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Professional Paper

Physics behind Road Safety and Traffic Control

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Abstract – **To ensure safe driving, it is essential to adhere to road signs and signals. Inattention can increase speed and jeopardize road safety and traffic control. Physics helps manage this risk, particularly by defining the breaking distance. This paper explores increasing speed is worthwhile and highlights physics' role in safer decision-making.**

Keywords –Traffic control, road safety, braking distance, speed.

I. Introduction

To ensure that the driver operates the driving car at an appropriate speed, it is must be emphasized that the importance of adhering to road signs and signals. Even a brief moment of inattention can result in an unintended increase in the speed, jeopardizing both Road Safety and Traffic Control. Physics plays a vital role in determining and managing this kind of risk, particularly by defining braking distance [10] [23]. By comparing the distance at which an approaching hazard appears to the breaking distance, the appropriate speed for maintaining road safety and control in traffic can be determined, by reducing the likelihood of an accident. This paper explores whether it is worthwhile for a driver to consciously increase the speed. Ultimately, the decision rests with us – would we make the same choice as the driver does? – Regardless of the choice, physics offers us valuable insights to guide safer decisions in any scenario. Not only the braking distance, in such a situation, the driver's reaction distance is even more important. This reaction distance is directly related to the reaction time [3]. The driver's abilities and his readiness to drive should tend to reduce this time, and thus reduce the reaction distance. In this way, the space for manipulating the stopping distance will increase, i.e., the possibility of the vehicle not reaching the danger before hitting it. This paper deals with the issue of the probability of a collision between a vehicle and a bicycle when the vehicle encounters it at an increased speed compared to the prescribed speed on the road. All this, as a result of the driver's decision whether to drive according to the rules of the road or not [4].

II. Distances that drives the driver crazy

A. From Reaction Time to Reaction Distance

As an unexpected, but one of the most important aspects of dealing with the uncertainty of risk occurrence in traffic is the **driver's reaction time.**

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A. From Reaction Time to Reaction Distance

As an unexpected, but one of the most important aspects of dealing with the uncertainty of risk occurrence in traffic is the **driver's reaction time**. It is defined as a time between the driver's danger perception and the reaction to it, as well [15]. Therefore, many independent circumstances can affect the duration of a driver's reaction time, particularly. It is not the same when a driver drives during the day or at night, and the difference between them is even more emphasised whether it is a young driver or an adult one. However, the most important circumstance of increasing the uncertainty of risk occurrence, when it comes to a danger in traffic, is the cognitive load of the driver. This cognitive load is initially aimed at the driver's abilities, but mostly at the driver's conscience of correct traffic, adhering to road signs and signals [8].

At a given moment, while driving conscientiously, the driver may reach a state of impaired cognitive load. An impaired cognitive load would imply overcoming the conscientiousness with awareness. The driver, with such an issue, is brought into a state of unconscious driving, which affects the driver's reaction time [5]. In general, most of the drivers, somehow, can deal with this issue, but unfortunately, there are also many of them that can not. Many studies support the same opinion that driver experience enhances reaction awareness, thereby reducing reaction time. Also a fact that a male driver can deal better with reducing the reaction time than a female one, sometimes stays so, but sometimes not. Nowadays, females have proven to be very good drivers just because of their high level of conscientiousness and awareness, which takes precedence over males once [6]. The only certain thing is that the use of psychotropic substances and driving under the influence of alcohol can only prolong a driver's reaction time, and thus increase the likelihood of a traffic risk occurring.

Ultimately, neither the experience of the driver nor the other driver's abilities can reduce the occurrence of traffic danger in order to reduce the time to react. The only thing the driver can do is to pay attention to road signs and signals, i.e., consciously adhere to the conscientious management of the vehicle within the prescribed limits. This means that if the prescribed speed limit is 50km/h, the driver must not knowingly drive at 55km/h, in continuation: 50km/h – initial driving speed and 55km/h – cheating driving speed [2] [15].

This paper does not emphasize the factors that influence the driver's reaction time, but emphasizes its constant value **(t=1.5seconds)**, which has been empirically obtained. To avoid confusion, this reaction time is not define as a reaction time of an expected event ($t_{expected}$=0.7seconds), nor as a reaction time of an unexpected event ($t_{unexpected}$=1.25seconds), but as a reaction time of a surprising event. Essentially, the surprising time is divided into two parts, i.e., 1.2 seconds perception time and 0.3 seconds the reaction time of the perception [4]. Accordingly, all conclusions shown about the impact of Physics on Road Safety and Traffic Control, in this paper, are just based on a constant value of driver's reaction time, which does not provide a wider framework for further consideration of modelling the time factor, which already defines a subjective character from driver to driver. Precisely because of that, this approach provides a general framework in which a single conclusion can be drawn: All drivers, regardless of their subjective characteristics, must adhere to what is meant by prescribed rules and norms on the road and in traffic [3].

