



# Variable Driver Responses to Yellow Indications: An Operational Challenge and Safety Concern

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Intersections require a variety of crossing and turning maneuvers resulting in potential conflicts between vehicles, pedestrians, and bicycles that can contribute to crash outcomes. Although intersections represent a small portion of the roadway network, they are overrepresented in crash statistics.<sup>1</sup> The National Highway Traffic Safety Administration reported in 2014 that 32,675 people died and 2,338,000 people were injured in motor vehicle crashes in the United States, and at signalized intersections, there were 4,825 fatal crashes and 855,000 injury crashes.<sup>2</sup>

Section 4D.26 of the *Manual on Uniform Traffic Control Devices* (MUTCD) explains that the Circular Yellow (CY) indication is used to warn drivers that the Circular Green (CG) indication has ended and that the Circular Red (CR) indication will be presented next. Additionally, it states that the yellow change interval should have a duration between 3–6 seconds with longer intervals used on higher speed approaches.<sup>3</sup> Yellow change intervals have been identified as potential challenges for both drivers and traffic engineers because at the CY onset, drivers must choose to slow down and stop at the stop line, or to proceed through the intersection.<sup>4</sup> This decision can be difficult as the duration of yellow change intervals are not determined in a consistent manner, the laws governing driver response to CY indications vary across states, and because drivers' judgement of speed and distance are imperfect.<sup>5</sup>

In 2013, the National Coalition for Safer Roads reported 697 people were killed and an estimated 127,000 people were injured in red-light running (RLR) crashes. Extensive research on signalized intersection safety in different countries has been performed and much of this work has considered driver's decisions to stop or proceed through an intersection during the yellow change or red clearance interval.<sup>6-11</sup>

## Background

Van der Horst and Wilmink (1986) suggested that the tendency of drivers to stop on yellow is based on driver behavior, the consequences of stopping, and the consequences of not stopping.<sup>12</sup> Driver decision making at the onset of the CY is complicated and affected by several variables including travel time, speed, type of intersection control, headway, coordination, approach grade, and yellow change interval duration. The consequences of stopping abruptly at the onset of the CY are most commonly associated with the threat of a rear-end crash (especially at higher deceleration rates in closely spaced traffic) and delay, while the consequences of not stopping relate to the threat of right-angle crash (if the driver proceeds through the intersection when there is not adequate time to clear the intersection before conflicting movements are released) and of citation.<sup>13</sup>

One of the fundamental problems at a signalized intersection is the dilemma zone. There are two general classes of dilemma zone conflicts, Type I and Type II. The Type I dilemma zone describes the possibility that a motorist presented with CY while approaching a signalized intersection may not be able to safely go through the intersection or stop before the stop line. Several factors can contribute to creating this scenario: intersection design, errors in signal timing,

and detector placement. The Type II dilemma zone is widely known as an area of intersection approach in which the driver has difficulty in correct decision making to stop or go. The driver may incorrectly decide to stop when the correct decision is to proceed and vice versa. Either type may cause an increase in conflicts and crashes.

The primary purpose of the yellow change interval is to warn drivers that the green interval has terminated and that the red indication will be displayed next.<sup>14</sup> A driver approaching a signalized intersection has two choices at the onset of the yellow change interval: (1) come to a stop at the stop line of the intersection or (2) clear the intersection before the onset of the CR indication.<sup>15</sup> The Type I and II dilemma zones are commonly used to explain driver error in making this choice. The red clearance interval is considered a factor of safety for collision avoidance for vehicles that entered the signalized intersection at the last moment of the yellow change interval. The aim of yellow change and red clearance intervals is to provide safe transition between all conflicting traffic movements at signalized intersections.

Drivers are provided guidance on the appropriate response to the clearance interval in each state through yellow light laws that can be classified into three types:

*Class 1* - vehicles can enter the intersection at any point during the yellow change interval and if entered during yellow, it is legal to be in the intersection during the red,

*Class 2* - vehicles cannot enter or be in the intersection on red, and

*Class 3* - vehicles should stop during the yellow indication, but they may proceed with caution through the intersection if it is not possible to do safely.<sup>16</sup>

Prior work has termed Class 1 to be a permissive yellow law and Class 2 and 3 to be restrictive yellow laws.

