Speed Advisory Sign - A Source of Potential Municipal Liability

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Civil liability is a powerful mechanism that has a large effect on the actions of our society. For larger entities such as municipalities, assets that have a continuous interaction with the general public means that the threat of being held liable for a loss is a constant reality. This is most evident in the transportation system where a municipality must constantly deal with possible budget restrictions, changes in the deterioration of the infrastructure, and the effects of weather which is often difficult to predict. When road deficiencies exist the actions of many entities become complicated, either to hide or expose the problem, sometimes to the detriment of reality.

Incorrect road signage can sometimes be an indicator of a hidden roadway problem. In the specific case of Speed Advisory signs, exposure of their incorrect posting can lead to the associated issue that a geometric problem exists within a road segment.

Figure 1: View of Turn sign with a Speed Advisory tab, on eastbound Beaverbrook Road in London, Ontario, indicating the speed at which eastbound vehicles can safely traverse the sharp "curve" at its intersection with Proudfoot Lane.

This article deals with a specific Speed Advisory tab that exists on the very sharp "curve" of Beaverbrook Road where it intersects with Proudfoot Lane in London, Ontario, as shown in Figure 1.

A resident in the area maintained a history of concerns to the City of London that his safety, and that of his fellow pedestrians, was in jeopardy due to the speed and volume of traffic passing through the dramatic curve. Our site examination revealed evidence of various markings at the curve indicating that a number of vehicles were in a state of loss-of-control. As an example, Figure 2 shows some tire marks caused by an eastbound vehicle that attempted to make a right turn to travel southbound onto Proudfoot lane. Unable to maintain its path in the curve the vehicle slid onto the sidewalk.

Figure 2: View, looking north-west, at the sharp "curve" where tire marks on the sidewalk indicate that an eastbound vehicle, approaching the camera, failed to negotiate the curve and slid onto the roadside.

Other subtle indicators at the site included damage to a nearby utility pole, as shown in Figures 3. A minute piece of debris within the scar of the pole could lead to the source of the striking object, as shown in Figure 4. Other indicators included the fact that both guardrails at the site were new, as shown in Figure 5, and some of the supporting posts exhibited evidence that the "w" rail had been pressed against them, as shown in Figure 6. Also, at the inner curb of the curve, there was evidence of scraps and scars indicating that eastbound vehicles were mounting the curb in their difficulties to make the right turn, as evidenced in Figures 7 and 8.

Figure 3: Evidence of a minor impact to a nearby utility pole.

Figure 4: View of minute debris still resting within the damage that could help to identify the source of the impact.

Figure 5: The presence of new guardrails would be another indicator of recent damage to them.

Figure 6: Damage to the wooden anchor post behind the guardrail suggested that previous impacts had occurred.

Figure 7: Evidence of scrapes and black tire marks on the edge of the curb indicative of contact by eastbound vehicles.

Figure 8: Evidence of scrapes and tire marks on the sidewalk at the edge of the curb indicating the presence of turning vehicles.

Gorski consulting became aware of the resident's complaint by chance, late in the process, on October 30th, 2014. His complaint was to be heard at a meeting of the City of London Civic Works Committee scheduled for Monday, November 3, 2014. We examined the geometry of the "curve" via Google Maps and determined that this was not any ordinary "curve". It was clear from the outset that the "curve" was actually the intersection of two roadways, Beaverbrook Avenue, which ran east/west and Proudfoot lane which ran north/south, as shown in Figures 9 and 10.

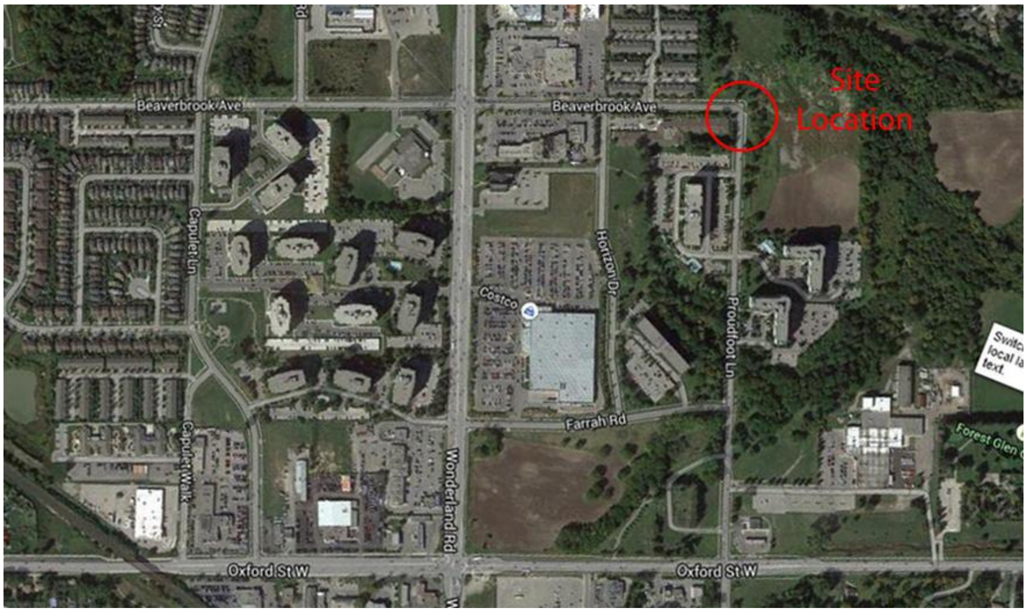

Figure 9: View of 90 degree "curve" and its location as a shortcut between the arterials roads of Wonderland Road and Oxford Street.

