describe the general quality of operations on a facility with defined traffic, roadway, and control conditions. Using a letter scale from A to F, a terminology for operational quality was created that has become an important tool in communicating complex issues to decision-makers and the general public. The HCM 2000 defines level of service as follows: "Level of service (LOS) is a quality measure describing operational conditions within a traffic stream, generally in terms of such service measures as speed and travel time, freedom to maneuver, traffic interruptions, and comfort and convenience."

A term level-of-service closely related to capacity and often confused with it is service volume. When capacity gives a quantitative measure of traffic, level of service or LOS tries to give a qualitative measure. Service volume is the maximum number of vehicles, passengers, or the like, which can be accommodated by a given facility or system under given conditions at a given level of service.

Level of service (LOS) qualitatively measures both the operating conditions within a traffic system and how these conditions are perceived by drivers and passengers. It is related with the physical characteristics of the highway and the different operating characteristics that can occur when the highway carries different traffic volumes. Speed-flow-density relationships are the principal factor affecting the level of service of a highway segment under ideal conditions.
UNIT 4

**Topic 1: Factors lessening benefits of signal coordination.**
Ans: Among the factors limiting benefits of signal coordination are the following:
- inadequate roadway capacity
- existence of substantial side frictions, including parking, loading, double parking, and multiple driveways
- wide variability in traffic speeds
- very short signal spacing
- heavy turn volumes, either into or out of the street

**Topic 2: Offset determination in a grid**
Ans: A one-way street system has a number of advantages, not the least of which is traffic elimination of left turns against opposing traffic. The total elimination of constraints imposed by the closure of loops within the network or grid is not possible. Fig. 38:9 highlights the fact that if the cycle length, splits, and three offsets are specified, the offset in the fourth link is determined and cannot be independently specified extends this to a grid of one-way streets, in which all of the north-south streets are independently specified. The specification of one east-west Street then locks in all other east-west offsets. The key feature is that an open tree of one-way links can be completely independently set, and that it is the closing or closure of the open tree, which presents constraints on some links.

**Topic 3: Types of delay**
Ans: The most common measure of operational quality is delay, although queue length is often used as a secondary measure. While it is possible to measure delay in the field, it is a difficult process, and different observers may make judgments that could yield different results. For many purposes, it is, therefore, convenient to have a predictive model for the estimate of delay.

Delay, however, can be quantified in many different ways. The most frequently used forms of delay are defined as follows:
- Stopped time delay
- Approach delay
- Travel time delay
- Time-in-queue delay
- Control delay

**Topic 4: Delay diagram**
Ans: All analytic models of delay begin with a plot of cumulative vehicles arriving and departing vs. time at a given signal location. Fig. 35:2 shows a plot of total vehicle vs time. Two curves are shown: a plot of arriving vehicles and a plot of departing vehicles. The time axis is divided into periods of effective green and effective red. Vehicles are assumed to arrive at a uniform rate of flow (v vehicles
per unit time). This is shown by the constant slope of the arrival curve. Uniform arrivals assume that the inter-vehicle arrival time between vehicles is a constant. Assuming no preexisting queue, arriving vehicles depart instantaneously when the signal is green (i.e., the departure curve is same as the arrival curve). When the red phase begins, vehicles begin to queue, as none are being discharged. Thus, the departure curve is parallel to the x-axis during the red interval. When the next effective green begins, vehicles queued during the red interval depart from the intersection, at a rate called saturation flow rate (s vehicle per unit time). For stable operations, depicted here, the departure curve catches up with the arrival curve before the next red interval begins (i.e., there is no residual queue left at the end of the effective green).

**Topic 5: Types of Actuated Control**

There are three basic types of actuated control, each using signal controllers that are somewhat different in their design:

1. Semi-Actuated Control
2. Full-Actuated Control
3. Volume-Density Control

**Semi-Actuated Control**

This type of controller is used at intersections where a major street having relatively uniform flow is crossed by a minor street with low volumes. Detectors are placed only on the minor street. The green is on the major street at all times unless a call on the side street is noted. The number and duration of side-street green is limited by the signal timing and can be restricted to times that do not interfere with progressive signal-timing patterns along the major street.

**Full-Actuated Control**

This type of controller is used at the intersections of streets or roads with relatively equal volumes, but where the traffic distribution is varying. In full actuated operation, all lanes of all approaches are monitored by detectors. The phase sequence, green allocations, and cycle length are all subjected to variation. This form of control is effective for both two-phase and multi-phase operations and can accommodate optional phases.

**Volume-Density Control**

Volume-density control is basically the same as full actuated control with additional demand-responsive features. It is designed for intersections of major traffic flows having considerable unpredictable fluctuations.
UNIT 5

Topic 1: Balancing Supply and Demand
Given the debilitating effects of congestion, why have governments permitted congestion to continue to increase? At root, traffic congestion is the result of an imbalance between supply and demand: more vehicles are attempting to use the same limited road space. One way to think about the problem is what happens when a handful of rice is poured into a funnel. If the spout of the funnel is too narrow, the rice backs up and can even stop the flow of rice. If the spout is sufficiently wide, the rice flows through unimpeded. Throughput can be maximized either by slowing the amount of rice poured into the funnel, what is known as “demand management,” or by increasing the size of the funnel, i.e. “capacity expansion.”

Topic 2: Application Techniques and Principles of reversible lanes.
Ans: Several factors influence the planning and design of reversible lanes. These include:
- Cost and the level of complexity and sophistication of traffic control.
- Functional type of roadway on which it is used.
- Purpose and/or intended goals for which it is used.
- Agency responsible for the planning, design, implementation, and management.

Topic 3: Reversible Traffic Lanes Best Practice
- Type of Location: Multi-lane roadways in which a directionally unbalanced traffic flow leaves one or more of the minor flow direction lanes underutilized and, in particular, segments with minimal turning and stopping maneuvers.
- Agency Practices: Corridor analysis for location suitability, traffic law enforcement.
- Frequency of Reanalysis: Two to three years in order to identify safety improvements or issues and assess congestion mitigation benefits.
- Supporting Policies or Actions Needed: Regional MPO and local city adoption of program and budgeting of funds.
- Complementary Strategies: Event management programs.
**Topic 4: Parking Management Benefits**

Ans:
- Facility cost savings. Reduces costs to governments, businesses, developers and consumers.

- Improved quality of service. Many strategies improve user quality of service by providing better information, increasing consumer options, reducing congestion and creating more attractive facilities.

- More flexible facility location and design. Parking management gives architects, designers and planners more ways to address parking requirements.

- Revenue generation. Some management strategies generate revenues that can fund parking facilities, transportation improvements, or other important projects.

- Reduces land consumption. Parking management can reduce land requirements and so helps to preserve greenspace and other valuable ecological, historic and cultural resources.

- Supports mobility management. Parking management is an important component of efforts to encourage more efficient transportation patterns, which helps reduce problems such as traffic congestion, roadway costs, pollution emissions, energy consumption and traffic accidents.

- Supports Smart Growth. Parking management helps create more accessible and efficient land use patterns, and support other land use planning objectives.

**Topic 5: Remote Parking and Shuttle Service**

Ans: Remote Parking (also called Satellite Parking) refers to the use of off-site parking facilities. This often involves shared facilities, such as office workers parking at a restaurant parking lot during the day, in exchange for restaurant employees using the office parking lot evenings and weekends.

It can involve use of public facilities, such as commercial parking lots. Remote parking can also involve use of parking facilities located at the periphery of a business district or other activity center, and use of overflow parking during a special event that attracts large crowds. Special shuttle buses or free transit service may be provided to connect destinations with remote parking facilities, allowing them to be farther apart than would otherwise be acceptable.

Another type of remote parking is use of Park & Ride facilities, often located at the urban fringe where parking is free or significantly less expensive than in urban centers.
15. TUTORIAL TOPICS AND QUESTIONS
   (NIL)
Q1: What are the Factors Affecting Data Collection
Ans: In some instances not all vehicles were able to be recorded due to uncontrollable factors in the field which are common in these types of surveys. Noted affecting factors on the missed out vehicles widely experienced by surveyors include:
Multiple vehicles traveling at a high rate of speed, possibly grouped closely together
Newly registered vehicles where paper license is in rear window,
Dirty license plates
Poorly lit vehicles with burnt out license plate illumination bulbs during the early AM and late PM hours

Q2: What are Origin-Destination Findings
Ans: The Origin-Destination Study results for the proposed west and north bypass alternatives were studied for the AM and PM peak hour and average daily traffic conditions using ‘Origin’ point analysis. Results indicate that the AM peak hour, PM peak hour and average daily traffic show similar trip distribution characteristics with a significantly high percentage of traffic estimated to travel the west bypass.

Q3: What are Traffic stream parameters
Ans: The traffic stream includes a combination of driver and vehicle behavior. The driver or human behaviour being non-uniform, traffic stream is also non-uniform in nature. It is influenced not only by the individual characteristics of both vehicle and human but also by the way, a group of such units interacts with each other. Thus, a flow of traffic through a street of defined characteristics will vary by both location and time corresponding to the changes in the human behavior.

Q4: Define Speed
Ans: Speed is considered as a quality measurement of travel as the drivers and passengers will be concerned more about the speed of the journey than the design aspects of the traffic

Q5: Define Spot Speed
Ans: Spot speed is the instantaneous speed of a vehicle at a specified location. Spot speed can be used to design the geometry of road like horizontal and vertical curves, super elevation etc. Location and size of signs, design of signals, safe speed, and speed zone determination, require the spot speed data. Accident analysis, road maintenance, and congestion are the modern fields of traffic engineer, which uses spot speed data as the basic input. Spot speed can be measured using an enoscope, pressure contact tubes or direct timing procedure or radar speedometer or by time-
lapse photographic methods. It can be determined by speeds extracted from video images by recording the distance traveling by all vehicles between a particular pair of frames
Q1. Define Running speed
Ans: Running speed is the average speed maintained over a particular course while the vehicle is moving and is found by dividing the length of the course by the time duration the vehicle was in motion. i.e. this speed doesn’t consider the time during which the vehicle is brought to a stop, or has to wait till it has a clear road ahead. The running speed will always be more than or equal to the journey speed, as delays are not considered in calculating the running speed.

