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Length of amber signals

Paper JCT Traffic Signals Symposium 2016

Datum 14 july 2016
Kenmerk CPX035/…
Eerste versie

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An amber signal marks the transition between ‘driving’ and ‘stopping’. But how long should amber be shown? In the Netherlands there has been a difference between the length of amber signals applied in practice, and the length advised in the available CROW-guidelines. This undesirable difference has been the reason for IVER to ask Goudappel Coffeng to conduct a study on the length of amber signals. The results of this study have been presented February 17th, 2016 at the Dutch Traffic Control Day and have now been adopted into an up-date of the CROW “Handbook Traffic Control 2014” as well.

The study is structured in three pillars; ’behaviour’, ‘big-data’, and ‘mechanics’. These pillars are preceded by an inventory in the form of a literature study and interviews with experts such as traffic behaviour psychologists, police, and road authorities. The focus of this paper is on motorized traffic. The research report which is written in Dutch also contains results for mopeds, cyclists and buses.

Literature study & expert-interviews
The meaning of amber in the Netherlands is the same as it is in the United Kingdom. In the Traffic Signs Regulations and General Directions 2016 the following definition can be found (Schedule 14 5 (9)):

'An amber signal. when shown alone, conveys the same prohibition as a red, except that, as respects any vehicle which is so close to the stop line that it cannot safely be stopped without proceeding beyond the stop line, it conveys the same indication as the green signal which was shown immediately before it.'

The United Kingdom uses a fixed amber time of 3 seconds. In the Netherlands as well as internationally, the duration of amber varies within 1 second. For 50 km/h (30 mph) roads amber signal durations of 3 seconds to 4 seconds are applied. For 70 km/h (43 mph) and 80 km/h (50 mph) roads the range is between 4 and 5 seconds. The guidelines given in the CROW Handbook Traffic Control are in the upper limits of the range in the Netherlands. The amber times applied in practice though, are in the lower limits of the range.

1 second extra amber halves red light negation
Changing the length of amber from the 'lower limit' to the 'upper limit' of the bandwidth (1 second extra), leads to an approximate halving of the red light violation. This decrease is demonstrated in several older and recent studies, and is confirmed in the data-analysis in this study as well. Another study although, has shown that the reduction of red light negation because of longer amber times, has no significant effect on the number of red light related accidents.

The literature study shows us a lot about how to calculate the length of amber: speed, perception response time (PRT) and deceleration. For speed is found that while using the 85 percentile value of the approach speed, the calculated amber time corresponds with most of the traffic. For PRT, the literature shows a value of 1,0 seconds (variation between 0.75 and 1,35 seconds). For deceleration it is not only important of what the vehicle is capable of, but especially of what the driver is prepared to do. This so-called 'comfortable deceleration' according to literature lies between 2,5 and 3,0 m/s^2.

Stop or drive on?
Three expert sessions have been held: one with a group of traffic behaviour psychologists, one with the police and one with a group of road authorities. From these sessions a consistent trend can be seen: there are roughly two types of road users: people who 'stop' and those who 'drive on'. According to the experts spoken to, the length of amber times is a search for the right balance.

With amber lengths too short, there is not sufficient time to make a safe stop resulting in a higher risk of rear-end accidents (due to unexpected strong braking by a forerunner). Not everyone is prepared to brake this hard for an amber light so a short length of amber means a higher chance of red light violation. All experts emphasize the

significance of credible amber times, and traffic control plans for the acceptance of traffic signals.

Behaviour

The results of the inventory have been tested in a field study. Trips were driven with a test panel, and a qualitative assessment has been made made of video recordings made at two traffic controlled intersections. The trips were done with an observer and dashcam recordings were made. After the trips interviews have been conducted as well.

The distinction between people who ‘stop’ or ‘drive on’ has been confirmed in the field study. Drivers decide to ‘stop’ or ‘drive on’ at the moment they were confronted with amber. No connection was found between the length of amber and the decision made.