The primary advantage of permissive yellow laws is to maximize the number of drivers who lawfully respond to the CY. The disadvantage of the permissive yellow law is that it can create a situation where the cross-street driver receives a CG but must yield the right-of-way (ROW) to a crossing vehicle on the alternate approach before entering the intersection, which can be of particular concern for a driver entering an intersection at the end of the yellow indication at a wide intersection without an all-read phase. Parsonson et al. (1993) indicate that about 60 percent of drivers do not understand that they should yield the ROW to crossing vehicles when they receive a CG. One solution recommended by Parsonson was to provide an all-red interval following the CY permitting vehicles to cross the intersection before conflicting traffic movements received a CG.<sup>17</sup>

Currently there are four states that follow the Class 2 restrictive yellow law and nine states that follow the Class 3 restrictive yellow law. The remaining 37 states follow the permissive yellow law (Class 1). Figure 1 displays yellow law classifications for each state as defined by NCHRP Report 731. A self-published report by

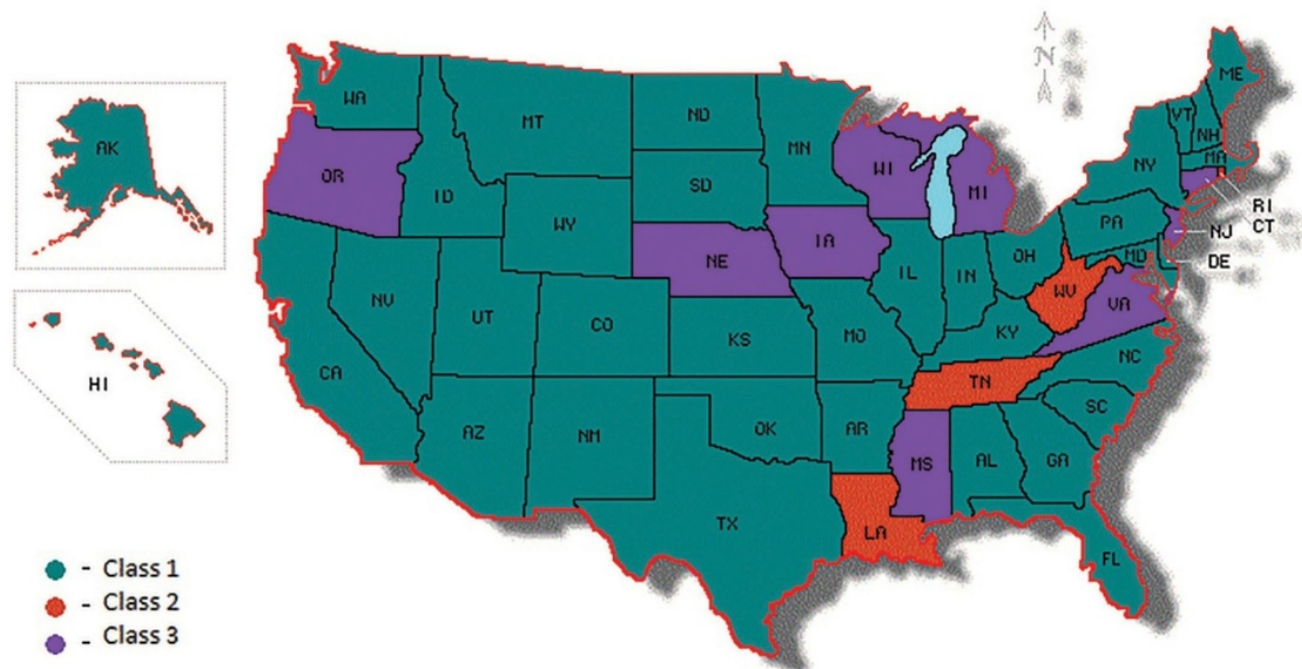


Figure 1. Classification of yellow light laws by state (NCHRP 731).

