Path intrusion information page

Path Intrusions are instances in which a vehicle was originally traveling in a different direction, then turns across the path of the primary driver. Another type of path intrusion involves a vehicle originally traveling in the same direction of the [primary/responding] driver and then turns across the primary driver’s path, these are referred to as “Cut-offs”.

Buttons along the top of the page allows the user to navigate to other spreadsheets that will directly correspond to a path intrusion response time analysis.

Small buttons [*], each identified by a letter or letters bring the user to a definition of the related variable.

Example: “A” refers to Anticipation. When “A” is clicked on, this will bring the user to the User’s Manuel, where Anticipation is defined and how it is measured.

In I.DRR, if the path intrusion was a vehicle that was originally traveling in the same direction, select “Being Cut off” from the drop down menu [1]. Otherwise, select “Path Intrusion”. Also, if Metric units are desired, check the “Check for Metric” box in the Menu.

Anticipation (A) In the research by Muttart (2002-2009), anticipation was objectively defined based upon what the subject driver knew before being exposed to the hazard or target. Anticipation is coded one through five. Subjects coded, 1, knew what was coming and what to do about it. Where subjects coded as, 5, did not know what would appear and were not informed of the appropriate
response. Since practice may also heighten anticipation, studies that exposed the subject drivers to a stimulus once have a higher anticipation rating than studies in which drivers responded several times to the same thing. In most real life cases, the appropriate selection would be the DEFAULT [5].

Note: The user may enter the case number, parties involved or any other identifying comment [3] and whether the [primary/responder] was engaged in the DRIVING task at the time or not (was a pedestrian or passenger) [4].

Experiment Type (EX) [6] is an indicator of the anticipation of the subject driver as well as the workload. Research has shown that as the complexity of the response task becomes more like a real life (real traffic) emergency response, response time will increase. Studies performed in a laboratory (press a button responses and/or no driving task) have reported faster response times than when using a low fidelity simulator (steering wheel and brake only). Low fidelity simulators report faster response times than closed course studies, which report faster response times than open roads or high fidelity simulators. In a real traffic situation, an investigator should usually select the default (4. Road/Hi Fidelity Sim) in the drop down menu [7].
**Objects (O):** If a driver is responding to only one object, select “1. Response to 1 object”. If a secondary hazard or task appears between 0.1 and 1.0 second after the onset of the first and 
*requires the driver to respond to that as well*, select “2. Response to multiple objects.” If it is unclear which to select, refer to chart 1.

<table>
<thead>
<tr>
<th>Time second hazard, object or task appears AFTER the first which requires the driver to respond</th>
<th>Select</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;0.1 sec</td>
<td>1. Response to 1 Object</td>
</tr>
<tr>
<td>0.1 ≥ t ≤ 1.0</td>
<td>2. Response to Multiple Objects</td>
</tr>
<tr>
<td>&gt;1.0 secs</td>
<td>1. Response to 1 object</td>
</tr>
</tbody>
</table>

Multiple responses are rare with a common circumstance being a driver responding to one object then a second object emerges resulting in a crash. Even if the driver did not respond to the second object, the user may evaluate a driver's ability to avoid the crash with a second object.

*Example:* A driver is dialing a telephone (one response) and 0.2 seconds later, has to respond to a pedestrian darting across the road (second hazard).

The example would represent a multiple response scenario thus selecting “2. Response to Multiple Objects” as the correct choice.

**Eccentricity (E)** is the number of degrees between where the driver is looking and where the hazard appears when it enters the perception threshold (landmark). The available research shows that an investigator may assume the driver is looking ahead, if there is no information to the contrary.

Eccentricity may be calculated using the following equation:

\[
\text{Eccentricity (deg)} = \tan^{-1}\left(\frac{\text{Lat.}}{\text{Long.}}\right)
\]

Where \(\tan^{-1}\) is the Arc Tangent, Long. is the longitudinal distance from the driver to the position straight ahead and adjacent to the nearest point of the intruder. Lat. Is the lateral distance from the longitudinal line to the closest position of the intruder at the onset of the intrusion.
The lateral distance is the distance from the perception threshold landmark (the stop line or analogous location) to impact. The longitudinal distance is the distance the main road driver is from impact when the intruder enters the perception threshold (crosses the stop line or analogous position or becomes discernable). The longitudinal distance may be calculated with the following equation.