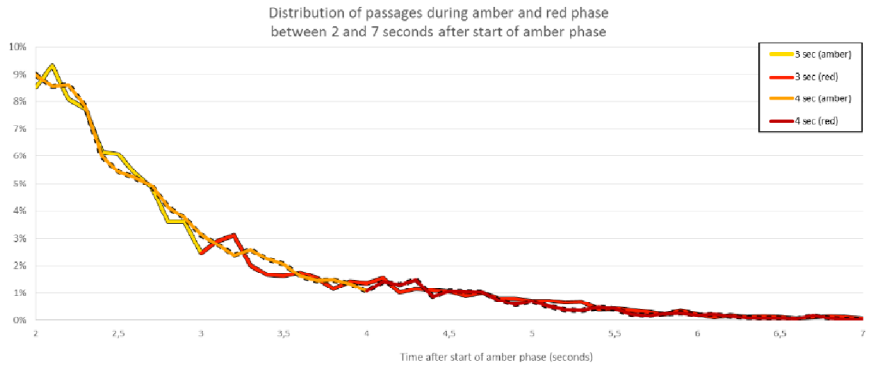
Big-data

Dutch traffic controllers collect comprehensive and reliable data. Data from nine traffic controlled intersections, controlled by three different road authorities, was used for analysis. The nine intersections contain 50 km/h (30 mph), 70 km/h (43 mph) and 80 km/h (50 mph) speed limits. After data-filtering 3,7 million valid measurements for straight ahead traffic and 0,9 million valid measurements for turning traffic were found.

For 5 of these nine intersections data are available with *different* amber lengths for the main directions. On 4 intersections measurements are made with amber lengths on the ‘lower limit’ and measurements on the ‘upper limit’ (1 second extra amber) of the bandwidth. For each amber length/intersection-combination a 4-week period is analyzed, separated by an adequate period of habituation (one year) to eliminate any possible transition effects. For the fifth 70 km/h (43 mph) intersection measurements of 3 amber lengths where made (3, 4 and 5 seconds) with a still adequate period of habituation of 6 months.

No change of behaviour with different amber length

The analysis shows that the length of amber has no effect on the behaviour of road users. The data analysis confirms the results of the behaviour survey: different amber lengths show no change in the behavioural patterns of road users. This is also shown in the graph below. The graph shows for one intersection the distribution of the amber- and red-runners for the period of 2 until 7 seconds after the start of amber. These graphs are comparable for 4 of the 5 intersections. The differences for the fifth intersection are explained by a change in the control plan (added green wave).



Even though there is no change in the behaviour: with a longer length of amber more vehicles pass during amber and less during red. The data-analysis shows a halving of the red light violation with an extra second of amber. On the 50 km/h (30 mph) and the 70 km/h (43 mph) intersections two thirds of the reduction fall in the first half of the extra second. On the 80 km/h (50 mph) intersection the reduction in the first half and the second half of the extra second is comparable. One of the intersections is equipped with a red light enforcement camera, the red light violation at this intersection is less than at the other intersections. Striking is that the reduction in violations in the first half of the extra second of amber is three quarters. At an intersection with red light cameras the *will*ingness of road users to stop is high. This result is an indication that a part of the road users *can* not anticipate the situation well enough, and unintentionally drive on.

An analysis regarding unwanted behaviour was done as well on road users who see a red light when they pass the distance loop and are driving on ('risk drivers'). The speed of these vehicles is high which can lead to serious accidents. The number of these risk drivers drops sharply with an extra second of amber (decrease factor of 3,8). This decrease is almost twice as strong as the red light violation.

Big-data is also used for speed analysis. The goal of these analyses is to get a good estimate for the parameter settings on calculations of the amber length. The real speed behaviour is shown to be different from the legal speed limit. The differences for the 85th percentile value can rise up to 10 km/h (6 mph) upward or downward. For turning traffic there is barely a difference in the speed of right and left turning traffic. The speed between the distance loop and the stop line loop is around 45 km/h (27 mph). It seems realistic to assume that for turning traffic the speed at the stop line is lower than 40 km/h (24 mph).

