Intelligent Transportation Systems: Hope for Today's Traffic?

Center for Sustainable Suburban Development
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Overview:

- personal mobility
- congestion
- vehicle emissions and fuel consumption
- intelligent transportation systems and examples
- other personal mobility options
Personal Mobility:

- personal mobility is an important part of a progressive society
- the automobile has become essential element of life
- our mobility is often restricted due to limitations in transportation infrastructure
- resource management problem:
  - if resources (transportation infrastructure) are limited and demand is high, congestion occurs
Roadway Congestion

- Texas Transportation Institute Annual Mobility Study:
  - http://mobility.tamu.edu/ums
  - congestion has grown everywhere in areas of all sizes
  - congestion occurs during longer portions of the day and delays more travelers and goods than ever before
  - billions of gallons of fuel are wasted every year, more emissions

“slow speeds caused by heavy traffic and/or narrow roadways due to construction, incidents, or too few lanes for the demand”
Air Quality

air quality in Southern California

Number of Exceedances


1980's

1990's
key factor: emission certification standards
General Solutions to Congestion

- **Manage Supply:**
  - build more lanes to increase roadway capacity
  - build more infrastructure for alternative modes (bike, rail, transit) *
  - shown to be more cost effective (Lipman, 2006)*
  - improve system operations (e.g., respond quickly to incidents)
  - implement *intelligent transportation system* techniques

- **Manage Demand:**
  - implement pricing mechanisms to limit use of resources
  - provide greater range of alternative modes
  - allow for alternative work locations and schedules
  - have employers provide travel support programs

- **Manage Land Use:**
  - implement better urban design
  - provide for mixed use development of land
  - increase housing and industrial density
  - allow for innovative planning and zoning
  - implement some type of growth management
United States Transportation Systems

- automobile-centric
- little demand and opportunity for alternative modes
- 1950’s – 1990’s: major build out of roadway network
- in many areas it is now difficult to construct new roadways:
  - higher population densities
  - land-use restrictions

from (Litman, 2001)
Transportation and Emissions Modeling

**Transportation Modeling:**
- wide variety of tools: travel demand modeling, macroscale to microscale operational models

**Microscale Emissions and Fuel Consumption Modeling:**
- prediction of second-by-second emissions and fuel consumption from a wide variety of vehicles
- based on real-world emissions measurements using a large set of driving conditions
Microscopic Traffic Models

- models individual behaviors of vehicles:
  - car following behavior
  - lane-change behavior

\[
\dot{x}_{n+1}(t + \Delta t_{n+1}) = S_{n+1} \frac{\dot{x}_n(t) - \dot{x}_{n+1}(t)}{[x_n(t) - x_{n+1}(t)]}
\]

\(\Delta t_{n+1} = \text{reaction delay}\)

\(S_{n+1}\): aggressive or passive behavior parameter

- PARAMICS integration with CMEM
- truck lane analysis
- HOT (high occupancy toll) lane analysis
- tunnel study
- BRT (bus rapid transit)
Roadway congestion is often categorized as different “levels of service” (LOS)
grades A – F: corresponds to traffic density
Congestion-Based Fuel Consumption and Emissions

- can plot as a function of average speed

![Graphs showing fuel consumption and emissions vs. speed](image)

- Fuel consumption
  - Congestion driving patterns
  - Steady-state driving patterns

- CO emissions
  - Congestion driving patterns
  - Steady-state driving patterns

- HC emissions
  - Congestion driving patterns
  - Steady-state driving patterns

- NOx emissions
  - Congestion driving patterns
  - Steady-state driving patterns
Congestion-Based Fuel Consumption and Emissions

• Anytime congestion brings average vehicle speed below 45 mph (for a freeway scenario), there is a net negative fuel consumption and emissions impact; vehicles are spending more time on the road and as a result fuel economy is worse and total emissions is greater

• If congestion brings average speed down from a freeflow speed of around 65 mph to a slower 45 - 50 mph, then congestion is actually helping improve fuel consumption and emissions