Q2: Define Journey speed
Ans: Journey speed is the effective speed of the vehicle on a journey between two points and is the distance between the two points divided by the total time taken for the vehicle to complete the journey including any stopped time. If the journey speed is less than running speed, it indicates that the journey follows a stop-go condition with enforced acceleration and deceleration. The spot speed here may vary from zero to some maximum in excess of the running speed. A uniformity between journey and running speeds denotes comfortable travel conditions.

Q3: Define Variations of Volume
Ans: The variation of volume with time, i.e. month to month, day to day, hour to hour and within an hour is also as important as volume calculation. Volume variations can also be observed from season to season. Volume will be above average in a pleasant motoring month of summer, but will be more pronounced in rural than in urban area. But this is the most consistent of all the variations and affects the traffic stream characteristics the least.

Weekdays, Saturdays and Sundays will also face difference in pattern. But comparing day with day, patterns for routes of a similar nature often show a marked similarity, which is useful in enabling predictions to be made.

Q4: Types of volume measurements
Ans: Since there is considerable variation in the volume of traffic, several types of measurements of volume are commonly adopted which will average these variations into a single volume count to be used in many design purposes.

1. Average Annual Daily Traffic(AADT) : The average 24-hour traffic volume at a given location over a full 365-day year, i.e. the total number of vehicles passing the site in a year divided by 365.
2. Average Annual Weekday Traffic(AAWT) : The average 24-hour traffic volume occurring on week-days over a full year. It is computed by dividing the total weekday traffic volume for the year by 260.
3. Average Daily Traffic(ADT) : An average 24-hour traffic volume at a given location for some period of time less than a year. It may be measured for six months, a season, a month, a week, or as little as two days. An ADT is a valid number only for the period over which it was measured.
4. Average Weekday Traffic(AWT) : An average 24-hour traffic volume occurring on weekdays for some period of time less than one year, such as for a month or a season.
Q5: Explain about Density
Ans: Density is defined as the number of vehicles occupying a given length of highway or lane and is generally expressed as vehicles per km. One can photograph a length of road $x$, count the number of vehicles, $n_x$, in one lane of the road at that point of time. Density is also equally important as flow but from a different angle as it is the measure most directly related to traffic demand. Again, it measures the proximity of vehicles in the stream, which in turn affects the freedom to maneuver and comfortable driving.
Five Marks of Questions with Answers

**Q1. Explain about Travel time, single vehicle & Time space diagram**
Ans: Travel time is defined as the time taken to complete a journey. As the speed increases, travel time required to reach the destination also decreases and vice versa. Thus travel time is inversely proportional to the speed. However, in practice, the speed of a vehicle fluctuates over time and the travel time represents an average measure.

Time-space diagram
Time space diagram is a convenient tool in understanding the movement of vehicles. It shows the trajectory of vehicles in the form of a two dimensional plot. Time space diagram can be plotted for a single vehicle as well as multiple vehicles. They are discussed below.

Single vehicle
Taking one vehicle at a time, analysis can be carried out on the position of the vehicle with respect to time. This analysis will generate a graph which gives the relation of its position on a road stretch relative to time.

**Q2. What are Automatic Counts, explain them**
Ans: The detection of vehicular presence and road occupancies has historically been performed primarily on or near the surface of the road. The exploitation of new electromagnetic spectra and wireless communication media in recent years has allowed traffic detection to occur in a non-intrusive fashion, at locations above or to the side of the roadway. Pavement-based traffic detection currently relatively inexpensive, will be met with fierce competition in the coming years from detectors that are liberated from the road surface.

The most commonly used detector types are:

**Pneumatic tubes.**
These are tubes placed on the top of road surfaces at locations where traffic counting is required. As vehicles pass over the tube, the resulting compression sends a burst of air to an air switch, which can be installed in any type of traffic counting devices. Air switches can provide accurate axle counts even when compressions occur more than 30 m from the traffic counter. Although the life of the pneumatic tubes is traffic dependant as they directly drive over it, it is used worldwide for speed measurement and vehicle classification for any level of traffic. Care should be exercised in placing and operating the system, to ensure its efficient operation and minimise any potential error in the data.

**Inductive loops.**
Inductive loop detector consists of embedded turned wire from which it gets its name. It includes an oscillator, and a cable, which allows signals to pass from the loop to the traffic counting device. The counting device is activated by the change in
the magnetic field when a vehicle passes over the loop. Inductive loops are cheap, almost maintenance-free and are currently the most widely used equipment for vehicle counting and detection. Single loops are incapable of measuring vehicular speed and the length of a vehicle. This requires the use of a pair of loops to estimate speed by analysing the time it takes a vehicle to pass through the loops installed in series. An inductive loop can also, to a certain degree, be used to detect the chassis heights and estimate the number of axles.

Q3: Explain Weigh-in-Motion Sensor types.
Ans: A variety of traffic sensors and loops are used world-wide to count, weigh and classify vehicles while in motion, and these are collectively known as Weigh In Motion (WIM) sensor systems. Whereas sensor pads can be used on their own traffic speed and axle weighing equipment, they are trigged by “leading” inductive loops placed before them on the roadbed. This scenario is adopted where axles, speed and statistical data are required. Some notable traffic sensors are

Bending Plates which contains strain gauges that weigh the axles of passing vehicles. Continuous electric signals are sent to the strain gauges, and these signals are altered as the plates are deflected by dynamic vehicular weight and measure the axle of the passing vehicles.

Capacitive Strip is a thin and long extruded metal used to detect passing axles. The force of vertical pressure applied to this strip by a wheel alters its capacitance, which can be converted to a wheel-weight measure when related to the speed of the vehicle. Capacitive strips can be used for both statistical data and axle configuration

Capacitive Mat functions in a similar manner as the capacitive strip but it is designed to be mobile and used on a temporary basis only.

Piezo-electric Cable is a sensing strip of a metallic cable that responds to vertical loading from vehicle wheels passing over it by producing a corresponding voltage. The cable is very good for speed measurement and axle-space registration, and is relatively cheap and maintenance free like a inductive loop if installed correctly.

Q4. Explain the procedure for Selection of Counting Sites
Ans: As stated earlier, the typical traffic counting system used by Roads Department composed of 64 permanent manual traffic counting stations and additional various special counting stations.

A specific location for counting site (permanent or temporary) must be determined on site. Where automatic counting system is to be used, the exact locations of loops should be decided while taking cognisance of the potential use of data collected. The following should be kept in mind before deciding on the counting site:
The road section should have uniform geometric characteristics along the road length and be away from junctions;
Location should be on a horizontal (flat) and geometrically straight road section;
Section of the road to have an uninterrupted traffic flow;
Sections where telephone lines or radio (mobile) are easily accessible or can be installed, if possible;
Section to have very little pedestrian or animal traffic;

To ensure that adequate attention is given to sections of roads constituting a specific traffic flow, roads should be divided into uniform sections according to traffic characteristics. Experience from many countries shows that although traffic volumes may grow over time, the relative variations of traffic at the various hours of the day of a month are often quite consistent year after year.

Q5: Explain Traffic Flow
Ans: Frequency of Traffic Counts
In order to predict traffic flow volumes that can be expected on the road network during specific periods, cognisance should be taken of the fact that traffic volumes changes considerably at each point in time. Three cyclical variations are of particular interest:

Hourly pattern: The way traffic flow characteristics varies through out the day and night;
Daily Pattern: The day-to-day variation throughout the week; and Monthly and yearly Pattern the season-to-season variation throughout the year

When analysing the traffic one must also be aware of the directional distribution of traffic and the manner in which its composition varies

Hourly patterns: Typical hourly patterns of traffic flow, particularly in urban areas, generally show a number of distinguishable peaks. Peak in the morning followed by a lean flow until another peak in the middle of the afternoon, after which there may be a new peak in the late evening. The peak in the morning is often more sharp by reaching the peak over a short duration and immediately dropping to its lowest point. The afternoon peak on the other hand is characterised by a generally wider peak. The peak is reached and dispersed over a longer period than the morning peak. However, in urban satellite towns, the morning peak may be too early and evening peak may be too late in comparison to the principal towns without significant midday peak

Daily patterns: The traffic volume generally varies throughout the week. The traffic during the working days (Monday to Friday) may not vary substantially, but the traffic volume during the weekend is likely to differ from the working days on different type of roads and in different directions. In Botswana many of the urban population goes to the rural areas during the weekends, hence a high variation of traffic on the urban – rural connector roads during weekdays and weekends.
Ten Objective Questions with Answers

Q1. The basic objective of traffic engineering is to achieve
   a) Efficient, free and rapid flow of traffic with least priority given to accidents
   b) Efficient, free and rapid flow of traffic with fewer accidents
   c) Efficient and rapid flow of traffic
   d) Rapid flow of traffic

Q2: The study of traffic engineering is divided into how many major categories?
   a) Five
   b) Six
   c) Seven
   d) Eight

Q3: The “3-Es” of traffic engineering stand for
   a) Enforcement, empowerment and eradication
   b) Engineering, education and expulsion
   c) Engineering, education and enforcement
   d) Engineering, education and enthusiasm

Q4: The traffic survey is conducted during
   a) Harvest season
   b) Harvest and lean season
   c) Rainy season
   d) Summer season

Q5: How many types of factors affect the traffic characteristics?
   a) One
   b) Two
   c) Three
   d) Four

Q6: The traffic volume is usually expressed in
   a) LMV
   b) PCU
   c) LCV
   d) HCV

Q7: The number of vehicles that pass through a transverse line of road at a given time in a specified direction is called
   a) Traffic studies
   b) Traffic flow
   c) Traffic origin
   d) Traffic destination
Q8: The traffic flow is
   a) Static
   b) Dynamic
   c) Static and dynamic
   d) May be static or dynamic

