Human driver vs. self-driving vehicles from the viewpoint of the compliance behaviour

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***Abstract*—There are even more studies on the possible effect of self-driving vehicles on traffic flows. Most of the studies showing improving conditions. Although that papers did not take into consideration the different compliance behaviour of human driver and self-driving vehicles. We examine in this paper a case study based on the assumption self-driving vehicles are strict rule-follower, till human drivers using the rules more as a frame based on their former experiences and understanding of the surrounding environment. The microscopic simulation supports the theory, that changing compliance level resulted in time losses for self-driving vehicles.**

Keywords*— *self-driving vehicles; traffic rules; compliance behaviour; microscopic simulation

I. Introduction

As the revolution of the self-driving vehicles is approaching, more and more researchers are dealing with the question: "What can bring us the self-driving traffic?". We can cite here the article by Daniel J. Fagnant [1], who is dealing with safety, congestion, and travel behavior, and finally stated travel time savings. Other papers are dealing with the social aspects like Jean-François Bonnefon [2] or Wilko Schwarting [3] or the research group by David Bissell.

Next to the human and social aspects we can also examine the law connected questions like Peterson [5] or even the authors of the book "The law and autonomous vehicles" [6]. Although social and legal issues are important the direct effect of self-driving vehicles will come to the traffic. There are several studies as well, from Talebpour [7], through Friedrich [8] to Wu et al. [9].

We had the feeling that all these papers and others have an imagination of a nice, well organized world, where self-driving vehicles travelling on its own, or sharing the space with human drivers, like Freidrich [8] or Gong and Du [1].

The problem is that our world now is not strictly rule-follower, therefore the comparison of human driver and self-driving vehicles regarding time savings, traffic flows are not fully correct. To be able to compare present situation and some penetration of self-driving vehicle into traffic flows, we have to take into consideration the compliance behavior of human drivers. We can see this question as a human-machine communication, where the human is the driver, the machine is the strict written rules of traffic. There are lot of researches on human machine interaction, like Baranyi [11], [12], or Johannsen [13]. We can learn from these either how to adapt the machine to be able for more convenient communication or how to take into account the human will. In our opinion in this case: human driver vs. traffic law, there is already an adaptation, till for lot of drivers rules are just the frame. There is a case study by R. Horváth [14]. At his observation most of the drivers ignoring the speed limit (30km/h instead of the normal speed of 50km/h in the area).

All these led us to the idea, we have to examine the possible effect of self-driving vehicles from the viewpoint of rule-following willingness of human driver (compliance behavior) vs. self-driving vehicles as strict rule followers.

As it is already clear even the issues regarding self-driving vehicles has several connection to different professions, although first it seems to be just a technical invention. It is therefore again a nice example that the built environment and its processes are chained, and everything from buildings to vehicles are just a small element of the whole system, which is driven by data and information as it is described in the BENIP logic (Built Environment Information Platform), introduced by B. Horváth et al. [15].

II. Literature Review

There are already researches dealing with the human factor of drivers and its connection to traffic rules. One simple aspect is speed. As Gaca [16] already stated the desired free flow speed vary from speed limit up and down (reduction and increase) independent from speed limit but dependent on road design and time of the day. In the case of self-driving vehicles, it will not vary. This is already a difference between human driver and self-driving vehicles. Sharma et al. [17] already suggested this idea, when they incorporate into their car-following model the compliance factor. But in general there are very few research on this aspect. Most of the papers dealing with compliance in connection of speeding, like shown at Conran [18], who examined the question under variable speed limits, or Tenkink, who focused the cases at railroad crossings. On the other hand, Kumar et al. built up a microscopic model to observe compliance behaviour, but again just in connection with speed limits. [20].

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III. Theoretical approach – practical cases

As shortly described above our idea is, that human driver compliance behaviour is not really strict. We believe that the compliance level is depending on the driver's understanding of the surround, as Stapleton [21] also stated.