\[
\text{Longitudinal distance} = (T_{\text{accel2}} - T_{\text{decel1}}) \times V_1 + d_0
\]

Where:

- \( T_{\text{accel2}} \) is the time for the intruder to accelerate
- \( T_{\text{decel1}} \) is the time of the primary driver’s pre-impact response
- \( V_1 \) is the velocity of the Primary
- \( d_0 \) is the distance of the Primary driver’s pre-impact maneuver
Below are some common eccentricities. Those mentioned at roadway locations are typical of the eccentricities if the intruder is starting from a stop or a very slow speed. If the intruder did not stop before entering the road, the roadway (not in-vehicle) eccentricities may be larger.

### Common eccentricities

- At roadside (2 lane road) \(~5 \text{ degrees}\) (2 to 6 degrees)
- At roadside (4 lane road) \(~8 \text{ degrees}\) (6 to 12 degrees)
- Speedometer/Instruments \(~16 \text{ degrees}\) (5 to 20 degrees)
- Driver’s side mirror \(~35 \text{ degrees}\) (25 to 40 degrees)
- Rear view mirror \(~27 \text{ degrees}\) (20 to 35 degrees)
- Passenger’s side mirror \(~50 \text{ degrees}\) (35 to 50 degrees)
- Radio/Center Console \(~50 \text{ degrees}\)
- Left window \((30 \text{ to } 120 \text{ degrees})\)
- Right window \((35 \text{ to } 100 \text{ degrees})\)

**Drive** has shown to be able to estimate response times even when eccentricity exceeds 50 degrees but the user should never enter a number greater than 50.

### Common Eccentricities

**Road type (Rd)** [8] is a term that describes the visual noise at the location. While many believe highways have less visual noise, highways in actuality have the greatest visual noise. This is due to the fact that highways involve higher speeds and greater optical flow making highways more complex. Highways are associated with higher response times (with all else being equal). These three terms are the only road types addressed enough in research to be included in I.DRR. Road type accounts only for a small change in driver response times and are indicative of the visual noise at the crash or near the crash location. The user should select the road type that best describes the case being investigated.
Driving (D) [9] - refers to the task of driving (Navigating, guiding, and controlling the vehicle - Alexander & Lunenfeld, 1975). Experiments have shown that the driving task is associated with an increased response time compared to experiments where no driving task was necessary (Cohen, 1987; Fambro, Koppa, Picha, and Fitzpatrick, 1997).

Natural Ambient Lighting (Lt) [10] refers to the time of day of the crash, more specifically, the lighting. Although most research and real life crash scenarios involve situations that are obviously dark or daylight, there may be situations where lighting is ambiguous. Generally, if the ambient light is:

<table>
<thead>
<tr>
<th>Foot Candles (lux)</th>
<th>Select</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greater than 30 fc (32 lux)</td>
<td>1. Daylight</td>
</tr>
<tr>
<td>0.3 – 30 fc (3.2 – 32 lux)</td>
<td>1.5 Dusk</td>
</tr>
<tr>
<td>Less than 0.3 fc (3.2 lux)</td>
<td>2. Dark</td>
</tr>
</tbody>
</table>

Care should be given anytime dusk or night is selected to assure that the intruder is easily identifiable as an immediate hazard. If the intruder is not easily identifiable, a “perception threshold” must be established. If a perception threshold has not been established, then refer to one of the nighttime analysis worksheets (Headlight analysis and/or Recognition distance sections).

Select “0. Seen starting from a stop” if the intruder started from a stop or came to a stop at some time immediately before impact. Because a vehicle starts off somewhat slowly, research has shown response times to a vehicle starting out from a stop is greater than if the intruder does not stop immediately before or during the intrusion. Also, drivers respond slower to vehicles that stop within the intersection.

Select “1. Never saw the intruder stopped” if the intruding object was not starting from a stop. Also, (The wording here is specific.) Although the intruder may have started from a stop, it is possible that when the intruder first became discernable the intruder was already moving.

Select Cut Off if a cut off analysis (since all cut offs involve moving vehicles, movement is not a factor for the response time in cut off situations).