Figure 1. shows a driving car moving on a road with an initial speed (speed limit) of 50km/h, i.e., the driver, who is driving, is in a normal state with the reaction time of 1.5seconds. For this reason, such a car movement is defined as a brief part of a complex motion with a constant speed (v_0), beginning from the start position till the moment of the driving car danger perception. At this speed, a driving car moves a distance of 20.8m (50/3.6m/s·1.5s=20.8m), so this distance is also defined as a distance before the driver starts braking, when it comes to a driving car danger, an oncoming bicycle, shown in the final position. Additionally, this distance is named in this paper as a **reaction distance** due to the reaction time. Moving at an increased speed of 55km/h, which is defined as a cheating speed, the same driving car moves a distance of 22.9m (55/3.6m/s·1.5s=22.9m) [7].

The difference between the two distances, acquired both at the initial speed (50km/h) and the cheating speed (55km/h), is almost 2.1m, at the same reaction time. Although is a small between distance, it may be fatal in terms of occurring a traffic risk, that may cost even an innocent life of the bicyclist, and also of the driving car driver. So, it is up to the driver to decide if is it worth cheating while driving or not.

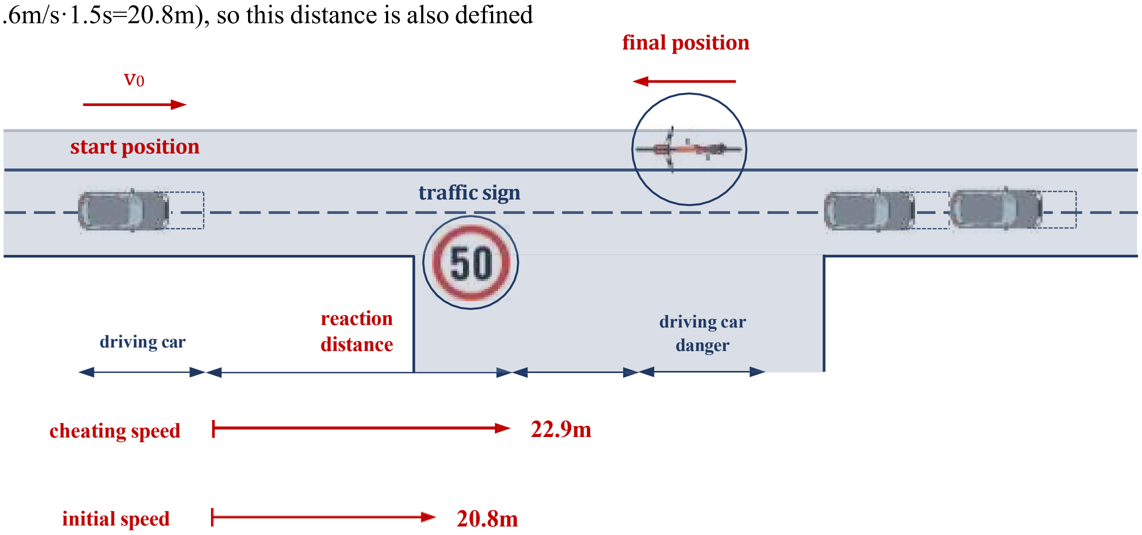

Fig. 1. Reaction distance showed when a driving car drives with an initial speed and with a cheating speed at the same reaction time.

B. Braking Distance can predict or not the Traffic Danger

When it comes to a **braking distance**, there is a definition that remains at the moment when the driver becomes aware of the traffic danger and begins to brake. So, the braking distance is named as the distance between the moment when the driver starts braking till the driving car stops. Braking distances are always the subject of study in Physics, when it comes to several factors that affect them. Namely, such distances depend directly on the driver's ability to consciously press the brake and thus generate as much deceleration as possible. The driving dynamic characteristics of the road, friction with the surface, driving car characteristics, the environment, and lateral friction are just some of the factors that affect the braking distances. However, when a general solution to such a problem needs to be given, all simplifications that dictate a constant value of the deceleration must be taken into account [12] [17] [18].