We dealt in this phase of our researches just with interurban situations. We know that interurban and extra urban conditions are totally different, therefore we have to define now, that we discuss just interurban conditions. Even at interurban conditions there are different situations. But we have to distinguish between to major groups: streets and junctions. Therefore we have to divide the compliance level question into two major groups:

- lanes without junctions (so the traffic flow itself)
- junctions with interaction between flows

A. *Lanes without junctions*

An interurban or extra urban lane can have two influencing factor on car drivers: speed limit and car-following situation. As cited already [14] the compliance level by decreasing speed limit is rather low, as R. Horváth shown not only the speed limit was ignored by the driver, but most of them overspeeded even the original (50 km/h) speed limit under a reduced speed limit of 30 km/h. If we do not take into consideration this speeding, just calculating with the disregard of the 30 km/h limit, the situation still bad. It resulted in an uninterrupted traffic flow in time and fuel savings. If drivers can drive with steady speed without deceleration and acceleration, it resulted in lower fuel consumption [22]. In this sense the disregarded speed limit is good for the environment (less pollution), good for the society (time saving), but very bad for the traffic safety which induced originally the speed limits in interurban surrounds. In this case we are focusing more on the time savings. If we have a 500 meters long lane (50 km/h) with 100 meters speed limit (30 km/h) in the middle, it is easy to understand that for a strict rule-follower the time needed to perform this lane is:

$$t_{av} = \frac{s_b}{v_b} + \frac{s_l}{v_l} = \frac{400}{\frac{50}{3,6}} + \frac{100}{\frac{30}{3,6}} = 40,8\ s \tag{1}$$

Although for a human driver with lower compliance level, the time, needed for this section is just:

$$t_h = \frac{s_b}{v_b} + \frac{s_l}{v_l} = \frac{500}{\frac{50}{3,6}} + \frac{0}{\frac{30}{3,6}} = 36\ s \tag{2}$$

where

- tav time for autonomous vehicles
- th time for human driver
- sb distance for base speed
- sl distance for limited speed
- vb base speed
- vl limited speed

It is even in this simple case clear that low compliance level resulted in time savings. Our presumption is that because of the autonomous cars have higher compliance culture (100%) the traffic congestion will be stronger in the area of any speed limit, which will affect to the vehicle travel time in that street.

B. *Junctions with interaction between flows*

More complex is the question of junctions. There are several cases (like roundabout, or yield control), where human drivers take risk. They do not calculate the exact safety distance and the time needed to take the action. They decide to go or stay and wait. But sometimes it is not possible to drive further on without taking the risk and believing the perception of the other driver. Till we have "just" self-driving vehicles and not a critical mass of connected cars, this "perception believing" will be missed. We are thinking the lack of it will slow down the traffic at roundabouts and yield control, due to the fact, a self-driving vehicle will not take any risk (as we can read in [2]), a self-driving vehicle will be always on the "safe side". Therefore the risky situations will be avoided. In our opinion it will lead to traffic jams.

IV. Simulation based control of the theory

As mentioned above in this example we are focusing on lanes with speed limits (in the future we will extend it to junctions to have a complex view on the question of compliance behaviour changes). So, to see the truth, we performed a microscopic simulation based on a real street in Győr (Hungary).

A. *The examined situation*

We examined a location near to the University of Győr. The selected street is the Szövetség Street and the selected section is between the Hédervári Street and Báthori Street. We choose this section because of the reduced speed area next to the kindergarten. The 30 km/h mark is only reasonable in 2 hours of the day, when the parents bring their children to the building, but during the day it is not necessary, although it is a permanent speed limit and as such valid all day and every day. On the other hand, most of the drivers are local, who are aware of the reason of the speed limit. Maybe this is the reason of the speeding described by R. Horváth in [14] during his video records taken at the same section.

Our concept was that the human drivers does not take into account the speed limit (as it is shown in [14]), but the autonomous cars not necessary knows, that the limit is not reasonable all day long, so every AV will slow down in this part of the street, and accelerate at the end of the rduced speed area back to 50 km/h, without the information, a junction is ahead. The whole section is 350m long, the speed reduced section start at 180m and it is 75m long.