• If relieving the congestion such that the average traffic speed increases back to the freeflow state, fuel consumption and emissions increases

• If the real-world stop-and-go velocity pattern of vehicles were somehow smoothed out where average speed was preserved, then significant fuel consumption and emissions savings could be achieved

• similar (but more complex) for arterial and residential roads

• fuel/emissions congestion effects are more pronounced with heavy-duty trucks (lower power-to-weight ratios)
Air Quality Impacts of HOV Lanes

Vehicle Activity

Fleet Composition

CMEM

Emission Rates (g/veh-mi)

Vehicle Occupancy Rates

Emission Rates (g/person-mi)
Emissions Comparison of HOV with Mixed Flow

Emissions & fuel per Vehicle Mile

Emissions & Fuel per Passenger Mile

Scenario | Condition
--- | ---
1 | HOV under-utilized
2 | typical conditions
3 | HOV well-utilized
4 | HOV over-utilized
HOV Lane Air Quality Findings

• Under the same traffic conditions, traffic dynamics in HOV lanes are not significantly different from those in mixed-flow lanes

• Travel speed in HOV lanes are relatively higher than that in MF lanes for most of the time.

• Under free-flow condition, extremely high speed travel in HOV lanes can result in higher emissions per vehicle-mile.

• With higher people-moving capacity, HOV lanes produce less emissions per person-mile across all scenarios.
Intelligent Transportation Systems

- improving capacity of existing infrastructure through the use of computers, communications, and control technology

<table>
<thead>
<tr>
<th>User Services Bundle</th>
<th>User Services</th>
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</table>
| Travel and Transportation Management     | • En-Route Driver Information  
• Route Guidance  
• Traveler Services Information  
• Traffic Control  
• Incident Management  
• Emissions Testing and Mitigation  
• Demand Management and Operations  
• Pre-trip Travel Information  
• Ride Matching and Reservation  
• Highway Rail Intersection |
| Public Transportation Operations         | • Public Transportation Management  
• En-Route Transit Information  
• Personalized Public Transit  
• Public Travel Security |
| Electronic Payment                       | • Electronic Payment Services |
| Commercial Vehicle Operations            | • Commercial Vehicle Electronic Clearance  
• Automated Roadside Safety Inspection  
• On-board Safety Monitoring  
• Commercial Vehicle Administration Processes  
• Hazardous Materials Incident Response  
• Freight Mobility |
| Emergency Management                     | • Emergency Notification and Personal Security  
• Emergency Vehicle Management |
| Advanced Vehicle Control and Safety Systems | • Longitudinal Collision Avoidance  
• Lateral Collision Avoidance  
• Intersection Collision Avoidance  
• Vision Enhancement for Crash Avoidance  
• Safety Readiness  
• Pre-Crash Restraint Deployment  
• Automated Highway System |
Intelligent Transportation Systems

- Electronic Payment Services
  - Payment Request
  - Payment
  - Financial Institution

- Driver & Traveler Services
  - Emergency Acknowledge
  - Emergency Notification
  - Route Request
  - Transit Schedules
  - Transit Requests

- Commercial Vehicle Operations
  - Route Information
  - Commercial Vehicle

- Commercial Vehicle
  - Traffic Information
  - Priority Requests

- Vehicle Monitoring & Control
  - Vehicle Status
  - Traffic Control Information
  - Basic Vehicle

- Manage Transit
  - Traffic
  - Manage Traffic
  - Traffic Information

- Manage Archive Data
  - ITS Planning Data
  - E911
  - Incident Data

- Emergency Services
  - Incident Notification

- 2-Way Wide Area Wireless
  - Yellow Pages
  - Route Guidance / Traffic Information
  - Directory Assistance
  - Cooperative Probe Data

- Broadcast Wide Area Wireless
  - Traffic Information
  - Traveler Information

- Dedicated Short Range Communications
  - Toll Collection
  - In-Vehicle Signing
  - Enhanced Data
  - Automated Highway System
  - Galileo Data
  - Intersection Collision Avoidance

