SECTION SPEED CONTROL AS EFFECTIVE TOOL TO IMPROVE ROAD SAFETY

PAVEL PŘIBYL

Summary: *The article presents results of measurement of the speed in the road tunnels which could be applied on the same way for open roads too. The Section speed control (SSC) method is used. This method is much more effective than point measurement which is still broadly used. The results show that the average speed decreases for 23 km.h-1in the Stahov tunnel in Pragueafter SSC had been installed. The standard deviation was also small and it means that a traffic flow is well harmonized. It decreases a volume of risk potential and enables to equip tunnel on optimal way from safety point of view.*

Keywords: *traffic parameters, speed control, traffic flow, road tunnels*

1. INTRODUCTION

The police statistic in the Czech Republic shows that about 38% of people killed on the CR roads are due to high speed. Nevertheless, a speed is very danger especially in a road tunnel, because a number of accidents in a tunnel have fatal consequences. This was the reason that speed management strategies have been tested and fixed in the Czech standards elaborated for road tunnels. The basic ideas are presented in the national standard for design of tunnels, ref. [1] und more technical orientated description contains technical standard TP98, ref. [2]. The technical and organizational means lies from physical traffic calming measures through variable warning signs to enforcement connecting to progressive penalty system. There is a lot of research that discussed speed reductions at danger places and as a result accidents and death are reduced. Best praxis is possible to see, for example in France where installations of a few hundreds of speed radars a few years ago have decreased number of fatalities at about fifty percent.

This article describes research and field tests of speed enforcement system worked up in the frame of research project SAFETUN (SAFe TUNnels). Three years project was supported by Ministry of Transport and project team created five organizations led by ELTODO EG.

The speed control and its improvement to the reduction of accident and death in the road tunnels was one of the topics elaborated by this project. More recently tests showed quite clearly that it is impossible to measure point speed in the tunnels. The effect of this measurement on

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number of accidents is even negative. Some drivers, going quickly through a tunnel and they slamming on their brakes when they recognize radar of a fixed measurement point. This maneuver is potentially very dangerous for all drivers.

2. SECTION SPEED CONTROL

With negative results of point measurement in mind, a very effective method known as point to point speed measurement was tested for a few years and now is mandatory applied in all tunnels in the Czech Republic with heavy traffic, see Ref. [2]. Point-to-point measurement or time-over-distance measurement is more frequently named as Section Speed Control (SSC). SSC is also used on highways especially at the positions where traffic fatalities occur very often.

There is one principal psychological advantage – whilst a radar measurement is provided in secrecy and police and radar are usually hided, the SSC plays with a driver absolutely fair-play. The section where SSC is installed is usually signed by special signs which warn that speed will be measured for example through the section of 3 kilometers. The driver getting from A to B without breaking the law will have not any problems.

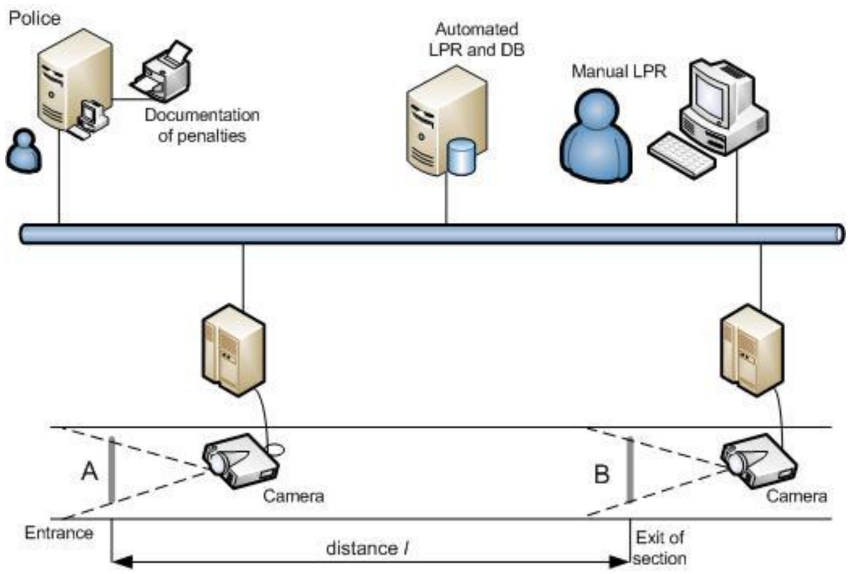

Fig 1. *Principal scheme of Section Speed Control*

The concrete principal scheme of the Section Speed Control measurement is depicted in Fig 1. The section of a speed measurement is marked by two white lines which determine exact length of the section. An image of the vehicle entering the monitored zone is captured and the same picture is then captured at the exit point. Because the length of measured section $l_{A,B}$ is known and the time difference Δt between enter and exit of the section is recorded, the section speed is simply calculated by the formula:

$$v_{av} = \frac{l_{A,B}}{\Delta t} \qquad (1)$$

Specific infrared camera positioned above a traffic lane pictured a front of a car and send it to a central unit. Central unit elaborates pictures from all connected cameras. Special software (LPR – License Plate Recognition software) is able to recognize a car number. Software mainly uses special procedures to recognize contour of a letter or a number and subsequently a procedure of pattern recognition is applied. The software is often based on a principle of artificial intelligence, as neural networks or fuzzy rules are.

