Speed Advisory Sign - Additional Testing

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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.

Testing at this site was conducted on October 31, 2014 and reported in an associated article ("Speed Advisory Sign - A Source of Potential Municipal Liability", November 11, 2014) posted to the Gorski Consulting website. Findings from that testing were reported from accelerometer readings from an instrumented vehicle passing through the curve.

The present article will repeat the tests with the inclusion of a ball-bank indicator, additional gauges and video cameras. The reason for this additional testing is to demonstrate the relationship between the readings of the ball-bank indicator and that of the accelerometer. Additionally, three simple "angle finding" gauges are also used to further explore the readings of the ball bank indicator and accelerometer.

Our additional testing was performed on November 7, 2014.

The curve in question was actually the intersection of two roadways, Beaverbrook Avenue, which ran east/west and Proudfoot lane which ran north/south, as shown in Figures 2 and 3.

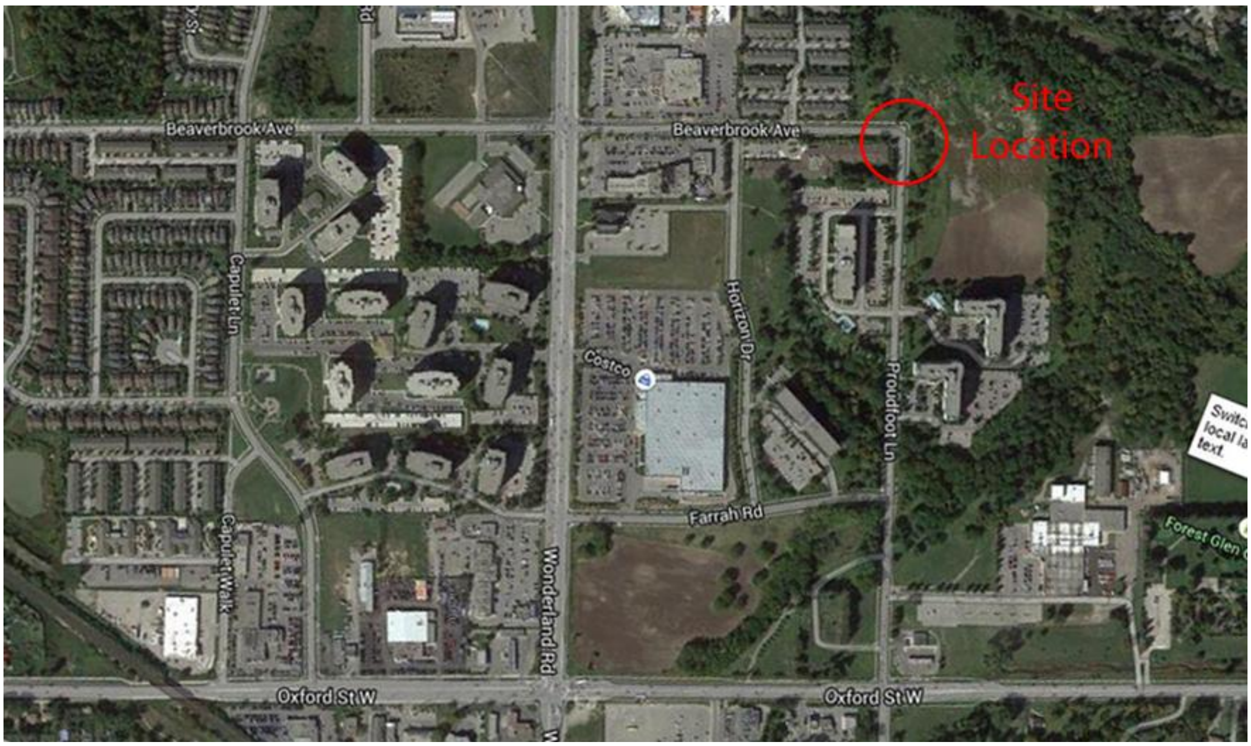


Figure 2: View of 90 degree "curve" and its location as a shortcut between the arterials roads of Wonderland Road and Oxford Street in London, Ontario.

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."