Q9: The most likely cause of accidents is
   a) Impatience in driving
   b) Slow speed of vehicle
   c) Pedestrians crossing the road
   d) Cattle crossing the road

Q10: The first stage in the traffic engineering studies is
    a) Traffic volume studies
    b) Spot speed studies
    c) Speed and delay studies
    d) Origin and destination studies
Fill in the blanks questions with answers

11. The **traffic stream** includes a combination of driver and vehicle behavior.
12. **Speed** is considered as a quality measurement of travel.
13. **Spot speed** is the instantaneous speed of a vehicle at a specified location.
14. **Running speed** is the average speed maintained over a particular course while the vehicle is moving.
15. **Journey speed** is the effective speed of the vehicle on a journey between two points and is the distance between the two points divided by the total time taken for the vehicle to complete the journey including any stopped.
16. **Density** is defined as the number of vehicles occupying a given length of highway or lane and is generally expressed as vehicles per km.
17. **Travel time** is defined as the time taken to complete a journey.
18. **Time space diagram** is a convenient tool in understanding the movement of vehicles.
19. **Pneumatic tubes** are tubes placed on the top of road surfaces at locations where traffic counting is required.
20. **Inductive loop detector** consists of embedded turned wire from which it gets its name.
UNIT 2

Two Marks of Questions with Answers

Q1. What are Parking Studies
Ans: Studies must be conducted to collect the required information about the capacity and use of existing parking facilities. In addition, information about the demand for parking is needed. Parking studies may be restricted to a particular traffic producer or attractor, such as a store, or they may encompass an entire region, such as a central business district.

Q2. Explain about Inventory of Parking Facilities:
Ans: Information is collected on the current condition of parking facilities. This includes:
   A. The location, condition, type, and number of parking spaces.
   B. Parking rates if appropriate. These are often related to trip generation or other land use considerations.
   C. Time limits, hours of availability and any other restrictions.
   D. Layout of spaces: geometry and other features such as crosswalks and city services.
   E. Ownership of the off-street facilities.

Q3: Explain about Duration and Turnover Surveys:
Ans: The accumulation study does not provide information on parking duration, turnover or parking violations. This information requires a license plate survey, which is often very expensive. Instead, modifications are often made to the field data collection protocols. Note that there is usually a tradeoff between data collection costs and study accuracy. Spending more time and money may increase accuracy, but at what point does the incremental change in accuracy become too expensive?

In planning a license plate survey, assume that each patrolling observer can check about four spaces per minute. The first observer will be slower, because all the license plate numbers will have to be recorded, but subsequent observers will be able to work much faster. The form shown below can be used for a license plate survey.

Q4: Explain the Impact of parking
Ans: Parking Policy has a direct impact on vehicular ownership and road space use. However, there are some ill effects of parking which are as follows:

1) Congestion
   One of the serious ill-effects of parking is the loss of street space and the attendant traffic congestion. The capacity of the streets is reduced, the journey speed drops
down and the journey time and delay increases. The operational costs of vehicles are thereby increased, causing serious economic loss to the community.

2) Accidents
The manoeuvres associated with parking and unparking are known to cause road accidents. Careless opening of the doors of parked vehicles, moving out of a parked position and bringing a car to the parking location from the mainstream of traffic are some of the common causes of parking accidents.

3) Obstruction to fire-fighting operations
Parked cars obstruct the movement of fire-fighting vehicles and greatly impede their operations. They also block access to hydrants and to buildings.

Q5. Explain about Domestic on-street parking scheme.
Ans: Parking management strategy for the Walled city of Jaipur (Jaipur Parking Demand Management Study by CRRI - 2006)
This city does not have parking policy in place but has proposed development of several multi storey parking lots to overcome congestion problems. Identified problem areas in the city are:
a. Unorganized parking spaces
b. On street parking spaces encroached by vendors and shoppers
c. Absence of planned spaces
d. Parking projects have come up but not a policy
e. Lack of enforcement
Three Marks of Questions with Answers

Q1. The features of the parking management in the new airport are:
Ans: Automated service which facilitates No Queuing and No Waiting by introducing the „Touch & Go” concept. Traffic management of the car parking area for customers and other services in front of terminal building comprises over 3500 car bays.

- Traffic management of the parking area in front of Cargo terminal building comprises around 153 Two-Wheeler bays, 125 car bays, 30 truck parking bays and Dock parking bays.
- Kerbside management at departure and arrival level includes VIP and VVIP Movement, Taxi”s/Cabs and Shuttle Buses
- Valet Services
- Management of public transport system like auto rickshaws, pre-paid taxi”s, fleet taxis, buses, government and staff vehicles in the parking area

Q2. What is Parking Space Inventory Survey
Ans: The first step in a parking survey is to collect data on the amount, type and location of space actually or potentially available for parking in an area. The area to be surveyed should first be delineated. The study area can be a street or an area covering a numbers of streets.

The study area is then sub-divided on a street-by-street basis and the sub-division marked on a map. Sketch plans of the streets are then prepared in advance. The data on parking facilities should be recorded on the sketch plans using suitable symbols. The items to be recorded should include the following:

i. Total length of kerb and lengths governed by no waiting and limited waiting restrictions (TDM Encyclopedia, 2008).
ii. Number of parking spaces provided in the street and street width.
iii. Location of bus stops, bus-bays, pedestrian crossings, fire hydrants, loading zones, taxi stands, driveways and other features that are likely to affect the use of the street for parking.
iv. Number and type of traffic signs for regulation of parking.
v. Private streets, service and rear-access alleys.

Q3. Explain about Questionnaire Type Parking Usage Survey
Ans: The questionnaire type parking usage survey involves interviews with the drivers who use the parking facilities. As a result, it is possible to collect information on the extent, to which the existing facilities are being used, the parking requirements at the prices existing at the time of the survey, the parking demand at different prices, the distribution of demand over area and time and the journey purposes of car parkers (Economic Survey of Delhi – 2005-06).

The survey can either be made by making enquires among the vehicle owners living in the vicinity of the survey area, or by making enquires among the drivers of vehicle seen to park in the area at the time of the survey.
In the former method, a sample of vehicle owners is selected from the list of vehicle owners and the questionnaires are delivered to them. Non-respondents can be followed up and the requirements of the sample are grossed up to the requirements of the whole population.
The second method suffers from a disadvantage that it misses information about potential parkers who never bring their vehicles to the survey area for want of space, but this can be overcome by a supplementary sample.

Q4. Parking management Strategies
Ans: Parking Management includes a variety of strategies that encourage more efficient use of existing parking facilities, improve the quality of service provided to parking facility users and improve parking facility design. Parking Management can help address a wide range of transportation problems, and help achieve a variety of transportation, land use development, economic, environmental objectives.
The various strategies are (Donald Shoup – 1999, TDM Encyclopaedia 2008):
- Establishing a parking plan
- Limit parking supply
- Prioritize use
- Regulate the parking facilities for efficiency
- Impose parking prices
- Tax parking facilities or their use
- Shared parking
- More accurate parking requirements
- Address spill over problems
- Parking maximums
- Allowing “in-lieu ”fees as an alternative to onsite parking
- Bicycle parking
- Unbundle parking
- Transportation Management Association(TMA)

Q5. Explain about Parking Pricing Mechanism
Ans: Parking Pricing means that motorists pay directly for using parking facilities. Parking Pricing may be implemented as a TDM strategy (to reduce vehicle traffic in an area), as a parking management strategy (to reduce parking problems in a particular location), to recover parking facility costs, to generate revenue for other purposes (such as a local transportation program or downtown improvement district), or for a combination of these objectives. Below are specific Parking Pricing techniques:
a. Wherever possible, charge motorists directly for using parking. If parking must be subsidized, offer comparable benefits for use of other travel modes, such as Cash Out payments (Poole, 2007).

b. Use variable rates that are higher for peak locations and times. Apply performance-based parking prices, which mean that prices are set so that about 15% of parking spaces are unoccupied during peak periods (Barbra J., 2001).
c. To increase revenues, expand when and where parking is priced rather than raising rates at existing priced facilities. This is more efficient and equitable, reduces spillover problems, and usually raises more total revenue.

d. Set parking prices to equal or exceed transit fares. For example, set daily rates at least equal to two single transit fares, and monthly rates at least equal to a monthly transit pass.

e. Minimize discounts for long-term parking passes. For example, set daily rates at least 6 times the hourly rates, and monthly rates at least 20 times daily rates. Even better, eliminate unlimited-use passes altogether (Deren Han, 2009).
Five Marks of Questions with Answers

Q1. Policy Study
Ans: Parking management when combined with appropriately priced parking, limit on parking space and improved access through other modes of transport, it is most effective in stimulating the switch from private cars to alternative modes of transport. There is, therefore, considerable opportunity to develop parking policy as an instrument to decongest, shift commuter choice towards public transport, and discourage car use.

Objectives of Parking Policy

- Demand Management
- Revenue generation
- Reducing congestion
- Reducing pollution

Support of economic development
- Support of mode shift to public transport

Factors Considered during the parking Policy

- Area
  - Characteristics of the area
  - Use of mode
  - Land use and density
  - Characteristics of retail and employment

- Implementation
  - Stakeholder involvement
  - Parking information
  - Analysis
  - Best practice
  - Monitoring

Q2. Explain the Ill effects of parking
Ans: Parking has some ill-effects like congestion, accidents, pollution, obstruction to fire-fighting operations etc.

1. Congestion: Parking takes considerable street space leading to the lowering of the road capacity. Hence, speed will be reduced, journey time and delay will also subsequently increase. The operational cost of the vehicle increases leading to great economical loss to the community.
2. Accidents: Careless maneuvering of parking and unparking leads to accidents which are referred to as parking accidents. Common type of parking accidents occur while driving out a car from the parking area, careless opening of the doors of parked cars, and while bringing in the vehicle to the parking lot for parking.