- Short Range Vehicle-to-Vehicle
  - Automated Highway System
  - Collision Avoidance
Example ITS Application: Intelligent Speed Adaptation

• process that monitors the current speed of a vehicle, compares it to an externally defined set speed, and takes corrective action

Different Forms:

• fixed: max permissible speed is set by the user; control system never exceeds this;

• variable: set speed is determined by vehicle location, where different speed limits are set spatially

• dynamic: speed is determined by time and location: temporal aspect varies based on road network conditions or weather

Driving Behavior Intervention:

• advisory, active support, and mandatory

Benefits: safety, lower congestion, lower environmental impacts
Intelligent Speed Adaptation Experimentation

Embedded Road Sensor Data

Traffic Management Center
Traffic Management Center
Traffic Management Center

Traffic Performance Measurement System (PeMS)

Wireless Communications Provider

System Server

Instrumented Vehicles

Internet

Vehicle Data
Intelligent Speed Adaptation: Preliminary Results

<table>
<thead>
<tr>
<th>Energy/Emissions</th>
<th>Non-ISA</th>
<th>ISA</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO2 (g)</td>
<td>5439</td>
<td>4781</td>
<td>-12%</td>
</tr>
<tr>
<td>CO (g)</td>
<td>97.01</td>
<td>50.47</td>
<td>-48%</td>
</tr>
<tr>
<td>HC (g)</td>
<td>3.20</td>
<td>1.90</td>
<td>-41%</td>
</tr>
<tr>
<td>NOx (g)</td>
<td>6.28</td>
<td>3.97</td>
<td>-37%</td>
</tr>
<tr>
<td>Fuel (g)</td>
<td>1766</td>
<td>1534</td>
<td>-13%</td>
</tr>
</tbody>
</table>

same travel time results:
Vehicular Ad-Hoc Networks (VANET)

- wireless communications vehicle-to-vehicle and vehicle-to-infrastructure is a hot research topic
- extension of wireless ad-hoc networking to mobile platforms
- many applications aimed at safety improvements
- other applications: self-organizing traffic information system
**Shared-Use Vehicle Systems**  
* (a.k.a. carsharing, station cars):  
  – organized short-term car rental  
  – joint access to a fleet of vehicles  
  – vehicles are used multiple times by multiple users

**Key Benefits:**

  – improves transportation efficiency:  
    • reduces number of vehicles to meet total travel demand  
    • results in better land use  
  
  – user cost savings: vehicle payments, insurance, maintenance, etc.  
  
  – environmental benefit: lower vehicle emissions/energy  
  
  – transit ridership: improves access to transit
Primary Shared-Use Vehicle System Models

CSOs: single stations

CITY

shared car parking

multiple stations

AIRPORT

EATERY

HOTEL

RESORT

SHOPS

station cars

school

home

office
Smart Parking

- parking is costly and limited in almost every major city in the U.S., contributing to increased congestion, air pollution, and driver frustration
- **Smart parking Management:**
  - use of advanced technologies to help direct drivers efficiently to available parking spaces
  - encourages transit ridership
  - lessens driver frustration
  - reduces congestion on roadways

- **Approaches:**
  - dynamic displays on roadway signs informing drivers of location and parking lot capacity
  - the Internet, and cell phones: providing space availability, location, and pricing information
**Transit Oriented Developments:**
- promote transit use through the integration of multiple transit options in high-density developments consisting of residential, commercial, and retail entities

**Bus Rapid Transit:**
- non-fixed rail transit system
- significantly less expensive than light-rail

**Innovative Mobility Modes:**
Summary and Future Directions

• Congestion will always be with us (induced demand effect)
• Necessity to go beyond an automobile-centric society
• Emissions: pollutant emphasis shift from cars to trucks to trains/ships
• Future Vehicles: hybrid electrics will continue to play an important role well into the future
• Application of Intelligent Transportation Solutions
• Increased automation in transportation