We know the how reaction times change when responding to a roadside path intrusion, versus a path intrusion that moved into the road without stopping. The difference between the two scenarios is that a path intruder if starting from a stop will likely be discerned shortly after it starts toward the road, while a path intruder who never stops will likely be perceived as an immediate hazard earlier.

In Figure 1 (below), you can see a responder who is faced with two possible situations. The driver on the left is stopped. Our responder will likely perceive the stopped red van as an immediate hazard that requires an emergency response when that van starts from the stop line.

To our responder’s right is a white pickup, for the sake of this discussion, we will assume the white pickup is traveling a rather high speed for that road. Drivers in our responder’s position do not begin an emergency response maneuver in response to a vehicle or pedestrian who is as far back as the pickup in Figure 1.

We know that a driver will perceive the intruder before it enters the road if it is traveling very fast. However, as crash reconstructionists, we do not know exactly when the synapses in the brain fired. Yet we do know the average PRT when responding to a vehicle starting from a stop (as shown to the left), and we do know the average PRT when responding to vehicles (or pedestrians) that do not stop before entering the subject driver’s road.

Driver response time to an intruder that does not stop before entering the subject’s path has been approximately 0.2 seconds shorter than when responding to a vehicle starting from a stop. From this we may conclude that drivers assume intruders will likely slow or stop before entering the road until a point they can perceive that it will not. No driver calculates the speed and stopping ability of an intruder, if this were common knowledge, there is no need for crash reconstructionists. Instead drivers’ rate safety based upon proximity more than speed. From the research, we can conclude that drivers first perceive intruders when approximately 0.2 seconds before they reach the stop line or analogous location. Therefore rather than surmise when a driver perceived a hazard, a better approach would be to report the average response time from the point the intruder crosses the stop line (or a pedestrian approaches the road edge).
The research shows us that if we start the PRT for pedestrians at the location which they land their last foot before the next foot enters the road, PRT will be similar to the time from when a car crosses the stop line.

![Figure 1]

The difference between these two scenarios is that a driver will likely perceive an intruder as an immediate hazard earlier when the pedestrian begins from an earlier position. I should stress my caveat here “all else being equal”. If we compare the response to a path intrusion at the road edge, to a vehicle that is relatively far from the intersection (as is the white pickup in Figure 1), all else is not equal. If we move the pedestrian very far from the road edge, visual eccentricity changes as does the immediacy of the hazard. When we examine all the driver response time literature to date, we can see that when the onset of the immediate hazard involves a time to contact of greater than 5 to 6 seconds, drivers do not respond with an emergency response (a pre-impact maneuver of 4 seconds or more is as common as reported unicorn sightings).

In most situations, those who responded in the research and in the real life situations from my research most likely had an assumption that the intruding pedestrian or driver was rational and would likely stop at some point before entering the road. There is always a constraint that the potential hazard of the pedestrian must exceed the potential hazards involved in locking the wheels.

**Topography (Tp)** [12] refers to the type of road the *intruder* is traveling on.

Select “1. Straight Road” if the intruder is entering a straight road segment.

*Example:* A driver is coming out of an intersection and up ahead a pedestrian runs into the road on a straight segment of road.

Select “2. Curve, Cue, Intersection” if the intruder is at a vertical or horizontal curve, at an intersection or if the Primary driver was specifically cued that a response was going to be necessary.

*Example:* An intruder is at a curve, intersection or if the primary driver is cued to respond

Select Cut Off if a cut off analysis (topography is not a factor for the response time in cut off situations).
Transition (Tr) [13] refers to the response portion of the perception-response time.
Some research studies stopped the response time measurement when the foot left the throttle, some stopped the clock when the foot touched the brake pedal and some accounted for the full response (up to first noticeable lateral movement when steering or up to full braking (ie. Skid marks).
Furthermore, some drivers may hover over the brake pedal in anticipation of an event or may be driving a commercial vehicle equipped with air brakes.

Air brakes are associated with an increased lag time before full braking. On the basis of several studies, the average leg movement time of drivers when responding to a road hazard is 450-500 ms. The average passenger car vehicle latency is 250 ms. These time change based upon the complexity of the response and are shorter when responding to being cut off (approximately 350 ms and 150 ms respectively). Leg movement times and vehicle latencies could be much longer if the driver is not confident in what they are perceiving or deciding, which is more common when the hazard is difficult to discern or when the driver is mentally overloaded. I.DRR makes an adjustment based upon any lag selected in the following way (brake lag secs minus the typical vehicle brake lag) [250 ms is the typical average brake lag for drivers in passenger vehicles].

