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STUDY OF DRIVERS' BEHAVIOUR AT A PASSIVE RAILWAY CROSSING

ABSTRACT

Problem: The number of killed and injured persons in incidents at railway level crossings is generally increasing on the Serbian Railways, particularly at passive crossings. In this paper we researched the direct behaviour of road traffic participants at a conventional railway passive crossing. Method: Direct observational study of drivers' behaviour at a level crossing. Results: Sixty-one road vehicle drivers were observed in the moments of train approach. The probability of crossing varies depending on the train distance and the time the driver has to cross the crossing. The drivers who have limited visibility cannot estimate the speed of the approaching train well and make more risky decisions. Conclusion: This study shows that the number of "risky crossings" is worrying as the result of such crossings is a large number of accidents with fatal consequences at the passive crossings in Serbia.

KEY WORDS

railway crossings, road driver behaviour, road safety, railway crossing safety

1. INTRODUCTION

There are 2,354 railway grade crossings on the territory of the Republic of Serbia. Out of this number of crossings, 588 or 25% are protected by active signalling devices, while 75% are protected by road signalling devices, such as signs indicating approach to a grade crossing, a stop sign and a St. Andrew's cross [1]. Among the active protection devices, light signals with half-barriers are used most often, while light signals alone are used very rarely. Within the period from 2002 to 2009 on the Serbian railways, there were 3,304 accidents altogether, where the percentage of accidents at the level crossings accounted for 21%, with the percentage of 30% of killed or severely injured persons. In the same period more than 120 persons were killed at crossings, out of which 79% at crossings with road traffic signs [1]. According to [2], the number of killed and injured persons in level crossing incidents is increasing from year to year, with considerable material damages. More worrying data were recorded only in the first five months of the year 2010, when 27 persons were killed and 25 were injured at the level crossings in Serbia. Compared to the year 2009, when during the whole year 8 persons were killed and 16 persons were injured, this is a worrying increase of accidents [1]. The analyses in [2] have shown that 95% of such accidents occurred because of the irresponsible behaviour of road traffic participants.

Passive devices offer no protection to drivers [3]. Such devices merely aid the drivers by providing information as to the presence of a crossing, and thus, the possibility of an approaching train [4]. At passive grade crossing, the driver functions as a detector of the signal, and the train is the signal [5]. Once a driver has recognized the presence of a crossing, it is the responsibility of the driver to also determine whether an approaching train is imminent [3, 6]. However, according to [7], drivers approaching may be uncertain about the probability of encountering a train, particularly at passive crossings. Decisional uncertainty may lead to inconsistent behaviour within and between drivers, particularly when a decision to stop at a level crossing is not feasible or not warranted [3]. A driver must determine how to respond, based upon a joint consideration of his own approach parameters and those of the train (e.g. direction of approach, speed, and distance) [8]. Personal circumstances also cause a driver to associate certain costs with the outcome of a decision to stop or not to stop. A person's perception of the probability of a given event is strongly influenced by past experience, [9] and the frequency with which the driver encounters a train at a crossing will influence the likelihood of that driver stopping. Even when a driver looks for a train, it may be difficult to accurately gauge the speed and arrival time of an approaching train. Once the train is detected, a driver must decide whether it is safe-to-proceed across the tracks and then take appropriate action. This decision will be guided by the driver's perceptual judgments of train velocity and distance [9].

The approach parameters of the drivers include the restriction of lateral sight distance. When there is limited sight distance it would be logical to assume that such restriction is associated with a greater incidence of collision because of greater hazard associated with the obstruction of lateral visibility [7, 10, 11]. They suggest that drivers compensate their behaviour (such as speed reduction) in response to the perceived risk associated with restricted visibility, particularly at a passive crossing [7, 12]. Such behaviour, proposed by [7] is expected to maintain a more-or-less constant safety margin.

This study has been done by observing and researching the behaviour of road traffic participants at the crossing protected by passive signalling devices, as a train approaches. This paper explores: (1) to what extent the drivers disregard the approaching train and cross in front of it; (2) if they decide to cross, how much of a safety margin they allow themselves; (3) if the safety margin is also affected by the distance of the train from the crossing and by the variations in the train speed; (4) the assessment of risky crossing when the vehicle crosses in front of an approaching train.

2. METHODOLOGY

2.1 Description of the observed crossing

The observed crossing is located in the south part of Serbia, in a populated area of Čapljinac near the city of Niš. The settlement is rural and the road is of a local character. The average daily traffic (ADT) is about 500 road vehicles. The approaching speed of road vehicles is limited to 30km/h.

