Supplementary Topics in Traffic Engineering

Masoud Ghodrat Abadi, PhD

Rohollah (Roham) Moghadam, PhD

WAVE

WORKFORCE FOR AUTONOMOUS VEHICLE ENGINEERING

SACRAMENTO STATE

MTI MINETA TRANSPORTATION INSTITUTE

Preparing Today's Workforce for Tomorrow's Autonomous Transportation: Bridging Electrical and Civil Engineering

Learning Objectives

1. **Define** key transportation terms such as human factors, LOS, and ITS.
2. **Describe** how human abilities and limitations affect transportation design.
3. **Explain** the roles of signifiers, constraints, and feedback in user interactions.
4. **Differentiate** basic roadway facility types and their ideal conditions.
5. **Apply** introductory LOS measures to simple transportation scenarios.
6. **Summarize** the main components and benefits of ITS and V2X technologies.

Human Factors

What is Human Factors?

"Human Factors is a body of knowledge about **human abilities**, human **limitations**, and other human **characteristics** that are relevant to design."

"Human factors engineering is the application of human factors information to the **design** of tools, machines, systems, tasks, jobs, and environments for safe, comfortable, and effective human use."

Human Factors

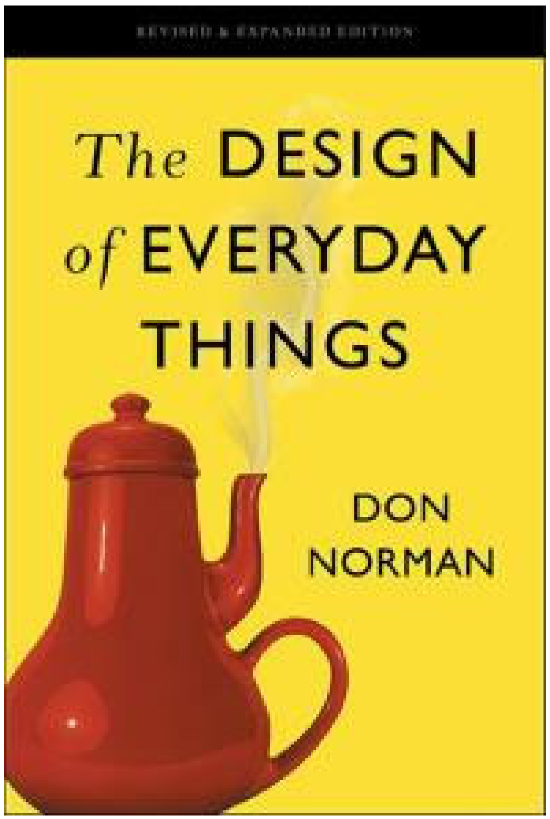
How does human factors apply to transportation?


This Photo by Unknown Author is licensed under CC BY-NC-ND


This Photo by Unknown Author is licensed under CC BY-NC-ND

This Photo by Unknown Author is licensed under CC BY-NC-ND

Human Factors



"Good design is actually a lot harder to notice than poor design…because good designs fit our needs so well that the design is invisible, serving us without drawing attention to itself."

Good Design vs. Bad Design

Conceptual Models

What is a mental model?

- Can be of people, the environment, or things
- Formed through experience, training
- Guides how we navigate the world

➢ How do we know that a vehicle is autonomous?

➢ Do we expect autonomous vehicles to behave the same as a conventional vehicle?

Signifiers, Constraints, and Feedback

Signifiers

Identify where and what specific action should take place.

This Photo by Unknown Author is licensed under CC BY-SA

Constraints

Intentional restrictions meant to guide user behavior.

This Photo by Unknown Author is licensed under CC BY

Feedback

Communicate the results of an action.