If "Hovering" [14] is selected, I.DRR will reduce the full response time by 400 ms. in path intrusion cases and 300 ms in cut off cases.
Turning (Tn) [15] - If a driver is engaged in a right or left turn, response times increased by approximately 0.26 seconds. This variable does not refer to a driver negotiating a curve.

Lanes Crossed (L) [Cut Offs ONLY] [16] If the user is investigating a CUT-OFF (vehicle changing lanes) case, the number of lanes crossed is a significant factor. There is the option of selecting one, two or three lanes. If selecting more than one (the next lane), you must be referring to a vehicle that made all lane changes continuously.

Example: A vehicle starts in the left lane, moves to the center lane, straightened for a short time and then continues to the right lane. This is NOT a continuous movement and selection 1 (“1. From Next Lane of Closer”) should be entered.

OUTPUT

Average PRT [1a] is the average of the two methods of estimating response time (equation and adjustment-to-baseline). Regarding the ranges offered, I.DRR offers “individual” and “scenario” based ranges. Individual refers to the range of responses for individuals (slightly larger) than the range of responses for each scenario type. The coefficient of variation (CV) of the perception response times of individual drivers is 0.35.
SD = PRT\textsubscript{Mean} \times CV

Where SD is standard deviation, PRT is the perception response time, and CV is coefficient of variation.

Example: A study measures the perception-response time for a daytime path intrusion at an intersection (a scenario). The range of possible outcomes for the average response time for that scenario has not varied by more than 0.4 seconds. The next individual who responds to a path intrusion at an intersection is also likely to response in the same time period, but is susceptible to human variances due to attention, search location, and other factors.

Total Stopping Distance or Total Steering Distance is the total distance necessary to perceive, respond and either decelerate to a stop or steer the desired lateral distance [1b] (that is entered by the user). If it is a “Steering Response” [2a], “Steering Response” should be selected.
Initial Speed [2b] is the speed of the Primary driver before any pre-impact maneuvers in either mph or km/h. The user defines which avoidance response, steering or braking. If Braking Response is selected, the “Avg. Deceleration Factor” must be entered. The average deceleration factor, in gs, is the average negative acceleration during the avoidance maneuver (skidding or deceleration).

If a braking response is selected, the calculation used is:

\[
\text{Total Stopping Distance} = PRT \times V + \frac{V^2}{2A}
\]
If **Steering Response** is selected, I.DRR asks for Lateral Distance Necessary to avoid. Enter the lateral distance that would be great enough to allow the Primary driver to steer around the intruder. The user must also enter “Avg. Lat. Friction” or average lateral friction. Research at Virginia Tech has shown the average lateral $g_s$ during a routine lane change is 0.07$g_s$. While research also shows us a vehicle MAY reach a peak lateral acceleration of 0.8 $g_s$ in a closed course test, in real life researchers are interested in the average lateral friction across the entire maneuver and it must be understood that a driver is attempting to avoid any crash, not just this particular crash. Therefore, a maximum average lateral acceleration value should not exceed 0.3 $g_s$. This is due in part to the fact that a vehicle does not begin the steer the moment the steering wheel is turned.

**Total Steering Distance** is calculated by the following equations (Daily, Shigemura & Daily, 2006)

<table>
<thead>
<tr>
<th>Imperial</th>
<th><strong>Total Steering Distance</strong> = $PRT \times V + 0.366 \times \text{mph} \times \text{SQRT} \left( \frac{\text{Latd}}{\text{Lat}_\mu} \right)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metric</td>
<td><strong>Total Steering Distance</strong> = $PRT \times V + 0.125 \times \text{km/h} \times \text{SQRT} \left( \frac{\text{Latd}}{\text{Lat}_\mu} \right)$</td>
</tr>
<tr>
<td>BOTH</td>
<td><strong>Total Steering Distance</strong> = $PRT \times V + 1.414 \times V \times \text{SQRT} \left( \frac{\text{Latd}}{g \times \text{Lat}_\mu} \right)$</td>
</tr>
</tbody>
</table>

Where:
- $PRT$ is average perception-response time
- $V$ is the velocity
- $\text{mph (or km/h)}$ is the initial speed of the Primary Driver
- $V$ is velocity in feet per second or metres per second
- $g$ is gravity (32.2 $f/s^2$ or 9.81 $m/s^2$)
- $\text{Latd}$ is the lateral distance necessary to avoid
- $\text{Lat}_\mu$ is the average lateral friction during the entire maneuver

I.DRR allows the user to define the uncertainty or robustness of a finding by calculating the stopping distance for drivers who are much faster or slower than average.