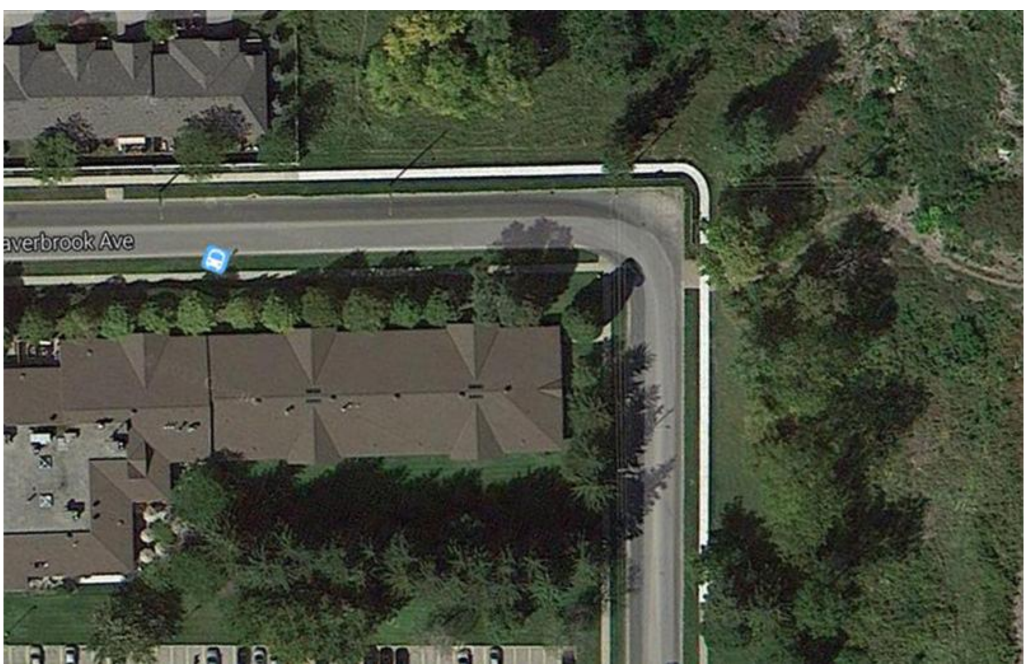

Figure 10: View of 90 degree "curve".

It was clear from the published communications with City staff that the City's future plans were to extend Beaverbrook Avenue in an eastward direction such that Proudfoot Lane would terminate at a "T" intersection. There was no timetable given as to when the vacant lands east of that intersection would be developed. Meanwhile the incomplete intersection remained unchanged. As the City of London expanded, the noted intersection began to receive more traffic as it began to be used as a short-cut around the higher-traffic, arterial roads of Wonderland Road and Oxford Streets.

Traffic volume reported on the City's website indicates about 8,000 vehicles per day pass through where Beaverbrook makes a right turn into Proudfoot Lane. Such volume is significant. Our general estimate indicates that the right "curve" at this location has a corner radius of approximately 11 metres or 36 feet. This radius is essentially no different than what would be expected at the intersection of low-volume, residential streets in the City.

The eastbound approach on Beaverbrook is partially signed with a Turn sign (Wa-1R) along with a Speed Advisory Tab sign (WA-7t) as per standard requirements generally adhered to throughout North America. As noted in the Book 6, Warning Signs, of the Ontario Traffic Manual (OTA):

"The Wa-7t ADVISORY SPEED tab sign provides motorists with guidance as to the maximum safe speed at which a particular hazard may be negotiated under favourable conditions."

Furthermore the OTA notes:

"The ADVISORY SPEED tab sign must not be posted until a safe advisory speed has been determined (e.g. through ball-bank indicator testing or an alternative method), and its use has been approved by the Road Authority having jurisdiction over the roadway."

The ball-bank indicator is a simple tool that identifies the lateral force being experienced by a test vehicle that is driven around a particular curve. As a test vehicle's speed increases the ball in the indicator will begin to be displaced to markings such as 10 degrees, as demonstrated in the figures below. Its design is able to take into account the effects of super-elevation (banking of a surface) and road cross-slope.

Historically, for highway conditions, the value indicated on a Speed Advisory tab has been that achieved by a test vehicle when the ball-bank indicator reaches an angle of 10 degrees.

Upon reading of the resident's concerns we performed testing at the site on October 31, 2014. Using an accelerometer in place of the ball-bank indicator we examined the lateral acceleration that was sensed when our test vehicle travelled eastbound around the "curve" close to the advisory speed of 30 km/h.

Figure 11: Example of a ball-bank indicator whose ball is sitting at rest ("0") indicating no let lateral force is being experienced.