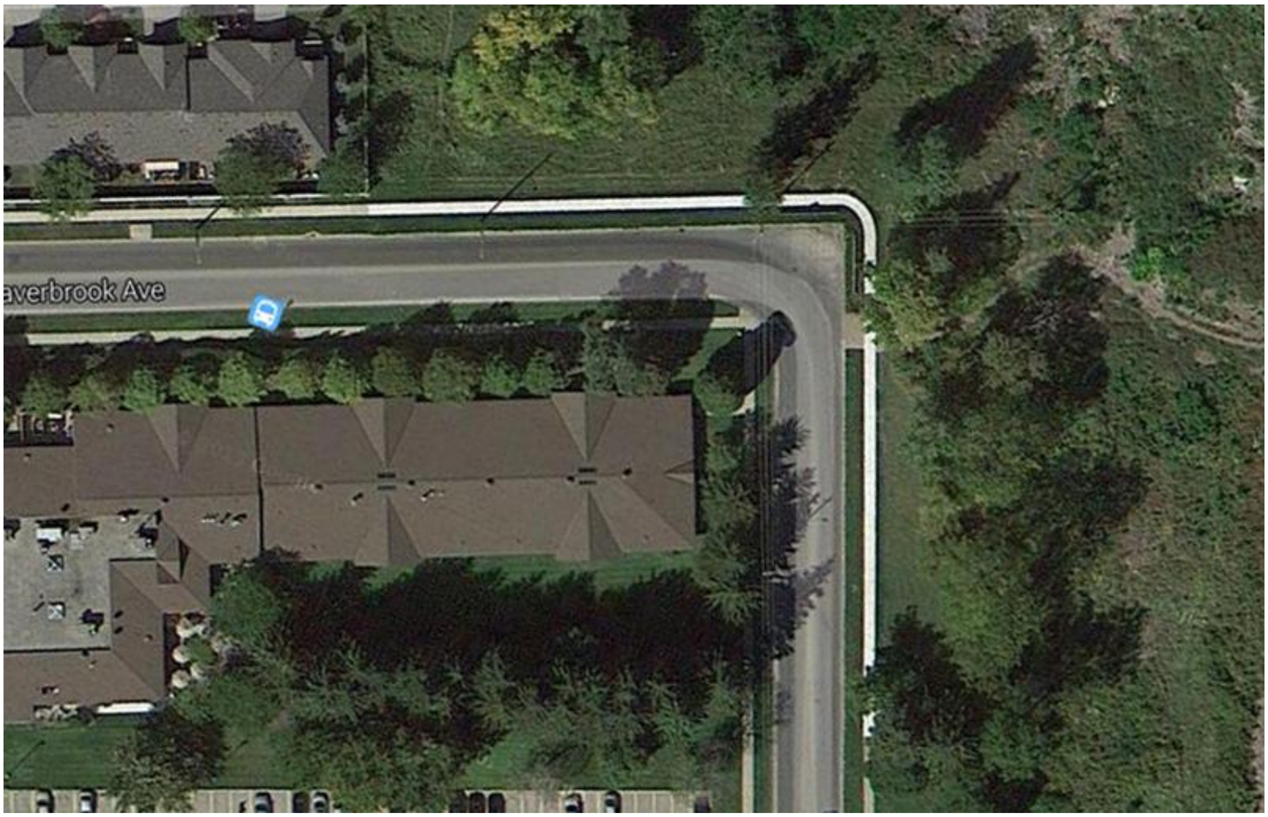


Figure 3: View of 90 degree "Curve".

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 demonstrated in Figures 3 and 4. As a test vehicle's speed increases the ball in the indicator will begin to be displaced to markings such as 10 degrees. When the ball in the ball bank indicator reaches a desired angle then the speed of the test vehicle is used as the Advisory Speed and his posted on the approach to the curve. The ball bank indicator's 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.

In our site testing of October 31, 2014 we used an accelerometer in place of the ball-bank indicator to determine 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 4: Example of a ball-bank indicator whose ball is sitting at rest ("0") indicating no let lateral force is being experienced.

Figure 5: 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 Oct 31st 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. Instead, the testing revealed lateral accelerations approaching 0.50g which are well beyond the recommendations.

As the recommended ball bank indicator was not used in our original testing we decided to conduct further testing to establish the relationship between the accelerometer readings and that of ball bank indicator. Thus in our testing of November 7th, we attached both to the test vehicle and completed another set of four tests.

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	32	31	32.5
2	26	26	27
3	31	31	32.5
4	29	30	31.5

Figures 6 through 9 display the graphs from the acceleration data that was sensed during these additional tests.

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.

Figure 10 shows the display from three of the video cameras used in our testing in Run #1. The large view in the centre of the figure was obtained from a camera pointing through the test vehicle's windshield at a housing which contained a set of gauges, which included the ball bank indicator, attached to the hood of the test vehicle.