**Example:** It is known that only about half of all drivers can be faster than average (yet 85% of drivers report themselves as being better than the average driver). What if a driver responded within a normal range but slower than average? How far would the driver need to stop or steer?

I.DRR offers the user the option of selecting the 5th through 95th percentile Stopping or Steering distance [2c]. The percentile stopping distance is calculated as:

**Total Steering Distance** = $PRT \times V + 1.414 \times V \times \text{SQRT} \left( \frac{\text{Latd}}{g \times \text{Lat}_\mu} \right)$

1. Substitute $PRT$ for $(PRT + SD \times E[Z])$
   \[= (PRT + SD \times E[Z]) \times V + 1.414 \times V \times \text{SQRT} \left( \frac{\text{Latd}}{g \times \text{Lat}_\mu} \right) \]
2. Substitute $SD$ for $[PRT \times CV]$
   \[= (PRT + [PRT \times CV] \times E[Z]) \times V + 1.414 \times V \times \text{SQRT} \left( \frac{\text{Latd}}{g \times \text{Lat}_\mu} \right) \]

Where:
- $PRT + SD \times E[Z]$ is the percentile stopping distance
- $SD = [PRT \times CV]$ is the standard deviation.
  - $SD$ represents +/- 34 percent of a population.
- $CV$ is the coefficient variation.
In Path intrusion cases, CV = 0.35
In Cut off cases, CV = 0.30
E[Z] is the expected Z value.

Therefore, percentile steering distance time is:

**Total Percentile Steering Distance** = (PRT + [PRT x CV] x E[Z]) x V + (1.41 x V x SQRT[(d/gf)])

Imperial **Total Percentile Steering Distance** = (PRT + [PRT x CV] x E[Z]) x V +0.366 x mph x SQRT(Latd/Latμ)
Metric **Total Percentile Steering Distance** = (PRT + [PRT x CV] x E[Z]) x V +0.125 x km/h x SQRT(Latd/Latμ)

\[
\text{Response Distance} = \approx 0.8 x 50 x 1.467 \quad \text{eq.3}
\]
\[
\text{Distance to Steer} = 0.365 x 50 x \text{SQRT}(1.7 / 0.7) \quad \text{eq.4}
\]
\[
\text{Total Steering Distance} = 58 \text{ feet} + 29 \text{ feet} \quad \text{eq.5}
\]
\[
\text{Time to steer} = d / V = 0.4 \text{ sec} \quad \text{eq.6}
\]

\[
\text{TOT. STEERING DIST.} \quad 29 \text{ feet}
\]

**AVG. Responses Dist.** 58 feet
95th percentile response Dist. 91 feet
Distance to Steer 29 feet

<table>
<thead>
<tr>
<th>Percentile</th>
<th>Z score</th>
</tr>
</thead>
<tbody>
<tr>
<td>5th</td>
<td>-1.645</td>
</tr>
<tr>
<td>15th</td>
<td>-1.033</td>
</tr>
<tr>
<td>25th</td>
<td>-0.67</td>
</tr>
<tr>
<td>33rd</td>
<td>-0.46</td>
</tr>
<tr>
<td>67th</td>
<td>0.46</td>
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<tr>
<td>75th</td>
<td>0.67</td>
</tr>
<tr>
<td>85th</td>
<td>1.033</td>
</tr>
<tr>
<td>95th</td>
<td>1.645</td>
</tr>
</tbody>
</table>

“Z” equals to one standard deviation. Z scores vary as follows:

**Example:** A 95th percentile response time is the response time at which 95% of the population is faster (smaller than) the whole population. Conversely, a 5th percentile response suggests that only 5% of all drivers would response faster.