3. Environmental pollution: They also cause pollution to the environment because stopping and starting of vehicles while parking and unparking results in noise and fumes. They also affect the aesthetic beauty of the buildings because cars parked at every available space creates a feeling that building rises from a plinth of cars.

4. Obstruction to fire fighting operations: Parked vehicles may obstruct the movement of firefighting vehicles. Sometimes they block access to hydrants and access to buildings.

Q3. Explain about Accident investigation
Ans: The accident data collection involves extensive investigation which involves the following procedure:

1. Reporting: It involves basic data collection in form of two methods:
   (a) Motorist accident report - It is filed by the involved motorist involved in all accidents fatal or injurious.
   (b) Police accident report - It is filed by the attendant police officer for all accidents at which an officer is present. This generally includes fatal accidents or mostly accidents involving serious injury required emergency or hospital treatment or which have incurred heavy property damage.

2. At Scene-Investigation: It involves obtaining information at scene such as measurement of skid marks, examination of damage of vehicles, photograph of final position of vehicles, examination of condition and functioning of traffic control devices and other road equipments.

3. Technical Preparation: This data collection step is needed for organization and interpretation of the study made. In this step measurement of grades, sight distance, preparing drawing of after accident situation, determination of critical and design speed for curves is done.

4. Professional Reconstruction: In this step effort is made to determine from whatever data is available how the accident occurs from the available data. This involves accident reconstruction which has been discussed under Section No.7 in details. It is professionally referred as determining behavioral or mediate causes of accident.

5. Cause Analysis: It is the effort made to determine why the accident occurred from the data available and the analysis of accident reconstruction studies.
Q4. Explain about In-out survey
Ans: In this survey, the occupancy count in the selected parking lot is taken at the beginning. Then the number of vehicles that enter the parking lot for a particular time interval is counted. The number of vehicles that leave the parking lot is also taken. The final occupancy in the parking lot is also taken. Here the labor required is very less. Only one person may be enough. But we won’t get any data regarding the time duration for which a particular vehicle used that parking lot. Parking duration and turn over is not obtained. Hence we cannot estimate the parking fare from this survey. For quick survey purposes, a fixed period sampling can also be done.
This is almost similar to in-out survey. All vehicles are counted at the beginning of the survey. Then after a fixed time interval that may vary between 15 minutes to i hour, the count is again taken. Here there are chances of missing the number of vehicles that were parked for a short duration.

Q5. What are the Causes of road accidents
Ans: The various causes of road accidents are:

1. Road Users - Excessive speed and rash driving, violation of traffic rules, failure to perceive traffic situation or sign or signal in adequate time, carelessness, fatigue, alcohol, sleep etc.

2. Vehicle - Defects such as failure of brakes, steering system, tyre burst, lighting system.

3. Road Condition - Skidding road surface, pot holes, ruts.

4. Road design - Defective geometric design like inadequate sight distance, inadequate width of shoulders, improper curve design, improper traffic control devices and improper lighting etc.

5. Environmental factors - Unfavorable weather conditions like mist, snow, smoke and heavy rainfall which restrict normal visibility and makes driving unsafe.

   1. Other causes - Improper location of advertisement boards, gate of level crossing not closed when required etc.
Ten Objective Questions with Answers

Q1: The first objective of the traffic volume studies is
a) To decide priority for improvement of roads
b) For geometric design
c) For computing roadway capacity
d) To plan traffic operation

Q2: Which of the following method is more accurate for traffic analysis?
a) Manual count
b) Automatic count
c) Average of manual and automatic
d) Past records

Q3: The outgoing and incoming traffic are counted at
a) Traffic intersections
b) Highway
c) Urban roads
d) Traffic symbols

Q4: The charts showing the variation of the traffic is called
a) Traffic chart
b) Trend chart
c) Variation chart
d) Traffic flow maps

Q5: The annual average daily traffic is calculated by the formula
a) ADT*DF*WF
b) ADT*DF*WF*SF
c) ADT*WF
d) ADT*SF

Q6: Parking facilities may be classified into how many types?
a) One
b) Two
c) Three
d) Four

Q7: The type of parking in which the vehicles are parked along the kerb is called
a) Kerb parking
b) Off-street parking  
c) Parallel parking  
d) Angle parking 

Q8. Which type of parking facility is convenient for all types of users?  
a) Kerb parking  
b) Off-street parking  
c) Parallel parking  
d) 90 degree parking 

Q9. The maximum number of cars can be parked in  
a) Kerb parking  
b) Off-street parking  
c) Parallel parking  
d) 90 degree parking 

Q10. The number of parking spaces for a kerb of 59m and having the length of car as 5.0m is  
a) 9  
b) 10  
c) 11  
d) 12
**Fill in the blanks questions with answers**

1. Parking Policy has a direct impact on vehicular ownership and road space use.

2. The manoeuvres associated with parking and unparking are known to cause road accidents.

3. The questionnaire type parking usage survey involves interviews with the drivers who use the parking facilities.

4. Parking Pricing means that motorists pay directly for using parking facilities.

5. Careless manoeuvring of parking and unpacking leads to accidents, which are referred to as parking accidents.

6. Capacity is defined as the maximum number of vehicles, passengers, or the like, per unit time, which can be accommodated under given conditions with a reasonable expectation of occurrence.

7. Highway capacity is defined by the Highway Capacity Manual as the maximum hourly rate at which persons or vehicles can be reasonably expected to traverse a point.

8. Level of service (LOS) qualitatively measures both the operating conditions within a traffic system and how drivers and passengers perceive these conditions.

9. The maximum theoretical capacity is \(1000V/S\)

10. Running speed of a vehicle is equal to Travel speed-delay
Q1: Explain about capacity
Ans: Capacity of a transport facility is defined as the maximum number of vehicles, passengers, or the like, per unit time which can be accommodated under given conditions with a reasonable expectation of occurrence.

Q2: Explaian about Level-of-Service(LOS)
Ans: Level of service of a traffic facility is a concept introduced to relate the quality of traffic service to a given flow rate. Level-of-Service is introduced by HCM to denote the level of quality one can derive from a local under different operation characteristics and traffic volume.

Q3: Explain about Multi lane highways
Ans: A highway is a public road especially a major road connecting two or more destinations. A highway with at least two lanes for the exclusive use of traffic in each direction, with no control or partial control of access, but that may have periodic interruptions to flow at signalized intersections not closer than 3.0 km is called as multilane highway.

Q4: what are the types of Highway classification:
Ans: There are various ways of classification of highways; we will see classification of highways according to number of lanes.
• Two lane highways.
• Multilane highways

Q5: What are the Highway Characteristics
Ans: Multilane highways generally have posted speed limits between 60 km/h and 90 km/h. They usually have four or six lanes, often with physical medians or two-way right turn lanes (TWRTL), although they may also be undivided. The traffic volumes generally varies from 15,000 - 40,000 vehicles per day. It may also go up to 100,000 vehicles per day with grade separations and no cross-median access. Traffic signals at major intersections are possible for multilane highways which facilitate partial control of access.
Q1: Explain Free-flow speed
Ans: Free-flow speed is the theoretical speed of traffic density, when density approaches zero. It is the speed at which drivers feel comfortable travelling under the physical, environmental and traffic conditions existing on an uncongested section of multilane highway. In practice, free-flow speed is determined by performing travel-time studies during periods of low-to-moderate flow conditions. The upper limit for low to moderate flow conditions is considered 1400 passenger cars per hour per lane (pc/h/ln) for the analyses. Speed-flow and density flow relationships are. These relationships hold for a typical uninterrupted-flow segment on a multilane highway under either base or no base conditions in which free-flow speed is known. Fig. 23:9 indicates that the speed of traffic volume up to a flow rate of 1400 pc/h/ln. It also shows that the capacity of a multilane highway under base conditions is 2200 pc/h/ln for highways with a 90 km/h free-flow speed.

Q2: How do you determine Level of Service
Ans: The level of service on a multilane highway can be determined directly based on the free-flow speed (FFS) and the service flow rate (vp) in pc/h/ln. The procedure as follows:

1. Define a segment on the highway as appropriate. The following conditions help to define the segmenting of the highway,
   • Change in median treatment
   • Change in grade of 2% or more or a constant upgrade over 1220 m
   • Change in the number of travel lanes

   The presence of a traffic signal
   • A significant change in the density of access points
   • Different speed limits
   • The presence of bottleneck condition

In general, the minimum length of study section should be 760 m, and the limits should be no closer than 0.4 km from a signalized intersection.

2. On the basis of the measured or estimated free-flow speed on a highway segment, an appropriate speed-flow curve of the same as the typical curves is drawn.
3. Locate the point on the horizontal axis corresponding to the appropriate flow rate (vp) in pc/hr/ln and draw a vertical line.
Read up the FFS curve identified in step 2 and determine the average travel speed at the point of intersection.
5. Determine the level of service on the basis of density region in which this point is located.

Density of flow can be computed as
\[ D = \frac{v}{S} \]
where, D is the density (pc/km/ln), vp is the flow rate (pc/h/ln), and S is the average passenger-car travel speed (km/h). The level of service can also be determined by comparing the computed density with the density ranges shown in table given by HCM.

To use the procedures for a design, a forecast of future traffic volumes has to be made and the general geometric and traffic control conditions, such as speed limits, must be estimated. With these data and a threshold level of service, an estimate of the number of lanes required for each direction of travel can be determined.

**Q3: Explain the Basic features of freeway**

Ans: Freeway provides uninterrupted traffic flow on a freeway. Traffic on freeway is free-flowing. All cross-traffic (and left-turning traffic) is relegated to overpasses or underpasses, so that there are no traffic conflicts on the main line of the highway which must be regulated by traffic lights, stop signs, or other traffic control devices.

Specific features are:
1. There are no signalized or stop-controlled at-grade intersections.
2. Direct access to and from adjacent property is not permitted.
3. Access to and from the freeway is limited to ramp locations.
4. Opposing directions of flow are continuously separated by a raised barrier, an at-grade median, or a continuous raised median.
5. The advantage of grade-separated interchanges is that freeway drivers can almost always maintain their speed at junctions since they do not need to yield to vehicles crossing perpendicular to mainline traffic.