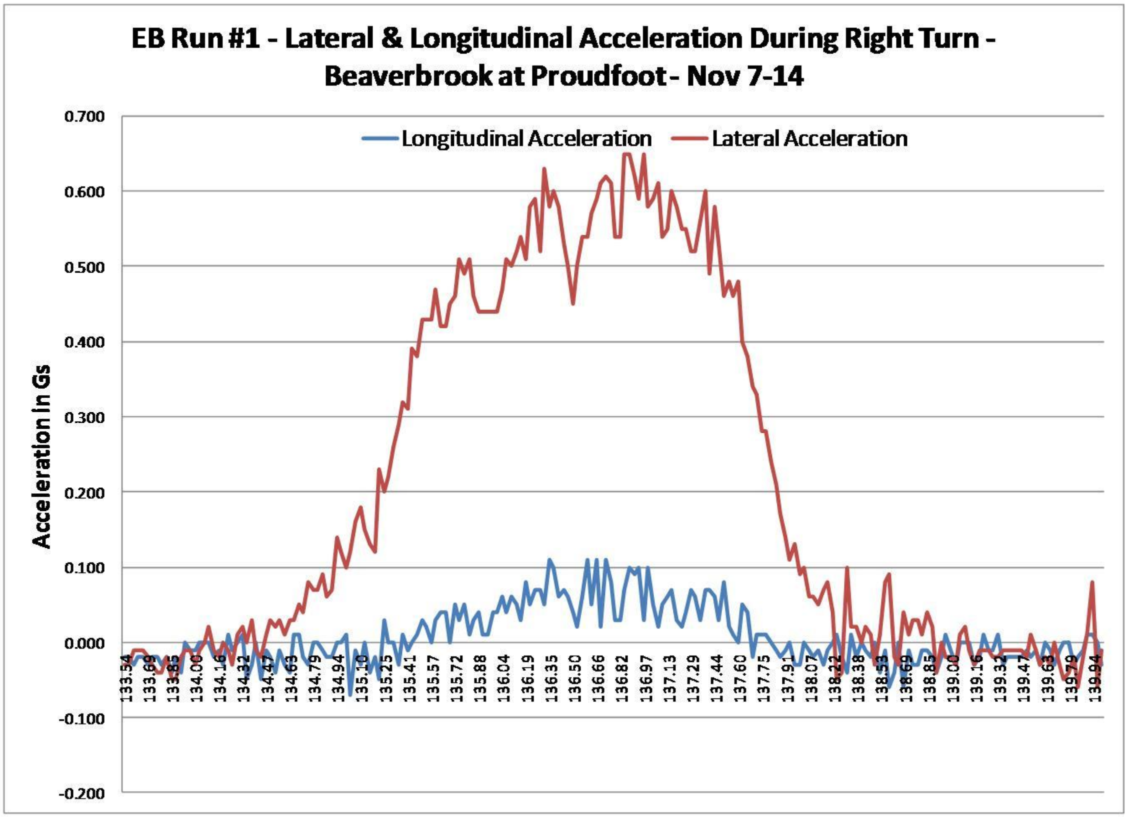


Figure 6: Eastbound Run #1

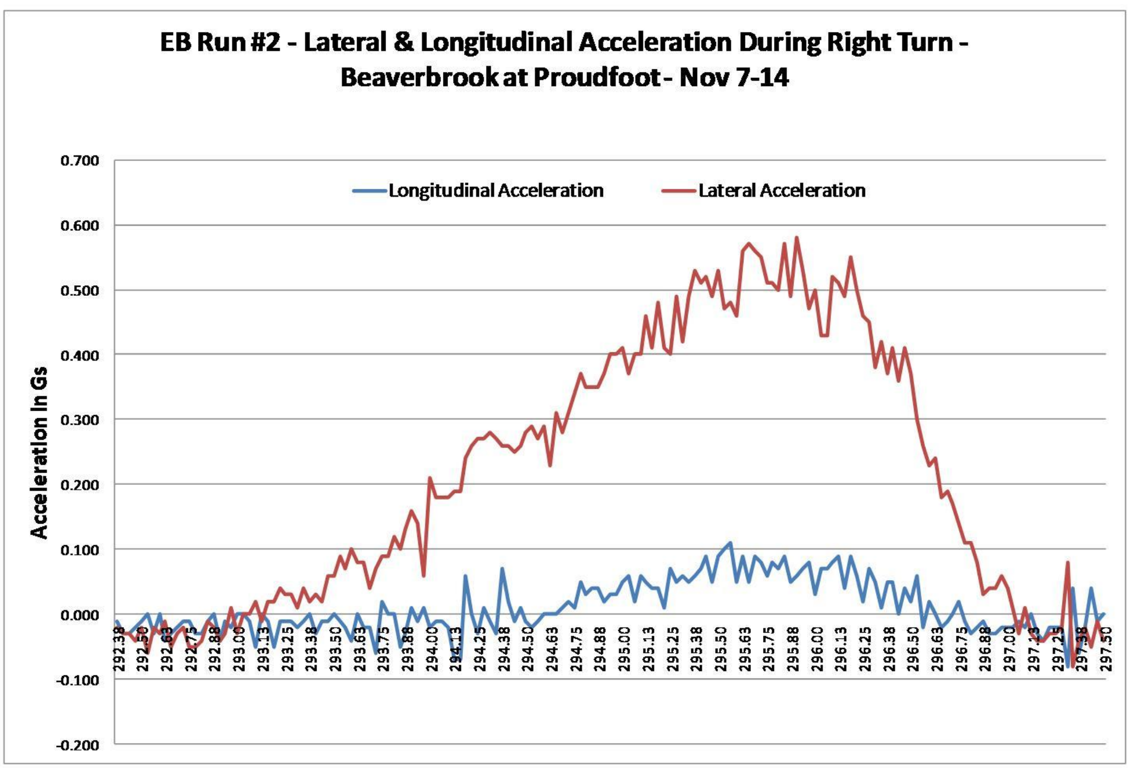


Figure 7: Eastbound Run #2

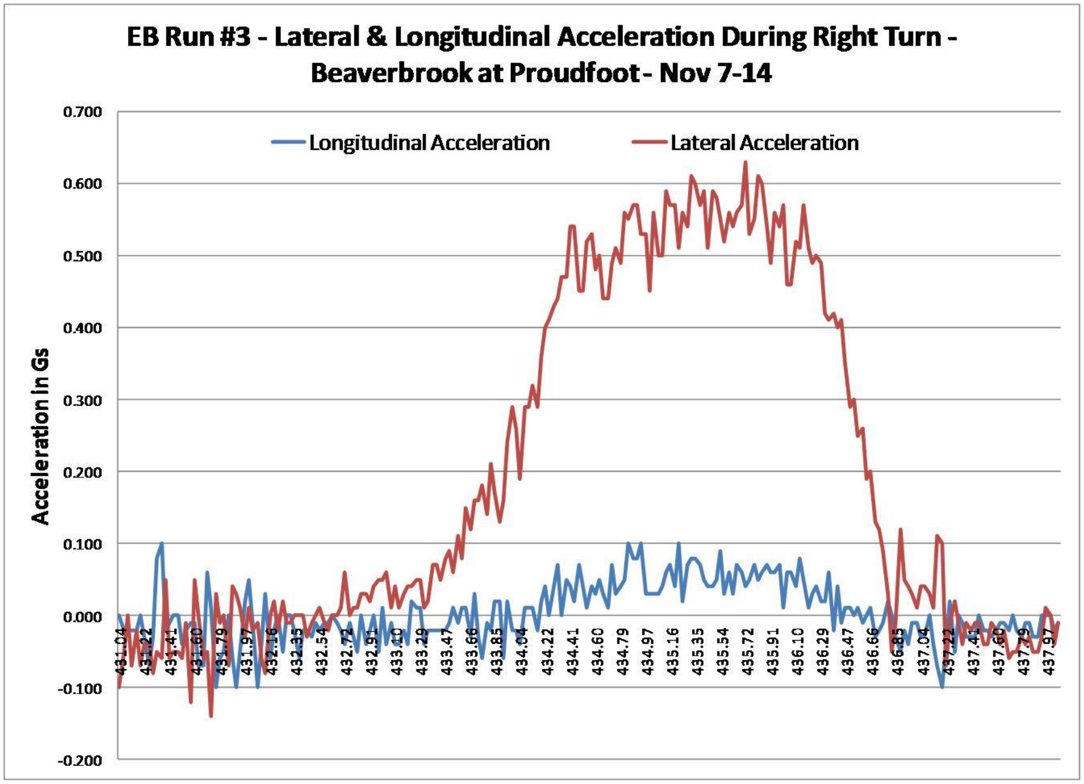


Figure 8: Eastbound Run #3

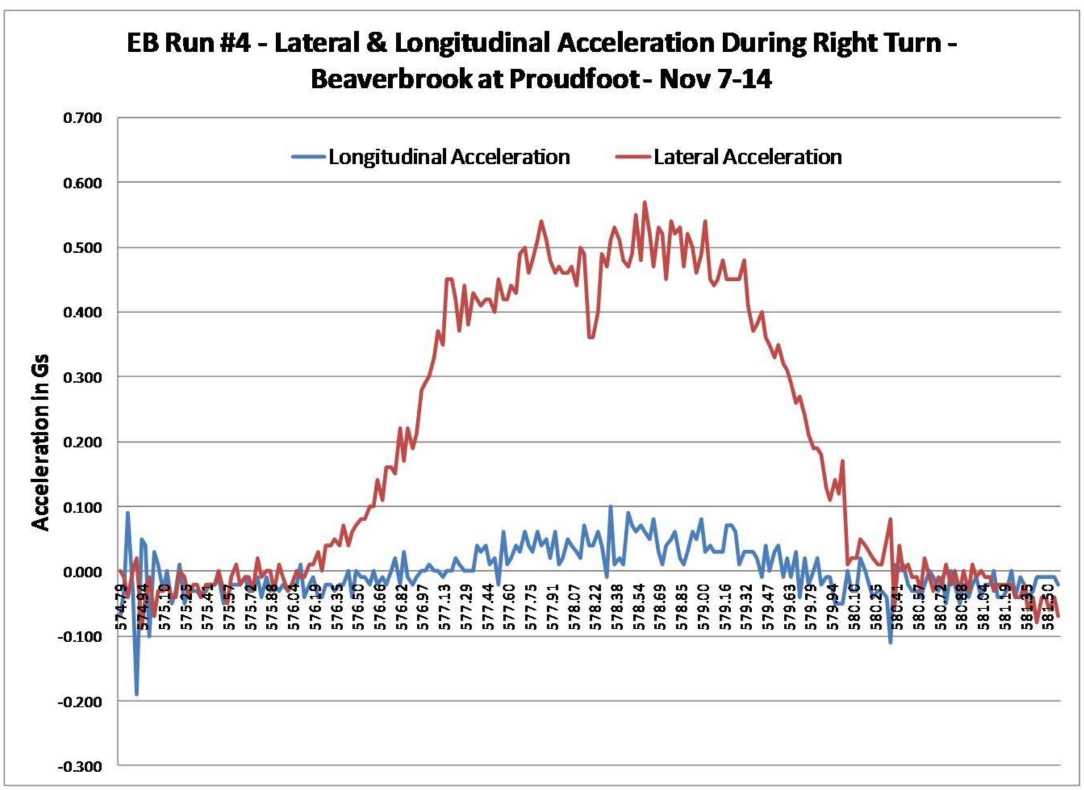


Figure 9: Eastbound Run #4

The other three, yellow gauges in Figure 10 are simple angle-finding instruments that one would buy at a home renovation store. The reason why these other three gauges exist is because their display is not as damped as the one from the ball bank indicator and they can also display a wider angle than the maximum 20 degrees shown on the ball bank display.