The railway is a trunk single-track railway, a part of the international Corridor 10. The traffic on the railway is mixed, passenger and freight. The realised number of trains is around 20 trains daily. The traffic on the line is mixed, passenger and freight. The railway is horizontal (0‰). The permitted speed on the railway is 100 km/h. The measured speed of trains over the crossing ranges from 30 to 95km/h. The crossing warning sign at the railway is located at a distance of 500m on both sides of the crossing.

Figure 1 shows the observed railway crossing which is protected by road traffic signs (a St. Andrew's cross and a stop sign) on both sides. On the east (E) and the west side (W) the railway warning

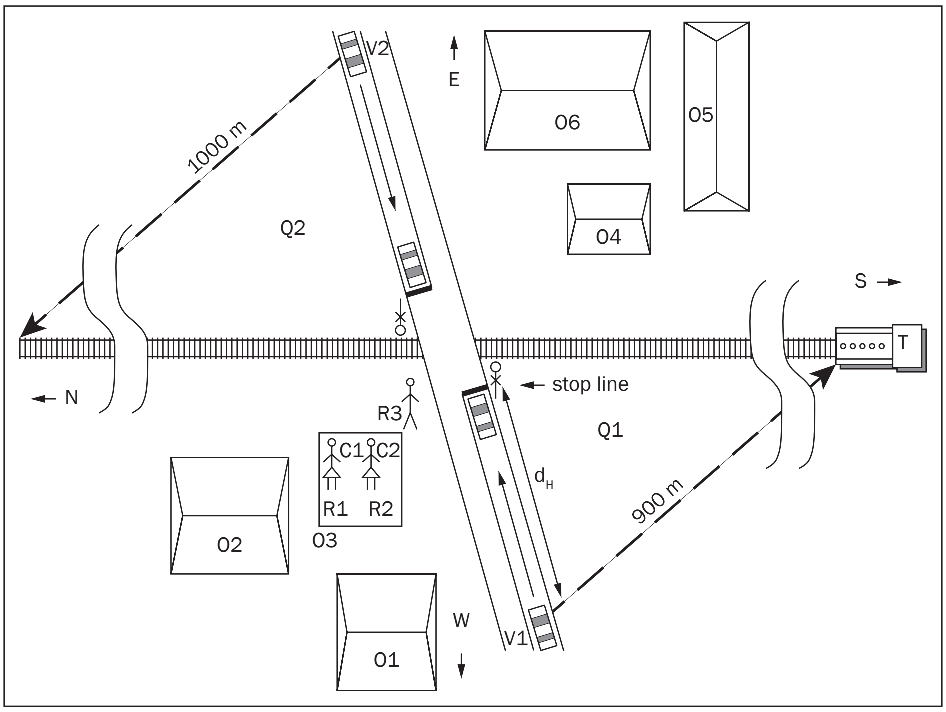

Figure 1 - Layout of the observed railway crossing

signs are set at about 5m from the rails. On the east side the road and railway are at the same level, while on the west side the road is in a slight rise compared to the rails. The road and the railway intersect at 60 degrees. The distance d_H is the sight distance measured along the highway from the nearest rail to the driver of the vehicle, which allows the vehicle to be safely stopped without encroachment of the crossing area.

The road vehicle driver (V1) coming from the south-west direction (S-W) has, in the length d_H, complete visibility of the tracks on their right hand side in the length of 900m southwards (S). The same driver does not see the other side of the line, north direction (N), because of objects (O1, O2, and O3) until they come to the stop line. On the contrary, the road vehicle driver (V2) who approaches the railway crossing from the north-east direction (N-E) has on their right hand side, within distance d_H, complete visibility of the tracks in the length of 1,000m northwards (N). The same driver does not see the other side of the line, south direction (S), because of objects (O4, O5, and O6), until they come to the stop line.

There have been several accidents at this crossing for the past ten years and three of them resulted in fatalities. According to the plans of the Serbian Railways company, the light signals with automatic half-barriers will be installed at this crossing.

2.2 Subjects of the study

The subjects of this paper were road traffic participants before the trains arrived at the crossing. The observation lasted for one week during spring. It was conducted in different periods of the day only during daylight hours. The period of the day during which the observation was made depended primarily on the frequency of rail traffic. The weather conditions were good, with good visibility.

2.3 Procedure of the observation and data processing

For the purpose of observing and recording the behaviour of road traffic participants at the chosen railway crossing, three researchers were involved simultaneously (R1, R2 and R3), as shown in *Figure 1*. Two researchers (R1 and R2) were located in a small official railway warehouse (O3) and they recorded the road traffic from that building, using two installed video cameras (C1 and C2). They were not visible by the traffic participants and neither did they affect their behaviour. The third researcher (R3) was located at the crossing in order to be able to observe the signalling devices at the railway and the appearance of the approaching train (T).

