Research Article

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Analysis and assessment of defectiveness of regulations for the yellow signal at the intersection

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Abstract: Imprecise and defective regulations should be eliminated in the operation of vehicles. The article discusses and evaluates the differences in legal acts regarding the requirements for the yellow signal at intersections with traffic lights. Poland has signed the Vienna Convention on signs and signals. When implementing it into Polish legislation, the original provision was changed slightly. The reason for the ban on entering the intersection during the yellow signal has been changed. As a result, an unfavorable situation arises for the driver without a good way out. In addition, a colloquial word was introduced, undefined – “rapid braking”. The changes introduced in relation to the Vienna Convention were analyzed and evaluated. Defects were found and the need and necessity of correction of the applicable provision were reported. The necessity to consider changing the provision in the Vienna Convention was also pointed out. There is a need to provide advance information about an upcoming change. These are activities in the operation of vehicles in road traffic from the area of active safety system. It may be possible to use e.g. a flashing signal in the final phase of displaying a solid green signal on the S1 signaling device for vehicles.

Keywords: traffic lights, intersection, yellow signal

1 Introduction

Poland is a European country and a member of the European Union (EU). The correct formulation of traffic regulations has a great impact on the safety system in car operation. They are a kind of operating procedure. Uniform rules on road traffic should apply in EU countries, especially when they have signed the Vienna Convention on Signs and Signals [1]. No restrictions on the freedom to cross borders allow foreigners to move on the roads of neighboring countries. In some states of the United States of America a flashing green signal means that there is no collision when turning left. This signaling device behavior is called “Advanced Green”. Among other things, traffic light regulations at intersections should be identical and comply with the Convention. It requires that for cars, the green signal be transmitted continuously. For pedestrians, a flashing signal may be given in the final phase. In Serbia, Croatia, Moldova, Austria, Lithuania and Slovakia, etc., it meets at intersections, flashing green at the signal end, at the S1 traffic light. These countries have signed the Convention. A flashing green signal is necessary but not in accordance with the applicable rule. In this way, information about the approaching end of this signal is sent in advance. A separate question is whether it is favorable or unfavorable for the security system. 100 years ago, in 1920, in Detroit – United States of America, William Potts introduced the yellow signal for the first time (as the third of the transmitted signals). Police officer William Potts was steering traffic at a very busy intersection. He turned on the right lights while looking at the intersection.

The tremendous technical progress has since created new possibilities. However, a yellow signal transmitted for a few seconds created a “dilemma zone” [2]. The driver must decide whether to continue driving and pass the traffic lights or to stop in front of the traffic lights. There is a risk of collision. In countries that have signed the Vienna Convention, the provisions regulating the operation of signaling at intersections are implemented into national legislation. In European countries, traffic lights cause similar problems when changing the green signal to yellow. Driving through an intersection in extreme situations can cause you to brake suddenly. Changing the signal without prior notice or by surprise the driver increases the risk of an accident. The development of devices in the field of control observed since then creates new possibilities for solutions, much more effective than those used so far.

The aim of the research is to analyze, compare and evaluate the relevant provisions of the Vienna Convention.
on Signs and Signals and the Regulation of the Minister of Infrastructure of the Republic of Poland on signs and signals [3] in terms of compliance and correctness. The thesis is as follows: traffic control at an intersection with traffic lights has systemic disadvantages. The scope of consideration covers two legal acts: the Vienna Convention [1] and the MI Regulation [3] on traffic lights at intersections. The subject of the research is a driver of a car traveling on an EU road at an intersection with traffic lights. The subject is law (contained in the security system). They concern the orders and prohibitions resulting from the transmission of signals by the signaling device at the intersection. They should generate appropriate behaviors of road users. Disclosure of any contradictions and irregularities will allow to introduce changes to improve the road safety system. The method used in the analysis and evaluation is based on deduction, induction and calculations of the kinematics and dynamics of the car’s movement at an intersection with traffic lights when changing traffic lights. The available literature did not find any analysis of the compliance and correctness of the national legal act with the Vienna Convention in this respect. The authors [2, 4, 5] dealt with the “dilemma zone” resulting from the existence of the yellow signal and the dangers caused by it. No publications were found that showed defects in provisions in national regulations.