Level of Service (LOS)

Uninterrupted vs. Interrupted Facilities

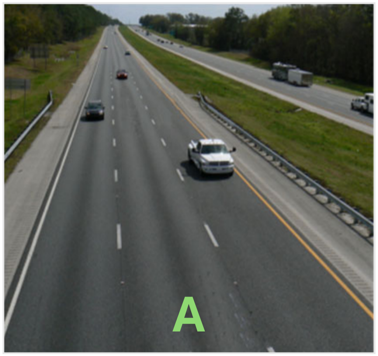
Uninterrupted Flow
Traffic flow influenced by characteristics of roadway and interactions of vehicles within the traffic stream

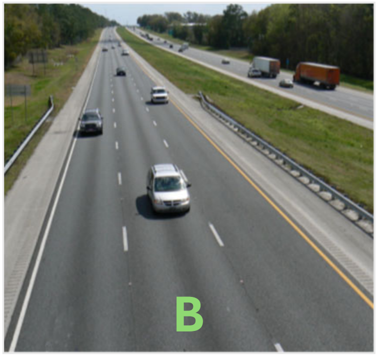
Interrupted Flow
Traffic streams also operate under the influence of traffic control devices

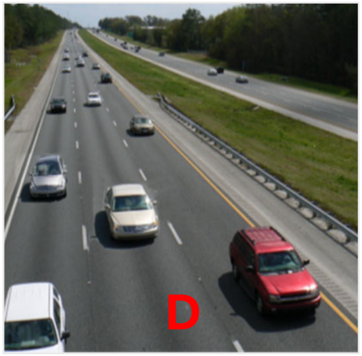
LOS Definition

- For *uninterrupted flow facilities*, **LOS** is a concept intended to capture factors such as **speed, travel time, freedom to maneuver, and safety**.
- LOS is a qualitative ranking of the traffic operational conditions experienced by users of the facility.
- Current practice designate six levels of service ranging from **A to F**.

LOS Levels







Freeway Definition

What is a **freeway**?

- Fully access controlled (access limited to on/off ramps)
- At least two lanes in each direction
- Divided by a full median
- Typically higher design standards (design speeds, lane widths, etc.)
- Analysis assumes that traffic is unaffected by merging or diverging traffic movements

Freeway LOS Procedure

1. Establish **Base Conditions** and Capacity

2. Estimate or Measure **Free-Flow Speed (*FFS*)**

3. Calculate Analysis **Flow Rate (v_p)**

4. Service Measure to **Determine LOS**

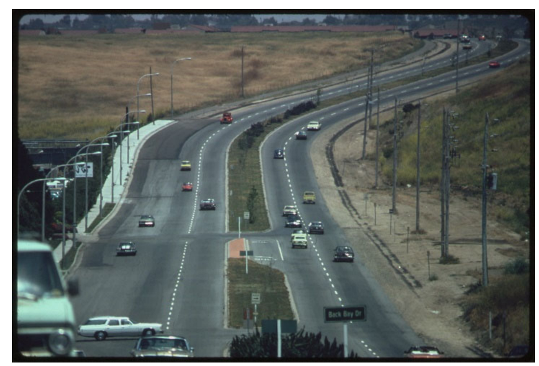
Base (Ideal) Freeway Condition

1. Level Terrain (Grades ≤ 2%)
2. Wide Lane Widths (≥ 12 ft [3.6 m])
3. Right Shoulder Widths (≥ 6 ft [1.8 m])
4. Only Passenger Cars
5. 6-mi or greater interchange spacing

LOS analysis is performed by making adjustments for prevailing conditions that are “less than ideal.”

Multilane Highway Definition

- Usually 4 or 6 lanes (total)
- Posted speed limit between 40-60 mph.
- Median treatment can be:
  - A painted stripe
  - A two-way left-turn lane, or
  - A full median
- Can have traffic signals
  - At least 2 miles apart
  - No significant queuing



Base (Ideal) Multilane Highway Condition

1. Level Terrain (Grades ≤ 2%)
2. Wide Lane Widths (≥ 12 ft [3.6 m])
3. Right Shoulder Widths (≥ 12 ft total both sides)
   - Total lateral clearance
4. No direct access point along roadway
5. Divided directional traffic
6. Only Passenger Cars
7. Free flow speed of 60 mph (100 kmph)

LOS analysis is performed by making adjustments for prevailing conditions that are “less than ideal.”