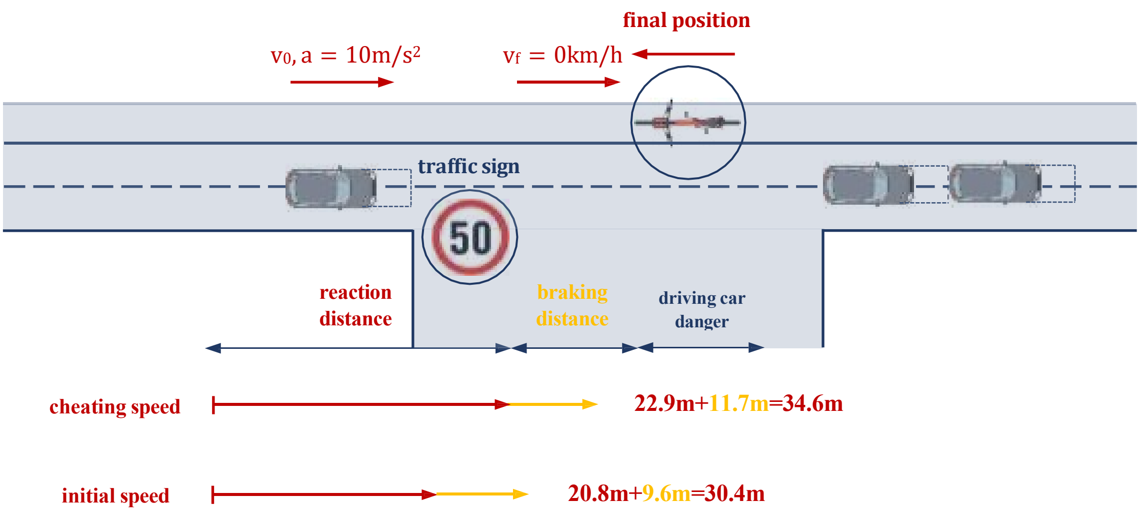

Fig. 2. Braking distance showed when a driving car drives with an initial speed and with a cheating speed at the same reaction time.

The constant value of deceleration **(a=10m/seconds^2)**, in this paper, is taken as an average value from empirical analyses, obtained as a result of the driver's willingness to deal with such a surprising event.

Figure 2 shows the essence of the braking distance, before the driving car reaches the traffic danger and stops. This part of the movement is defined as a brief part of the complex motion, discussed in part *A. From Reaction time to Reaction Distance*, with a deceleration of the initial speed or the cheating speed. Accordingly, the only thing known, when determining this distance, is that the driving car should eventually stop, i.e., it should completely expend its speed ($v_f = 0\text{km/h}$). With this, the driving car will reach the final position, i.e. it will reach the danger, without hitting it or hitting it by throwing it out.

Braking distance can be calculated by the formula:

$$v_f^2 = v_0^2 - 2ad \quad \Rightarrow \quad 0 = v_0^2 - 2ad \quad \Rightarrow$$

$$\Rightarrow \quad d = \frac{v_0^2}{2a}$$

where all the contained variables are shown or discussed before in the paper [10] [11].

Moving at the initial speed of 50km/h, the driving car moves additional 9.6m ($d=(50/3.6m/s)^2/(2\cdot 10m/s^2)=9.6m$) – the barking distance, so the total distance before it stops is 20.8m+9.6m=30.4m. If the driving car is moving at the cheating speed of 55km/h, than it moves additional 11.7m ($d=(55/3.6m/s)^2/(2\cdot 10m/s^2)=11.7m$) – the barking distance, so the total distance before it stops is 22.9m+11.7m=34.6m.

The difference between the two distances, acquired both at the initial speed (50km/h) and the cheating speed (55km/h), is 4.2m, that is doubled than 2.1m, the between reaction distance. This fact indicates that with just a reckless increase in speed by 5km/h, the reaction distance doubles compared to the braking distance. This can be not only a warning to the driver, but also a philosophy of driving the driving car [14].

C. Stopping distance – to be or not to be!?

Stopping Distance = Reaction Distance + Braking Distance (S=R+B)

A simple mathematical sum can provide the answer to the question of whether a driving car will hit the bicycle or not, which means to be or not to be. By summing the reaction distance and the braking distance, a driver can be aware of what the **stopping distance** means [20]. In this case, the stopping distance is defined as the known distance of the driving car's danger (bicycle), except for the reaction distance. The driver's assessment of the distance to the traffic is, in most situations, accurate, as shown by many studies. This refers to the fact that when the driver is in a normal state, he can react appropriately and in a timely manner, in order to avoid the traffic danger by achieving an adequate stopping distance. This driver awareness will not accurately define the stopping distance, but it will encourage him to use his awareness to reduce reaction time, which in turn directly affects reaction distance, and thus braking time [21] [22].

The stopping distance of a driving car danger can be calculated by the formula:

$$d^* = d - s$$

, where d is the known distance that a driver can predict about the traffic danger and s is the reaction distance.

