Impact of Light Rail Crossings on Vehicle Travel Times

Brian Gaas

Abstract. Portions of Calgary's light rail system (the C-Train) operates at grade, parallel to roadways. The public has expressed concern that an upcoming expansion to the rail network will negatively impact vehicle travel times at intersections where the C-Train track and roads intersect. This study was created to quantify the effects of existing C-Train/vehicle conflicts on vehicle travel time. It utilized C-Train arrival and departure times, GPS locations of a pace car, and automated Bluetooth detectors to characterize vehicle travel times through a major intersection during peak volume hours. The combined results suggest that delays caused by conflicts with the C-Train are common, and the resulting delays are similar in duration to the delay caused by regular signal cycles.

INTRODUCTION

A major part of The City of Calgary's public transit system is the C-Train, a 118 km light rail system comprised of two lines that meet in the downtown core. The Red Line runs from the South to Northwest, and the Blue line extends from the West to the Northeast. Around one million passengers per week take the C-Train to access the downtown core (City of Calgary 2017), with most riders taking the Red (South) line, followed by the Red and Blue (North) lines, and lastly the Blue (West) line. Calgary is developing a third route called the Green Line that will add an additional 20 km of track from the Southeast to North central Calgary.

Much of the C-Train runs at grade, with tracks located either on one side of parallel roadways or in the median. An example of the latter is 36 St NE (Figure 1). In this configuration, the Northbound traffic is on the East side of the C-Train tracks, and Southbound traffic is on the West side. Six of the 12 standard turning movements result in vehicles crossing the C-Train track. At the 36 St/32 Ave NE intersection, 58% of the approximately 16,000 vehicles entering the intersection cross the C-Train tracks (City of Calgary 2011). This is a signalized intersection, and travel times for vehicles crossing the tracks depend on the signal timing. In addition to normal signal timing, vehicles may also be delayed by the C-Train blocking the intersection.

Part of the Green Line is expected to run at grade in the median, similar to the configuration at 36 St NE. The plan has led to concerns from Calgarians regarding the travel time delays to vehicles this configuration may impose. In response, the City of Calgary conducted a study to quantify the current travel time delays created by running the C-Train at grade in the median.