**Q4: What is Basic freeway segment**

Ans: Basic freeway are that part of segment of freeway which are outside of the influence area of ramps or weaving areas of freeway. We can see in Fig.24:1 that a basic freeway segment is independent of the ramps and weaving areas and the flow in such section occurs smoothly at the much larger rates. Merging and diverging of traffic occurs where on-or-off ramps join the basic freeway segment. Weaving occurs when vehicles cross each other’s path while travelling on freeway lanes. The
exact point at which basic freeway segment begins or ends - that is, where the influence of weaving areas and ramp junctions has dissipated - depends on local conditions, particularly the level of service operating at the time. If traffic flow is light, the influence may be negligible, whereas under congested conditions, queues may be extensive.

**Q5: What are the Factors affecting Capacity**

**Ans:** Roadway conditions Roadway conditions include geometric and other elements. In some cases, these influence the capacity of a road; in others, they can affect a performance measure such as speed, but not the capacity or maximum flow rate of the facility. Roadway factors include the following:

1. **Number of lanes:** Number of lanes decided for basic freeway is five or more than five but if number of lanes is less than five then capacity of freeway is reduced.
2. **Lane widths:** If the lane width is less than the specified lane width for basic freeway segment, i.e. 3.6m then capacity is reduced because traffic flow tends to be restricted.
3. **Shoulder widths and lateral clearances:** Shoulder width and lateral clearance influences the capacity of freeway. When lane widths are less than 3.65 m, drivers are forced to travel closer to one another laterally than they would normally desire. Drivers tend to compensate for this by reducing their travel speed. The effect of restricted lateral clearance is similar. When objects are located too close to the edge of the median and roadside lanes, drivers in these lanes will shy away from them, positioning themselves further from the lane edge hence capacity is reduced.
4. **Design speed:** Freeway is designed for free flow speed around 120 km per hour, if some vehicle is moving less than the design speed then capacity of freeway.
5. **Grades:** Effect of grade depends on both the length and slope of the grade. Traffic operations significantly affected when grades of 3% or more are longer than one quarter miles and when grades are less than 3% and longer than mile. The effect of heavy vehicles on such grades is much greater.
Q1: Explain Highway Capacity
Ans: Highway capacity is defined by the Highway Capacity Manual as the maximum hourly rate at which persons or vehicles can be reasonably expected to traverse a point or a uniform segment of a lane or roadway during a given time period under prevailing roadway, traffic and control conditions. The highway capacity depends on certain conditions as listed below:

01. traffic conditions: It refers to the traffic composition in the road such as the mix of cars, trucks, buses etc in the stream. It also include peaking characteristics, proportions of turning movements at intersections and the like.

2. Road way characteristics: This points out to the geometric characteristics of the road. These include lane width, shoulder width, lane configuration, horizontal alignment and vertical alignment.

3. Control conditions: This primarily applies to surface facilities and often refer to the signals at intersections etc. Again, capacity can be defined for a point or uniform section. Capacity is estimated for segments having uniform conditions. Points where these conditions change represent the boundaries where separate analysis may be required. Capacity is the maximum ow rate that a facility. This maximum ow rate is taken for the worst 15 minutes of the peak hours. Capacity is measured as a reasonably expected value and not the maximum ow rate ever observed in the facility. This is because the measured capacity at a single location will show significant variation from day to day. Further, local driving habits also produce variations in the observed capacity.

Q2: What are the Factors affecting level of service
ANS: The level of service can be derived from a road under different operating characteristics and traffic volumes.

The factors affecting level of service (LOS) can be listed as follows:
1. Speed and travel time
2. Traffic interruptions/restrictions
3. Freedom to travel with desired speed
4. Driver comfort and convenience
5. Operating cost.

Highway Capacity Manual(HCM) used travel speed and volume by capacity ratio (v/c ratio) to distinguish between various levels of service. The value of v/c ratio can vary between 0 and 1.
Depending upon the travel speed and v/c ratio, HCM has defined six levels of service, level A to level F based on a graph between operating speed and v/c. Level of service A represents the zone of free flow. Here the traffic volume will be less, traffic will be experiencing free flow also. The drivers will be having the complete freedom to choose their desired speed. Even at maximum density, for this LOS the average spacing between vehicles is 167 m.

Lane changes within the traffic stream, as well as merging and diverging movements, are made relatively easy. The effect of minor incidents and point breakdowns are easily aborted at this level.

Level of service B represents zone of reasonably free flow. Free flow speeds are still maintained at this level of service. The drivers freedom to choose their desired speed is only slightly restricted. The lowest average spacing between vehicles is about 100 m. The effects of small incidents and point breakdowns are still easily contained.

At level of service C, the presence of other vehicles begins to restrict the maneuverability within the traffic stream. Average speeds remain at or near the free flow speed level, but significant increase in driver vigilance is required at this level. Minimum average spacing between the vehicles is in the range of 67 m. Queues may be expected to form behind any significant blockage. At level of service D, the average speeds begin to decline with increasing ows. Freedom to maneuver within the traffic stream is noticeably restricted. At this level, density deteriorates more quickly with ow. The spacing between the vehicles is about 50 m. As the traffic stream has little space to absorb disruptions, minor incidents can lead to queuing of vehicles.

Level of service E defined operation at capacity. At this level, the stream reaches its maximum density limit. There will be no usable gaps in the stream and even slight disruptions will cause a breakdown, with queues forming rapidly behind the disruption. Maneuvering within the traffic stream becomes extremely difficult. Level of service F describes conditions in a queue that has formed behind a point of breakdown or disruption. As vehicles shu_e through the queue, there may be periods when they move quickly, and others when they are stopped completely. Thus this level of service is used to describe the point of breakdown as well, eventhough operations downstream of such a breakdown may appear good. Level of service F represents the region of forced ow, having low speed, and complete breakdown of the system.
Q3: What are the methodologies for Basic freeway sections and multilane Highways.
Ans: Analysis Methodologies for Basic Freeway Sections and Multilane Highways
The characteristics and criteria described for freeways and multilane highways in the previous section apply to facilities with base traffic and roadway conditions.

In most cases, base conditions do not exist, and a methodology is required to address the impact of prevailing conditions on these characteristics and criteria. Analysis methodologies are provided that account for the impact of a variety of prevailing conditions, including:
- Lane widths
- Lateral clearances
- Number of lanes (freeways)
- Type of median (multilane highways)
- Frequency of interchanges (freeways) or access points (multilane highways)
- Presence of heavy vehicles in the traffic stream
- Driver populations dominated by occasional or unfamiliar users of a facility

Some of these factors affect the free-flow speed of the facility, while others affect the equivalent demand flow rate on the facility.

Q4: Explain the concept of Base condition of basic freeway segment
Ans: The base conditions under which the full capacity of a basic freeway segment is achieved are good weather, good visibility, and no incidents or accidents. For the analysis procedures in this chapter, these base conditions are assumed to exist. A set of base conditions for basic freeway segments has been established. These conditions serve as a starting point for the
1. Lane widths of 3.6 m,
2. Clearance of 1.8 m between the edge of the travel lanes and the nearest obstructions or objects at the roadside and in the median,
3. Free-flow speed of 120 km/h for freeways,
4. Only passenger cars in the traffic stream (no heavy vehicles),
5. Level terrain,
6. No no-passing zones on two-lane highways, and
7. No impediments to through traffic due to traffic control or turning vehicles.

Base conditions for intersection approaches include the following:
1. Lane widths of 3.6 m,
2. Level grade,
3. No curb parking on the approaches,
4. Only passenger cars in the traffic stream,
5. No local transit buses stopping in the travel lanes,
6. Intersection located in a non central business district area, and
7. No pedestrians

Q5: Explain the factors affecting Capacity
Ans:

Roadway conditions
Roadway conditions include geometric and other elements. In some cases, these influence the capacity of a road; in others, they can affect a performance measure such as speed, but not the capacity or maximum flow rate of the facility. Roadway factors include the following:

1. Number of lanes, Number of lanes decided for basic freeway is five or more than five but if number of lanes is less than five then capacity of freeway is reduced.
2. Lane widths, If the lane width is less than the specified lane width for basic freeway segment, i.e 3.6m then capacity is reduced because traffic flow tends to be restricted.
3. Shoulder widths and lateral clearances, shoulder width and lateral clearance influences the capacity of freeway. When lane widths are less than 3.65 m, drivers are forced to travel closer to one another laterally than they would normally desire. Drivers tend to compensate for this by reducing their travel speed. The effect of restricted lateral clearance is similar. When objects are located too close to the edge of the median and roadside lanes, drivers in these lanes will shy away from them, positioning themselves further from the lane edge hence capacity is reduced.
4. Design speed, freeway is designed for free flow speed around 120 km per hour ,if some vehicle is moving less than the design speed then capacity of freeway.
5. Grades: Effect of grade depends on both the length and slope of the grade. Traffic operations significantly affected when grades of 3% or more are longer than one quarter miles and when grades are less than 3% and longer than mile. The effect of heavy vehicles on such grades is much greater.

Traffic conditions
Traffic conditions that influence capacities and service levels include vehicle type and lane or directional distribution.
Vehicle type The entry of heavy vehicles - that is, vehicles other than passenger cars (a category that includes small trucks and vans) - into the traffic stream affects the number of vehicles that can be served. Heavy vehicles are vehicles that have more
than four tires touching the pavement. Trucks, buses, and recreational vehicles (RVs) are the three groups of heavy vehicles.

1. They are larger than passenger cars and occupy more roadway space; and
2. They have poorer operating capabilities than passenger cars, particularly with respect to acceleration, deceleration, and the ability to maintain speed on upgrades.

