# Time For Tractor-Trailer To Complete A Lane Change

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How long does it take a Tractor-trailer (TT) to complete a lane change on a typical, multi-lane highway? We have conducted some detailed testing that can provide an answer to this question and this is the subject of the present article. However, as we will soon discover, the answer is not that straight forward. As we will soon see, it depends on what you define as the beginning and end of the lane change.

Before discussing the issue of lane change we want to describe the equipment and procedures used in the testing. Figure 1 shows a screenshot taken from an Adobe Premiere video project that shows the views of six video cameras used in our testing.

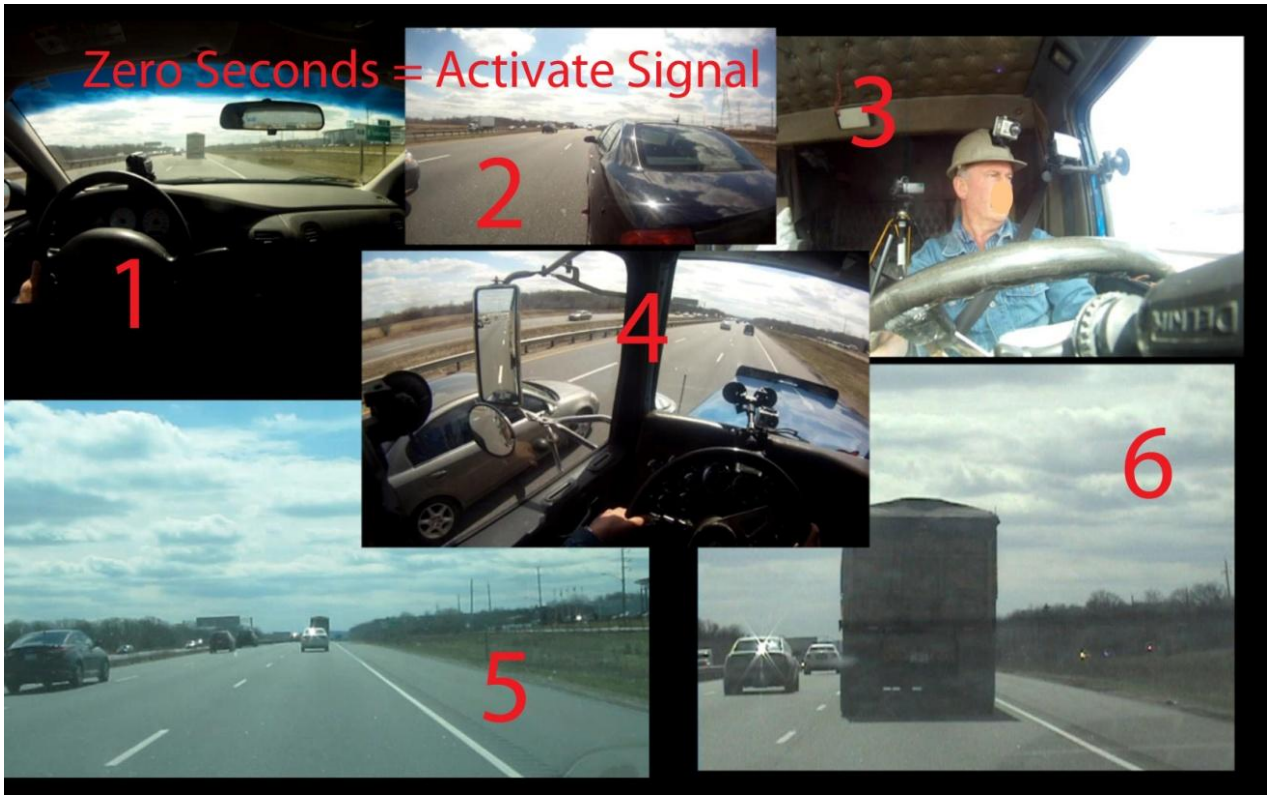


**Figure 1: Truck driver activates his turn signal.**

This testing involved a Western Star road tractor and two passenger cars. All three vehicles were fitted with video cameras as they drove along a multi-lane highway in Southern Ontario. The original purpose of the testing was to move the vehicles into various orientations with respect to each other to demonstrate what was visible from each driver's point of view.

At one point during this extended testing we isolated a short piece of video where the driver of the Western Star tractor-trailer performed a lane change, from the right lane, into the centre lane of a three-lane highway. The video segment we have selected is comprised of only 10 seconds of time and the screenshots we will show are taken at half-second intervals.