Figure 12: Advisory Speed on a highway is determined when the speed of the test vehicle causes the ball in the ball-bank indicator to move to the 10 degree position.

The lateral acceleration that was documented in our testing can be matched with the readings of the ball bank indicator by noting the following, as taken from the authoritative manual "A policy on Geometric Design of Highways and Streets", AASHTO, 1994:

"In a series of definitive tests it was concluded that safe speeds on curves were indicated by ball bank readings of 14^0 for speeds of 30 km/h or less, 12^0 for speeds of 40 and 50 km/h, and 10^0 for speeds 55 through 80km/h. These ball-bank readings are indicative of side friction factors of 0.21, 0.18, and 0.15, respectively, for the test body roll angle and provide ample margin of safety against skidding."

Thus, a side friction factor (lateral acceleration) of 0.21 should have been experienced by our test vehicle if the 30 km/h Speed Advisory was appropriate. There are no other influences, such as super-elevation, at the curve to speak of .

Our testing was documented with three video cameras, as shown in Figure 13. A camera pointing at the vehicle's speedometer captured the current speed of the vehicle. A camera pointing forward through the vehicle's windshield captured the general location of the vehicle as it passed through the site. A camera mounted to the right corner of the front bumper provided a precise indicator of the vehicle's position with respect to the features of the curve.

Figure 13: Example from our eastbound Test #1 showing the views from three video cameras as the accelerometer data was being collected. This view is at the precise location, on our eastbound approach to the curve, when the acceleration data began to be documented for display in Figure 14.

During our tests the vehicle's speedometer displayed the following speed (in km/h).

Test #	Speed at Beginning of Steering	Speed at Middle of Turn	Speed at End of Steering
1	34	28	28
2	25	25	30
3	28	27	28
4	36	25	27
5	28	27	28.5
6	30	30	31
7	26	25.5	26.5
8	26	26	27
9	26	26	27

Figures 14 through 22 are charts that were developed from our test results. The red line in each chart indicates the lateral acceleration. The blue indicates the longitudinal acceleration.

As an example we can examine the data contained in the first eastbound run in Figure 14. The chart shows a 5 second time interval between 90.2 and 95.2 seconds during which our test vehicle travelled around the curve. At the beginning of the charted values the vehicle's speed was 34 km/h, dropped to 28 km/h in the middle of the turn and at the end it was 28 km/h. The drop in speed was because we had to brake substantially to reduce our speed. This was because we had to assume that the speed advisory of 30 km/h was correct, however, as we approached the turn it was obvious that our speed was too high and we had to apply our brakes resulting in the noted variations in the longitudinal acceleration.

Because of the orientation of the accelerometer in the vehicle the longitudinal acceleration (blue line) had positive values whenever the vehicle slowed down and negative values whenever it sped up. This is explained in the captions shown in Figure 14.

In Figure 15 we indicate that the longitudinal acceleration contains a slight, natural "bump" in its values indicating that the vehicle slows down, not because the brake pedal is applied, but because, due to the major change in direction, the vehicle's tires scrub along the surface as the tire force is used up to cause the change in direction.

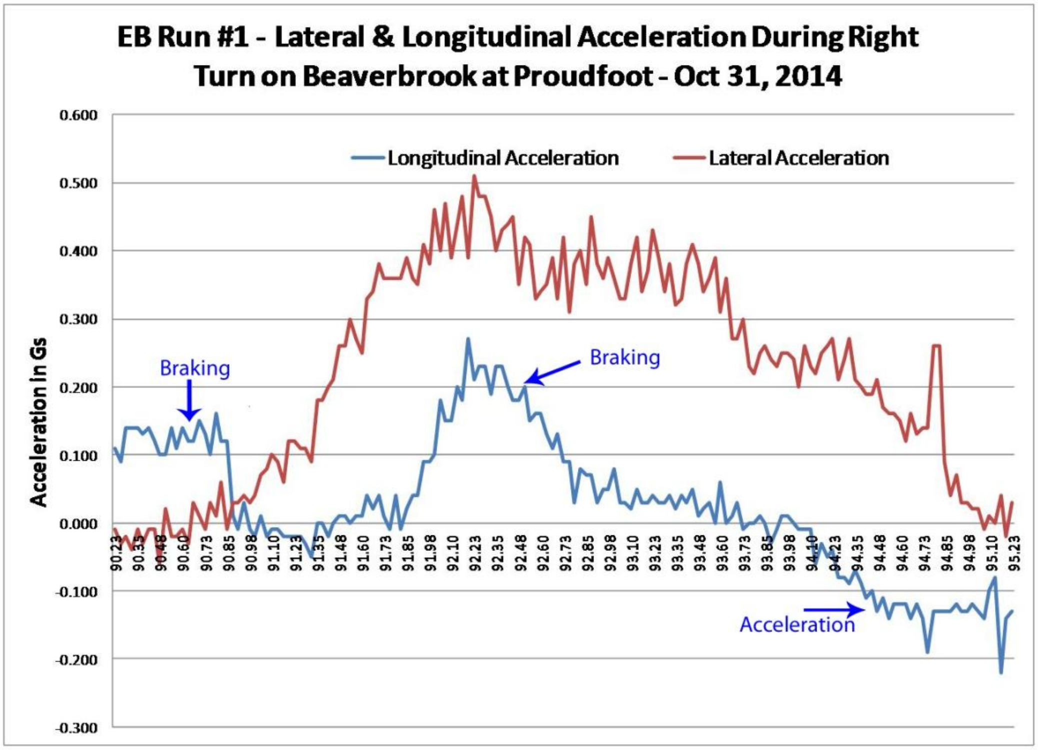

Figure 14: Test #1, eastbound on Beaverbrook.