Directional
Multiple-choice questions

1. The weaving manoeuvres is a type of
   a) Merging
   b) Diverging
   c) Intersection
   d) Crossing.

2. Which of the following does not affect traffic flow?
   a) Vehicles travelling at speed
   b) Length of the vehicle
   c) Weather conditions
   d) Geometric design

3. The speed at which the value of time headway is lowest represents the
   a) Optimum speed
   b) Maximum speed
   c) Maximum headway
   d) Minimum headway

4. In countries like USA and UAE, which of the regulation is followed?
   a) Keep to left
   b) Keep to right
   c) Keep to middle
   d) Follow intersection

5. When the gap of the vehicle changes to a smaller lane then it is called
   a) Lane change
   b) Forced lane change
   c) Simultaneous lane change
   d) Voluntary lane change

6. The vehicles per unit length at any instant of time is called as
   a) Density
b) Jam density  
c) Maximum density  
d) Traffic flow

7. The distance between the two consecutive vehicles is called  
a) Space headway  
b) Time headway  
c) Jam density  
d) Traffic flow

8. The maximum jam density occurs at  
a) Zero speed  
b) 15th percentile speed  
c) 30th percentile speed  
d) 98th percentile speed

9. If the space headway is 7m, then the jam density in vehicle/km is  
a) 142  
b) 144  
c) 145  
d) 146

10. The minimum space headway increases with  
a) Increase in length of vehicle  
b) Increase in width of vehicle  
c) Increase in weight of vehicle  
d) Increase in width of pavement
Fill in the blanks

1. Land use, transportation and road network plans are **Inter linked**
2. The main cause of accidents in urban areas is **Improper planning**
3. The first stage in the function of traffic engineering department is **Collection of data**
4. Traffic forecast is not influenced by **Weather**
5. Demographic factors do not include **GDP**
6. The NHDP are being undertaken by private companies on basis of **BOT**
7. The traffic will increase if the **Price of vehicles decreases**
8. The traffic population is estimated by **Geometric method**
9. Major stresses in CC pavement is **Wheel load and warping stress**
10. The unit of ‘K’ is **Kg/cm³**
UNIT 4

Two Marks of Questions with Answers

Q1: What are the Factors affecting coordination
Ans: There are four major areas of consideration for signal coordination:
1. Benefits
2. Purpose of signal system
3. Factors lessening benefits
4. Exceptions to the coordinated scheme

Q2: What are the Factors lessening benefits of signal coordination.
Ans: Among the factors limiting benefits of signal coordination are the following:
• inadequate roadway capacity
• existence of substantial side frictions, including parking, loading, double parking, and multiple driveways
• wide variability in traffic speeds
• very short signal spacing
• heavy turn volumes, either into or out of the street

Q3: Explain the Time-space diagram and ideal offsets
Ans: The time-space diagram is simply the plot of signal indications as a function of time for two or more signals. The diagram is scaled with respect to distance, so that one may easily plot vehicle positions as a position of time.

Q4: what is the Effect of vehicles queued at signals
Ans: It sometimes happens that there are vehicles stored in block waiting for a green light. These may be stragglers from the last platoon, vehicles that turned into the block or vehicles that came out of parking lots or spots. The ideal offset must be adjusted to allow these vehicles, to avoid unnecessary stops. The ideal offset can then be given as:
\[ t_{ideal} = L_S - (Qh + Loss1) \] (38.3)
where, \( Q \) = number of vehicles queued per lane, veh, \( h \) = discharge headway of queued vehicle, sec/veh, and \( Loss1 \) = loss time associated with vehicles starting from rest at the first downstream signal.

Q5: Explain the Offset determination in a grid
Ans: A one-way street system has a number of advantages, not the least of which is traffic elimination of left turns against opposing traffic. The total elimination of constraints imposed by the closure of loops within the network or grid is not possible. Fig. 38:9 highlights the fact that if the cycle length, splits, and three offsets are specified, the offset in the fourth link is determined and cannot be independently specified extends this to a grid of one-way streets, in which all of the north-south streets are independently specified. The specification of one east-west Street then locks in all other east-west offsets. The key feature is that
an open tree of one-way links can be completely independently set, and that it is the closing or closure of the open tree, which presents constraints on some links.
Three Marks of Questions with Answers

Q1: What are the Types of delay
Ans: The most common measure of operational quality is delay, although queue length is often used as a secondary measure. While it is possible to measure delay in the field, it is a difficult process, and different observers may make judgments that could yield different results. For many purposes, it is, therefore, convenient to have a predictive model for the estimate of delay.

Delay, however, can be quantified in many different ways. The most frequently used forms of delay are defined as follows:
• Stopped time delay
• Approach delay
• Travel time delay
• Time-in-queue delay
• Control delay

Q2: Explain about Approach Delay
Ans: Approach delay includes stopped-time delay but adds the time loss due to deceleration from the approach speed to a stop and the time loss due to re-acceleration back to the desired speed.

It is found by extending the velocity slope of the approaching vehicle as if no signal existed. Approach delay is the horizontal (time) difference between the hypothetical extension of the approaching velocity slope and the departure slope after full acceleration is achieved. Average approach delay is the average for all vehicles during a specified time period.

Q3: Explain about Control Delay
Control delay is the delay caused by a control device, either a traffic signal or a STOP-sign. It is approximately equal to time-in-queue delay plus the acceleration-deceleration delay component.

Delay measures can be stated for a single vehicle, as an average for all vehicles over a specified time period, or as an aggregate total value for all vehicles over a specified time period. Aggregate delay is measured in total vehicle-seconds, vehicle-minutes, or vehicle-hours for all vehicles in the specified time interval. Average individual delay is generally stated in terms of seconds per vehicle for a specified time interval.

Q4: Explain about Delay diagram
Ans: All analytic models of delay begin with a plot of cumulative vehicles arriving and departing vs. time at a given signal location. Fig. 35:2 shows a plot of total vehicle vs time. Two curves are shown: a plot of arriving vehicles and a plot of departing vehicles. The time axis is divided into periods of effective green and effective red. Vehicles are assumed to arrive at a uniform rate of flow (v vehicles per unit time). This is shown by the constant slope of the arrival curve. Uniform
arrivals assume that the inter-vehicle arrival time between vehicles is a constant. Assuming no preexisting queue, arriving vehicles depart instantaneously when the signal is green (i.e., the departure curve is same as the arrival curve). When the red phase begins, vehicles begin to queue, as none are being discharged. Thus, the departure curve is parallel to the x-axis during the red interval. When the next effective green begins, vehicles queued during the red interval depart from the intersection, at a rate called saturation flow rate (s vehicle per unit time). For stable operations, depicted here, the departure curve catches up with the arrival curve before the next red interval begins (i.e., there is no residual queue left at the end of the effective green).

Q5: Explain about Uniform Delay
Ans: Uniform delay is the delay based on an assumption of uniform arrivals and stable flow with no individual cycle failures. Fig. 35:3, shows stable flow throughout the period depicted. No signal cycle fails here, i.e., no vehicles are forced to wait for more than one green phase to be discharged. During every green phase, the departure function catches up with the arrival function. Total aggregate delay during this period is the total of all the triangular areas between the arrival and departure curves. This type of delay is known as Uniform delay.
Q1: What are the Basic Principles of vehicle actuated signals
Ans: As stated earlier, Vehicle-Actuated Signals require actuation by a vehicle on one or more approaches in order for certain phases or traffic movements to be serviced. They are equipped with detectors and the necessary control logic to respond to the demands placed on them.

Vehicle-actuated control uses information on current demands and operations, obtained from detectors within the intersection, to alter one or more aspects of the signal timing on a cycle-by-cycle basis. Timing of the signals is controlled by traffic demand.

Actuated controllers may be programmed to accommodate:
• Variable phase sequences (e.g., optional protected LT phases)
• Variable green times for each phase
• Variable cycle length, caused by variable green times

Such variability allows the signal to allocate green time based on current demands and operations. A proper clearance interval between the green & the red phases is also ensured.

Q2: What are the Advantages of Actuated Signals
Ans: The various advantages of actuated signals are stated below:
• They can reduce delay (if properly timed).
• They are adaptable to short-term fluctuations in traffic flow.
• Usually increase capacity (by continually reapportioning green time).
• Provide continuous operation under low volume conditions.
• Especially effective at multiple phase intersections.

Disadvantages of Actuated Signals
The main disadvantages are as following:
• If traffic demand pattern is very regular, the extra benefit of adding local actuation is minimal, perhaps non-existent.
• Installation cost is two to three times the cost of a pre-timed signal installation.
• Actuated controllers are much more complicated than pre-timed controllers, increasing maintenance costs.
• They require careful inspection & maintenance to ensure proper operation.

Q3: Explain the types of Actuated Control
Ans: There are three basic types of actuated control, each using signal controllers that are somewhat different in their design:
1. Semi-Actuated Control
2. Full-Actuated Control
3. Volume-Density Control
Semi-Actuated Control
This type of controller is used at intersections where a major street having relatively uniform flow is crossed by a minor street with low volumes. Detectors are placed only on the minor street. The green is on the major street at all times unless a call on the side street is noted. The number and duration of side-street green is limited by the signal timing and can be restricted to times that do not interfere with progressive signal-timing patterns along the major street.

Full-Actuated Control
This type of controller is used at the intersections of streets or roads with relatively equal volumes, but where the traffic distribution is varying. In full actuated operation, all lanes of all approaches are monitored by detectors. The phase sequence, green allocations, and cycle length are all subjected to variation. This form of control is effective for both two-phase and multi-phase operations and can accommodate optional phases.

Volume-Density Control
Volume-density control is basically the same as full actuated control with additional demand-responsive features. It is designed for intersections of major traffic flows having considerable unpredictable fluctuations.

Q4: Explain about Phase design
Ans: The signal design procedure involves six major steps. They include:
(1) phase design,
(2) determination of amber time and clearance time,
(3) determination of cycle length,
(4) apportioning of green time,
(5) pedestrian crossing requirements, and
(6) performance evaluation of the design obtained in the previous steps.

The objective of phase design is to separate the conflicting movements in an intersection into various phases, so that movements in a phase should have no conflicts. If all the movements are to be separated with no conflicts, then a large number of phases are required. In such a situation, the objective is to design phases with minimum conflicts or with less severe conflicts.