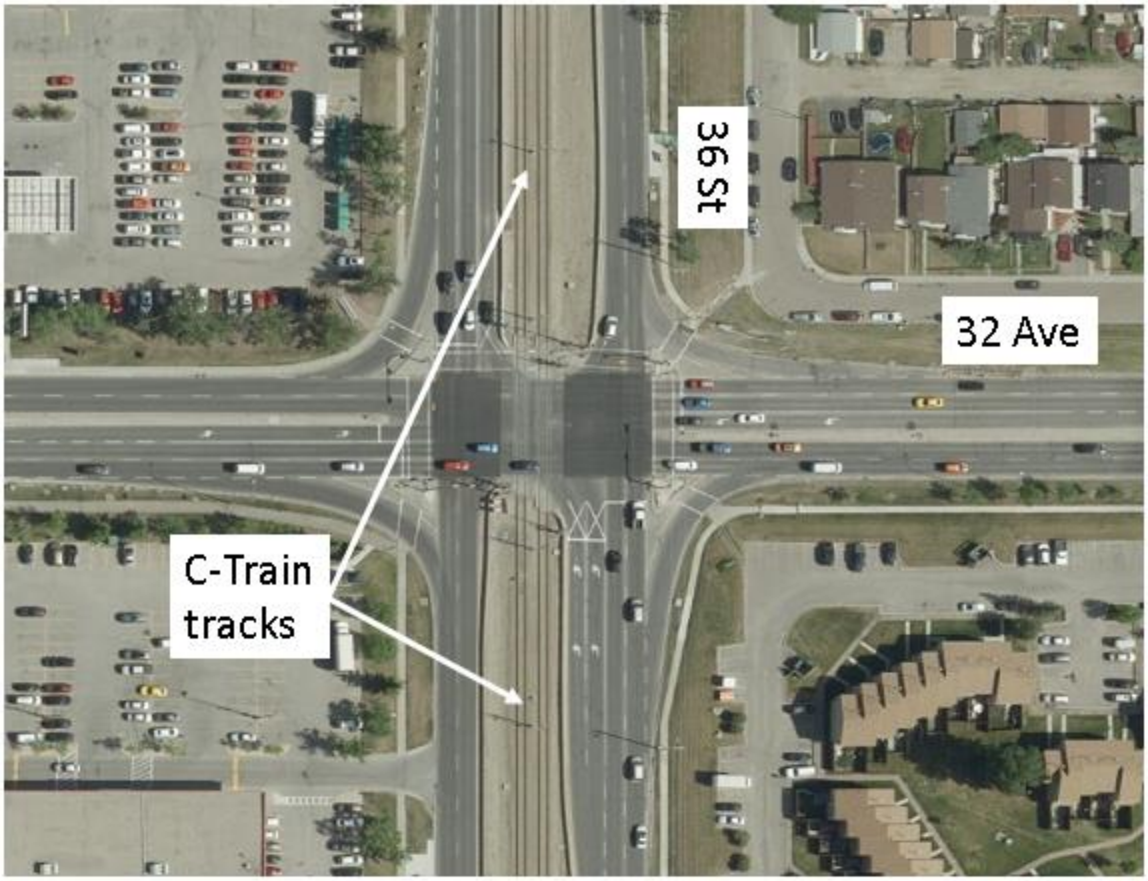

Figure 1: 36 St (N/S) and 32 Ave (E/W) with the C-Train running down the 36 St median

METHODS

Data collection

The intersection of 36 St and 32 Ave NE was selected as the primary study area due to its relatively high volume, large proportion of traffic crossing the tracks, and simple intersection design (Figure 1). Vehicle travel times through the intersection were analyzed using three sources of information: train arrival and departure times, time-series of GPS locations from a pace car, and automated Bluetooth detectors. For each turning movement, travel times of the pace car and Bluetooth detections were estimated for the following scenarios: “free-flow” (travel time not affected by traffic signals or the C-Train), “signal” (travel time increased by encountering a red light), and “train” (travel time increased by encountering the C-Train). This study focused on travel times during morning (07:00-09:00), mid-day (11:00-13:00), and afternoon (16:00-18:00) peak travel hours.

Travel times for the C-Train were collected along a 1.3 km segment of 36 St NE between the Rundle (South) and Whitehorn (North) train stations. Data collectors used synchronized clocks to record the arrival and departure times of trains heading in both the north and south directions.

A small GPS device was placed in a pace car that drove a prescribed route through the 36 St and 32 Ave NE intersection (Figure 2A). The GPS provided positional information at a one second resolution as the pace car crossed the intersection (Figure 2B). Vehicle position was cropped to a consistent area centered on the intersection, and travel time calculated from the start and end points. A data collector noted if the pace car was delayed by the signal and/or presence of a train on the tracks.