Questions can be formulated: can legal provisions contain faulty information? If such formulations were included, should we accept or tolerate them? Are we obliged to eliminate them from existing legislation? Should imprecise information be clarified or removed from the legal provision? What level of irregularity is acceptable and which is not?

2 Comparative analysis of the examined provisions

The provisions in the (applicable to traffic participants) law regarding the yellow signal displayed after the green signal on the S1 traffic light for cars will be compared. The Vienna Convention on Signs and Signals [1] states:

“(a) non-flashing lights: (iii) yellow light which should appear alone or simultaneously with red light; if it appears by itself, this means that no vehicle should cross the stop line or pass behind the signal, unless the vehicle is so close when the light comes on that it cannot stop before the stop line or in sufficient safety conditions.”

The Ordinance of the Minister of Infrastructure on road signs and signals [3] states:

“6.2.1. Base sequence signals. The following light signals are used for drivers of vehicles: – a yellow signal indicating the prohibition of entering behind the siren, unless the vehicle is so close to the traffic light that it cannot be stopped in front of it without sudden braking when the signal is started”.

The key difference is in the fragments of sentences:

- Convention: “A vehicle can no longer stop in front of the stop line or in front of the traffic light in conditions ensuring sufficient safety”, and therefore for such a case then the entry ban does not apply, because the driver cannot stop in conditions ensuring sufficient safety,
- Regulation: “A vehicle cannot be stopped without sudden braking”, Therefore, when the vehicle stops abruptly, the entry ban does not apply to this situation and you can enter after the signal. However, if a vehicle brakes suddenly and it is not possible to stop the vehicle in front of it, then what? In this situation, the exemption from the ban does not apply and entering the signaling device would commit an offense.

This situation may occur when, despite the sudden braking (the car being too close to the traffic light), we will not be able to stop in front of the traffic light. A vehicle is forced to go behind the signaling device, in which case the exemption from the ban does not apply. This record shows that despite the fact that we are not able to stop the vehicle while the yellow signal is being displayed, it is forbidden to enter the intersection. This is an obvious error. The driver is then in the “inability zone” to implement the ban. A mistake was made in national law by making such a change.

3 Kinematic analysis of a possible scenario

The stopping distance of the car (Figure 1) consists of the distance traveled during the driver’s reaction, the distance traveled during the rise of braking force, and the braking distance [6].

Calculations of the stopping distance were made according to the relationship (1) with the following assumptions:
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Figure 1: Graphic representation of the stopping distance of a car – three components

- Signaling regulating traffic at intersections, located in places where the speed limit 50 km/h applies.
- The calculations also took into account the values: maximum steering response time and maximum braking force rise time [6].

The input data and calculation results are presented below. Calculations of the stopping distance were carried out according to the formula (1) for a simplified “trapezoidal” time course of braking deceleration:

\[
S_z = S_{rk} + S_{nh} + S_h = V_p \cdot t_{rk} + V_p \cdot \frac{t_{nh}}{2} + \frac{V_p^2}{a \cdot 2}
\]  

where:
- \(S_z\) – stopping distance of the vehicle,
- \(S_{rk}\) – distance traveled during the driver’s response,
- \(S_{nh}\) – distance traveled during braking force build-up,
- \(S_h\) – distance traveled "during braking" with a constant deceleration,
- \(V_p\) – value of speed at the access to the intersection - permissible, determined by the recipe,
- \(t_{rk}\) – driver response time,
- \(t_{nh}\) – braking force rise time.

At the most favorable, best atmospheric conditions and efficient car, the maximum deceleration deceleration was assumed to be \(a = 8 \text{ m/s}^2\). The assumed reaction time of the driver \(t_{rk} = 1.2 \text{ s}\) and the braking force rise time \(t_{nh} = 0.4 \text{ s}\) were taken into account (for the assumed parameters [6]). Then the minimum value of the stopping distance of the car will be \(S_{zmin} = 32 \text{ m}\). The car traveling at a speed of \(V_p = 50 \text{ km/h}\) (13.89 m/s = 14.0 m/s) can travel while the yellow signal is being displayed (yellow = 3 s) road \(S_{Yellow} = 41.7 \text{ m}\).

When arriving at the traffic light when the yellow signal is displayed, may there be a state in which, despite a sudden braking, we will not stop the vehicle in front of the traffic light? Yes, these possibilities are not excluded and may occur. There are also extreme scenarios in operation.

