CENTRE FOR SMART TRANSPORTATION
DEPARTMENT OF CIVIL & ENVIRONMENTAL ENGINEERING
FACULTY OF ENGINEERING
UNIVERSITY OF ALBERTA
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# Reliability Considerations in Bus Route Service Planning

*Rajib Sikder and Amy Kim*

UNIVERSITY OF ALBERTA

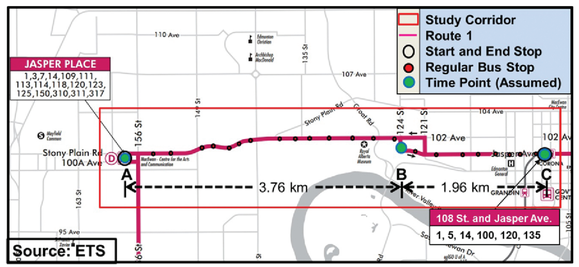
## Objectives

- Assess transit service reliability of an Edmonton Transit Service (ETS) bus route, applying well-established performance metrics
- Develop a framework for incorporating Transit Signal Priority (TSP) and schedule redesign, in order to reduce bus travel time variability

## Methodology

### Study Area

- Stony Plain Road from Jasper Place Transit Centre to 108 Street/Jasper Avenue (downtown) in the City of Edmonton
- 6 km, with 26 bus stops in the EB direction
- Bus **Route 1** during **AM peak** (6:45 - 8:45 AM)




### Data

- ETS's Automatic Passenger Count (APC) data from September 2 through December 1, 2012
  - Scheduled and observed arrival & departure times
  - Boarding, alighting and departing passenger volumes

### Study Framework

**Determine & assess benefits of active TSP application on bus corridor**

**Develop new schedule**

- Incorporate travel time benefits of TSP
- Reduce travel time variability and schedule deviation[4*]

min
- Generalized Schedule Deviation
- Variation of Schedule Deviation

**Reliability performance evaluation**

*** Assumptions**
- Travel time is a random variable with known probability distribution
- Bus always departs on schedule at beginning of route (transit centre)
- Driver will speed up when bus is late to a stop and slow when late

## Bus Service Reliability Metrics

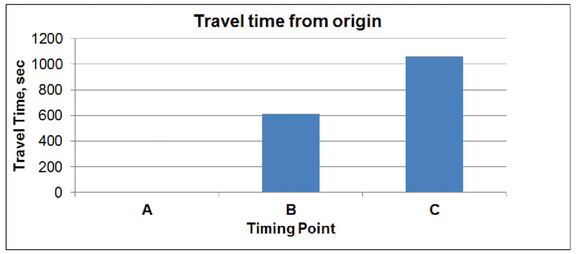
| Operational Characteristic | Performance Index | Description |
|---|---|---|
| Travel Time Variation | Coefficient of variation of travel time [1] | *Ratio of the standard deviation of travel time and average travel time* |
| Variation in Schedule Adherence | Departure based On-Time performance [2] | *% of buses that departed within 1 min early to 5 min late at a bus stop* |
| Headway Variation | Coefficient of variation of headway [2] | *Ratio between the standard deviation of bus headway and average bus headway at a bus stop* |
| Waiting Time Variation | Coefficient of variation of waiting time [3] | *Ratio between the standard deviation of waiting time and average waiting time** |

* waiting time is defined here as the difference between schedule departure time and actual departure time