There is no precise methodology for the design of phases. This is often guided by the geometry of the intersection, the flow pattern especially the turning movements, and the relative magnitudes of flow. Therefore, a trial and error procedure is often adopted. However, phase design is very important because it affects the further design steps.

Further, it is easier to change the cycle time and green time when flow pattern changes, where a drastic change in the flow pattern may cause considerable confusion to the drivers. To illustrate various phase plan options, consider a four
legged intersection with through traffic and right turns. Left turn is ignored. The first issue is to decide how many phases are required. It is possible to have two, three, four or even more number of phases.

**Q5: Explain the Importance of signal phasing and cycle length**

**Ans:** The traffic engineer may well be faced with a situation that looks intimidating, but for which the community seek to have smooth flow of traffic along an arterial or in a system. The orderly approach begins with first, appreciating the magnitude of the problem. The splits, offsets, and cycle length might be totally out of date for the existing traffic demand. Even if the plan is not out of date, the settings in the field might be totally out of date, the settings in the field might be totally different than those originally intended and/or set. Thus, a logical first step is simply to ride the system and inspect it. Second, it would be very useful to sketch out how much of the system can be thought of as an open tree of one way links.

A distinction should be made among

• streets that are one way
• streets that can be treated as one-way, due to the actual or desired flow patterns
• streets that must be treated as two-ways
• larger grids in which streets interact because they form unavoidable closed trees and are each important in that they cannot be ignored for the sake of establishing a master grid which is an open tree
• smaller grids in which the issue is not coordination but local land access and circulation Downtown grids might well fall into the last category, at least in some cases. Third, attention should focus on the combination of cycle length, block length and platoon speed and their interaction. Fourth, if the geometry is not suitable, one can adapt and fix up the situation to a certain extent. Another issue to address, of course, is whether the objective of progressed movement of traffic should be maintained.
Objective Type Questions

Q1. To reduce the conflict points which method is preferable?
   a) Restricting the entry in one side
   b) Widening of the roads
   c) Use of traffic signals
   d) Diverting the traffic

Q2. One of the disadvantages of traffic signals is
   a) Provide orderly moment at intersection
   b) The quality of the traffic flow improves
   c) Traffic handling capacity increases
   d) The rear end collision increases

Q3. The traffic signals that are installed for pedestrians are called
   a) Traffic control signals
   b) Pedestrian signals
   c) Special traffic signals
   d) Automatic signals

Q4. The clearance time for amber is usually
   a) 0.5sec
   b) 1sec
   c) 1.5sec
   d) 3sec

Q5. In trial cycle method, the average time headway is assumed as
   a) 2sec
   b) 2.5sec
   c) 3sec
   d) 3.5sec
Q6. The number of cycles for a trial period of 45 sec is
   a) 20
   b) 22
   c) 25
   d) 30

Q7. If the number of cycles in trial cycle method is 20, for traffic of 170 on one road and 160 on other road, then calculate the total green time in sec
   a) 38
   b) 39
   c) 40
   d) 41

Q8. In approximate method of signals, the average time taken to cross by the pedestrian is
   a) 4sec
   b) 5sec
   c) 6sec
   d) 7sec

Q9. There is a traffic flow of 250 vehicles on road A and 200 vehicles on road B, if the green signal time on road A is 15 sec, then the green signal time of road B is
   a) 10sec
   b) 11sec
   c) 12sec
   d) 13sec

Q10. If the amber time at a signal is 3 sec and the green signal time is 25sec, find the red signal time
   a) 22sec
   b) 21sec
   c) 28sec
   d) 29sec
Fill in the Blanks

1. The **time-space diagram** is simply the plot of signal indications as a function of time for two or more signals.
2. A **one-way street** system has a number of advantages, not the least of which is traffic elimination of left turns against opposing traffic.
3. **Approach delay** includes stopped-time delay but adds the time loss due to deceleration from the approach speed to a stop and the time loss due to re-acceleration back to the desired speed.
4. **Control delay** is the delay caused by a control device, either a traffic signal or a STOP-sign.
5. **Uniform delay** is the delay based on an assumption of uniform arrivals and stable flow with no individual cycle failures.
6. **Vehicle-actuated control** uses information on current demands and operations, obtained from detectors within the intersection, to alter one or more aspects of the signal timing on a cycle-by-cycle basis.
7. **Semi-Actuated Control** is used at intersections where a major street having relatively uniform flow is crossed by a minor street with low volumes.
8. **Volume-density control** is the same as full-actuated control with additional demand-responsive features. It is designed for intersections of major traffic flows having considerable unpredictable fluctuations.
9. The objective of **phase design** is to separate the conflicting movements in an intersection into various phases, so that movements in a phase should have no conflicts.
10. The splits, offsets, and cycle length might be very out of date for the existing traffic demand.
UNIT 5

Two Marks of Questions with Answers

Q1: Explain how Congestion’s Impact on Economic Productivity
Ans: So, how important is congestion? Theoretically, faster travel speeds (lower congestion) should drive transportation costs down. These lower costs affect the bottom line for firms—lower costs mean higher potential for profits and lower prices for consumers. This is borne out by empirical research.

Economists Remy Prud’homme and Chang-Woo Lee conducted some of the first major contemporary studies, finding that higher travel speeds expanded the labor and employment pool in cities. For every 10% increase in travel speeds, labor markets expanded by 15% and productivity by 3%.26 While their original study focused on cities in France, an extension to include larger cities in other countries (but not the U.S.) found similar results.27 Other European researchers have found that slower growth in core urban areas in the Netherlands can be attributed to the “negative congestion effects caused by traffic jams.

Q2: Explain about Balancing Supply and Demand
Ans: Given the debilitating effects of congestion, why have governments permitted congestion to continue to increase? At root, traffic congestion is the result of an imbalance between supply and demand: more vehicles are attempting to use the same limited road space. One way to think about the problem is what happens when a handful of rice is poured into a funnel. If the spout of the funnel is too narrow, the rice backs up and can even stop the flow of rice. If the spout is sufficiently wide, the rice flows through unimpeded.37 Throughput can be maximized either by slowing the amount of rice poured into the funnel, what is known as “demand management,” or by increasing the size of the funnel, i.e. “capacity expansion.”

Q3: What is the Use of Reversible Direction Lanes
Ans: One of the most current ways around the world of the usage of RLS is the construction work zone. Reversible lanes are well suited for bridges and within tunnels because at these areas it is desirable to maintain adequate capacity within the restricted right-of-ways of work zones.

Q4: Explain about reversible traffic lanes
Ans: Reversible traffic lanes add peak-direction capacity to a two-way road and decrease congestion by borrowing available lane capacity from the other (off-peak) direction. Reversing lanes reduces congestion for handling special event traffic, during morning and evening commutes when an incident blocks a lane, or when construction or maintenance activity is present on the road.
Q5: Explain the Application Techniques and Principles of reversible lanes.
Ans: Several factors influence the planning and design of reversible lanes. These include:
- Cost and the level of complexity and sophistication of traffic control.
- Functional type of roadway on which it is used.
- Purpose and/or intended goals for which it is used.
- Agency responsible for the planning, design, implementation, and management.
Three Marks of Questions with Answers

Q1: Explain about Reversible Traffic Lanes Best Practice
Ans:
- Type of Location: Multi-lane roadways in which a directionally unbalanced traffic flow leaves one or more of the minor flow direction lanes underutilized and, in particular, segments with minimal turning and stopping maneuvers.

- Agency Practices: Corridor analysis for location suitability, traffic law enforcement.

- Frequency of Reanalysis: Two to three years in order to identify safety improvements or issues and assess congestion mitigation benefits.

- Supporting Policies or Actions Needed: Regional MPO and local city adoption of program and budgeting of funds.

- Complementary Strategies: Event management programs.

Q2: What are the Parking Management Principles
Ans: These ten general principles can help guide planning decision to support parking management.

1. Consumer choice. People should have viable parking and travel options.

2. User information. Motorists should have information on their parking and travel options.


4. Efficient utilization. Parking facilities should be sized and managed so spaces are frequently occupied.

5. Flexibility. Parking plans should accommodate uncertainty and change.

6. Prioritization. The most desirable spaces should be managed to favor higher-priority uses.

7. Pricing. As much as possible, users should pay directly for the parking facilities they use.

8. Peak management. Special efforts should be made to deal with peak-demand.

9. Quality vs. quantity. Parking facility quality should be considered as important as quantity, including aesthetics, security, accessibility and user information.
10. Comprehensive analysis. All significant costs and benefits should be considered in parking planning.

**Q3: What are Parking Management Benefits**
Ans:
- Facility cost savings. Reduces costs to governments, businesses, developers and consumers.
- Improved quality of service. Many strategies improve user quality of service by providing better information, increasing consumer options, reducing congestion and creating more attractive facilities.
- More flexible facility location and design. Parking management gives architects, designers and planners more ways to address parking requirements.
- Revenue generation. Some management strategies generate revenues that can fund parking facilities, transportation improvements, or other important projects.
- Reduces land consumption. Parking management can reduce land requirements and so helps to preserve greenspace and other valuable ecological, historic and cultural resources.
- Supports mobility management. Parking management is an important component of efforts to encourage more efficient transportation patterns, which helps reduce problems such as traffic congestion, roadway costs, pollution emissions, energy consumption and traffic accidents.
- Supports Smart Growth. Parking management helps create more accessible and efficient land use patterns, and support other land use planning objectives.

**Q4: Explain about Shared Parking**
Ans: Shared Parking means that a parking facility serves multiple users or destinations (“Shared Parking,” VTPI, 2005). This is most successful if destinations have different peak periods, or if they share patrons so motorists park at one facility and walk to multiple destinations. Parking facilities can be shared in several ways.