Looking at Figure 1 we have numbered the video cameras from 1 to 6, as can be noted by the large red numerals. Camera 1 is a view from the interior of a passenger car that we will call "CAR 1". This camera was mounted just behind the driver's head and is pointing forward through the vehicle's windshield. If you look closely, just beyond the steering wheel of CAR 1, you will see a video camera that is mounted to the top of the dash of the vehicle and that is Camera 6. Camera 6 is also pointing forward through the windshield of CAR 1 except that its view is "zoomed in" so that you have a much narrower field of view than the wide angle view shown in Camera 1.

When you look ahead in the views of Camera 1 and Camera 6 you will see that they are both showing the rear end of a trailer of a tractor-trailer combination. That trailer is being hauled by the Western Star tractor which is one of our vehicles that we instrumented as was part of our testing.

Camera 3 is a view from the interior of the cab of the Western Star. Camera 3 is mounted to the dash and pointed backwards toward the seated position the driver. In Camera 3 you can see that the driver is wearing a construction helmet and there is a camera mounted to the front of the helmet, which is Camera 4. Because Camera 4 is anchored several inches above the driver's eyes its view shows slightly more of the road below the road tractor than the driver can actually see.

Camera 2 shows the view of our Car 2. Camera 2 is mounted to the left end of a horizontal pole that itself is anchored to a bicycle rack at the rear of Car 2. Thus Camera 2 is able to show most of the exterior of the rear and left side of the Car 2 as well as the surrounding roadway.

Camera 5 is a view from a camera mounted to the dash of Car 2 and is pointing forward through the vehicle's windshield. In Figure 1 Car 2 is located two cars behind Car 1. In other words, there is another, unrelated car positioned between Car 1 and Car 2. If you look closely over the vehicle shown in front of Car 2 you might be able to detect the top portion of the trailer of the Western Star in the distant background.

## Discussion of the Lane Change

In Figure 1 the driver of the Western Star is preparing to make a lane change. Thus in Camera 3 we can see that the driver is looking to his left toward his exterior mirror to see if the way is clear for him to commence the lane change. What he is capable of seeing is shown in Camera 4. So Camera 4 shows that there is a tan passenger car located at the left front wheel of the Western Star. This tan passenger car is travelling faster than the Western Star so the truck driver is waiting for that vehicle to proceed further ahead before initiating the lane change. In Camera 6 we can see the view

through the windshield of Car 1 which is directly behind the Western Star. The view from Camera 6 shows the back of the Western Star trailer and it also shows the tan car just to the left of the Western Star.

Camera 5 is the view through the windshield of Car 2 and we can see that there are at least three vehicles in the far left lane while the middle lane is essentially clear up to the location of the tan car that is presently beside the left front of the Western Star Tractor. Thus the driver of the Western Star tractor notices that the centre lane will be clear once the tan car passes and therefore he will make the lane change.

The view in Figure 1 is the precise instant that the left- turn taillight begins to illuminate as observed from Camera 6. Thus at this instance the truck driver has just activated his left turn signal as an indication of his intent to begin the lane change. As can be seen in the top left corner of Figure 1 we have referenced this specific time as "Zero" in order to relate it to the remaining figures that show the events a 0.5 seconds intervals.

Figure 2 is a screenshot shown the content of the video taken 0.5 seconds after the scene shown in Figure 1. Figure 2 shows that the tan car has advanced slightly forward as shown in the view of Camera 4 (driver's helmet camera). The truck driver is still looking to his left toward his exterior mirror. The view of the rear of the trailer (Camera 6) shows that there is no indication that the trailer has started to move to the left within the lane.


Figure 2: Conditions at 0.5 seconds.

Figure 3 shows the scenario at 1.0 seconds. The tan car is still advancing with respect to the Western Star and the truck driver continues to look to his left. As an indication of the commencement of the lane change we might want to focus on the steering wheel of the truck as shown in Camera 3 as well as the truck driver's hands with respect to the edges of the frame and any ribs located on the rim of the steering wheel. Comparing the views in each figure it is possible to estimate the steering wheel motions and therefore determine when the truck is expected to commence its lane change. The views from Figure 1, 2 and 3 do not indicate any obvious steering wheel rotation.


Figure 3: Conditions at 1.0 seconds.

In Figure 3 we begin to notice that the car that was positioned between CAR 1 and CAR 2 has begun to move to the left within its lane and we will see shortly that it is beginning to change lanes into the centre lane where the driver of the Western Star truck is intending to go.

Figure 4 is view at 1.5 seconds. Here the truck driver is shown with his head turned to look ahead and this is confirmed by the changed view shown in the helmet camera (Camera 4). The tan car continues to move forward with respect to the truck. In Figure 4 we noticed that the truck driver began to steer slightly to the right, not the left, as one might expect. We appreciate that his action is not readily noticeable in the 0.5 second intervals shown in these frames. This rotation occurred for about 0.5 second and then the driver began to turn the steering wheel to left shortly after the view shown in Figure 5 which is at 2.0 seconds.