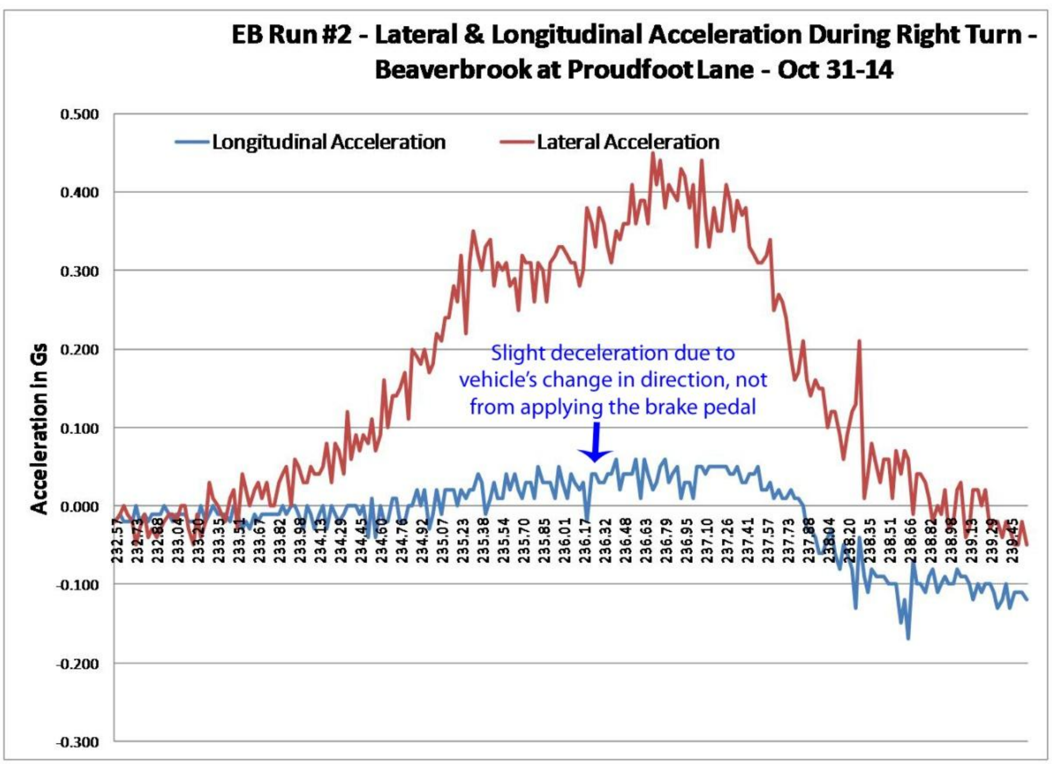

Figure 15: Test #2, eastbound on Beaverbrook.