The yellow signal (in accordance with applicable regulations) lasts 3 s. A typical, common speed limit in cities is 50 km/h and 60 km/h. For a higher speed value we have even more difficult conditions for the driver. There may be situations when the signal changes from green to yellow when the vehicle is in an area close enough to the traffic light that it will not be able to brake during the yellow signal. Another solution is not sudden braking in front of the traffic light. Despite the highest possible deceleration values, it will not be possible to stop the car. The value of the stopping distance in this situation is greater than the distance to the signaling device. This is the area of “impossibility” (a kind of trap) that causes you to enter behind the signaling device displaying the yellow signal (Figure 2).

An incorrectly worded provision creates a dead end – the driver has no choice but to commit an offense. The lack of advance information favors this. Thus, at a distance greater than 32 m to the stop line, the driver braking with maximum force, the braking system (“sudden braking”) is able to stop the vehicle in front of the signal. Then the driver has the right not to comply with the ban on entering the intersection at the yellow signal. The driver can cross the detention line without committing an offense.

When the yellow signal is given by the traffic light and the vehicle is less than 32 m to the stop line or traffic light, it is not possible to stop in front of the traffic light. Even when it is at maximum strength, it “brakes rapidly”. In this case, the exemption from the entry ban does not apply with the wording of the law: “that he cannot be stopped in front of him without sudden braking”. Thus, entering the intersection while displaying the yellow signal will commit an offense, despite the fact that it is not possible to stop the car. This is an unacceptable defect in the law in force in an EU Member State.
Another problem is to use the term “hard braking” without defining it. The concept of “sudden braking” is included in the regulation of the Ministers of Infrastructure and Interior and Administration on road signs and signaling [4]. It does not define the term “hard braking”.

The stopping route in use of a vehicle (especially in the safety system) is of great importance due to the occurrence of road accident hazards. Not specifying the above mentioned determination causes its free interpretation. Because, among other things, “braking violence” determines the possibility of entering the intersection during the displayed yellow signal, it should be precisely defined. It is inappropriate to use it in the current provision and it is practically not defined and this is currently the case.

In the publication space you can find a description of emergency braking, e.g.:

“emergency braking (rapid), consisting of vigorous pressing on the brake pedal to stop the vehicle in the shortest possible time. In the last braking phase, if possible, depress the clutch pedal to prevent the vehicle engine from stopping. However, the pressure on the brake pedal must not block the wheels, which not only increases the braking distance, but can also cause a dangerous casting of the car. This type of braking is recommended in hazardous situations, such as unexpected pedestrian crossing.”

The concept described in this way is imprecise, and the Regulation does not refer to such a definition. Colloquially, it seems clear and obvious. It would be precise, for example, to define: conditions on the road and the range of values of the decelerations caused during braking. Example: adhesion coefficient \( \mu = 0.8 \); deceleration \( a = 8.0 \text{ m/s}^2 \).

The parameters described in this way are measurable and allow to assess (with a certain tolerance range, e.g. 10%) whether braking was rapid or not.

The spatial-time convergence of the process should take into account the value of a much longer braking distance – \( S_z \) of the braking car in relation to the shorter distance to the braking line, if the car is closer to the \( S_1 \) signal. The driver should be informed much earlier about the upcoming signal change, so that he can make a decision earlier and react accordingly. The following factors should be considered: steering response time, braking time, limited deceleration, braking distance, yellow signal display time (green). In addition, the position of the vehicle in front of the traffic light should be taken into account when changing the transmitted signal [2, 4, 5]. In the operation of vehicles, the safety system in question does not sufficiently take into account the restrictions resulting from ergonomic principles.

Figure 3 shows examples of stopping routes for six selected vehicle positions, against the background of the signal display by the traffic light.

The scenarios show the possible course of the predicted traffic of cars that the change of signal found in individual zones. The lack of advanced information favors the existence of a “dilemma zone” and an “impossibility zone”. The selected input values are to show the results by analyzing the phenomenon in extreme conditions.

The calculated value of the stopping distance significantly exceeds the length of the stopping distance when it is closer than 32 m to the signaling device. The above calculations can and should be the basis for requesting a change in the law in order to eliminate absurdities in the operation of vehicles. The law should specify for them a framework that takes into account the comments from tests conducted on vehicles in traffic.