Figure 4: Conditions at 1.5 seconds.


Figure 5: Conditions at 2.0 seconds.

Meanwhile, we can see in Camera 5 (through windshield of CAR 2) that the car between the two CARs is continuing to change lanes into the centre lane. Note that, by Figure 5 the left turn signal on the Western Star trailer has been illuminating for 2. 0 seconds so the driver of the car which is changing lanes is aware that the truck will also be steering into that centre lane. Yet, shortly after  Figure 3 (or shortly after 1.0 seconds) the truck driver begins moving his head to look ahead and, although the car behind him might begin to be visible in the truck driver's mirror, the truck driver is not looking into that mirror at this particular time.

At Figure 6, or 2.5 seconds, the truck driver is still looking ahead and not into his driver's exterior mirror yet the car behind him is well into the centre lane and would be visible in the truck driver's left exterior mirror if the driver was looking there. Yet, the car driver should be aware of the truck driver's intentions as the trailer's turn signal has now been activated for 2.5 seconds.


Figure 6: Conditions at 2.5 seconds.

Shortly after Figure 6 the truck driver begins to turn his head to look in his left exterior mirror.

The view shown in Figure 7 is at 3.0 seconds and we see that the truck driver has now turned his head to the left and would likely see the car behind him which is already halfway into the centre lane. However the truck had already commenced steering to the

left shortly after Figure 5, or shortly after 2.0 seconds. It also begins to be apparent in Camera 6 of Figure 7 that the rear of the Western Star trailer is beginning to move toward the left portion of the lane.


Figure 7: Conditions at 3.0 seconds.

Now, one can appreciate that a conflict can unfold. From the viewpoint of the truck driver, he looked in his left exterior mirror and there were no vehicles visible in the centre lane and so he activated his left turn signal. One might argue that this the point when the changing of the lanes had commenced. Yet, one second after activation of that turn signal one can distinguish that the car between the two CARs has already moved into the left portion of its lane and that, prior to that point, the driver of that car had already made up his/her mind to change lanes. Yet we do not see any change in the lateral position of the rear of the trailer and therefore, from the viewpoint of the car driver, the car commenced its change of lanes before the truck commenced its change of lanes. Because the tractor-trailer combination is so long, the turning of the truck's front wheels causes a delay in changing the lateral motion of rear of the trailer. So from the viewpoint of the car driver it appears that the truck commences its change of lanes later than it actually does.

Figures 8 and 9 are views at 3.5 and 4.0 seconds respectively and we can see that the car is perhaps 3/4 into the centre lane and that the truck driver is observing that car in his left exterior mirror while his tractor-trailer continues its motion into the centre lane. This action continues in Figures 10 and 11 at 4.5 and 5.0 seconds.


Figure 8: Conditions at 3.5 seconds.


Figure 9: Conditions at 4.0 seconds.


Figure 10: Conditions at 4.5 seconds.


Figure 11: Conditions at 5.0 seconds.

Figures 12 and 13 show the views at 5.5 and 6.0 seconds respectively and here it can be appreciated that the car has essentially completed its motion into the centre lane whereas the centre of the rear of the Western Star trailer is barely across the lane dividing line at Figure 13. This indicates how much faster a lane change can be performed by a car versus a tractor-trailer.


Figure 12: Conditions at 5.5 seconds.

While the truck driver had been observing the motion of the car behind him he then turns his head away shortly after Figure 9, or at 4.0 seconds, even though the left rear wheel of his trailer is only passing over the lane dividing line so the rear end of the trailer is just beginning to enter the centre lane . It is likely that, at this point, the truck driver has convinced himself that there is no longer any danger of the car driving into the side or rear of his trailer and so he focuses on the road ahead of him. The truck driver had not been looking ahead of him for about 1.5 to 2.0 seconds as a result of his focus on the car behind him.

As we review Figures 13 through 21 we see the motion of the Western Star tractor-trailer through to a time 10.0 seconds. Throughout this time the truck driver continues to look ahead and does not re-check in the left, exterior mirror. The information he has observed has assured him that there is no need to re-check that mirror. Although additional figures will not be shown we can indicate that about 7.0 seconds after Figure 21 the left (fast) lane becomes clear and the vehicle that performed the lane change behind the Western Star tractor-trailer then steered into the far left lane and passed the truck.


Figure 13: Conditions at 6.0 seconds.


Figure 14: Conditions at 6.5 seconds.


Figure 15: Conditions at 7.0 seconds.


Figure 16: Conditions at 7.5 seconds.


Figure 17: Conditions at 8.0 seconds.


Figure 18: Conditions at 8.5 seconds.


Figure 19: Conditions at 9.0 seconds.


Figure 20: Conditions at 9.5 seconds.