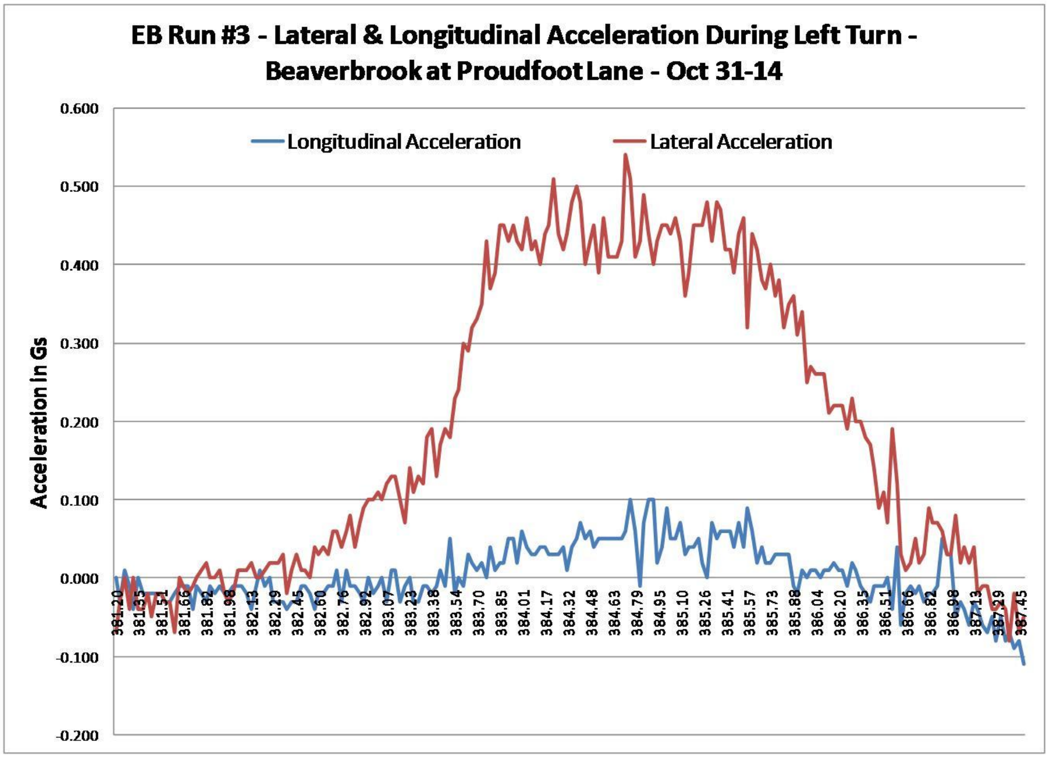

Figure 16: Test #3, eastbound on Beaverbrook.

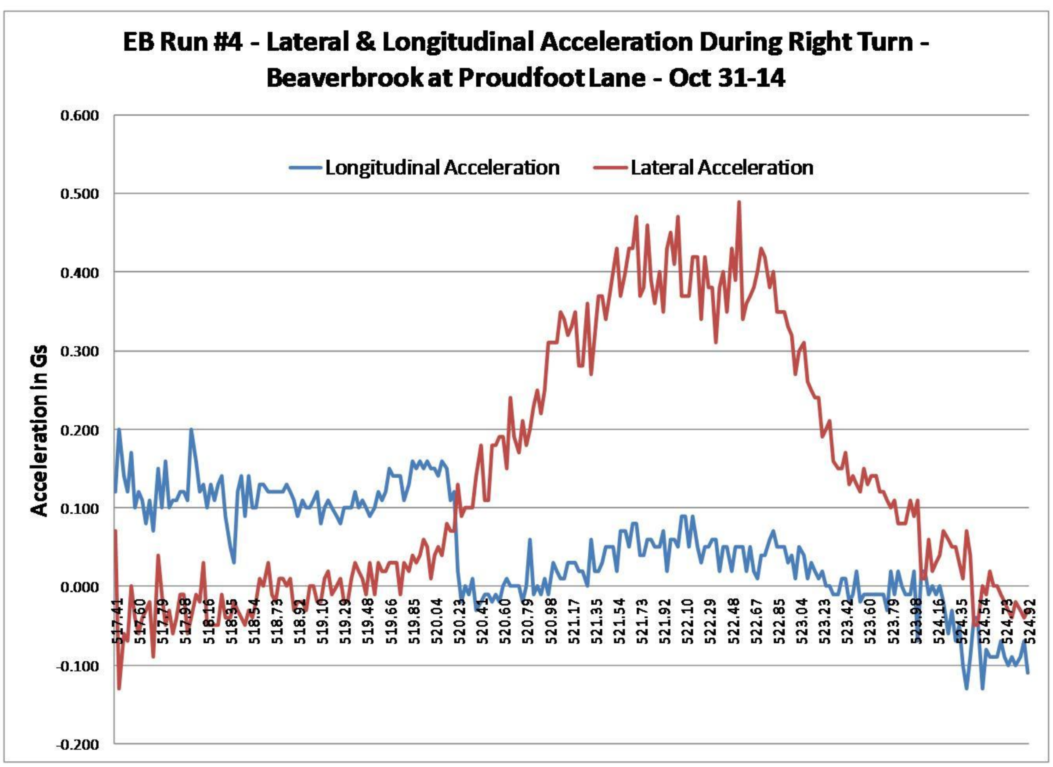

Figure 17: Test #4, eastbound on Beaverbrook.