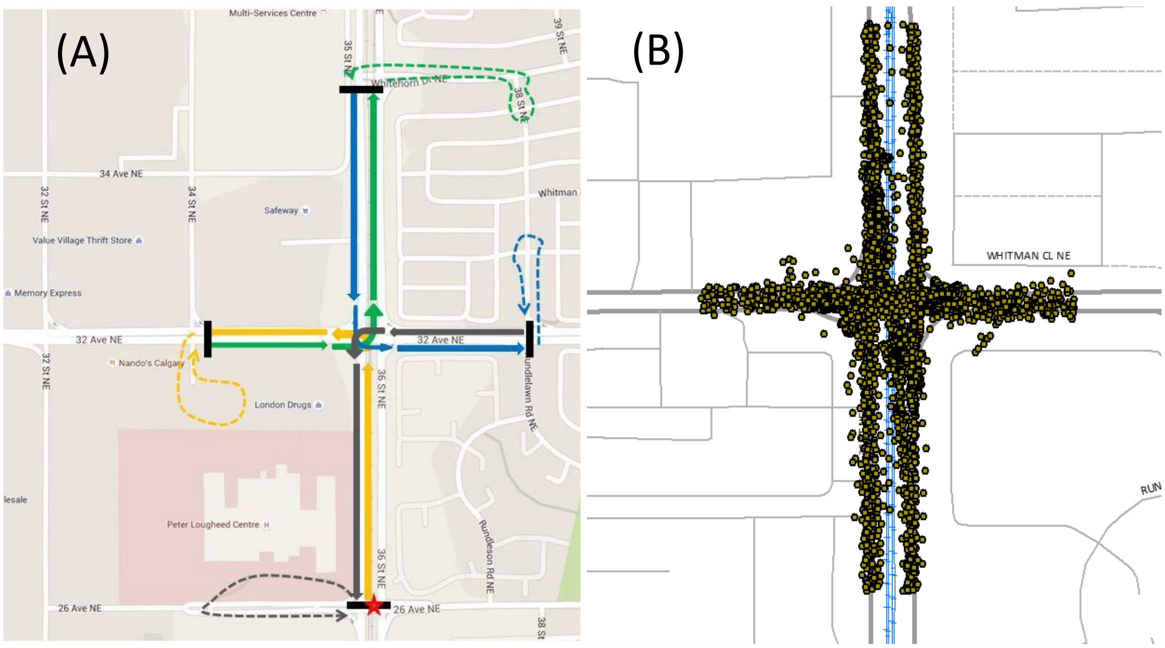

Figure 2: Pace car path (A) and GPS hits at one second resolution along the path (B)

Six Bluetooth detectors were placed around the study area (Figure 3). The detectors record the time and unique identifier of an active Bluetooth device entering the ~100m detection radius. The travel time is calculated from the timestamps when the same Bluetooth device identifier is picked up by detectors at different locations. One detector was placed along each of the four legs around the 36 St and 32 Ave NE intersection to determine the travel times of vehicles crossing the intersection, and one detector each at the Rundle (Rail_S) and Whitehorn (Rail_N) train stations. The Bluetooth detectors were placed to replicate the pace car route as closely as possible, though some of the devices needed to be closer together to avoid picking up signals from outside the study area. The Bluetooth detectors along 32 Ave NE (Turn_L and Turn_R detectors) were placed more than 100m from the train tracks to avoid contamination by Bluetooth signals from C-Train riders. Potential outliers were filtered out based on travel time and dwell time (amount of time spent in the 100m detection area).

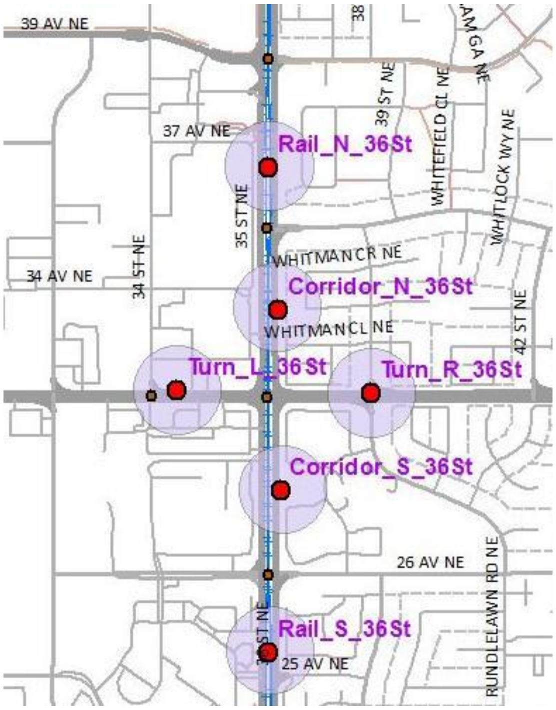

Figure 3: Bluetooth detector locations (red dots) and 100m detection radii (purple translucent circles)

RESULTS

<u>C-Train platform</u>

Trains from both the northbound and southbound directions spent around 30 seconds at the platform across all peak hours (Table 1). Approximately 20 unique trains travelled the segment between Rundle and Whitehorn during each of the morning and afternoon peaks, with a new train arriving around every 5 minutes. During the mid-day peak, trains arrived every 10 minutes, resulting in ~12 unique cars travelling the line in each direction. The C-Train took approximately 80 seconds (01:20) to travel the segment in either direction.