In the angle-finder gauges there is weight at the bottom of the red needle, below the needle's anchorage so that, as the turn begins, the weight in the needle is displaced to the outside, or left , and the point of the needle moves to the right. Thus the needles in these gauges move in the opposite direction to the ball in the ball bank indicator.

At the upper left of Figure 10 we see the view from a video camera that is pointed at the speedometer of the test vehicle. Thus we are able to document the speed of the test vehicle at the time that the angles are displayed in the gauges.

At the upper right of Figure 10 is a view from a video camera pointing toward a large protractor that is mounted to the steering wheel of the test vehicle. Thus we are also able to examine when the steering commences into the turn, how much steering is induced and how fast the steering wheel is turned.

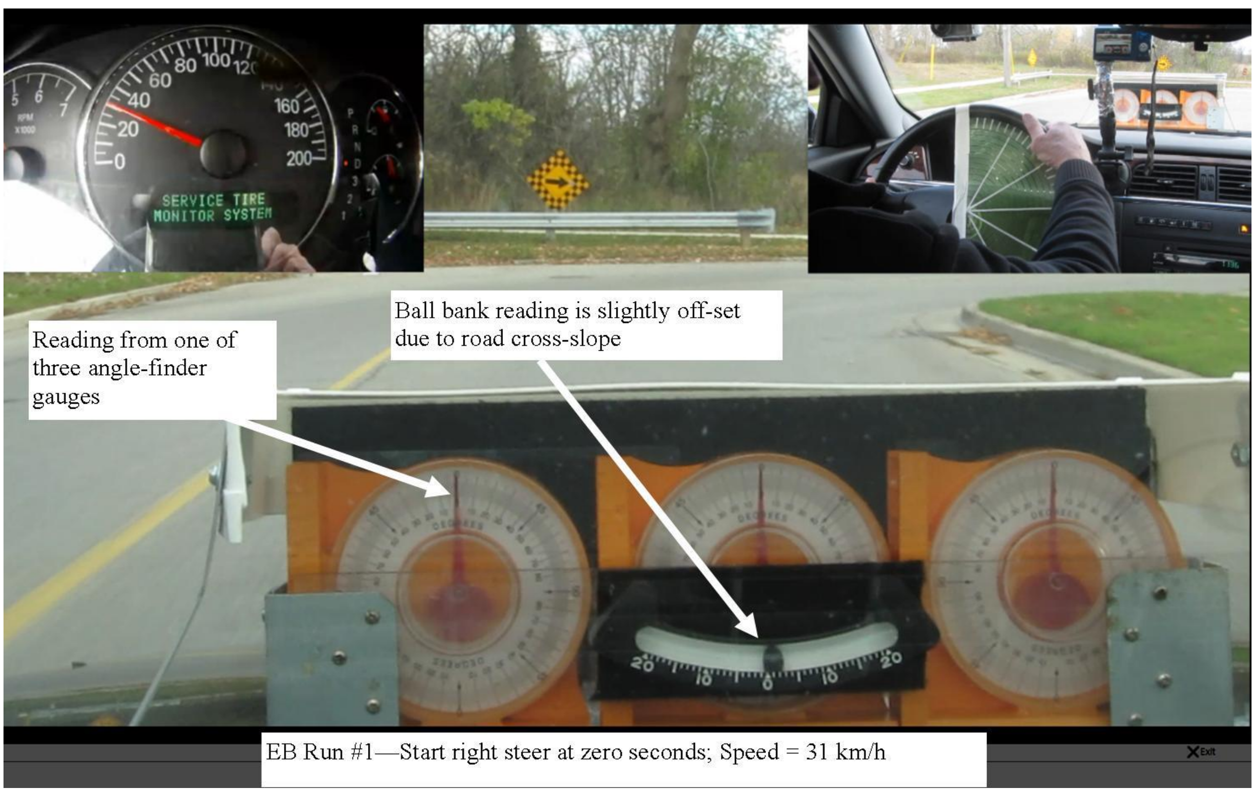
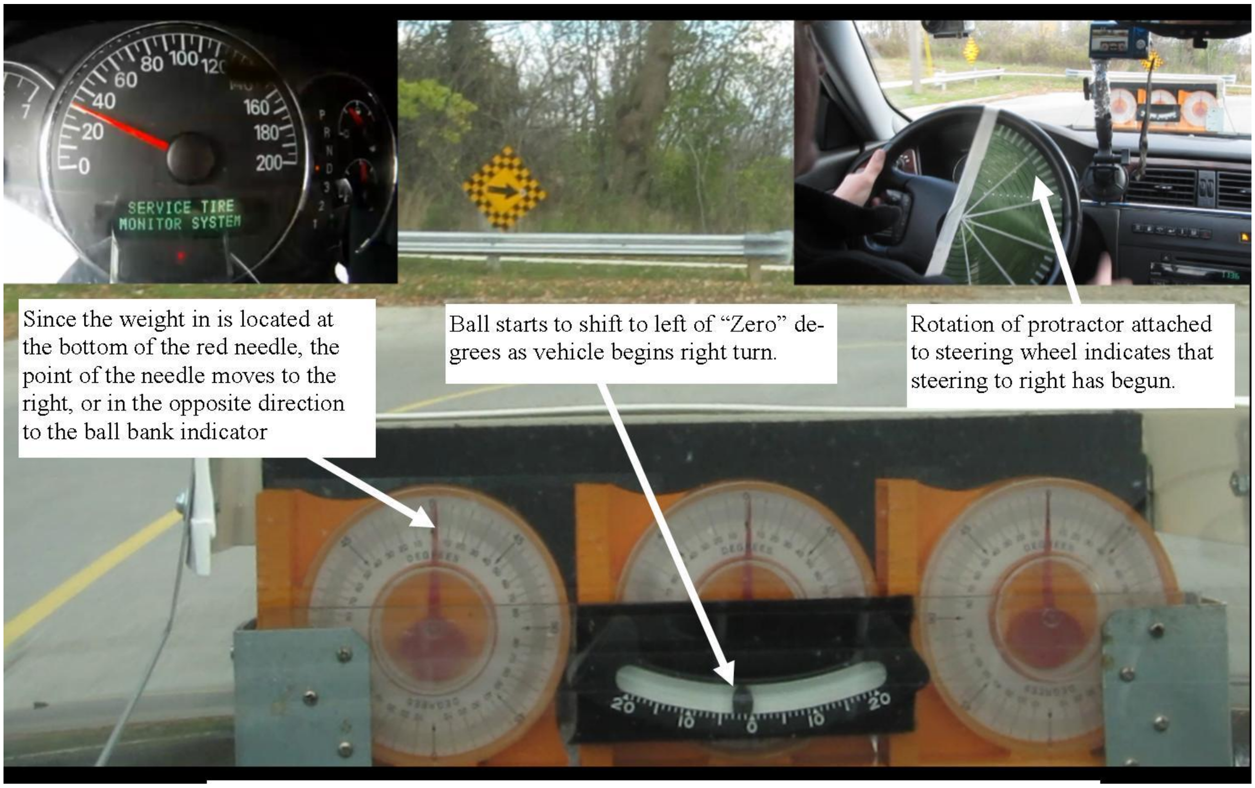