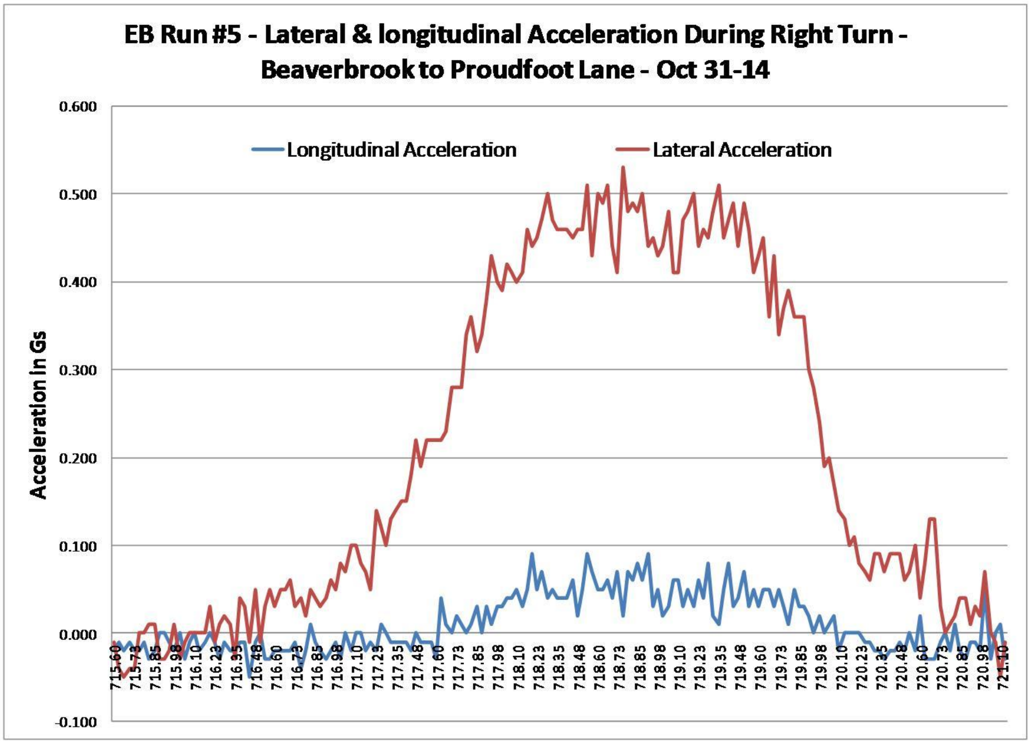

Figure 18: Test #5, eastbound on Beaverbrook.

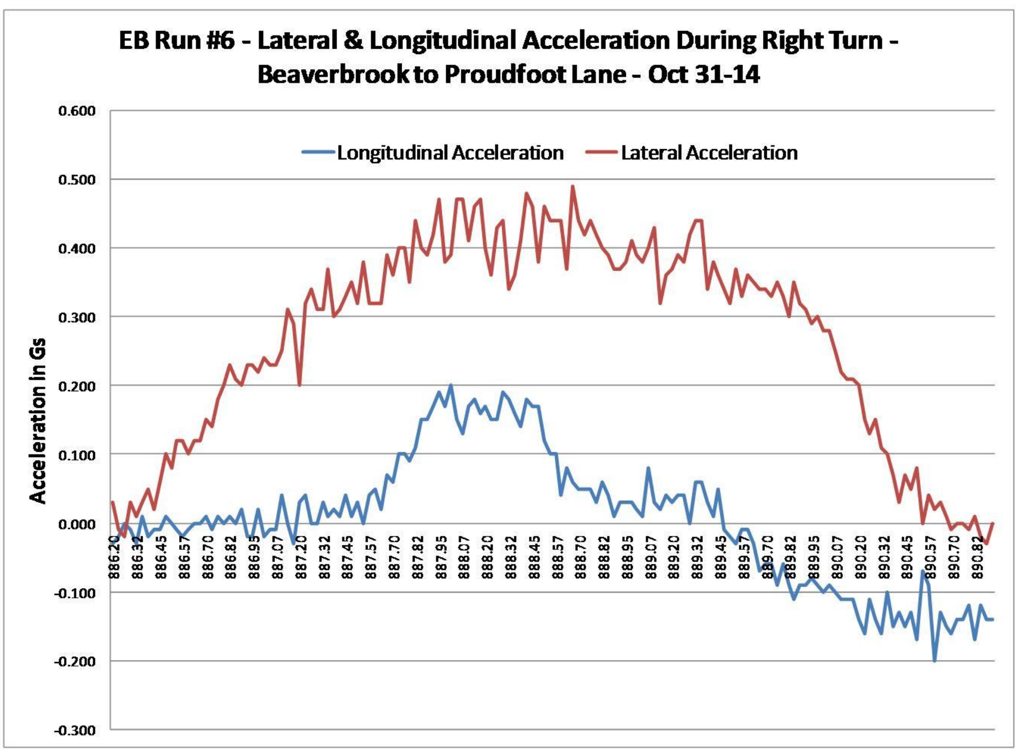

Figure 19: Test #6, eastbound on Beaverbrook.