Fig 1. - Speed limit on the street (30 km/h) (source: Google Streetview)

As the picture (fig. 1.) shows the street is straight, but it is clear urban conditions with so called open bike path on both sides (yellow arrowas are showing this). Traffic is vary during the time of the day. In peak hours there is really have traffic, but out of peak this is a very calm street (as in the time of the picture was taken).

B. *Microscopic simulation of the site*

We built the traffic model of the street in PTV-VISSIM where we used the above mentioned parameters. We used two kind of vehicle types, cars with human drivers and autonomous vehicles. The driving behaviour model of the human drivers are based on Wiedemann 74 car following model while in the case of AVs we used the Wiedemann 99 model. The speed reduced area (30 km/h) applied to the autonomous cars only, the human drivers could go through the street with 50km/h. In order to build the model more realistic, at the end of the street we used another speed reduction to 20 km/h. This speed limit affect both kind of vehicles and it simulate the effect of the slown down due to the roundabout at the end of the street.

In Figure 2. we marked the 75m long reduced speed are and the environment of the street. In our examination we studied the summarized travel times and average travel times with different level of traffic in two cases. In one examination we simulated the traffic with only human drivers with growing traffic volume. In the second observation we examined the opposite of that, the fully AV case.

Our simulations lasted 1 hour long (3600s) and we increased the traffic volume with 100 cars in each step from 100 to 2000 veh/hour. It means 20 independent set of simulation runs. Each of the sets consists 5 simulation runs with 5 different random seeds, to avoid unexpected effects of the random numbers. The calculations are based on the average value of the five different random seeds.

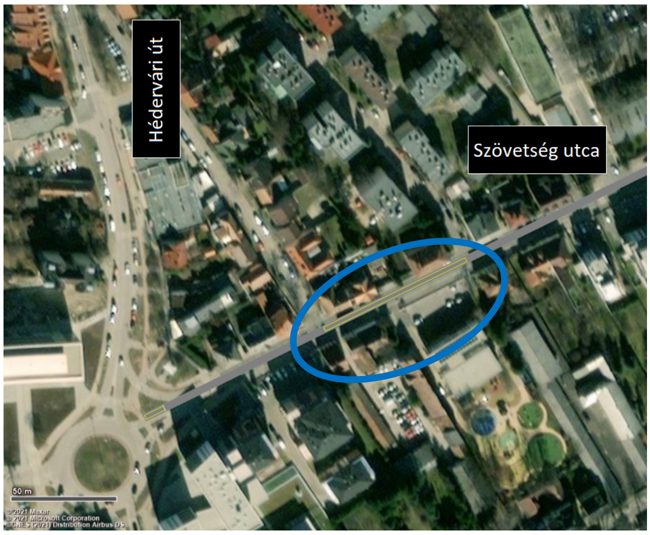

Fig 2. - The examined street in PTV-VISSIM environment

C. *Results of the simulation runs*

We compare the two cases on the basis of the average and the total travel time through the whole section.

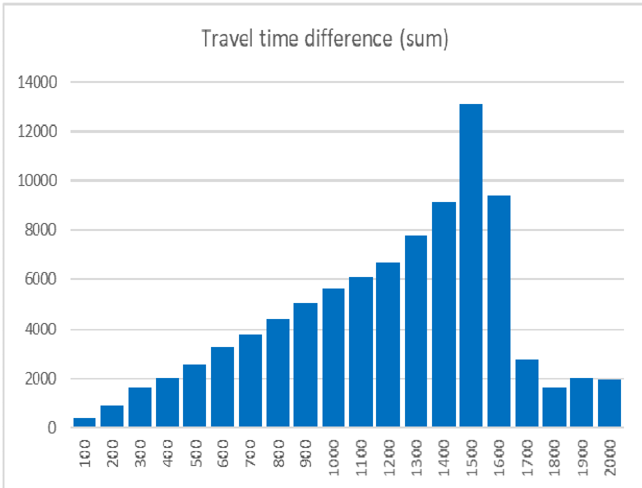

Fig 3. Summarized travel time differences

As we can see in the diagram, the autonomous cars have higher travel time values, with the rise of traffic volume, the travel time differences are growing constantly. The turning point is about 1500 veh/hour, where the road reached its capacity.