Fig 2 shows practical output elaborated by software which is used also in the Czech tunnels. Couple of license plates together with time stamps determines time Δt.

Fig 2. *Photo at entry of measured section (left) and the same car at exit (right). The recognize LP on left hand site*

3. REASONS WHY CONTROL SPEED IN ROAD TUNNELS

The European commission DG TREN published realistic prediction of traffic growth between year 2005 and 2020. It is forecasted that number of personal cars will be about 25-35% higher than in the year 2005. It is also known that 2% of GDP of the whole EU is vanished due to congestion at present. There are different possibilities how to help solve tremendous traffic problem. Very rapid and progressive solution is application of Intelligent Transport Systems (ITS) which could improve mobility and safety on principle about tens of percent.

Fundamental solution how to improve mobility and safety is to build new road infrastructure, as a matter of course with new tunnels. Underground traffic is sometimes known as “fourth dimension of traffic”. Building of a tunnel is quite expensive and it is necessary to optimize investments and operational costs. The separate part of a total cost is a cost of traffic, technological and safety systems. The amount of these subsystems is usually between 10 and 15% of a complete price of a whole tunnel buiding. There are mandatory subsystems as ventilation and lighting in a tunnel. These subsystems are designed by standard procedures and it is very complicated to minimize a cost of them. The final price of tunnel equipment is essentially influenced by complex safety system. The safety system has to be evaluated by a risk analysis which determines quantitative or qualitative parameters of a risk and social acceptable risk.

It is very well known that speed and number of accidents are connected very close. The trial on the M1 motorway in Great Britain showed causality crashes reduced by 36% during the year when speed enforcement system and connecting penalty system were in operation, ref. [3]. Long term research in Germany showed very similar results. The highway traffic on the A3 has been controlled by a set of variable message signs influencing a speed of cars. The number of fatalities decreased about 35% during the time when the system for speed control was in operation, ref. **Error! Reference source not found.**.

It is possible to conclude that risk and to him equivalent and necessary technical equipments of a tunnel are directly and close connected to an operational speed in a tunnel. By the higher speed is necessary to apply also more and more expensive safety equipments and safety systems. Lower speed improves driver behavior and his reaction to an extraordinary situation and this fact reduced significantly number of accidents in a tunnel. Speed harmonization means that the drivers accepted allowed speed, so the speed difference between the quickest and the slowest vehicle is getting lower and also standard deviation of the speed is low. This process significantly influences a safety.

Very important is also influence of harmonized traffic flow to a ventilation system. A more consistent and harmonic traffic flow will reduce car pollutions which decreases operational cost of ventilation.

4. PRACTICAL MEASUREMENT IN STRAHOV TUNNEL

Strahov tunnel is very important for the traffic management in the whole Prague. A closing only one line, for example due to accident influences negatively traffic in large traffic areas in a few minutes. Tunnel is 2200 m long and it connects north and south part of inner traffic circle. The two tubes with two traffic lines each, transfer about 30-40 000 cars per day. The slope of the tunnel is 3,6%. According Czech standards the tunnel belongs to the highest safety category A, which means that it is equipped by a newest technology inclusive videodetection system. It checked the whole profile of the tunnel and it is able to recognize an accident or a stopping car in a few second.

All traffic accidents in the Czech tunnels are monitored on a systematic way beginning at the year 2002. The duty to monitor and evaluate all extraordinary events (accidents, fatalities, fires) follows from the European Directive 54/2004/ES, ref. [5]. It stated that each member state has to evaluate regularly all events occurring on trans-European road network and to bring solutions how to restrict similar events in a feature to ensure higher level of safety for tunnels users. The generic idea of this Directive is to bring the same level of safety in an arbitrary tunnel around the Europe.

From point of view of the number of accidents in the Strahov tunnel the safety situation was not too much good and it was higher than it was expected. Preliminary consideration supposed that an unsuitable speed could be reason. The following measurement made in the tunnel in the frame of SAFETUN project disclosed that about 14% of the cars have average speed in the tunnel higher at least about 20 km. The columns of histogram in the Fig. 3 show the number of cars in a one traffic line during January (17.1-30.1) and the numerical value in the same column shows the number of drivers who exceeded permitted speed at least for 20 km per hour. These driver are potential danger for another drivers because the tunnel and its traffic design are not designed for theirs speed.