A piece of information on the oncoming train was obtained by visual observing of the signal devices on the railway on the part of the third researcher. A railway station is around 1.5km away from the crossing northwards. An entrance signal at the railway station is at a distance of 500m from the crossing while the distance signal of the automatic railway block is at a similar distance on the south side. If the train travels from the north to the south, the distance signal shows a signal for allowed driving and if it travels from the south to the west, the entrance signal to the station shows a signal for allowed driving. Around five minutes passes from the moment of the signal change to the moment when the third researcher notices the train. This was sufficient time for the other two researchers to prepare video cameras for recording. The distance of train spotting by the third researcher from the crossing is 1,000m northwards and 900m southwards.

After noticing the signal change which indicates that a train will soon appear, he would inform the other two researchers to prepare for camera recording. The recording lasted until the train arrived at the railway crossing. The third researcher would start the stopwatch at the moment of spotting the train and measure the time the train needs to reach the crossing. Then the researcher recorded the following: (1) the moment of spotting the train, (2) the moment of the train arrival at the crossing, (3) the direction of the train movement, and (4) the train type.

After performing the recording in the field, the video recordings and the data collected were analysed. Based on all of the collected data, an appropriate database was made which served as the basis for further research.

For each particular train arrival the analysis of video recordings was done and the major data for this research were considered, such as: (1) the moment the vehicle arrives at the crossing, (2) whether the driver stopped in front of the approaching train or continued driving, (3) the moment when the road vehicle crossed the crossing, (4) the driver's behaviour before crossing, whether they stopped, decelerated or passed the crossing without deceleration, and (5) the moment of the train arrival.

In further research of this matter each particular road vehicle that approached the railway crossing from the moment when the researcher noticed the train to the moment when the train arrived at the crossing is called a "case". The arrival of the vehicles that stopped before the train passing is defined as the time when the road vehicle stopped at the stop line. For those drivers who did not stop at the crossing the time when the vehicle entered the railway loading gauge was recorded. The moment of the road vehicle's crossing is defined as the vehicle's exit from the railway loading gauge.

3. RESULTS AND DISCUSSION

3.1 Crossing behaviour

During the observation period, 61 cases of approaching vehicles were recorded at the observed railway crossing.

A total of 35 drivers (57%) preceded the crossing after spotting an approaching train. Out of these 35 drivers, 17 of them (48%) decelerated, 10 drivers (29%) stopped before proceeding, while 8 drivers (23%) did not stop nor slowed down before crossing. In one case, the driver was already on the tracks 8 seconds before the arrival of the train and drove backwards. The research in signal detection theory has shown that because the frequency of trains at grade crossings is so low, drivers tend to bias their behaviour toward not stopping [5].

The appropriateness of either response will vary as a function of the value of the parameters such as, whether or not the passive warning systems were noticed, when the train was noticed, the acceleration ability of the vehicle, and a host of personality factors.

In our patterns the behaviour of most drivers (48%) corresponds to the observational studies which have found that drivers tend to slow down as they approach a railway grade crossing [3], possibly to scan for approaching trains. Drivers usually slow down in advance of crossing so that they can stop safely if a train is approaching. This is a required safe driving practice in conformance with [13].

Drivers who stopped before proceeding showed a safer behaviour. According to [13] a stop sign or other traffic control device requiring a stop is posted at the crossing so that "...the drivers shall stop before the stop line, and while stopping shall listen and look in both directions along such track for signals indicating the approach of a train or other vehicle, and shall not proceed until it is safe to do so" (p. 26).

However, the observation of 8 drivers (23%) who neither stopped nor slowed down at the crossing supports [14] regarding their belief in the commonness of "critical incidents" which seem to be unsafe behaviour. When drivers ignore warning signals and signs at level crossing often in attempt to "beat the train", this act can be interpreted as risk taking [15].

The fact that half the vehicles crossed the crossing in front of the oncoming trains induced the question of the behaviour of drivers when they have good visibility and when they have not. In this case there were all conditions for such research as the observed crossing has a limited sight distance at two (Q1 and Q2) of the four quadrants in *Figure 1*.

Furthermore, the behaviour of the drivers who had good and limited visibility of the trains that approached the crossing has been analysed. It has been found that out of 61 cases there were 27 (44%) drivers who had absolutely good visibility of the train that approached the crossing. Out of those 27 drivers, 14 drivers (58%) crossed the crossing, while 12 (42%) stopped and waited for the train to pass. The remaining 34 drivers (56%) had a limited visibility of the approaching train, out of which 20 drivers (59%) crossed the crossing and 14 stopped (41%).

The analysed safety margin, which is the time interval from the moment a road user has left the crossing area to the moment a train arrives at the crossing area, ranges from 10 to 86s. The mean safety margin of crossing is 32.7s. The dangerous interval, which is the time a road vehicle spends in the crossing area, ranges from 2 to 4s.

