Improving the Effectiveness of Smart Work Zone Technologies
ICT R27-155

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Outline

• Background on smart work zones

• Evaluation of smart work zones in microsimulation

• Representative findings
IDOT Motivation

- Work Zone Safety and Mobility
  - Safety Policy 3-07
    - The overall goal of this policy is to reduce and eliminate crashes and fatalities, and to mitigate congestion due to work zones
- IDOT has utilized smart work zone technology for several years
- This research project was initiated with the goal to provide a better understanding of the most efficient, accurate, and cost-effective system deployments for various work zone conditions
IDOT Motivation (cont.)
Smart Work Zones

The use of sensors, computers, and portable changeable message signs to collect and convey real-time traffic information to motorists.
Smart Work Zones (cont.)

The use of sensors, computers, and portable changeable message signs to collect and convey real-time traffic information to motorists.

Research project with UIUC
Research Project Objective

- **Goal**: Improve efficiency of work zone ITS:
  - Back of queue detection
  - Travel time/delay estimation
  - Speed estimation

- **Approach**: Compare a variety of work zone deployment scenarios to:
  - Analyze sensor deployment configurations
  - Assess data processing algorithms

- **Outcome**: Work zone ITS cost vs. accuracy of the estimated queue length, travel time/delay, and speed
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Proposed Microsimulation Approach

- Extract the traffic data directly from Aimsun
  - use as ground truth
- Compare the estimates with the ground truth
  - compute the error
  - compare the performance across configurations of networks
  - compare the performance across algorithms
Modeling of Two Work Zones: I-57

- Southbound on I-57 near Mt. Vernon in Jefferson County, District 9
- Simulated congested traffic from 3:30~6:00 PM on November 26, 2014
- Eight (8) radar sensors and one (1) RTMS* sensor (SB7) were deployed

*Remote Traffic Microwave Sensor
Modeling of Two Work Zones: I-80

- Eastbound on I-80 west of the Des Plaines River in Will County, District 1
- Simulated congested traffic from 3:30~6:00 PM on May 1, 2015
- Eight (8) radar sensors and five (5) RTMS sensors were deployed
**Goal:** Model “virtual” sensors with realistic errors in the microsimulation environment.

- **Types of errors:**
  - Measurement noise
  - Inconsistency due to placement and orientation
  - Missing data
  - Occlusion
Goal: Model “virtual” sensors with realistic error in the microsimulation environment.

• Typical sensors used in work zones:
  – RTMS
    • Pro: Less prone to occlusion
    • Con: Difficult to install and calibrate
  – Doppler radar
    • Pro: Easy installation
    • Con: Large error in slow traffic conditions
  – LER* (iCone)
    • Pro: Fast and easy deployment
    • Con: Less accurate volume data

*Low-Energy Radar
Three algorithms were implemented covering different levels of complexity:

- **Simple**: Interpolate the sensor measurement in space
  - **Pro**: Easy to implement
  - **Con**: Instantaneous estimates changes in time

- **Intermediate**: Smooth measurements in time and space
  - **Pro**: Smoother changes of estimates in travel time
  - **Con**: Degraded performance in online estimation

- **Advanced**: Integrate traffic models with measurements
  - **Pro**: High performance in traffic condition estimation
  - **Con**: Difficult to implement
Completed Evaluation

• Estimated quantity:
  – Traffic velocity (for traffic velocity estimation)
  – Queue length (for back of queue detection)
  – Travel time (for travel time estimation)

• For each quantity:
  – Evaluated different sensor deployments that varied in:
    • spacing of sensors
    • types of sensors
    • accuracy of sensors
  – Evaluated three algorithms:
    • simple, intermediate, and advanced
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• Representative findings
Representative Findings: Velocity Estimation

- The benefit per sensor is marginal at less than 0.5 miles interval spacing.
- The advanced algorithm significantly outperforms other algorithms.
Representative Findings: Velocity Estimation

- Types of sensors have insignificant effect on the velocity estimation.
- Higher accuracy of sensors provides marginal benefit.
Representative Findings: Queue Estimation

- Denser spacing than 1 mile interval provides insignificant improvements.
- The advanced significantly outperforms other algorithms.
Representative Findings: Queue Estimation

- Types and accuracy of sensors do not have significant influence on queue estimation.
- The advanced algorithm is relatively more sensitive to the types of sensors.
Representative Findings: Travel Time Estimation

- All algorithms have poor performance in travel time estimation across different sensor configurations.
- Algorithms with predictive models should be used for an accurate travel time estimation.

![Graph showing the Mean Absolute Error (MAE) of travel time against spacing of sensors. The graph compares Simple, Intermediate, and Advanced algorithms.](image-url)
Representative Findings: Cost Performance

- Advanced algorithms can reduce the number of sensors needed, however they require significant effort for implementation.
- At the same cost, adding more lower cost radar sensors provides more benefit than fewer more expensive RTMS sensors.
Challenges in Data Quality

- **Missing data:**
  - Example: I-57 Southbound, 11/26/2014, 2-11PM
  - 20.87% of speed data is missing
  - Vehicle count is set to 0 (unrealistic)
Challenges in Data Quality

• Inconsistent data:
Challenges in Data Quality

• Causes for data quality issues:
  – Malfunctioning sensors
  – Inappropriate calibration of sensors
  – Principle limitation of sensors
  – Cellular network issues (e.g., cellular tower maintenance)

• Ongoing efforts:
  – Vendors are actively increasing the reliability of sensors.
  – Vendors collaborates with cellular providers to increase the reliability of cellular communication.
  – IDOT will start to investigate these issues through collaboration with vendors, now that this issue come to light.
Findings: Summary

• The spacing of sensors is important for all applications (velocity, queue length, and travel time estimation).
  – However, additional sensors spaced closer than a 0.5 mile interval provide marginal benefits.
• The advanced algorithm has the potential to improve the estimation accuracy and reduce cost.
  – However, it requires significant effort to implement.
• The accuracy of sensors provides marginal benefits, although the reliability of sensors should be improved.
• All algorithms implemented provide poor travel time estimation. Accurate travel time estimation requires predictive models.
Questions?

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