- Shared Rather Than Reserved Spaces. Motorists share parking rather than being assigned reserved spaces. For example, 100 employees can usually share 60-80 spaces, since at any time some are on leave, in the field, commuting by an alternative modes or working another shift. Hotels, apartments, and dormitories can share parking spaces among several units, since the number of vehicles per unit varies over time. Sharing can be optional, so for example, motorists could choose between $60 per month for a shared space or $100 for a reserved space.

- Share Parking Among Destinations. Parking can be shared among multiple destinations. For example, an office building can share parking with a restaurant or
theater, since peak demand for offices occurs during weekdays, and on weekend evenings for restaurants and theaters. Sharing can involve mixing land uses on single site, such as a mall or campus, or by creating a sharing arrangement between sites located suitably close together.

Q5: Explain about Remote Parking and Shuttle Service
Ans: Remote Parking (also called Satellite Parking) refers to the use of off-site parking facilities. This often involves shared facilities, such as office workers parking at a restaurant parking lot during the day, in exchange for restaurant employees using the office parking lot evenings and weekends.

It can involve use of public facilities, such as commercial parking lots. Remote parking can also involve use of parking facilities located at the periphery of a business district or other activity center, and use of overflow parking during a special event that attracts large crowds. Special shuttle buses or free transit service may be provided to connect destinations with remote parking facilities, allowing them to be farther apart than would otherwise be acceptable.

Another type of remote parking is use of Park & Ride facilities, often located at the urban fringe where parking is free or significantly less expensive than in urban centers.
Five Marks of Questions with Answers

**Q1: Explain about Unbundle Parking**

Ans: Unbundling means that parking is rented or sold separately, rather than automatically included with building space. For example, rather than renting an apartment with two parking spaces for $1,000 per month, the apartment would rent for $800 per month, plus $100 per month for each parking space. This is more equitable and efficient, since occupants only pay for parking they need.

Parking can be unbundled in several ways:

- Facility managers can unbundle parking when renting building space.
- Developers can make some or all parking optional when selling buildings.
- In some cases it may be easier to offer a discount to renters who use fewer than average parking spaces, rather than charging an additional fee. For example, an office or apartment might rent for $1,000 per month with two “free” parking spaces, but renters who only use one space receive a $75 monthly discount.
- Parking costs can be itemized in lease agreements to help renters understand the parking costs they bear, and to help them negotiate reductions.
- Informal unbundling can be encouraged by helping to create a secondary market for available spaces. For example, office, apartment and condominium managers can maintain a list of residents who have excess parking spaces that are available for rent.

**Q2: What are the application of VGRID to vehicular flow homogenization**

Ans: The goal of VGrid is to smoothen traffic flow through the use of a distributed computation grid network and the dissemination of traffic data through VANET. In order to quantify this, we define a set of metrics we will use to describe traffic flow.

The primary metric is the speed variance normalized to the average speed, which indicates the amount of acceleration and deceleration vehicles experience. Without VGrid, drivers lack precise speed and position information about the vehicles around them, which may lead to overreaction to changes in speed, causing accidents or unneeded slowdowns. If variance is low, traffic flows at a more constant rate and this scenario occurs less often.

This homogenization also affects the throughput, the number of vehicles exiting a section of roadway in a fixed time interval, and the latency, the amount of time it takes vehicles to exit a section of roadway, are indicators of the overall performance of the system. Therefore, the goal is to minimize variance and latency and to maximize throughput.
Q3: Explain about Minimizing and Balancing Congestion
Ans: One of the recommendations made in the final report for the FHWA project Signal Timing Under Saturated Conditions was to devote the agency's best resources to its worst congestion problems. Leading practitioners, as reported in that work, recommended:

- Make use of every available feature, however esoteric, to improve green time efficiency in favor of the congested movements. This requirement might be seen as conflicting with a realistic understanding of maintenance limitations, but it need not be so. An agency can reconcile both these objectives by ensuring that the extreme operational efforts are spent wisely and not wasted on intersections that operate routinely and don't need such efforts.

- Devote the agency's best operational experts to the most congested problems, and be prepared to support their extended observation and experimentation in pursuit of a solution.

Smooth Flow
Many agencies now use advanced analysis tools to optimize and evaluate traffic signal operation. But the optimizations and the evaluation measures are surrogates for the "measurements" made by motorists. For example, motorists do not separately measure time delayed and time not delayed. They measure total travel time, and travel time reliability.

All motorists apply a greater penalty to time delayed than time not delayed. But motorists also evaluate the cause of the delay when assessing blame, and delay caused by congestion is counted less against the agency than delay caused by red lights, especially when the other movements of the intersection are perceived to be underutilized. These situations are a leading cause of complaint calls.

Q4: Explain about Signal Timing Versatility
Ans: Closely related to a predictable and consistent response is the need for versatility in signal timing. If the solution space is divided into only four zones, and if that solution space overlays a wide-ranging condition space, then each plan in the solution space must provide acceptable operation even at the boundaries of the condition to which it is applied. In highly dynamic cases, more than four solutions may be required, but that increased dynamic nature still will demand versatile signal timing solutions.

But most computer-based analysis of traffic signals applied by practitioners, both for optimization and simulation, considers the traffic demand as a steady state. Thus, signal timing approaches are evaluated by their performance during the narrowly unique conditions usually characterized by a 15-minute period rather than by the range of conditions over the hours of the daily schedule for which those timings will
be used, and for the months and years over which that daily schedule will be used. The best agencies address this by one of two approaches:

- Implement a system capable of continuous optimization. That system may use normal traffic actuated features at the local controller, including gapping out, hold release, phase skipping, and volume-density features. Alternatively, it may use a more centralized or regionalized adaptive control based on network objectives. In all cases, the effectiveness of the system depends on detection. Design for versatility. The best agencies are able to understand signal timing effectiveness over a range of conditions by looking at the breadth of the solution rather than by seeking a narrow optimum. For example, a progression-based solution that works for heavy traffic will also work for light traffic. Even one car in the network will move unimpeded. This is a variation on Dr. Messer's observation, that such solutions a.) Provide a predictable target into which motorists will fit their behavior, and b.) Work over the broadest range of actual conditions. Agencies that are constrained by resources on a range of fronts can still maintain good basic service if they consider versatility in their methods and solutions.

Q5: What are the Transportation systems management and operations (TSMO):
Ans: An integrated program to optimize the performance of existing infrastructure through the implementation of systems, services, and projects designed to preserve capacity and improve security, safety, and reliability.

The term includes improvements to the transportation system such as:
- Traffic detection and surveillance,
- Arterial management,
- Freeway management,
- Demand management,
- Work zone management,
- Emergency management,
- Electronic toll collection,
- Automated enforcement,
- Traffic incident management,
- Roadway weather management,
- Traveler information services,
- Commercial vehicle operations,
- Traffic control,
- Freight management, and
- Coordination of highway, rail, transit, bicycle, and pedestrian operations.

ITS initiatives and programs got underway in Europe, Japan, the US and other countries. In general, ITS began with an exploration of technologies and their applications through research and operational tests. Within a few years, attention moved into a deployment phase focused on encouraging wide-scale deployment of
ITS. The USDOT, for example, set a deployment goal and began measuring deployment through “a few good measures”.

Even as this was happening the focus broadened to include integration of systems. Systems needed to be integrated to share data and information and, in some case, control. The transportation community learned about architecture and standards and incorporated new skill sets, such as system engineering, into its repertoire. Today, ITS architectures exist in the US, Canada, Europe, Japan and elsewhere.
Multiple-choice questions

Q1. The first stage of parking lot is
   a) Entrance
   b) Acceptance
   c) Storage
   d) Delivery

Q2: Which of the following relationship is correct?
   a) Travel speed= running speed
   b) Travel speed< running speed
c) Travel speed>running speed
   d) Travel speed=1.5 times of running speed

Q3: The distance between the two consecutive vehicles is called
   a) Space headway
   b) Time headway
   c) Jam density
   d) Traffic flow

Q4. The equivalency factor for car recommended by IRC is
   a) 0.5
   b) 1.0
   c) 1.5
   d) 2.0

Q5: The specifications for road signs are specified by
   a) IRC 6
   b) IRC 21
   c) IRC 67
d) IRC 97

Q6: On a 2 phase road, the saturation flow on road A is 1000 and normal flow is 250, whereas on road B the saturation flow is 1500 and normal flow is 500, the total red time is 10 sec, find optimum cycle length
   a) 35sec
b) 36sec
c) 37sec
d) 38sec

Q7: Land use, transportation and road network plans are
a) Inter linked
b) Intra linked
c) Not linked
d) Depends on the network

Q8: The first stage in the function of traffic engineering department is
a) Planning and design
b) Collection of data
c) Investigations
d) Finance

Q9: Demographic factors do not include
a) GDP
b) Population in urban cities
c) Population in rural areas
d) Overall population

Q10: The NHDP are being undertaken by private companies on basis of
a) Profit
b) Revenue
c) BOT
d) Commission basis
1. Reversible lanes are well suited for bridges and within tunnels because at these areas it is desirable to maintain adequate capacity within the restricted right-of-ways of work zones.

2. Shared Parking means that a parking facility serves multiple users or destinations.

3. Remote Parking (also called Satellite Parking) refers to the use of off-site parking facilities.

4. Unbundling means that parking is rented or sold separately, rather than automatically included with building space.

5. An integrated program to optimize the performance of existing infrastructure through the implementation of systems, services, and projects designed to preserve capacity and improve security, safety, and reliability.

6. ITS initiatives and programs got underway in Europe, Japan, the US and other countries.

7. The USDOT, for example, set a deployment goal and began measuring deployment through “a few good measures”.

8. Systems needed to be integrated to share data and information and, in some case, control.

9. Land use, transportation and road network plans are Inter linked.

10. The first stage in the function of traffic engineering department is Finance.
17 BEYOND SYLLABUS TOPICS WITH MATERIAL
18 RESULT ANALYSIS-REMEDIAL/CORRECTIVE ACTION
19 RECORD OF TUTORIAL CLASSES
20 RECORD OF REMEDIAL CLASSES
21 RECORD OF GUEST LECTURERS CONDUCTED