Real Time Driver Information for Congestion Management

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Outline

➢ Introduction
➢ Objectives
➢ Methodology
  ➢ Data Collection
  ➢ Data Screening/Information Synthesis
  ➢ Real Time Information Dissemination
  ➢ Driver Behavior and Active Traffic Management Strategies
➢ Case Studies
➢ Conclusions and Recommendations
Introduction and Objectives

- Problem: Traffic Congestion
- Conventional Solution: Build our way out of congestion – costly and ineffective!
- Alternative Solution: Active Traffic Management Strategies
- Focus: Real Time Traffic Information
- Impact: Congestion mitigation via Driver’s decision making process at pre-trip planning and en route

Objectives:
- Conduct a literature review on past and current research efforts on data collection methods and technologies, data screening and information synthesis, information dissemination, impact on driver’s behavior, and active traffic management strategies
- Review selected case studies
Real Time Traffic Information

1. Data collection
2. Data screening and processing
3. Information Synthesis
4. Information Dissemination
5. Congestion management and mitigation
6. Driver behavior
STEP 1: DATA COLLECTION
Definition

- Backbone of real-time traffic information system
- Functionality (point sensors, point-to-point, and area-wide sensors)
  - Point sensors (fixed sensors)
  - Point-to-point (detect vehicles at multiple locations or floating car data)
  - Area-wide sensors (fleet of probe vehicles)
Data Collection Technologies/Methods

- Manual counts:
  - Dependent on traffic data observer
  - Traffic data accuracy may not be acceptable

- Pneumatic Tubes:
  - Rubber tubes placed across the road
  - Detects vehicles based on pressure changes
  - Simple but limited lane coverage
  - Efficiency is highly dependent on the weather, temperature, and traffic conditions

- Piezoelectric sensors:
  - Placed in a groove made along the road surface of the lane(s) of interest
  - Volumes, speed, classification and weigh-in-motion
Data Collection Technologies/Methods

- Magnetic loops (Inductive Loops):
  - Conventional, intrusive, weather resistant, high maintenance, short lifetime
  - Vehicle counts, lane occupancy, and speed

- Passive and active infra-red:
  - Non-intrusive, but not weather resistant and no good lane coverage
  - Vehicle counts, classification and speeds

- Magneto-Meters (Passive Magnetic Sensors):
  - Intrusive, not accurate when vehicles follow too closely
  - Traffic counts, speeds, and vehicle classification
Data Collection Technologies/Methods

- Microwave Radar Detector:
  - Non-intrusive, weather resistant
  - Vehicle counts, speeds, and simplified vehicle classification
  - Frequency modulated type (Detects stopped vehicles - Unlimited lane coverage)
  - Continuous wave type (Does not detect stopped vehicles - Limited lane coverage)

- Ultrasonic and Passive Acoustic:
  - Non-intrusive, sensitive to temperature and weather conditions
  - Vehicle counts, speeds, and vehicle classification
Data Collection
Technologies/Methods

- Video Image Detection:
  - Non-intrusive, not weather resistant
  - Vehicle counts, classification, and speed

- Floating Car Data (FCD):
  - Vehicles are equipped with a mobile phone or GPS
  - Vehicle coordinates, travel time, speed, direction of travel (section measurement data)
  - Accurate information on traffic conditions
  - GPS-based, Cellular-based, Automatic Vehicle Identification (AVI)
Data Collection

Technologies/Methods

- Bluetooth Technology
  - Non-intrusive, cost effective, weather resistant, reliable
  - Media access control (MAC) address for tracking vehicles and Travel time data

- Emerging Technologies
  - Autonomous vehicles technologies: driverless cars
  - V2V and V2I Technologies: Wireless communication between vehicles and roadside units
  - Traffic speed, traffic conditions, OD flows, route choice, incident locations, and many other data types
V2V and V2I

- Equipped with wireless devices
- DSRC (Seven channels-5.9GHZ band-3000ft)
- RSU
- V2V and V2I
- Vehicle Ad-hoc Network (VANET)
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<td>Vehicle coordinates, travel times, route information, ... etc In-vehicle and RSU</td>
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- Depends on human factors
- Accuracy depends on weather
- Limited lane coverage
- Limited lane coverage
- Short lifetime
- Does not work properly in bad weather
- Limited lane coverage
- Not able to differentiate between two vehicles following too closely.
- Some types are not able to detect stopped vehicles
- Sensitive to temperature and weather condition
- Affected by weather conditions
- Some care may not have GPS or cell phones
- Sensitive to weather
- Low market penetration at first implementation
STEP 2: DATA PROCESSING
Definition

Data Sources → Data Fusion → Data Screening → Data Imputing → Information Synthesis → Current and Predicted Traffic Information → Pre-Trip Planning