Järnlström (2014) disagreed with the classification of four state laws (Connecticut, Louisiana, Tennessee, and West Virginia) in NCHRP Report 731.<sup>18</sup> It was suggested that the yellow law classification for these states should be changed from Class 2 to Class 1 for three states and the Connecticut State law categorization should be changed from Class 3 to Class 1. The difference in classifications likely results from subtle differences in the language included in the brief legal definitions. If the word “warned” appeared in the definition Järnlström argued the law should be classified as permissive. Two knowledgeable transportation professionals could review the same definitions and arrive at alternative conclusions as to the correct interpretation. Regardless, a challenge for drivers is introduced when they cross state boundaries and in doing so become bound by a yellow light law with distinctly different requirements.

### Driving Manual Language

State Departments of Motor Vehicles publish driver training manuals (DTM) which include text and figures used to explain driving laws. There is a section in each of the 50 DTMs that describes the meaning and/or appropriate driver response to CY. This section of text was transcribed into table format, and each research team member independently reviewed the text to classify the possible scenarios described, and which state driver training manuals they were described in. Through discussions, the individual rankings were compared until a consensus was reached. Ultimately, the language used to describe what drivers should do in response to a steady CY includes one of four possible situations. These four situations are entirely derived from the DTM language in all 50 states, however 6 state driver training manuals do not provide direct instruction to drivers about how to respond to the CY, and therefore cannot be classified.

**Situation 1:** The vehicle should avoid entering the intersection during the CY. The vehicle is far enough away from the stop line at the onset of the CY that the driver is able to decelerate and stop safely at the stop line. There are 40 states which include this language in their driver training manuals (Figure 2).

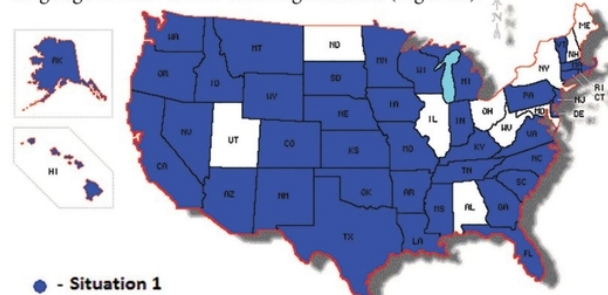


Figure 2. Forty states include situation 1 in their driver training manuals.

**Situation 2:** If the vehicle is too close to stop safely, the vehicle should continue through the intersection with care. The vehicle is close enough to the stop line at the onset of the CY that drivers can

clear the intersection. There are 19 states that include this language in their driver training manuals (Figure 3).

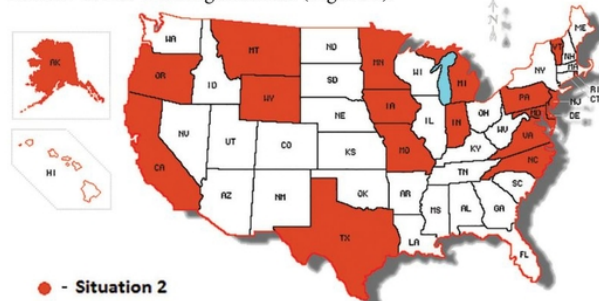


Figure 3. Nineteen states include situation 2 in their driver training manuals.

**Situation 3:** Accelerating to beat the light is illegal. The vehicle typically is not close enough to the stop line to clear the intersection at the current approach speed, so the driver accelerates. Nine states include this language in their driver training manuals (Figure 4).

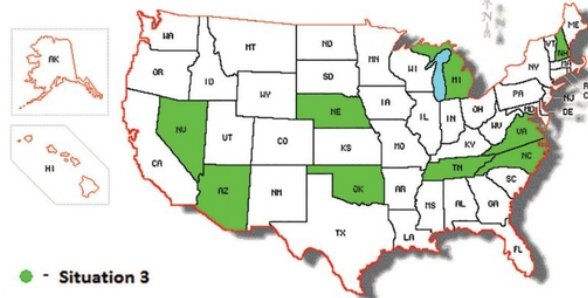


Figure 4. Nine states include situation 3 in their driver training manuals.