The known distance, where the bicycle is, compare to the driving car, is **(d=30m)**, as a referent value, taken in this paper. Moving with the cheating speed of 55km/h, the driving car is certainly in a disadvantageous position, compared to the moving of the driving car with the initial speed of 50km/h. Therefore, in the paper, the disadvantageous position is briefly shown with a reaction distance of 22.9m and appropriate stopping distance of 7.1m (d^*=30m–22.9m=7.1m) [19].

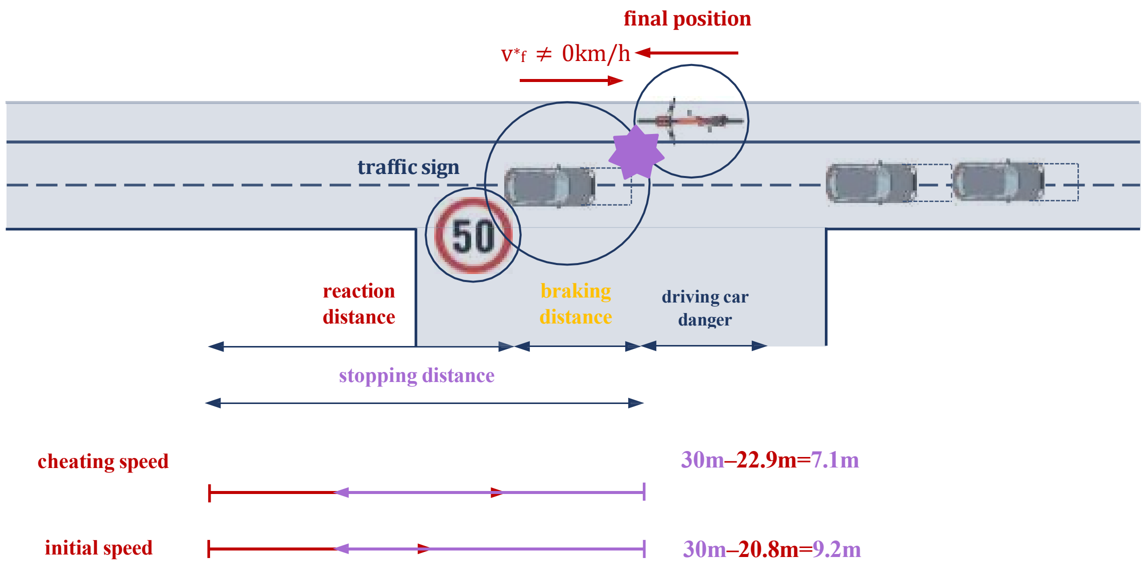

Fig. 3. Stopping distance showed when a driving car drives with an initial speed and with a cheating speed at the same reaction time.

As it is shown in Figure 3., by moving with a cheating speed of 55km/h, there is less distance from the driving car to the driving car danger, compere to the moving with an initial speed of 50km/h, where the remaining distance to the driving car danger is wider (9.2m>7.1m).

By comparing the final speed of the driving car (v^*_f), with the real cheating speed of 55km/h, before it hits the bicycle or it doesn't, using the formula:

$$v^{*2}_f = v_0^2 - 2ad^* \quad \Rightarrow \quad v^*_f = \sqrt{v_0^2 - 2ad^*}$$

, a clear answer of this to be or not to be, can be given.

The final speed of the driving car is calculated almost at a value of 34.5km/h ($v^*_f = \sqrt{(55/3.6\text{m/s})^2 - 2 \cdot 10\text{m/s}^2 \cdot 7.1\text{m}} =$ =34.5km/h), which means that comparing with a value of 55km/h, this value is lower. This approach to determining the final speed, compared to the existing one, the cheating speed of 55km/h, which is controlled by the driver, does not state that the danger occurs at a speed of 34.5km/h, which means that at a speed of 55km/h all this would have a fatal end. So, by controlling the speed, the driver can only use Physics to prevent a fatal outcome, and of course that is the goal of this paper.

III. Conclusion

The concept of using fundamental sciences, such as Physics, in traffic engineering, especially when it comes to Road Safety and Traffic Control, is based on defining a framework that provides a clear position in relation to solving a traffic problem accompanied by a driving car danger [1] [24]. In this paper, the framework is set on the basis of three characteristic distances: reaction distance, braking distance and stopping distance, which are defined depending on the start position, in which the driving car is located, and the final position, in which the driving car danger is located. By manipulating these three distances, starting from the driver's abilities, up to his willingness to approach the management of the vehicle on the road seriously, the conclusion is reached that the driver is the one who is primarily responsible, first of all for himself, and then for others. According to this, Physics can only teach the driver about reckless driving, through a small increase in speed, as it was shown in this paper just a 5km/h, but cannot decide on his behalf how he will act. Therefore, this seriousness of the problem from a subjective perception must not be allowed to experience objectivity, because the better we react as individuals, the better we influence others in the environment.

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