Data Archival → En Route Planning
Data Processing

- Data summarization
  - Descriptive statistics (central tendency and dispersion)
- Data cleaning
  - Data errors: detection of errors and outliers
  - Missing data: data imputing with interpolation-based methods and simple linear regression method from recent and historical data
- Data reduction
  - Multiple data sources-large data sets- difficulty to process (Minimized)
  - Two levels data reduction approach (at acquisition level and at data fusion level)
STEP 3: INFORMATION DISSEMINATION
Definitions

- Distribution of extracted information to road user to influence driver decisions
- Information includes:
  - Travel times
  - Speeds
  - Delay
  - Congestion
  - Bottlenecks queues and
  - Incidents downstream
- Various technologies are used by state DOTs
Highway Advisory Radio

- Information is distributed via broadcast radio
- Traffic delays, emergency operations and construction updates, ... etc
- Can reach many travelers at any given time (within the broadcast range)
- Drawbacks:
  - Low power and poor signal quality (AM broadcast band) normally due to weather
  - Requires drivers to take action (turn on the radio to the appropriate station)
Dynamic Message Signs (DMS)

- Also known as CMS and VMS
- Can be programmed to display any combination of characters
- Flexibility to be either permanently fixed or portable devices
- Effective message on a DMS must have five elements: Problem, Location, Effect, Attention, Action
- Incident warning, slow-downs, upcoming speed changes, road work, alternative routes, etc
- Must be able to be read at least twice while traveling at the posted speed limit (MUTCD)
Telephone Information Services (511)

- “511” currently stands as the U.S. official traveler information telephone number
- Pre-recorded messages telling highway conditions, transit agencies and other travel information
- Operated by state and local transportation agencies
- 39 states actively use 511
Most drivers have access to the social networks via smartphones’ applications (Twitter, WAZE, INRIX, Way to Geaux, Beat the Traffic)

Smartphones are used to inform public of roadway incidents in real-time

Few studies examined how social media influences behavior

Usage percentages of 41 states and Washington, DC
REAL TIME INFORMATION AND DRIVERS’ BEHAVIOR
Impact of Real time information on drivers’ behavior

- Drivers react to information in terms of route choice, trip time choice, travel speed, etc.
- One study showed that drivers receiving information with smartphones reacted to daily variation in travel times
- Another study showed the effectiveness of DMS in terms of speed reduction and crash rate reduction
- Some studies indicated that in-vehicle traffic information could be distracting due to information overload; other studies showed otherwise
- Several studies showed that real-time traffic information improves the overall performance of the road network.
ACTIVE TRAFFIC MANAGEMENT STRATEGIES
Dynamic Lane Use (Shoulder Control)

- Dynamic opening of a shoulder lane to traffic or dynamic closure of travel lanes temporarily
- Ideal for congested and high transit volume freeways
- Shoulder running is based on traffic volume, travel speeds, incident presence
- Complementary ATM: variable speed limit, queue warning signs
- Benefits:
  - Postponed onset of congestion
  - Increased capacity
  - Improved trip reliability and travel times
- Challenges:
  - Informing the public when shoulder running is allowed
  - Possible bottlenecks at the end of the open shoulder segment
Dynamic Lane Use (Shoulder Control)
Dynamic Merge (Junction Control)

- Adjustment or closure of a lane or lanes upstream of an interchange.
- Ideal for congested freeway with high merging volumes
- Benefits:
  - Delayed onset of congestion
  - Increased capacity
  - Improvement of traffic efficiency and reliability
- Challenges:
  - Gaining public support
  - Design and operations of the junction control area
- Data necessary: Maximum capacity of upstream lanes, Traffic volumes on general purpose lanes and merging ramps, Travel speeds, Incident presence and location
Dynamic Merge (Junction Control)
Variable Speed Limits

- Changeable signs that reduce the speed limit in 5 mph increments downstream
- Ideal for congested freeways and areas prone to adverse weather
- Roadway or weather sensors are used with variable speed limits
- Benefits:
  - Improved traffic flow
  - Uniform traffic slowing or speed harmonization
- Few challenges with public support and operations of variable speed limits
- Enforcement issues
- Data required: Traffic volumes, Travel speeds, Local climate and weather conditions, Incident presence and location
Variable Speed Limits
Queue Warning and Dynamic Message Signs (DMS)

- Queue warning signs alert drivers of queues or backups downstream
- Loop detectors are used to help identify possible queues backing up
- Benefits:
  - Reduced congestion
  - Reduction of rear-end crashes and improved driver safety
- Challenges:
  - Data quality and reliability
  - Determining appropriate location for sensors
  - Public awareness
  - Operations and management
- Data required: Traffic volumes, Travel speeds, Travel times, Incident presence and locations.
Queue Warning and Dynamic Message Signs (DMS)
Dynamic Route Guidance (DRG)

- Develops optimal real-time distribution of traffic
- Different algorithms are used according to congestion levels and real-time traffic conditions
- DMS or in-vehicle systems are used to inform drivers with recommended routes
- Data required: Congestion information, Travel times
Dynamic Route Guidance (DRG)
Adaptive Ramp Metering