The drivers who did not cross in front of the trains experienced waiting of varying amounts of time. Among the 26 drivers who did not cross the waiting time varied from 2 to 63s. The mean waiting time of road vehicles at the crossing was 19.7s. The mean waiting time for drivers who had unobstructed view was 21s, while the drivers who had obstructed view waited on the average for 18.7s. A different behaviour of the drivers at the observed railway crossing as the trains were approaching is presented in *Table 1*.

The group of drivers who crossed the crossing in front of the oncoming trains without deceleration (8 vehicles or 23%) was analysed with particular attention. It was presumed that this group of drivers had absolute good visibility of the approaching train, and on the basis of this they decided not to reduce speed and to cross, believing that the crossing is safe. Analys-

Table 1 - Data of the road drivers' behaviour at the observed railway crossing

Drivers behavior	Data of the observed cases	Cases of unobstructed view	Cases of obstructed view
Stop in front of train	26 of 61 (43%)	12 of 26 (46%)	14 of 26 (54%)
Cross in front of train	35 of 61 (57%)	15 of 35 (43%)	20 of 35 (57%)
Stop before proceeding	10 of 35 (29%)	3 of 10 (30%)	7 of 10 (70%)
Slow before proceeding	17 of 35 (48%)	9 of 17 (53%)	8 of 17 (47%)
Did not stop or slow	8 of 35 (23%)	2 of 8 (25%)	6 of 8 (75%)
Probability of crossing	0.57	0.58	0.55
Mean waiting time	19.7 s	21s	18.7s
Mean safety margin	32.7 s	41.5 s	26.8 s

ing these data it has been shown that our presumption was incorrect. Six out of eight drivers (75%) had visibility of the approaching train only from the stopping line. By further analysis of the video recordings it has been concluded that the speeds of the vehicles of this group of drivers in the stopping zone were not very high (less than 30km/h), but they were very risky. It might be that this group of road drivers guess that a train will not arrive at that moment, and if a train arrives that they will have sufficient time to brake and stop or to speed up and exit the crossing. This crossing is considered to be a "risky crossing". The behaviours in our pattern have shown that drivers opted for a risky crossing not only because of reduced visibility but probably because of familiarity and unsafe behaviour which are repeated many times at the same crossing without harmful consequences. In [16] it is also suggested that successful crossings in front of a train constitute reinforcement, thereby making the same behaviour more likely to occur in the future. According to [10] the driver's response to a potential hazard is a function of both the perceived probability of the adverse event occurring and of the driver's understanding of the severity of the consequence of the event.

3.2 Probability of crossing

For the purpose of determining the probability of driver's crossing in front of an approaching train, in this work the function of probability of the driver's crossing has been researched through the following: the train distance, the time remaining to the train arrival, and the speed of an approaching train. The train distances and the remaining time until train arrival at the crossing are significantly correlated ($R = 0.799, p = 0.00$) and also the time until train arrival and train speed ($R = -0.468, p = 0.00$). This indicates that drivers estimating the distance of the train from the level crossing have good assessment of the time remaining until the train arrival. The train distances and train speed have minimal correlation ($R = 0.057, p = 0.66$). In other words, the drivers cannot judge the speed of the train well on the basis of the approaching train distance.

The Analysis of Variance (*ANOVA*) test was calculated to determine the differences between these two groups of drivers with these three essential parameters. According to a multi-factor ANOVA test, there were significant statistical differences between the two groups of drivers; those who waited for the train to pass and those who crossed the railway crossing. These differences are found in the average values of assessment of the time remaining to train arrival ($sig = 0.000$) and the distance of the approaching train to the level crossing ($sig = 0.000$). Such significant differences were not found considering the speed of the approaching trains ($sig = 0.769$).

The relevance of a single-factor ANOVA test when drivers judge the distances of oncoming trains is that this test shows that there are significant differences between drivers who stopped and those who crossed in front of the oncoming trains ($F = 12.81, p < 0.0001$). *Figure 2* shows the probability of a driver crossing in front of an approaching train which is determined as a function of train distance from the railway crossing at the moment of vehicle arrival.