**Situation 4:** The vehicle should continue through the intersection if the light turns yellow while in the intersection. If the vehicle is in the intersection at the onset of the CY, the driver should just continue through the intersection. There are 21 states that include this language in their driver training manuals (Figure 5).

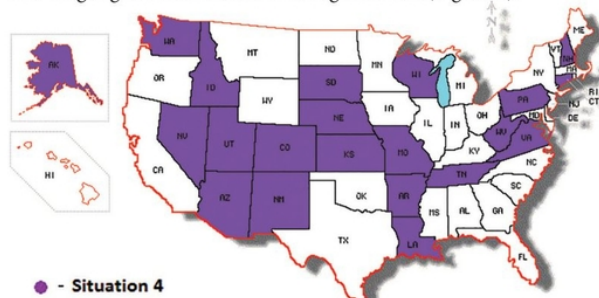


Figure 5. Twenty-one states include situation 4 in their driver training manuals.

Much of the previous research on driver behavior at the CY onset has focused on the lead vehicle. One seemingly unanswered question

is how do the characteristics of the following vehicle, specifically following headways and vehicle classification, influence the behavior of the lead vehicle? The phrase, “You must stop if it is safe to do so” appears in 11 driver training manuals. This language is ambiguous in defining unsafe stopping conditions. One possible interpretation of an unsafe stopping choice is related to the likelihood of a rear-end collision. The likelihood of a rear-end collision is influenced by the headway and classification of the lead and following vehicles involved. These two issues are considered in the following cases.

**Case 1:** Both the lead and follow vehicles at the CY onset are passenger cars. Most drivers will proceed through the intersection when within 2.5 seconds of the stop line.<sup>13</sup> Headway, speed, and perception reaction time (PRT) can play a vital role in the driver decision making of the following vehicle. Drivers may be hesitant to stop at the CY onset when closely followed due to increased rear-end crash risk. Allsop et al. indicated that drivers of following vehicles were more likely to be RLR at the CY onset when the headway of following vehicles was less than 2 seconds.<sup>19</sup>

**Case 2:** A heavy vehicle (HV) following a passenger car at the CY onset. According to Gates and Noyce (2010), vehicle type has a significant effect on the rate of deceleration and RLR.<sup>8</sup> HVs behave differently at the CY onset due to characteristics of the vehicle and driver. The difference in driver behavior of passenger cars and HVs (i.e., single unit trucks, recreational vehicles, buses, and semi-trailers) has been previously investigated.<sup>20</sup> HVs were less likely to stop when the CY was displayed and they were more likely to perpetrate RLR. Gates and Noyce (2010) state that HVs cannot stop as rapidly as passenger cars and the operational cost of HVs is higher when delayed. Also, the deceleration rate of HVs in dilemma zones has been shown to be lower than passenger cars when stopping.<sup>21</sup>

**Results**

The classification of guidance provided to drivers in driver training manuals indicate that six states provide Class 0 (do not fit any of three classes), two states provide Class 1 guidance, six states provide Class 2 guidance, and 36 states provide Class 3 guidance (Figure 6 A). However, the findings from NCHRP Report 731 analysis of yellow

light laws classified 37 states as Class 1, four states as Class 2, and nine states as Class 3 (Figure 6 B). Table 1 illustrates the comparison between NCHRP Report 731 and DTM Classifications. Based on this classification scheme, language that appears in state laws and driver training manuals may lack the needed degree of specificity.

Table 1. Comparison between NCHRP Report 731 and driver training manuals classifications.

NCHRP Report 731			Driver Manual Language			
Class 1	Class 2	Class 3	Class 0	Class 1	Class 2	Class 3
37	4	9	6	2	6	36
74%	8%	18%	12%	4%	12%	72%

For example, the 2015 *Montana Driver Training Manual* states that, “A steady yellow signal means “CAUTION.” Cautiously enter the intersection. The signal is about to turn red. Do not enter an intersection against a steady yellow light unless you are too close to stop safely.” This driver training manual guidance should be classified as a Class 3. The Montana yellow law indicates that, “Vehicular traffic facing a steady circular yellow or yellow arrow signal is warned that the traffic movement permitted by the related green signal is being terminated or that a red signal will be exhibited immediately thereafter. Vehicular traffic may not enter the intersection when the red signal is exhibited after the yellow signal.”<sup>25</sup> The language in the Montana yellow law should be classified as Class 1. The slight variations in language may cause confusion regarding what the correct action should be at the onset of the yellow indication.