Table 1: Summary of C-Train operations

Peak Hour	Dwell Time [a]		Arrival Frequency [b]		Travel Time [c]		Count	
	NB	SB	NB	SB	NB	SB	NB	SB
07:00-09:00	00:25	00:32	05:04	06:10	01:22	01:17	23	20
11:00-13:00	00:27	00:32	10:08	10:25	01:23	01:16	11	12
16:00-18:00	00:32	00:28	05:42	05:38	01:27	01:17	21	19

Notes: NB = Northbound; SB = Southbound

(a) Amount of time a train stayed at the platform boarding or discharging passengers

(b) The length of time between subsequent arrivals on the same side of the track

(c) Time it took for a train to travel between stations, excluding dwell time

Based on the start and end time of each train, a C-Train (either Northbound or Southbound) was on the track segment between the Rundle and Whitehorn stations for around 30 minutes of the morning and afternoon peak hours, and during 15 minutes of the mid-day peak (Table 2). During the observed periods, Northbound and Southbound trains were travelling the same segment of track at the same time 28% of the morning peak, 0% during mid-day, and 55% of the afternoon peak. Overall, trains occupied the track segment for ~40 minutes of each 2 hour period (the value is lower for the afternoon peak compared to the morning peak because more trains overlapped, resulting in lower overall track occupancy).

Table 2: C-Train track occupancy

Peak Hour	Time on Single Track [(a)]	Simultaneous Transit [(b)]	Time Segment in Use [(c)]	Track Occupancy [(d)]
07:00-09:00	28 min	28%	49 min	41%
11:00-13:00	15 min	0%	30 min	25%
16:00-18:00	27 min	55%	39 min	33%

(a) Amount of time that at least one side of the track was occupied. Not cumulative between sides of the track
(b) Proportion of time when trains in opposite directions were on the same segment at the same time
(c) Amount of time that one or more trains occupied the segment
(d) Proportion of 2 hour time block when trains were crossing the segment

<u>Pace car</u>
Free-flow travel times were around 27 seconds (Table 3). The mean travel times during the signal scenario and train scenario were 85 seconds (01:25) and 135 seconds (02:15), respectively. The mean delay due to signal timing was 45 seconds, while the mean delay due to the C-Train was 84 seconds (01:24). Overall, the delay caused by the C-Train was around twice the delay caused by the traffic signal. The pace car was stopped by a train around 27% of the time, which is similar to the estimated track occupancy from C-Train operations (Table 2). Considering the signal and train encounter rates, a weighted average of travel times suggests that drivers could expect an overall 50 second delay compared to free-flow travel times.

Peak Hour	Statistic	Total Travel Time			Delay From		Signal Encounter Rate	Train Encounter Rate
		Free-Flow	Signal	Train	Signal	Train		
07:00-09:00	Mean	00:28	01:14	01:52	00:39	01:20	56%	28%
	Maximum	00:34	01:56	02:41				
11:00-13:00	Mean	00:24	01:17	02:04	00:43	01:27	67%	25%
	Maximum	00:32	01:52	02:57				
16:00-18:00	Mean	00:30	01:43	02:49	00:53	NA	58%	29%
	Maximum	00:40	02:01	04:35				

Table 3: Summary of pace car results

<u>Bluetooth detectors</u>
A Gaussian mixture model was used to identify travel time clusters corresponding to the three scenarios, and to calculate the mean travel time for each scenario. The mean of the clusters corresponds to mean travel time for drivers experiencing a given scenario, while the mixing

proportions (relative areas of the Gaussian curves) correspond to the proportion of drivers that experience the scenario (Figure 4).