Figure 10: View at beginning of steering into the right turn.

The view in Figure 10 is taken precisely when we began to steer to the right during our first eastbound run. This is precisely at the beginning of the data displayed in the chart shown in Figure 6. One can see in Figure 6 that both the longitudinal and lateral accelerations are near "zero" at the start of the steering input.

Figure 11 shows the scenario at 1.00 seconds after the steering was commenced. Note that the black ball in the ball bank indicator has started to move to the left of the "zero". The red needles in the three angle-finder gauges also begin to move to the right.

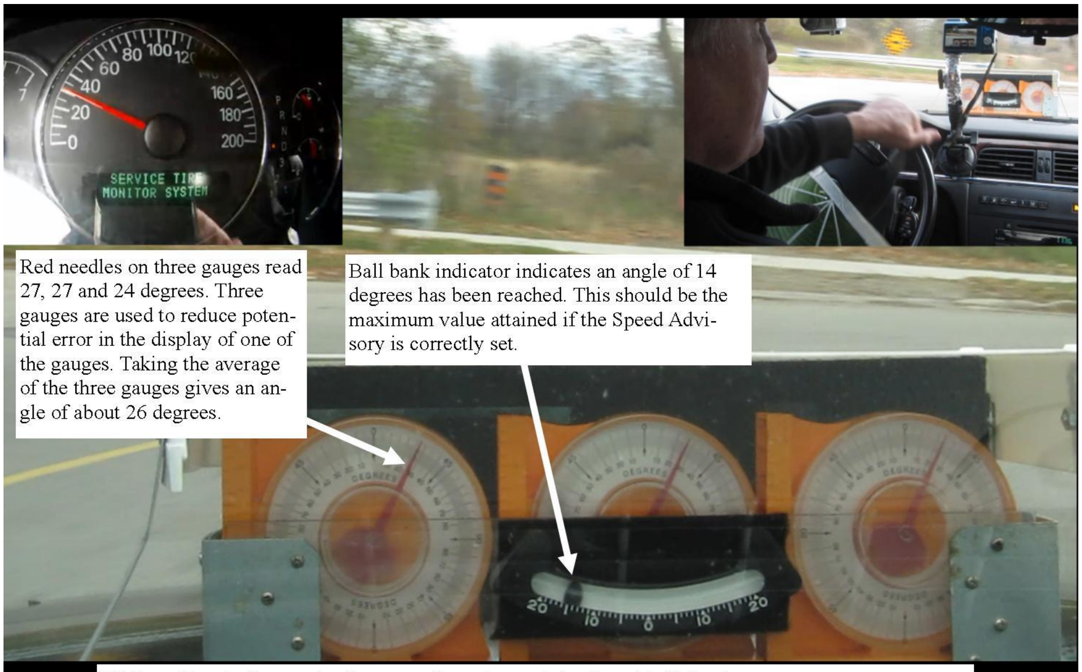


EB Run #1— At one second after start steering to right; Speed still 31 km/h

Figure 11: Scenario at 1.00 seconds after the steering has commenced.