4 Analysis of test results

Cars 1 and 2 (Figure 2), when the signal changes to yellow in this position, have no chance of stopping in front of the signal. Car 3 braking with a maximum deceleration value has a chance to stop in front of the traffic light. Cars 4, 5, 6 have the option of stopping at smaller (than maximum) deceleration values. Cars 3 and 4 in the dilemma zone can cross the stop line or stop. Cars 5, 6 must stop. Similarly (Figure 3), the issue of driver behavior after receiving a signal is presented depending on the place where it was received. In the 3 scenario, the cars with a yellow signal (for this position) are not able to stop in front of the traffic light. At the same time, the existing provision in the Regulation on Signs and Signals does not exclude such a situation from the ban on entering the stop line or the signaling device.

This issue has demonstrated a serious problem in existing, current legislation on the operation of vehicles in an EU Member State. It is necessary to make in-depth analysis and propose changes in the provisions of applicable legal regulations in road traffic. The current regulations applied at the intersection cause a situation in which a “dilemma zone” and “impossibility zone” appear. In the “impossibility zone”, the driver’s action ends with an offense.

Currently, the problem considered here is not noticed by those responsible for the safety system in the operation of vehicles, of which legal regulations are an element. Also, the introduction of the word ‘sudden braking’, whose meaning is undefined, is unacceptable. The most accurate are the words of William Thomson – Lord Kelvin:
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Figure 3: Graphic representation of sending a yellow signal for various positions of the car relative to the traffic light and possible subsequent proceedings

“If you can measure and express in numbers what you are talking about, you really know something about it. If you cannot measure and express in numbers, your knowledge is meager and unsatisfactory.”

Therefore, if the wording is to remain in applicable law, it should be clarified.

5 Summary and conclusions

By implementing the signed Vienna Convention on Signs and Signals into national legislation, its entry has been amended in the fragment in question. As a result, before the intersection, an area was created in which the exclusion regarding the prohibition of crossing the stop line or crossing the signaling device while the yellow signal is displayed does not apply. The entry ban applies and at the same time it is not possible to comply with this ban. Legislators do not seem to notice this. It should be written in the Regulation on signs and signals exactly as it is written in the Vienna Convention on signs and signals.

In addition, the words “rapid inhibition” were introduced whose meaning is undefined. This is an unspecified formulation of the current provision and this situation should not take place. The records should be changed, re-developed and saved in applicable law. Enter the deceleration values that will be considered as rapid braking. Drivers, when using vehicles in road traffic, should be supported by clear, understandable, correct and correctly worded regulations. This also applies to the process of controlling road users and supervising compliance with applicable requirements. In the event of compliance with the Vienna Convention on signs and signals, the problem of not defining the words ‘sudden braking’ will cease to matter.

At the same time, they should be assisted by technical devices enabling advanced information. Technical progress and development of devices allow the use of vehicles and road infrastructure solutions that support reasonable participation in traffic in this area. The law should specify a framework that takes into account the comments from tests conducted on vehicles in traffic.

The safety system of road users may not contain defects leading to violations. The intersection and the situation must be noticed in time when it is reached by road users. Each traffic participant at the intersection should be informed about upcoming changes in advance so that he can: adjust the speed value, finish leaving the intersection or abandon entry. At the same time, this avoids colliding with the braking vehicle. This can be accomplished sim-
ply by entering a flashing green signal at the signal end on the S1 traffic light. However, this requires a change in the provisions of the Vienna Convention on signs and signals.

Mathematical formulas based on the theoretical course of the phenomenon were used, the error of the method of analysis of the examined process can be ignored. The inaccuracy of determining the speed of vehicles will negligibly affect the determination of the distance. The speed measurement error is small and negligible in qualitative assessment. The calculations were made taking into account the three significant digits of the numbers on which the operations were performed. The results were also given as three significant figures. Such simplification is contained in so-called “engineering inaccuracy” and is acceptable. The adopted simplifications are sufficient to draw qualitative conclusions of the analyzed problem. The calculations made were used to qualitatively assess the analyzed phenomenon.

Without clear, understandable and flawless regulations, it is difficult to effectively manage the security system. An unclearly formulated law leads to a free understanding of it. In specific situations, it results in a blurred interpretation.

References