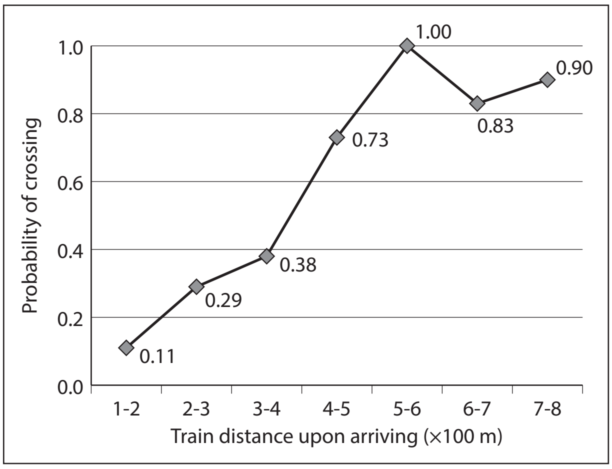

Figure 2 - Probability of crossing as function of the train distance from the crossing

The probability of road traffic participants passing over the crossing depending on the train distance from the crossing should have linear dependency on the size of that distance and be a linearly decreasing function from 1 to 0 ($y = 0.145x + 0.023, R = 0.917$). Since this function shows a deviation from complete linearity, it was determined by a statistical test that there was no significant difference between the expected function and the obtained function. The critical value is $\chi^{2(6)}_{0.05} = 12.592$. The actual value is $\chi^2 = 4.705 < \chi^{2(6)}_{0.05} = 12.592$, so it may be said that the obtained function does not deviate significantly from the expected value. The distance of the train from the crossing affects the probability of crossing in the expected manner, i.e. drivers tend to decide on the safety of proceeding across the tracks when the train is at greater distances. According to [8, 17] the drivers seem to have accurately gauged the distance of the train from them.

When drivers judge the remaining time of the trains arriving at a crossing, there were significant differences between the drivers who stopped and those who crossed in front of the oncoming trains ($F = 15.36, p = 0.0002$). *Figure 3* shows the effect of the remaining time until train arrival at the crossing on the road drivers' decision to cross.

The probability of road traffic participants to cross over the crossing in the remaining time until train arrival has linear dependency on the size of

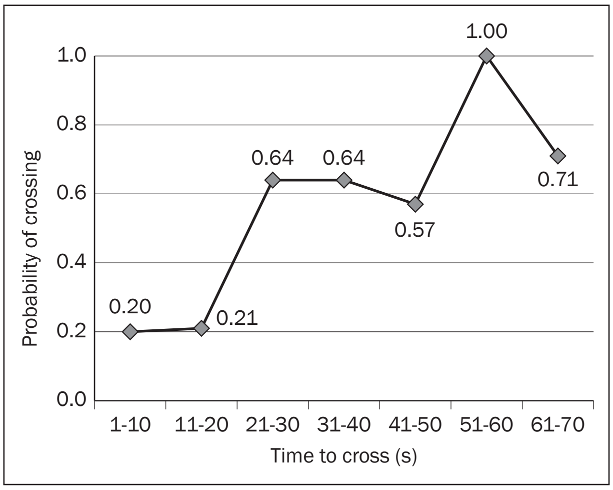

Figure 3 - Probability of crossing as function of the time remaining until train arrival

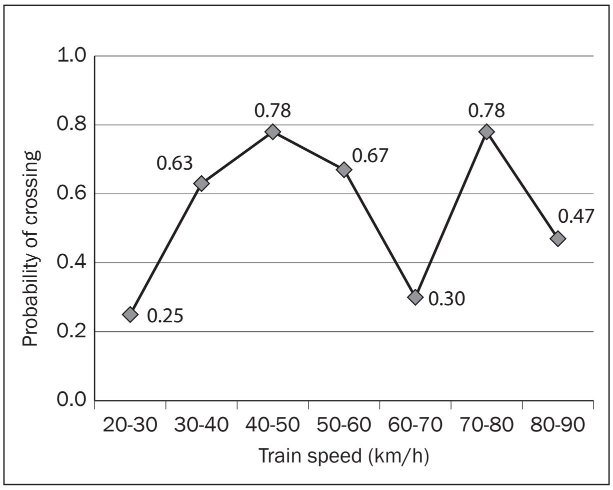

Figure 4 - Probability of crossing as function of train speed

that time $(y = 0.140x + 0.078, R = 0.874)$. It turned out that there was no statistically significant difference between the compared characteristics. The critical value is $\chi^{2(6)}_{0.05} = 12.592$. The actual value is $\chi^2 = 10.694 < \chi^{2(6)}_{0.05} = 12.592$. In respect of such results this assumption is accepted and the functional dependency in *Figure 3* shows that drivers are much more inclined to cross when the time remaining for the train approach is longer. These results correspond to the results of analysis [8, 17] which does suggest that drivers were as a group accurately gauging the time available to cross.

No one crossed the crossing less than 10s before the train arrival. The longest waiting time for the drivers who decided not to cross was 63s. This case happened when a slow train (30km/h) arrived. The shortest distance of the train from the crossing when the drivers decided not to cross was 40 to 150m.