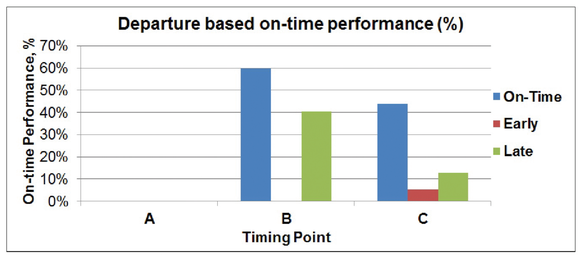
## Results

### APC Data Analysis

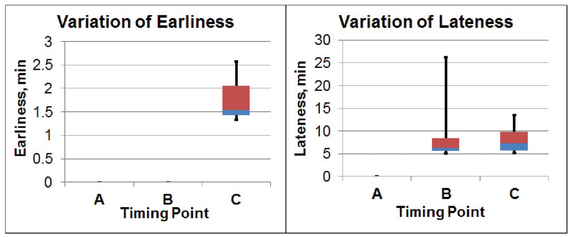
#### Travel time



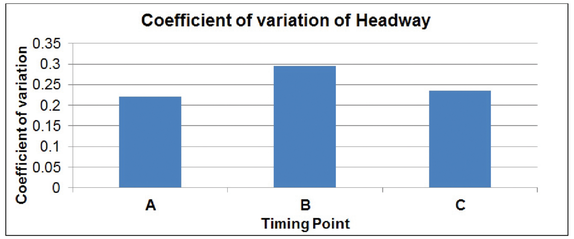

#### Earliness / Lateness



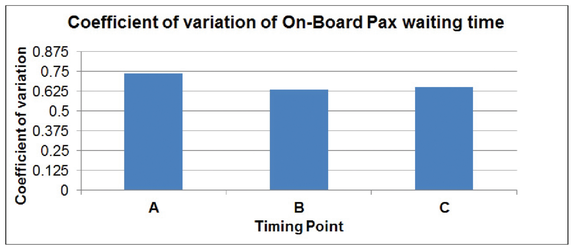

#### Earliness / Lateness (cont'd)




#### Headway Variation




#### Waiting Time Variation




### Application of New Schedule

#### Model Results

| Case | Weighting Factors | | |
|---|---|---|---|
| | *Earliness* | *Lateness* | *Variation of Schedule Deviation* |
| 1 | 1 | 1 | 1 |
| 2 | 1 | 1 | 3 |
| 3 | 1 | 2 | 1 |
| 4 | 1 | 2 | 2 |

| Case | Schedule Departure Time (sec) | | | | | |
|---|---|---|---|---|---|---|
| | *BASE* | | | *TSP* | | |
| | A | B | C | A | B | C |
| 1 | 0 | 818 | 1356 | 0 | 680 | 1132 |
| 2 | 0 | 820 | 1360 | 0 | 682 | 1136 |
| 3 | 0 | 848 | 1388 | 0 | 704 | 1160 |
| 4 | 0 | 840 | 1381 | 0 | 697 | 1156 |

### Simulation Results (VISSIM Microsimulation)

| Performance Measure | Base Existing Schedule VS TSP New Schedule | | | |
|---|---|---|---|---|
| | Case 1 | Case 2 | Case 3 | Case 4 |
| Total Travel Time (sec) | -187 (-15%) | -186 (-15%) | -170 (-13%) | -189 (-15%) |
| CoV, Departure Time at B | -0.018 (-67%) | -0.018 (-86%) | -0.019 (-70%) | -0.019 (-70%) |
| CoV, Arrival Time at C | -0.012 (-48%) | -0.013 (-65%) | -0.014 (-56%) | -0.015 (-60%) |
| % Earliness at B (%) | -2 (-100%) | -2 (-100%) | -2 (-100%) | -2 (-100%) |
| % Lateness at B | -79 (-87%) | -75 (-82%) | -81 (-89%) | -87 (-96%) |
| % Earliness at C | -5 (-100%) | -5 (-100%) | -5 (-100%) | -5 (-100%) |
| % Lateness at C | -46 (-72%) | -53 (-83%) | -55 (-86%) | -60 (-94%) |
| Total Cost of Schedule Deviation (sec) | -33.04 (-14%) | -63 (-15%) | -53 (-18%) | -63.65 (-16%) |
| CoV of Wait Time for On-Board Pax at B | 0.11 (92%) | 0.15 (125%) | 0.16 (133%) | -0.11 (-92%) |
| CoV of Wait Time for On-Board Pax at C | -0.05 (-19%) | -0.08 (-29%) | -0.14 (-52%) | -0.27 (-100%) |
| CoV of Headway at B | -0.018 (-17%) | -0.018 (-17%) | -0.038 (-35%) | -0.028 (-26%) |
| CoV of Headway at C | -0.027 (-25%) | -0.037 (-35%) | -0.037 (-35%) | -0.057 (-53%) |

## Conclusions & On-going Work

- An improved schedule can be developed with TSP (reduced travel time) and explicit reliability considerations in scheduling
- APC data demonstrates that on-time performance deteriorates along corridor – highly unreliable service (OTP<70%, TCQSM[1] ) is observed at timing points B and C
- Schedule with higher costs assigned to lateness and variation in schedule deviation (Case 4) may provide more reliable service
- Future work:
  - Additional data analysis on a larger APC data set (2 years of data),
  - Improvements to the optimization model specification
  - Application of framework to another major bus corridor(s) within the city

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## References

1. El-Geneidy, A. M., Horning, J., & Krizek, K. J. (2010). Analyzing transit service reliability using detailed data from automatic vehicle locator systems. *Journal of Advanced Transportation, 45*(1), 66-79.
2. Kittelson & Associates, I., Brinckerhoff, P., KFH Group, I., Institute, T. A., & Arup. (2013). *TCRP Report 165: Transit Capacity and Quality of Service Manual* . Transportation Research Board.
3. Turnquist, M. A., & Bowman, L. A. (1980). The effect of network structure on reliability of transit service. *Transportation Research Part-B, 14*, 79-86.
4. Yan et al. (2012). Robust optimization model of schedule design for a fixed bus route. *Transportation Research Part C, 25, 113-121.*