Two-Lane Highway Definition

- One travel lane in each direction, and typically undivided
- Used for lower traffic volume situations
- Generally have free-flow speeds ranging between 45 and 65 mi/hr
- Have wide-ranging design standards
- May have occasional traffic signals or even stop-control
- In order to pass a vehicle, the opposing lane must be used (except for where passing lanes are provided)

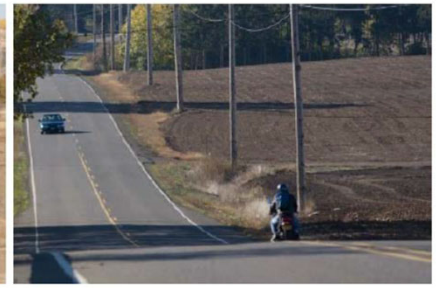
LOS Considerations

- Unlike freeways and multilane highways, both directions must be considered in the LOS analysis
  - Traffic in the opposing direction influences the passing opportunities for vehicles in the direction of interest

- Terrain can have a more significant effect due to restrictions on passing-sight distance

Two-Lane Highways: Examples

Commuter Routes



Access Routes

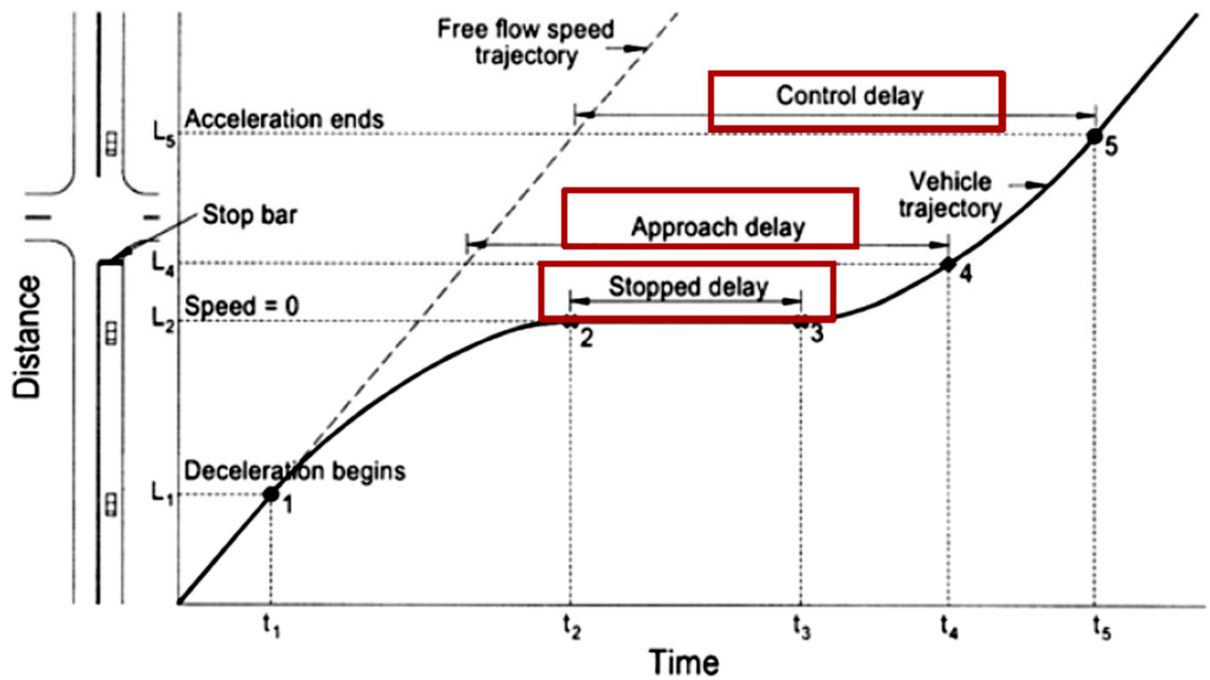
Through Routes

Base (Ideal) Two-lane Highway Condition

1. Level Terrain (Grades ≤ 2%)
2. Wide Lane Widths (≥ 12 ft [3.6 m])
3. Shoulder width (≥ 6 ft [1.8 m])
4. No direct access point along roadway
5. Only Passenger Cars
6. 0% no-passing zones on the highway segment
7. No impediments to through traffic due to traffic control or turning vehicles

LOS at Interrupted Facilities

- The performance measure that is used to assess level of service for signalized intersections is **delay**.



Calculating Control Delay

- Average Control Delay per Vehicle:

$$d = d_1 + d_2 + d_3 \qquad \text{Eq. 7.27}$$

Where:
d = average signal delay per vehicle in seconds,
d_1 = average delay per vehicle due to uniform arrivals in seconds,
d_2 = average delay per vehicle due to random arrivals in seconds, and
d_3 = average delay per vehicle due to initial queue at start of analysis time period, in seconds.

Intelligent Transportation Systems (ITS)

What is ITS?

- Intelligent Transportation Systems (ITS) use advanced technologies to improve transportation safety, efficiency, and sustainability.