Our classification shows that only 4 percent of states follow Class 1 guidance in driver training manuals, but the vast majority of state laws (74 percent) are classified as Class 1 in NCHRP Report 731. The results also indicate that 12 percent of states follow Class 2 guidance in DTMs and 8 percent of state laws classified as Class 2 in NCHRP Report 731. The large percentage of states (72 percent) follow Class 3 guidance in DTMs and 18 percent of state laws were classified as Class 3 in NCHRP Report 731. The results indicate an apparent inconsistency between the DTMs and yellow state laws (Figure 6).

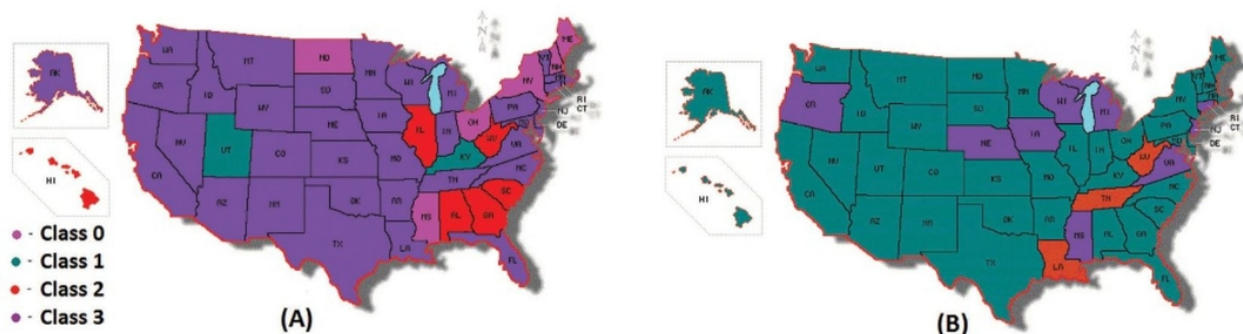


Figure 6. Classification of yellow light guidance in driver training manuals (A) and state laws (B)

## Conclusions

Based on the consideration of yellow light laws and the driver training manual guidance from across the country, several conclusions can be reached.

Many driver training manuals provide yellow light guidance that may be confusing to drivers when considered in conjunction with the associated state law. A large percentage of states (72 percent) follow Class 3 guidance in DTMs while the vast majority of states laws (74 percent) were categorized as Class 1 in NCHRP Report 731. The inconsistency between state yellow laws and DTM guidance is another example of inconsistencies that may contribute to variability of driver comprehension and decision making in response to circular yellow indications.

The inconsistency between permissive and restrictive yellow laws poses a meaningful conflict. This conflict can create confusion for drivers when traversing state boundaries. The most concerning conflict is when a driver travels from a state with a permissive yellow law to a state with a restrictive yellow law as red clearance intervals may be less frequent contributing to angle crashes. Conversely, drivers accustomed to permissive yellow laws may anticipate lead vehicles continuing through intersections on CYs rather than stopping, contributing to rear-end crashes.

Finally, the guidance provided to drivers in driver training manuals is highly variable between states even between states with identical or nearly identical laws. The CY definition communicated to drivers in driver training manuals should be more consistent to mitigate misinterpretation and transferability across state lines.

## Recommendations

There is a need to adopt a uniform legal interpretation of the circular yellow indication across state boundaries. This need has been recognized by transportation professionals for some time, but has yet to result in meaningful change. A less commonly discussed aspect of yellow light comprehension and decision making is the guidance provided by driver training manuals. In conjunction with the institution of consistent legal interpretation across state boundaries, the translation of these laws into consistent driver training manual guidance cannot be ignored. Perhaps there is an opportunity to refine and improve driver training manual guidance as a half measure to the modification of state law. [itej](#)

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