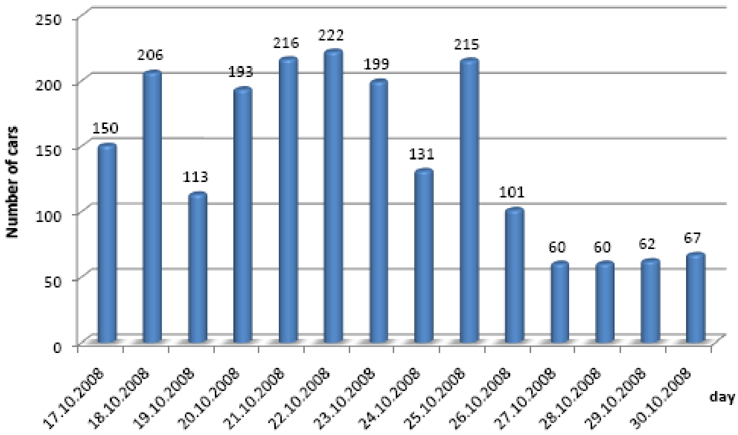

Fig 3. *The whole number of cars and number of cars exceeded speed more than for 20 km within 14 days*

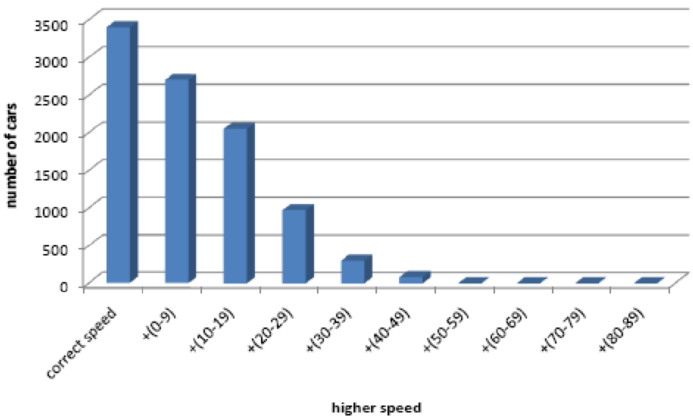

Fig 4. *Absolutely exceeding of the permitted speed*

Even more potentially danger situation shows next Fig 4. It is typical example of speed measurement of one line between 6 and 12 hours. Figure depicts how many cars exceed the permitted speed. The total number of cars respecting speed regulation was 3200 (100%), but

900 drivers run over 20-29 km faster. More than 50 drivers drove for about 50 km faster and there were even drivers exceeded the speed about 70 kilometers. This situation is absolutely alarming from safety point of view.

5. PROVISION HOW TO IMPROVE BEHAVIOR OF DRIVERS

The complex measurements and evaluation provided for Strahov tunnel showed that it is necessary to reduce a real speed in the tunnel by restrictions connected with penalties for drivers. The reason is simply. Tunnel is equipped on very progressive way. There are active (LED) speed limitation traffic signs around the whole profile of tunnel. The warning displays are placed on different points in the tunnel, the special warning is also before the tunnel, nevertheless only a lot of drivers do not respect it.

There are two basic possibilities how to measure speed. Very traditional method is point measurement mostly provided by different type of radars. The experiment to install and to measure in the tunnel, respectively 50 m beyond portal, was absolutely failed. The drivers knowing the position of radar braked very rapidly before entering its position and this spot was very dangerous from safety point of view. This was the reason that section speed control has been applied in the frame of OPTUN project.

The field test has been distributed through thee years to get a lot of statistical numbers and to be sure that SSC could really influence a driver behavior. The measurement of speed in the tunnel is provided by microwave sensors mounted under roof of the tunnel. There was not any speed measurement during the year one of pilot test. The example of evaluated data is in the Tab.1. The average speed is 76,6 $km.s^{-1}$ but potentially very dangerous is a high number of standard deviation. For example at October 2^{nd} is $s = 17{,}31$ $km.s^{-1}$ and it means that some drivers drove quite slowly and others drove very fast. It is very dangerous and probability of accident is quite high.