Mechanics

The third pillar of the project is to make calculations to determine the length of amber: make it possible to stop bases on PRT, vehicle speed and deceleration. In the mechanics formula for the length of amber it is important to choose parameter settings which reflect the behaviour of the majority of the road users. The researchers have based these parameters on the value found from the literature and big-data.

A comparison of three scenarios (low – middle – high) shows that:

- An amber length of 3 seconds for 50 km/h (30 mph) is on the low side;
- An amber length of 5 seconds for 70 km/h (43 mph) is on the high side;
- An amber length of 4 seconds for 80 km/h (50 mph) is on the low side.

Analyses of the length of amber applied in Dutch practice (50 km/h (30 mph): 3 seconds; 70 km/h (43 mph) and 80 km/h (50 mph): 4 seconds) show that the deceleration needed for all speed-limits is higher than the upper limit for comfortable deceleration. To complete the driving task drivers need to brake harder than they are (on average) prepared to do. With the length of amber advised by CROW (50 km/h (30 mph): 4 seconds; 70 km/h (43 mph) and 80 km/h (50 mph): 5 seconds) the deceleration needed for 50 km/h (30 mph) and 70 km/h (43 mph) is more than comfortable (below 2,5 m/s^2). For both situations (Dutch practice and CROW advice) the deceleration needed is not consistent for the different speed-limits, as shown in the following table. In the third row the deceleration needed for the situation in the UK (3 sec. amber) is included.

Deceleration	**50 km/h (30 mph)**	**70 km/h (43)**	**80 km/h (50 mph)**
Dutch practice	3,5 m/s^2	3,2 m/s^2	3,7 m/s^2
CROW guidelines	2,3 m/s^2	2,4 m/s^2	2,8 m/s^2
UK fixed 3 seconds	3,5 m/s^2	4,9 m/s^2	5,6 m/s^2

Conclusions and recommendations

The study shows that the length of amber has no influence on the behaviour of people ('willingness' to stop). The number of red light runners decreases strongly when amber length is extended. The decrease in the number of risk riders is almost double the decrease in red light runners. These results indicate that some of the road users can not anticipate the situation well enough and therefore unintentionally run red lights.

The length of amber must be long enough for road users to make a safe stop. It is needed to choose credible parameters in the formula for the length of amber. The researchers advise a value of 1,0 s for the Perception Response Time (PRT). For speed one must judge if the speed limit is corresponding with the situation. If not, the researchers advise to use the 85th percentile value for speed.

The researchers advise to use a comfortable deceleration ((2,5 - 3,0 m/s^2) and make a consistent choice for each speed. Combined with the principle that the length of amber must fall in the found bandwidth of used amber lengths (2,8 - 3,2 m/s^2) the available range is 2,8 - 3,0 m/s^2. Using the effects found in the experiments extending the amber length (strong reduction red light violation and very strong reduction risk riders) the advice is to use 2,8 m/s^2 for deceleration.

Using the advised parameters gives amber lengths which correspond well with the results of the analyses. The researchers therefore advise that the amber lengths corresponding to those in the table below be applied.

Length of amber in seconds	speed (maximum of speed limit and 85 percentile of measured speed)		
	50 km/h (30 mph)	**70 km/h (43 mph)**	**80 km/h (50 mph)**
motorized straight ahead traffic	3,5	4,5	5,0
motorized turning traffic	3,0	3,0	3,0

Reactions

The results have been presented to and discussed with stakeholders IVER, CVN and police. These parties support the results of this study. The report is presented to CROW with this support. The recommendations are adopted in an update of the CROW “Handbook Traffic Control 2014”. The results were also presented 17 February 2016 at the Dutch Traffic Control Day with very positive reactions.

The report can be downloaded at: http://www.crow.nl/downloads/pdf/verkeer-en-vervoer/publicatie/eindrapport-geeltijden-iver_januari2016.aspx.