According to the results of ANOVA analysis, when drivers judge the speed of trains, there was no difference between drivers who stopped and those who crossed in front of the trains $(F = 0.087, p = 0.769)$. The probability of crossing relative to the train speed at the moment of arrival of a road vehicle at the crossing can be seen in *Figure 4*.

Since the train speed is inversely proportional to the time remaining for the road vehicle crossing, the assumption is that it should also influence the decision to cross. The relation between the train speed and the probability of crossing shown in *Figure 4* does not show the expected interdependency of the train speed and the probability of crossing $(y = 0.017x + 0.483, R = 0.167)$. The critical value is $\chi^{2(6)}_{0.05} 12.592$. The actual value is $\chi^2 = 14.324 > \chi^{2(6)}_{0.05} = 12.592$ so this assumption is not accepted. The observation in [17] suggests that the perception of train speed, particularly for those trains at some distance from the crossing, is a difficult one.

It is shown that the analyses of probability of crossing in the function of visibility of an approaching train can give useful additional data about the driver's behaviour. The results of these observations have shown that the overall probability of crossing in case when drivers have obstructed views of the tracks was 0.55. The value for unobstructed view was 0.58. These values do not differ reliably from each other as shown in *Table 1*. Such results do not correspond to the expected value of probability of crossing as it is expected that the probability of crossing declines when conditions make it difficult to determine a safety margin accurately.

3.3 Analysis of safety margin

A more direct measure of the driver's judgment of the train speed can be obtained by observing the safety margin of crossing by the drivers who crossed in the function of train speed. Assuming there is a minimum margin that a safe driver would need before choosing to cross, one would expect that margin to be consistent regardless of whether the train speed is accurately gauged [8].

For this work a ratio between the safety margin and speed of an approaching train has been analysed. In our samples of approaching trains, two various speed intervals at which the majority of trains travelled have been separated. Accordingly, the trains were divided into two groups: (a) trains speed under 70km/h and (b) trains speed over 70km/h. The mean safety margin for trains travelling at under 70km/h was 44.69s and the mean safety margin for those travelling over 70km/h was 24.68. The *F*-test has shown that these two groups of drivers are homogenous, $(sig = 0.052 > 0.05)$ while the t-test has shown that $(sig = 0.041 < 0.05)$. It means that these two groups of drivers differ in av-

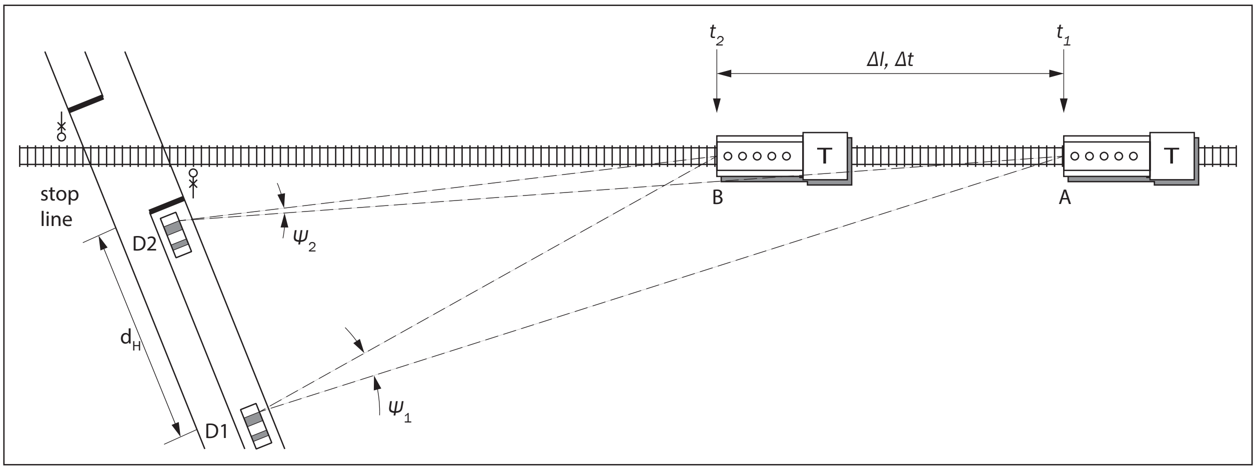

Figure 5 - Change of the visual angle Ψ of a driver for the oncoming train in dependence on the position of the vehicle: (D1) driver at the beginning of d_H, (D2) driver on the stop line.

erage values of safety margins for train speed under 70km/h and over 70km/h.

These results correspond to the results of [17], where the perception of the train speed is more difficult especially for trains at a greater distance. Moreover, according to [16] drivers tend to decide on the safety of proceeding across the tracks when the train is at greater distances, when the change in visual angle is slow and they are more likely to underestimate the train's speed.