Tab. 1: *Average speed and its standard deviation-without speed measurement, without SSC control: reference year*

datum	29.9	30.9	1.10	2.10	3.10	4.10	5.10
$\bar{v}$ [$km.h^{-1}$]	81,84	81,91	77,81	79,00	79,13	78,08	77,72
s [$km.h^{-1}$]	8,34	13,52	13,10	17,31	11,16	5,89	7,94

The second phase of experiment supposed to install Section speed control without any warning to drivers. SSC was really installed in August and evaluation of the first results was surprising for all. The speed was at once lower for about 23 $km.h^{-1}$. The reason could be only one. The drivers saw something extraordinary in the tunnel –new cameras and the lines on the road and they deduced that it should be something as a speed control. It should be that different papers describing foreign experiences were published in the same time and the drivers drove often in western countries of Europe where these systems were in operation. But it was really surprising because the average speed was newly about 53,5 $km.s^{-1}$ and standard deviation significantly decreases too.

Tab 2. *Average speed and its standard deviation- speed measurement installation but out of operation, without warning signs*

datum	27.9	28.9	29.9	30.9	1.10	2.10	3.10
$\bar{v}$ [$km.h^{-1}$]	53,15	53,22	52,39	52,78	53,74	54,43	53,23
s [$km.h^{-1}$]	5,15	5,58	5,60	5,35	4,50	2,78	4,86

Installation of warning signs informing drivers that a speed is measured had started third phase of field tests, . These signs are very important. They informed driver in advance that the speed will be measured. It is important also from psychological point of view because it forms fair play relation to the drivers and they usually respect it.

The table 3 presents the results after installation of traffic warning signs which were placed in the sufficient distance before the SSC. It is possible see that there is not significant influence coming from installation of warning signs. The average speed is slightly above allowed speed which is in the city 50 $km.s^{-1}$ and standard deviation is also very low. It shows that a traffic flow is quite well harmonized as is very important from safety reasons.

Fig 5. *The warning sign "Measurement of the speed" before the portal of Strahov tunnel*

Tab 3. *Average speed and its standard deviation- speed measurement in operation and warning signs are installed*

datum	25.10	26.10	27.10	28.10	29.10	30.10	31.10
$\bar{v}$ [$km.h^{-1}$]	53,38	53,72	53,21	53,58	53,79	54,24	53,90
s [$km.h^{-1}$]	5,17	4,91	5,71	5,20	3,85	2,35	3,29

The summary and graphical presentation is pictured in the next figure.

6. CONCLUSIONS AND NEXT WORK

Optimization of tunnels equipments is crucial question for safety of users from one side and for cost of investment and operation for a state or a municipality from the other side. It is very dangerous for drivers if is tunnel designed not sufficiently. There is very expensive operation and service when a tunnel is over-equiped. To find a proper balance helps using of risk analysis. The original method based on probabilistic trees and expert system CAPITA had been developed in the frame of OPTUN project. All analysis showed the huge importance of speed of cars in a tunnel to a resulting risk. The concrete measurement in the longest tunnel in Prague confirmed preliminary consideration that drivers do not respect prescribed speed which is in the city 50 $km.h^{-1}$ although there is a set of traffic signs.

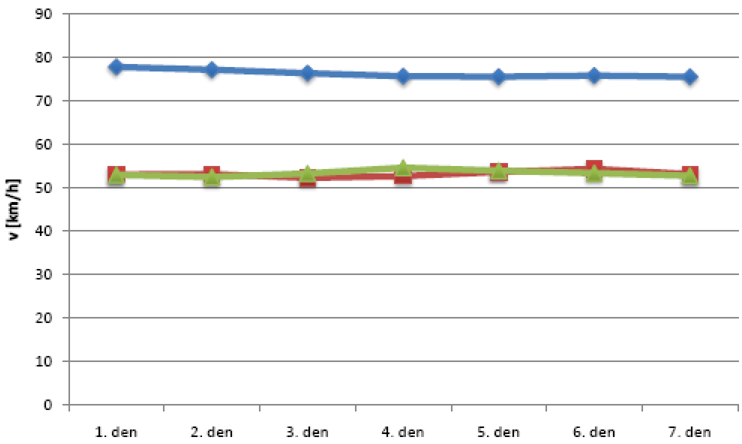

Fig 6. *Three phases of field tests of SSC in the Strahov tunnel*

(without SSC – blue curve above; SSC in operation with/without warning signs – red/green curve);

measured for seven days (1.den … 7. day)

The research project OPTUN had demonstrated that installation of Section speed control is extremely efficient and it influences behavior of drivers on very significant way. Decreasing of speed and mainly harmonization of traffic flow through tunnel improve results of risk analysis and tunnel could be designed on optimal way.

The positive results of this long term experiments have been worked up into new version of the Czech standard TP98 "Tunnel equipments and systems" on the following way. All tunnels corresponding to the highest safety category[1] (it is category A) shall be equipped by SSC.

New research project supported by Ministry of transport SAFETUN continues in a developing of the risk analysis method CAPITA. The accent is on a deploying of the method into broad praxis and to optimize the equipment of tunnels.

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1 The safety categories A, B, C, C-H, D and D-H are defined in the standard TP98