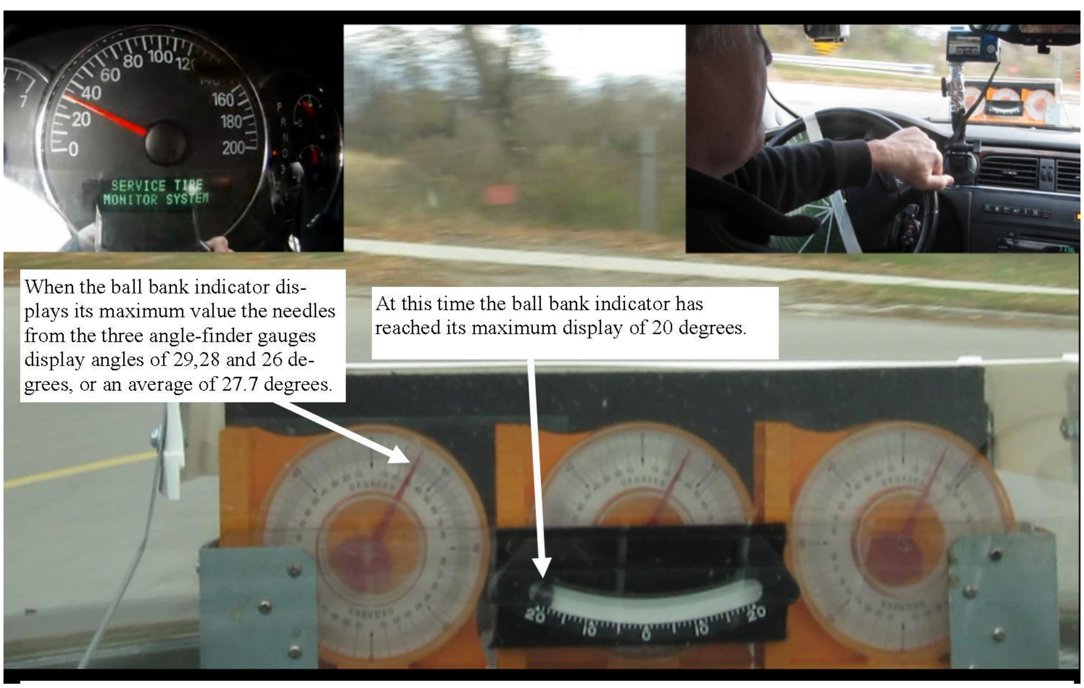
The amount of steering input can be seen by comparing the position of protractor on the steering wheel between Figures 10 and 11.

Figure 12 shows the scenario at 2.00 seconds after the steering has commenced. Here the black ball in the ball bank indicator has moved to a position of about 14 degrees. It can be recalled from our previous discussion that this is the maximum angle that the bank indicator should display if the 30 km/h Speed Advisory was set properly. Thus the ball bank indicator should not display a higher value throughout the remainder of the turn. The three angle-finder gauges display an average value of about 26 degrees. However, as can be seen in Figure 13, at 2.33 seconds after the commencement of steering, the black ball in the ball bank indicator has moved to the maximum that it is capable of displaying, or 20 degrees. At this time the three angle-finder gauges display an average value of about 27.7 degrees. Furthermore, Figure 14 shows the scenario 3.00 seconds after the commencement of steering. Here the black ball of the ball bank indicator is at its maximum reading of 20 degrees because it is incapable of displaying a higher value.



EB Run #1— At 2 seconds after start of steering to right; Speed is 31 km/h

Figure 12: Scenario at 2.00 seconds after commencement of steering.



EB Run 1—At 2.33 seconds after start steering —Ball bank indicator reaches maximum of 20 degrees; Speed is 31 km/h

Figure 13: Scenario at 3.00 seconds after commencement of steering.

Figure 14: Scenario at 3.00 seconds after commencement of steering.

Thus, even though the ball bank indicator cannot tell us the actual value of the lateral acceleration, the three angle-finder gauges provide us with some guidance. The red needles of these gauges display values of 30, 32 and 30 degrees, or an average of about 30.7 degrees. And we can recall from Figure 12 that their average value when the ball bank indicator reached its maximum of 20 degrees was 27.7 degrees. So this gives us an indication of the additional lateral acceleration that the ball bank indicator could not display because the value was beyond its range of display.

The accelerometer data shown in Table 1 provides further information about the relationship between the accelerometer readings and the gauges.

Table 1:

Time After Beginning of Steering	Time From Data During Testing (In Seconds)	Longitudinal Acceleration	Lateral Acceleration
Zero	133.53	-0.020	-0.030
1.00 Seconds	134.53	-0.040	0.020
2.00 Seconds	135.53	0.020	0.430
2.33 Seconds	135.86	0.030	0.460
3.00 Seconds	136.53	0.020	0.500

At 2.00 seconds (or 135.33 seconds from the data table) the lateral acceleration reported by the accelerometer was 0.430g, at 2.33 seconds it was 0.460g and at 3.00 it was 0.500g. One might conclude from this data that, when the ball bank indicator reads 14 degrees the accelerometer senses about 0.430g and at 20 degrees the accelerometer senses about 0.460g.

Unfortunately the relationship is not so precise. In reality the data from the accelerometer shows some scatter. One needs to take a closer look at the data in the vicinity of the precise time to appreciate this . So, for example, the raw data around the time of 2.00 seconds, say between 1.50 and 2.50 seconds is shown in Figure 15.