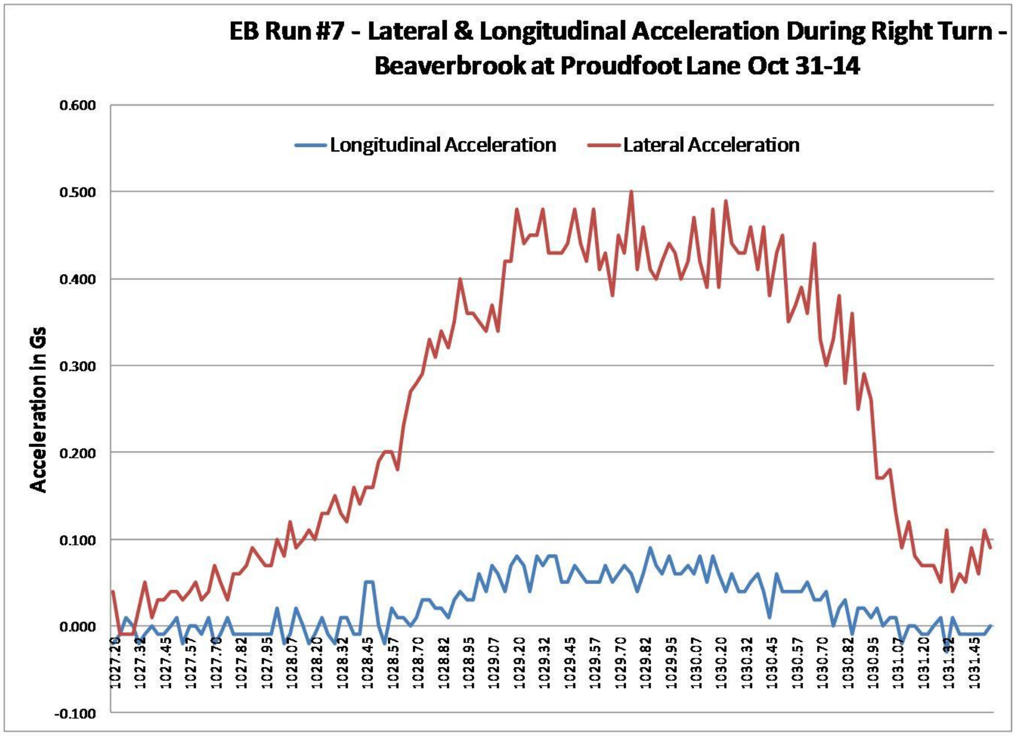

Figure 20: Test #7, eastbound on Beaverbrook.

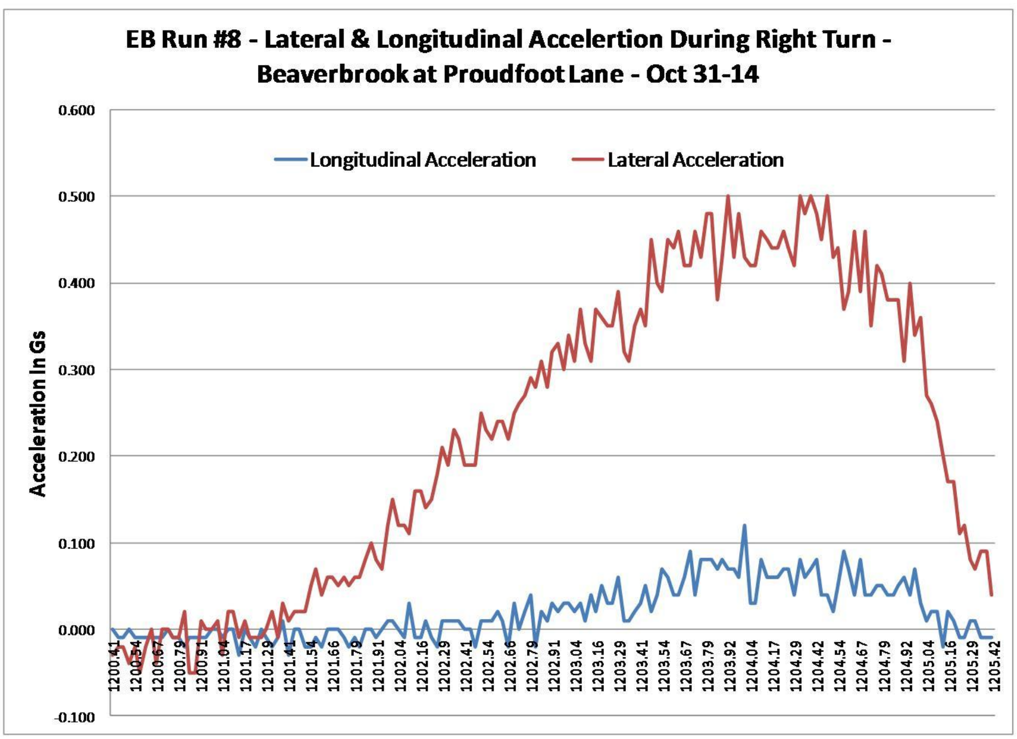

Figure 21: Test #8, eastbound on Beaverbrook.