- Metering rates are altered according to traffic conditions
- Ideal for freeways with recurring breakdowns, congested metropolitan areas and stop-and-go traffic conditions

Benefits:
- Decreased crash rates in controlled areas
- Increased traffic volumes and speeds
- Relatively low construction cost

Challenges:
- Potential violations
- Negative public perception of ramp delay to local traffic

Data required: Traffic volumes, Travel speeds, Ramp demand and geometry, Crash history
Adaptive Ramp Metering
Advanced Arterial Traffic Control (AAC) system

- Managing traffic flow throughout the arterial network including signalized intersections
- Different sensors (e.g. loop detectors) are used
- Signal controllers to continuously adjust signal timing
- Allow a platoon of vehicles to pass through few intersections continuously

Benefits:
- Reduce travel time and congestion
- Improve safety
CASE STUDIES
Dynamic lane use control, dynamic speed limits, queue warning and adaptive ramp metering strategies.

- Green arrows indicate a lane is open.
- Yellow arrows provide warnings to proceed with caution.
- Red X signifies the lane is closed - drivers should begin to merge out of the closed lane.
- 30% reduction in collision and 22% increase in roadway capacity.
Smart Lanes: Minnesota DOT
Multiple ATM Strategies: Virginia DOT

- A major project dealing with active traffic management on Interstate 66 by 2015.
- 34 miles along I-66 from the District of Columbia to Prince William County
- Multiple active traffic management strategies and technologies.
- Dynamic shoulder use will be allowed.
- DMS and lane control systems to alert drivers.
- Other ATM strategies and technologies will be implemented.
Multiple ATM Strategies: Virginia DOT

Exact project layout and type of ATM strategy utilized in each segment
Variable Speed Limits: Missouri DOT

- Variable speed signs along I-270 and I-255 in St. Louis, MO
- Aided in the reduction of crashes and some congestion
- Enforcement was challenging due to driver confusion
- Variable speed limits were converted into variable advisory speeds
- Yellow and black color stating “Advisory When Flashing”
- Advisory speed range increases from 10mph in extreme congestion, to 60mph during very light traffic
- 10% increase in average throughput, reduction in congestion
- 4.5% to 8% crash reduction
- Upcoming congestion, inclement weather conditions, work zone lane closures or stopped vehicles ahead
- Dynamic Message Signs
Variable Speed Limits: Missouri DOT

MoDOT variable advisory speed sign
Multiple ATM Strategies: Texas DOT (Austin)

- Variable speed limits
  - Harmonized traffic flows, reduced the amount of lane changing conflicts, and provided improved safety on freeways
  - Reduced the likelihood and severity of conflicts

- Shoulder lane use
  - Reduced traffic density and increased operational speed
  - Speed at the end of the shoulder use segment decreased
  - Safety on the corridor was improve
  - Comprehensive evaluation is required

- Ramp Metering Strategy
  - Reduced the average number of stops per vehicle
  - Homogenous speed among vehicles
  - Reduced corridor delay
  - Overall network delay increased because of vehicles queuing during the peak traffic on ramps
Multiple ATM Strategies: Texas DOT (Houston)

- Queue warning system
  - Combat the bottleneck issue at an interchange.
  - Higher average speeds and reduced variance of driver speeds over all lanes.
  - 5% to 7% reduction in rear-end crashes at I-610, while no significant change at US 59.
  - Speed variance reduces.
  - Longer study be conducted.
Conclusions

- No single data collection technology or method can provide accurate widespread coverage of the network under all weather and traffic conditions.

- Today’s technology is geared more towards point to point measurements rather than point measurements. Travelers are more interested in such information (e.g. travel time, delay, etc.).

- Accurate real time traffic information requires integration of several data sources and advanced data processing tools to remove erroneous data and impute missing data.

- Next generation technology for V2V and V2I offers a solution to today’s limitations on network coverage at low cost infrastructure, as well as a more efficient and accurate dissemination tool.
Conclusions

- The effect of real time information on pre-trip planning and en route decision making is evident but difficult to measure.
- Social media is effective in information dissemination and used by 41 states.
- DMS is recognized to be the mostly used technology by different TMCs.
- The abundance of data can lead to a wealth of information and subsequently information overload if disseminated to travelers. Travelers should customize the information based on their travel needs.
Conclusions

- Short term predictive information is very useful to travelers at the pre-trip planning stage
- As data sources increase, more advanced data mining algorithms are required to deal with big data
- Current active traffic management strategies rely on traffic information relayed to management centers and travelers
- Case studies reviewed show use of multiple strategies at the same time is more effective
Recommendations

- What is the required traffic data accuracy?
- What are the most effective traffic data screening methods to be used?
- What are the most effective ways to disseminate the extracted traffic information to the drivers?
- What is the impact of information on drivers’ behavior and the congestion management?
- What Integrated active traffic management strategies can aid in reducing congestion?
THANK YOU!