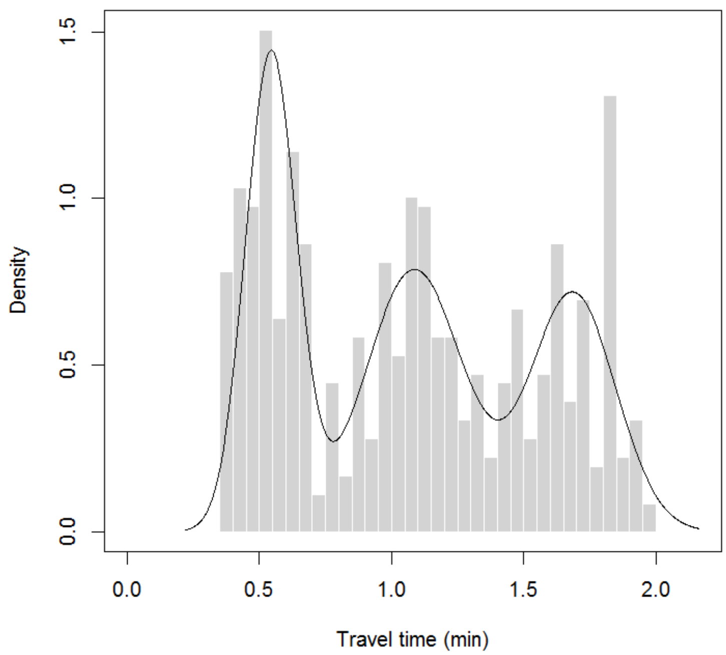

Figure 4: Example Gaussian mixture decomposition of Bluetooth travel times

In all but one case (North to East movement), Gaussian mixture model clusters corresponding to the free-flow (first peak), signal (second peak), and train (third peak) scenarios were identified. Based on two-dimensional histogram results (not shown), there was no indication that the clusters were associated with time of day instead of traffic flow. Higher order harmonics were also observed, potentially reflecting vehicles that waited multiple light cycles before completing their trip.

Free-flow travel times were consistently around 30 seconds for all turning movements, with travel times increasing by 20 seconds (67%) under the signal scenario and 47 seconds (157%) under the train scenario (Table 4). The delay under the train scenario was around twice the delay under the signal scenario, and added approximately 30 seconds to the travel time. The free-flow travel time derived from the Bluetooth devices was the same as the pace car. However, the travel times associated with the signal and train scenarios were only half those observed by the pace car. In general, vehicles captured by the Bluetooth detectors encountered free-flow, signal, and train scenarios in approximately equal proportions. Although this result matches the estimated track occupancy values (Table 2) and train encounter rate (Table 3), the Bluetooth data includes a higher proportion of vehicles encountering free-flow conditions than the pace car did. A weighted average using the Bluetooth-derived delay times and encounter rates resulted in an estimated 24 second increase in travel time compared to the free-flow scenario.

Mean Travel Time			Scenario Encounter Rate			Scenario Difference		
Free-flow	Signal	Train	Free-flow	Signal	Train	Free-flow versus Signal	Free-flow versus Train	Signal versus Train
00:30	00:51	01:17	26%	36%	36%	00:20	00:47	00:26

Table 4: Summary of Bluetooth results

North-South travel times between Rundle Station and Whitehorn Station

The free-flow travel time between train stations was anticipated to be around one minute, based on an ~1 km distance and 60 kph speed limit. Two clusters of travel times were identified, corresponding to the free-flow and signal scenarios. The mean travel time in the free-flow scenario was 79 seconds (01:19), which is nearly identical to the travel times of the C-Train. The mean travel time under the signal scenario was 112 seconds (01:52), which is around 30 seconds longer than it takes the train to traverse the same distance due to traffic signals. A mean delay of 30-40 seconds along 36 St (North/South) was also observed in the pace car data. Approximately 67% of drivers experienced free-flow conditions. Overall (scenario) weighted travel time was 90 seconds (01:30), resulting in C-Train travel times that were around 10 seconds faster than car travel times.

CONCLUSION

This study was designed to characterize the impact of C-Trains operating in road medians on vehicle travel times. The magnitudes of the impacts were determined for 36 St for different delay scenarios. The results suggest that the C-Train has a negative impact on the travel times of vehicle attempting to cross the 36 St/32 Ave intersection. The magnitude of the delay caused by C-Train operation was similar to the delay caused by a signal cycle, though the magnitude of the delays differed depending on the method used to collect the travel time information. The relative importance of delays from the C-Train depends not only on the length of the delay, but also on how frequently a train delay is encountered compared to a signal light delay. Travel times between train stations were faster for C-Train passengers than for drivers due to delays at the traffic signal.

ACKNOWLEDGEMENTS

I'd like to acknowledge the crew that supplied the information for this involved work: J. Cheung, J. Kester, M. Muggridge, D. Mutlow, L. O'Reilly, and K. Wang. A. Norrie assisted with the C-Train data summary. Additional thanks to J. Malzer for providing me with such an interesting project.

REFERENCES

City of Calgary. 2017. Spring 2017 MLP ridership summary. Produced by Calgary Transit, City of Calgary.

City of Calgary. 2011. Six hour intersection count. Data accessed May 2018.

Author's Information:
Brian Gaas
Senior Data Analyst
Transportation Data and Forecasting Division
City of Calgary
800 Macleod Tr
Calgary, Alberta T2P 2M5
Phone +001 403.268.2472
Email: brian.gaas@calgary.ca