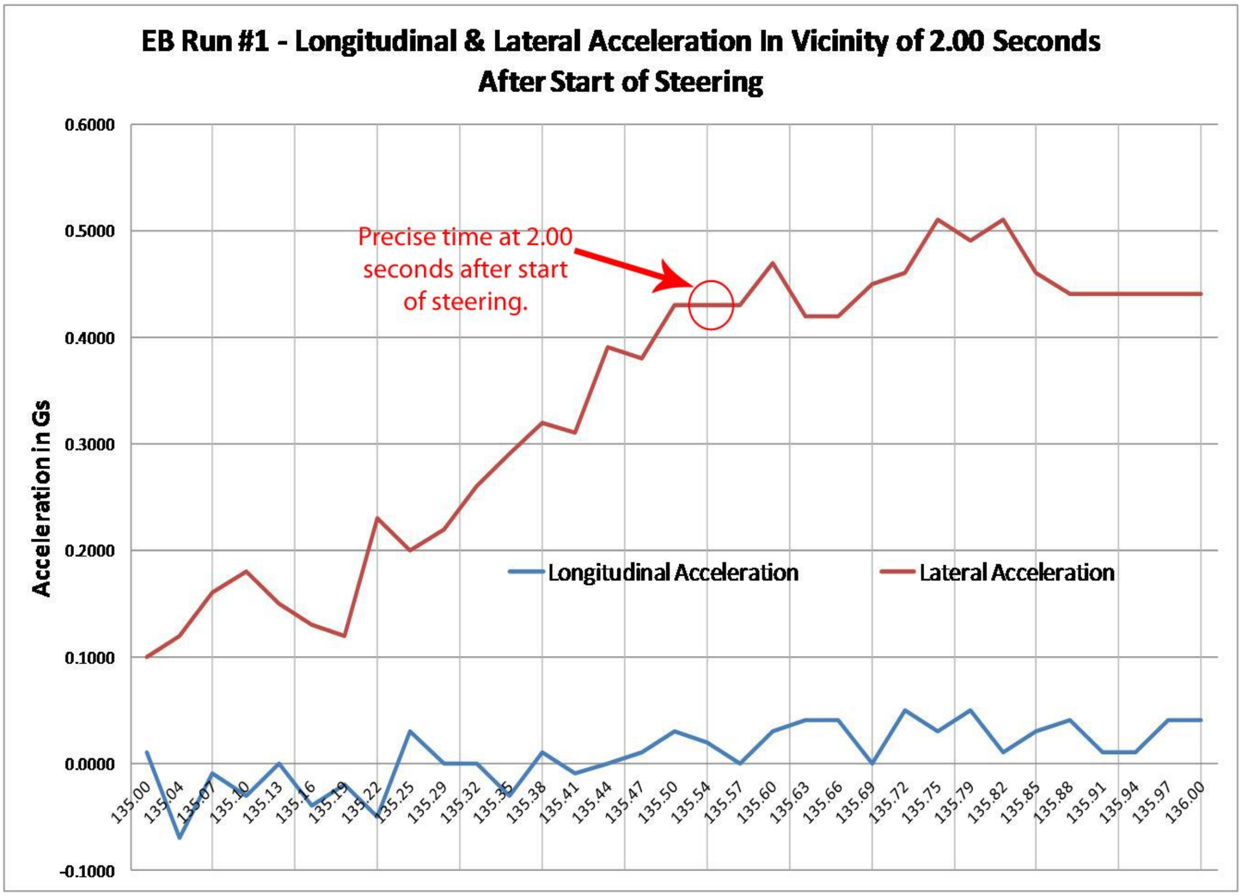


Figure 15: Close-up view of raw data from accelerometer between 135.00 and 136.00 seconds, or 1.50 to 2.50 seconds after the start of steering.

In this 1 second of data, the lateral acceleration rises from about 0.3g to around 0.5g and this is a rapid increase. Yet we know that the motion of the black ball in the ball bank indicator is damped as evidenced by the fluid in the casing where the ball resides. Thus the reaction of the ball to the instantaneous changes in the lateral acceleration is slow, much slower than the changes in value sensed and displayed from the accelerometer, or the less damped motions of the needles of the three angle-finder gauges . So in the present scenario, where the vehicle makes a very quick change in direction over a short time and distance, the ball bank indicator is unlikely to be a good indicator of the precise lateral acceleration at a specific time. Instead the ball bank indicator is designed to provide an indication of the lateral acceleration over longer curves where the lateral acceleration changes less dramatically. This is a fact that should be kept in mind when comparing the results of the ball bank indicator to the data from an accelerometer or to that of other gauges.

Another test that could provide a more accurate comparison between the gauges and the accelerometer data is one where the test vehicle travels around a continuous circular path, over an extended time, such as in a roundabout. We conducted such at test a new roundabout at the intersection of Wonderland Road and Sunningdale Road in north-west London, Ontario. This test was carried out on the same date, November 7, 2014, as the testing that was performed at the curve of Beaverbrooke and Proudfoot.

On November 7, 2014 we also conducted testing on four S-curves of Adelaide Street, just north of the City of London. We had performed previous accelerometer testing on these curves and presented the data in four previous articles ("The Seven S-Curves of Adelaide", Parts I to IV, September, 2012) posted to the Gorski Consulting website.

The results of these additional tests will be reported in an additional article posted shortly to the Gorski Consulting website.

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