It is shown that the analyses of probability of crossing as well as consistency of the safety margin in the function of visibility of an approaching train are significant for this work. An analysis of the safety margin data revealed the means of 26.75s and 41.50s for obstructed and unobstructed views, respectively (*Table 1*). The importance of F-test has shown that these two groups of drivers are homogenous ($sig = 0.133 > 0.05$), while the t-test has shown that ($sig = 0.019 < 0.05$). It means that these two groups of drivers differ in average values of safety margins for obstructed and unobstructed views, respectively.

The results show that drivers who have obstructed visibility of an oncoming train let themselves a smaller safety margin. One of the possible reasons for this phenomenon could be that such drivers who have limited visibility judge the train speed from the stopping line. The assumption is that it is more difficult for the drivers from the stop line (*D2*) to estimate the speed of the oncoming train than drivers who are at some distance from the railway crossing (*D1*), due to small visual angle (Ψ_2), as shown in *Figure 5*. According to [16], drivers who are at some distance from the level crossing judge the speed of the oncoming train in addition to the increasing the size of the train in their field of vision, and as we have anticipated and shown in *Figure 5*, it may be due to a clearer vision of the displacement of train (Δl) from one position (*A*) to another position (*B*), in a given time interval (Δt).

4. CONCLUSION

Human factors are a relatively new field of research in rail safety, particularly in the developing countries such as Serbia. Many of the protection and warning devices used at level crossings are based on tradition, without any research and development of human factors and technical design.

This kind of level crossings in Serbia are not adequately equipped with modern devices which are standardised, used and are part of the National Railway Level Crossing Safety Strategy in the developed countries. In such circumstances, the safety at level crossings in Serbia mostly depends on human and physical factors. This conclusion is shown on the pattern in this study and also corresponds to [18] who has said, no matter how skilled or experienced a driver is, the physical environment and engineering systems of a level crossing may be contributed to a collision between a road vehicle and a train.

The study of the probability of crossing shows that linear functionality of the train distance from the crossing well approximates the empirical values, and the drivers make a good judgement of the distance of an approaching train from them ($p < 0.0001$). It is also shown that the probability to cross in front of an approaching train when they have more available time to the train arrival is higher ($p = 0.0002$). However, the probability of crossing does not feature the expected dependence on the train speed ($p = 0.769$).

The analysis of the safety margin has shown lower values of the safety margins for the faster trains. The achieved results suggest that judging the train speed is difficult for drivers, especially for those who have limited visibility of the oncoming train ($sig = 0{,}041$). Significant finding of this work is the conclusion that the drivers who have limited visibility more easily make decisions to proceed in front of an approaching train, leaving a smaller safety margin ($sig = 0{,}019$). In [16] it is also suggested that the perceptual illusions made the estimation of safety margins difficult for the driver. This presumption is to be studied in further research in this field on a larger sample.

The results of this study show that this kind of crossings safety in general depends on a variety of unsafe driver behaviours. The education of drivers referring such unsafe behaviours is a difficult process, so that appropriate technical solutions might be the best to prevent unsafe influence of human factors. According to [19], "the form of traffic control implemented at a railway level crossing greatly affects the decision that has to be made by the driver of the road vehicle on the safety of the crossings".

Physical factors of this kind of level crossings, according to this research, have influence on the quality of the train-related information needed by the drivers to take appropriate action when approaching the level crossing. These include, but are not limited to, failure to detect a train before it reaches the crossing, failure to recognize the potential hazard of a train and failure to correctly estimate when the train will arrive at the crossing [18].

In Serbia, the protection of level crossings by modern signalling and safety devices is performed gradually and depends on the dynamics of limited fund provision, lack of legal regulations, standards and national strategy. Furthermore, the statistics show that the drivers' unsafe behaviour continues even after traffic control implementation. According to statistics [2], 21% of persons were killed at level crossings with signalling and safety devices.

This study, which is one of only few studies in this field in Serbia, clearly shows that further research of the drivers' behaviour at passive and active level crossings has to be continued in order to improve the safety at level crossings.

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REZIME

ISTRAŽIVANJE PONAŠANJA VOZAČA NA PUTNOM PRELAZU S PASIVNIM SISTEMOM ZAŠTITE

Problem: Broj nastradalih i povređenih osoba u udesima na putnim prelazima na Srpskim železnicama je u porastu, posebno na putnim prelazima sa pasivnim sistemom zaštite. U ovom radu predstavljeni su rezultati posmatranja neposrednog ponašanja učesnika u drumskom saobraćaju na putnom prelazu koji je obezbeđen samo drumskom signalizacijom. Metoda: Direktno posmatranje ponašanja vozača na putnom prelazu. Rezultati: Zapažanja su urađena na šezdeset jednom vozaču drumskih vozila u trenutku približavanja voza. Pokazalo se da verovatnoća prelaska varira u zavisnosti sa udaljenošću voza i vremenom koje je vozaču preostalo da pređe putni prelaz. Rezultati su pokazali da vozači koji imaju ograničenu preglednost ne mogu dobro proceniti brzinu dolazećeg voza i usled toga donose rizičnije odluke. Zaključak: Ovo istraživanje je pokazalo da je broj "rizičnih prelazaka" zabrinjavajući i kao rezultat toga je prisutan veliki broj udesa sa fatalnim posledicama na putnim prelazima sa pasivnim sistemom zaštite u Srbiji.