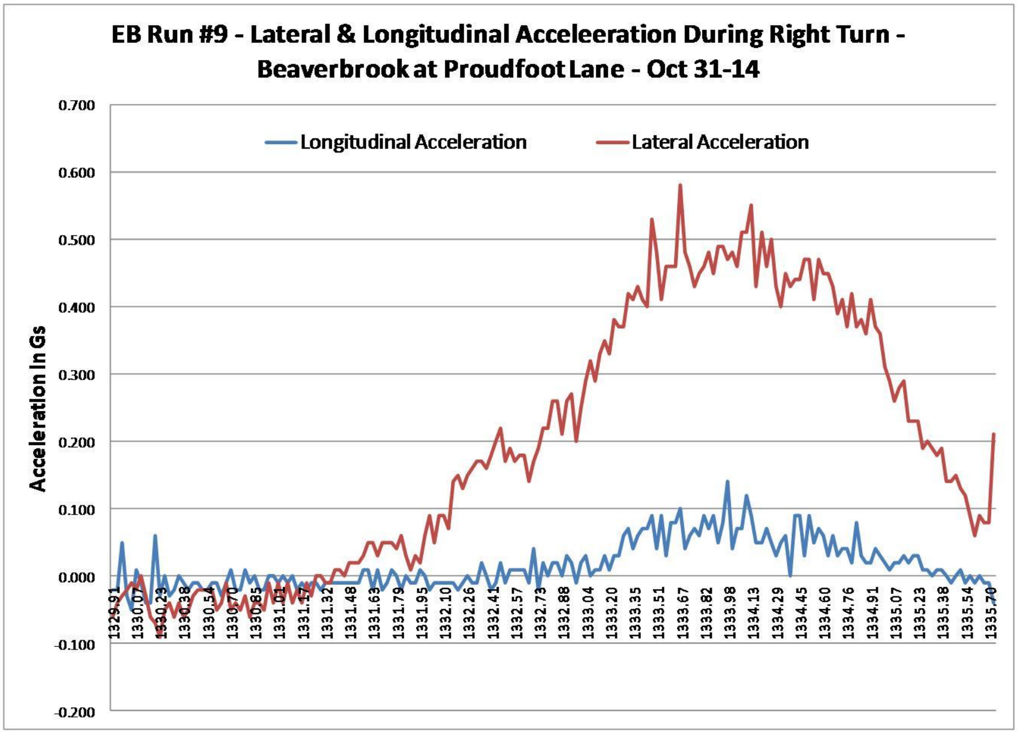

Figure 22: Test #9, eastbound on Beaverbrook.

Before discussing our test results we want to include a brief theoretical discussion.

There is a limit to the available friction which is commonly depicted by the term "Friction Circle". The tire force can be visualized as an imaginary ring around the vehicle. When cornering the vehicle's inertia wants to cause the vehicle to travel in a straight line however the turning of the front wheels causes an interaction between those tires and the road surface causing a force to pull the vehicle into the intended circular path. Thus we have an interplay between the centrifugal force, which wants to pull the vehicle to the outside of the curved path, and the centripetal force which wants to pull the vehicle toward the inside of the circular path.

The centrifugal force becomes larger when a vehicle's speed increases or the driver attempts a more dramatic change in direction. The balance between the two forces is overcome when the centripetal force has reached its maximum and can no longer maintain the vehicle within the intended curved path an then the vehicle slides to the outside of the curve.

The centripetal force can be increased by incorporating a proper super-elevation or cross-slope in the curve. Sliding out can also occur however, if the centripetal force is too small, such as when the road surface becomes wet or covered in snow or ice.

When braking or acceleration occurs the available tire force is used up in the longitudinal direction thus shrinking the size of the imaginary ring of tire force that remains, and reducing the centripetal force that keeps the vehicle along its intended curved path. If a driver applied maximum braking, or throttle, while conducting a sharp turn almost all of the available tire force could be used up (the ring would become very small), and there would be minimal tire force available to complete the sharp turn. The vehicle would then slide to the outside of the intended curve.

As can be seen in our data, in all nine eastbound tests the lateral acceleration was well beyond the 0.21g that is the standard value that should exist when the Speed Advisory is set for 30 km/h. This means that vehicles passing through the curve at the Advised speed use up a precariously large amount of the available tire force. This means that small changes in the centrifugal or centripetal force could result in a destabilizing condition and a resultant loss-of-vehicular control by the driver.

The installation of the 30 km/h Speed Advisory tab below the Turn sign is a standard procedure to inform drivers of the safe speed at which they can travel through the curve. Yet during our 9 eastbound runs the speed of our vehicle was below 30 km/h in the middle of each turn. Only one test (#6) was performed 30 km/h while the remaining tests were run between 26 and 28 km/h. Yet, in all of these tests the lateral acceleration was well beyond the recommended 0.21g. In all the tests the lateral acceleration approached or exceeded 0.50g. That is a large difference compared to the recommendations.

As the City of London's staff were required to set the Advisory Speed based on the readings obtained from a ball-bank indicator it is difficult to believe that they would not have observed the excessive readings. Yet, when complaints were registered by the noted resident, City staff responded as follows:

"There is nothing wrong with the road in question, not the design and not the high traffic volume. There is proper signage that drivers should follow."

Even if the staffer was unaware that their calculations were in error the City of London would undoubtedly be held liable for any collision consequences.

Past research ("Turn Speeds and Crashes Within Right-Turn Lanes", K. Ftizpatrick & W. Schneider, Texas Transportation Institute, 2005) has demonstrated that the average speed of vehicles traversing such a sharp "curve" will be about 22 km/h while 85% of drivers will travel at a speed below 25.3 km/h. Both of these are substantially below the Advisory Speed at the Beaverbrook-Proudfoot site.

Although the speed of any colliding vehicles would likely be low it is important to clarify that this speed is not the only issue. An eastbound vehicle that crosses over the centre-line and strikes an opposing vehicle would likely strike the left side of the opposing vehicle, and the driver's door would be a probable target. An impact, even at a moderate speed, into a driver's door would increase the probability of injury since a driver is always present and there is less protection in this type of impact. So the significance of posting an incorrect Speed Advisory is not exaggerated. If a significant collision occurred at this curve it would be easy to demonstrate the negligence of the City and the court penalty could be substantial.

Gorski Consulting has continued its evaluation of this site via additional testing conducted on November 7, 2014. In that testing we attached a ball-bank indicator, additional gauges, the accelerometer, and additional video cameras. This testing included runs through other curves in the vicinity so that comparisons can be made the present site. The results of this testing will be reported shortly in a future article.

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