In Figure 4. we can see the average travel time values, which are constantly growing till they reach the saturation point at around 1500-1600 veh/hour. In the case of human drivers the road capacity were 1580 vehicle per one hour, while in the case of autonomous vehicles this value hardly reached the 1500 veh/hour.

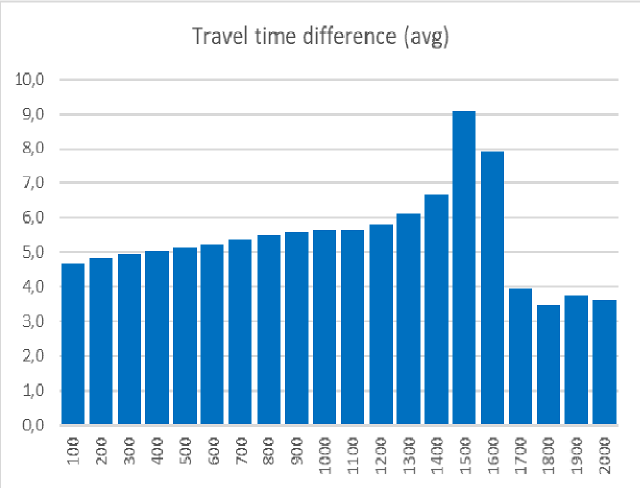

Fig 4. Average travel time differences

As the diagrams show the capacity of the road is 4-5% higher in the case of human drivers, because of the safer traffic and bigger compliance culture of AVs. With the growth of the traffic volume the average travel times are also increasing, but only to the point, where the next intersection's slowing down impact affect to the traffic. After that turning point the difference between the travel time of AVs and human drivers decrease drastically.

V. Remarks and Definitions

As result of our examination on human drivers compliance behaviour we can introduce the term compliance level. It is clear that several studies are dealing with the level of driver compliance in connection with e.g. VSL [23]. There are clear usage of driver compliance level, although their result are opposite of our simulation runs.

Therefore, to be clear we suggest to use compliance level in connection of speed as the result of number and measure of speeding at speed limit. It means compliance level is 100% if there is no speeding. Compliance level is 0% if there is no car with legal speed. The question is in between.

Now we are introducing the indicator Compliance Level. An indicator like this has to inherit the share of the speeding vehicles but also the degree of over speed. The both parts hat to be in the same direction of scaling (it means better is higher or better is smaller). We are choosing at this indicator the better is higher. Therefore we suggesting an indicator with two parts: 1. the share of non-speeding vehicles and 2. the average degree of speeding (rate of speeding to speed limit). Based on these theoretical considerations our suggestion is for CL (Compliance Level) like following (you can see the original one, based on the theory and the mathematically simplified formula):

$$CL = \frac{N_t - N_s}{N_t} \cdot \frac{N_t \cdot v_l}{\sum_1^{N_t} v_i} = \frac{(N_t - N_s) \cdot v_l}{\sum_1^{N_t} v_i} \qquad (3)$$

where

- N_t total number of observed vehicles
- N_s number of vehicles with overspeed
- v_l speed limit
- v_i speed of the i^{th} vehicle

VI. Conclusions

Due to the difference on compliance level of human drivers and self-driving vehicles the running time of a given lane is higher at self-driving vehicles. It resulted in time loss at self-driving vehicles. On the other hand, it can cause also traffic jam at higher amount of vehicles arriving to the given lane. Based on this experiment it is necessary to revised the former statements on better traffic flow conditions in the era of self-driving vehicles due to the compliance level of human drivers.

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