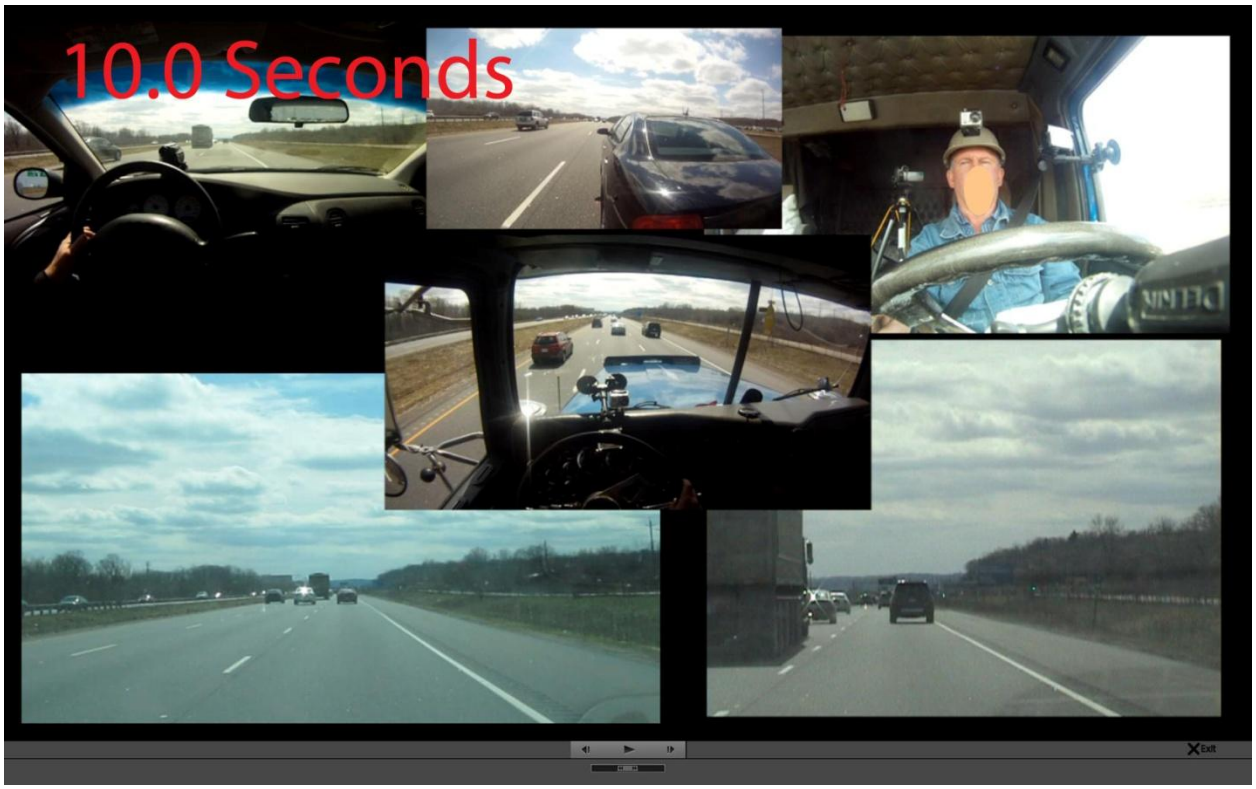


Figure 21: Conditions at 10.0 seconds.

While conducting analysis in the Adobe Premiere video project it is possible to stop the video at individual frames (i.e., every 30th of a second), to magnify the view of individual cameras or to select as many or few cameras to be included in the viewing screen. For example, in the original testing a total of 13 video cameras were used however not all of these can be displayed for the purposes of this article. Thus we can conduct a more detailed analysis of this testing than what is shown in these 0.5 second frames.

## How Long Does It Take For A Tractor-Trailer To Complete A Lane Change?

So, using the above testing as a guide, how long might it take a tractor-trailer to complete a lane change?

The obvious consideration is that it depends how you define a "lane change". There is no obvious, standard definition of when a lane change begins and when it ends and that is important when this answer is provided as a specific number that is used to determine guilt or fault in a motor vehicle collision.

A reasonable argument can be made that a lane change commences as the driver first begins to signal his intention to change lanes. In our example the lane change would commence at the "Zero" time of Figure 1. The end of such a lane change could be

assumed when the vehicle is squared up within the lane that it moved into. Using this definition in our example, the Western Start tractor-trailer is not completely squared up in the lane at Figure 21. Thus it could be determined that the lane change took about 10.0 seconds to complete. Other interpretations could be used to suggest that the lane change was completed in a shorter time.

Whatever definitions are used there should be some discussion about the fluidity of what is meant by the phrase "lane change". The best way to discuss this issue is to use a real life example of a lane change, as was demonstrated here, and to explain how one definition might be different from an another while providing some specific data of the elapsed time involved.

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