Key Goals:	- Reduce traffic congestion - Improve road safety - Enhance mobility - Reduce environmental impact
Examples:	- Traffic signal control systems - Electronic toll collection - Smart navigation systems - Caltrans Performance Measurement System (PeMS).

Components of ITS

SENSORS (CAMERAS, RADAR, LIDAR)

COMMUNICATION SYSTEMS

CONTROL SYSTEMS

DATA PROCESSING & AI

WIRELESS COMMUNICATION BETWEEN VEHICLES AND INFRASTRUCTURE

Vehicle-to-Everything (V2X) Communications

- Improve safety, traffic efficiency, and enable autonomous driving.

- Main V2X Categories:
  - V2V: Vehicle to Vehicle
  - V2I: Vehicle to Infrastructure
  - V2P: Vehicle to Pedestrian
  - V2N: Vehicle to Network
  - V2G: Vehicle to Grid

Technologies Enabling V2X

- Communication Technologies:
  - DSRC (Dedicated Short Range Communication)
  - C-V2X (Cellular Vehicle-to-Everything)
  - 5G Networks
  - Edge Computing
  - AI & Data Analytics

Benefits and Future of V2X

- Benefits:
  - Fewer crashes
  - Less congestion
  - Better fuel efficiency
  - Supports autonomous vehicles

- Future Trends:
  - Fully connected smart cities
  - Autonomous driving ecosystems
  - Integration with AI and IoT

References

- Chapanis, A. (1991). To communicate the human factors message, you have to know what the message is and how to communicate it. Human Factors Society Bulletin, 34(11), 1–4.Federal Highway Administration. (2023).
- Manual on Uniform Traffic Control Devices for Streets and Highways. U.S. Department of Transportation.
- Kenney, J. B. (2011). Dedicated short-range communications (DSRC) standards in the United States. Proceedings of the IEEE, 99(7), 1162–1182. https://doi.org/10.1109/JPROC.2011.2132790
- Mannering, F., & Washburn, S. (2020). Principles of highway engineering and traffic analysis (7th ed.). John Wiley & Sons.
- Roess, R. P., Prassas, E. S., & McShane, W. R. (2019). Traffic engineering (5th ed.). Pearson.
- Transportation Research Board. (2016). Highway Capacity Manual (6th ed.). National Academies of Sciences, Engineering, and Medicine.