KLJUČNE REČI

putni prelazi; ponašanje vozača drumskog vozila; bezbednost na putu; bezbednost na putnom prelazu.

LITERATURE

[1] Serbian Rail Expert Service. *Reports of Safety and Functionality of Serbian Railways*. Annual reports; in Serbian, 2002-2009

[2] Serbian Rail Administration. *Statistics on accidents at Serbian Railways*; in Serbian, 2009

[3] **Ward, N.J.**, **Wilde, G.J.S.**: *A comparison of vehicle approach speed and braking between day and night-time periods at an automated railway crossing*, Safety Science, Vol.19, 1995, pp. 31–44

[4] **Hauer, E**: *Flashing lights and bells at grade crossing: Present problems and directions of the future*. TP 5308E. Montreal, Quebec: Transportation Development centre, 1984

[5] **Raslear, T.G.**: *Driver Behavior at Rail-Highway Grade Crossings: A Signal Detection Theory Analysis*. Safety of Highway-Railroad Grade Crossings. Research Needs Workshop, Volume II – (Report No. DOT/FRA/ORD/14.2, DOT-VNTSC-FRA-95-12.2, pp. F9-F56). U.S. Department of Transportation, Washington, D.C, 1996

[6] **Russell, E.** et al.: *Study of drivers behavior at passive railroad-highway grade crossings*, Kansas State University Manhattan, KS 66506, 2007

[7] **Ward, N.J.**, **Wilde, G.J.S.**: *Driver approach behavior at an unprotected railway crossing before and after enhancement of lateral sight distances: An experimental investigation of a risk perception and behavioral compensation hypothesis*, Safety Science, Vol. 22, No. 1-3, 1996, pp. 63–75

[8] **Meeker, F. L.**, **Barr, R. A.**: *An observational study of driver behaviour at a protected railroad grade crossing as trains approach*, Accident Analysis & Prevention, Vol. 21, No 3, 1989, pp.255-262

[9] National Transportation Safety Board. *Safety Study: Safety at Passive Grade Crossings Volume 1: Analysis* (NTSB/SS-98/02). Washington, D.C.: National Transportation Safety Board, 1998.

[10] **Caird, J.K.**, et al.: *Human Factors Analysis of Highway-Railway Grade Crossing Accidents In Canada*, Transportation Development Centre Transport Canada, 2002

[11] **Wigglesworth, E.C.**: *Report on human factors in road-rail crossing accidents*, Melbourne, Victoria, Australia: Ministry of Transport, 1976

[12] **Moon, Y.J.**, **Coleman, F.**: *Driver's speed reduction behavior at highway rail intersections*. In Paper Preprints of the 78th Annual Meeting of the Transportation Research Board [CD-ROM], Washington, DC: TRB. 1999

[13] *Railroad - Highway Grade Crossing Handbook, Railroad - Highway Grade Crossing Handbook - Revised Second Edition* 2007, FHWA-SA-07-010. Federal Highway Administration, 2007

[14] **Wilde, G.J.S.**, **Cake, L.J.**, **McCarthy, B.A.**: *An observational study of driver behaviour at signalized railroad crossings*. Kingston, Ontario: Canadian Institute of Guided Ground Transport, Queen's University, 1976

[15] **Reason, J.**: *Managing the risks of organizational accidents*. Brookfield: Ashgate, 1997

[16] **Leibowitz, H. W.**: *Grade crossing accidents and human factors engineering*, American Scientist, 1985, 73, 558-562

[17] **Meeker, F.**, **Fox, D.**, **Weber, C.**: *A comparison of driver behavior at railroad grade crossings with two different protection systems*, Accident Analysis and Prevention, Vol. 29, No. 1, 1997, pp. 11–16

[18] **Carrol, A.**, **Multer, J.**, **Marcos, S.**: *Safety of highway-railroad grade crossing: Use of auxiliary external alerting devices to improve locomotive conspicuity*. Cambridge: U.S. Department of transportation, 1995

[19] **Cairney, P.**: *Prospects of improving the consipicity of trains at passive railway crossings*, (No. CR 217), Canberra: Australian Transport Safety Bureau, 2003