



# Interreg



## Danube Transnational Programme

### RADAR

Project co-funded by European Union funds (ERDF, IPA, ENI)



# Your Road Safety is on our RADAR.

## O.T.3.1.h Pilot Actions on 4 (6) Road Safety Thematic Areas

TA5 COVID-19 - HUNGARY

 RADAR – Risk Assessment on Danube Area Roads

 <https://www.interreg-danube.eu/radar>

<b>Internal Report Hierarchy Level</b>			
<b>Activity Number</b>	A.T4.3	<b>Activity Title</b>	Pilot Actions TA5 and TA6
<b>Work Package Number</b>	WP5 extension	<b>Work Package Title</b>	Strategy and Plans (RISM and Covid 19) extension directive and
<b>Authors (per company, if more than one company provide it together)</b>	Gábor Pauer, KTI Szilárd Szigeti, KTI		
<b>Status (F: final, D: draft, RD: revised draft):</b>	F		
<b>Version Number</b>	3.0		
<b>File Name</b>	20211105_Pilot Action_TA5_Hungary_v3.0_KTI.docx		
<b>Issue Date</b>	25.08.2021.		
<b>Project start date and duration</b>	June 1, 2018 – 42 months		

## Revision log

Version	Date	Reason	Name and Company
1.0	14.09.2020.	Draft Report	Gábor Pauer, KTI Szilárd Szigeti, KTI
2.0	25.10.2021	Revision according to quality review	Gábor Pauer, KTI
3.0	05.11.2021	Revision 2 <sup>nd</sup> round	Gábor Pauer, KTI

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## Abbreviation list

AADT	Annual Average Daily Traffic
ARM	A family of reduced instruction set computing (RISC) architectures for computer processors
iRAP	International Road Assessment Programme
ITS	Intelligent Transport System
KTI	KTI Institute for Transport Sciences Non-profit Ltd.
PA	Pilot Action
PECA	PEdestrian Crossing Analyzer application
PP	Project Partner
RADAR	Risk Assessment on Danube Area Roads
TA	Thematic Area
WP	Work Package

# 1 Executive summary

The RADAR (*Risk Assessment on Danube Area Roads*) project implements learning and transnational cooperation activities at different levels to help the responsible road safety organizations in the Danube area identify risk on their road networks and also helps them reduce risk systematically, by improving infrastructure and road layout. RADAR addresses all road users but pays particular attention to vulnerable road users as well as to safety on major roads near schools. It also holistically approaches the issue of safety and tackles speed as a major risk on roads. By the extension of RADAR, the transport safety related aspects of the COVID 19 pandemic, and the Amendment (Directive 2019/1936) of the Directive 2008/96/EC on road infrastructure safety management are also considered in the project.

As part of the extension of the fifth Work Package, PP3-KTI performed a Pilot Action (PA) to test a proposed solution related to one of the additional Thematic Areas (TA), namely TA5: Transport Safety and COVID 19. The pilot used previous results and experiences in the field of speed management following work on Thematic Area 3 (ITS and speed management), addressing also the safety of pedestrians (Thematic Area 2 - Road safety of vulnerable road users). The COVID 19 pandemic made it even more important to address safety issues arising from higher vehicle speeds due to the reduction of traffic volume, as pointed out by the latest research<sup>1</sup>.

According to the results of our previous Pilot Action in WP5 (Activity 5.3 - Pilot Action ITS for speed management), vehicle activated signs near the roads proved to be effective in reducing the operational speed of the traffic and the number of speed violators. In accordance with this, a new ITS solution was developed in Hungary addressing speed issues at pedestrian crossings. The referred ITS device consists of:

- a pedestrian crossing warning sign with interior lighting and a LED text (Lassíts! – “Slow down!”) that should be placed 50-100m in front of the pedestrian crossing, and
- a yellow blinker to be placed right near the pedestrian crossing.

A speed measuring radar and a WiFi transmitter complement both elements of the device. It operates based on the presence and speed of arriving vehicles, while it is also able to collect the speed data. The threshold value of speed required for operation of the device can be determined by the analyst/operator. Note that the Pilot Action did not include any investments in the development or installation of the ITS device.

During our Pilot Action, the effects of the presented ITS solution were assessed at one location by measurements. Speed data have been analysed using mathematical-statistical methods. The device proved to be effective in terms of reducing the average and v85 speeds, and the ratio of speeders. The average speed decreased by 6.9% 50 meters in front of the pedestrian crossing, and 9.3% in the line of the crossing. An interesting observation was that the device achieved greater effects under daylight visual condition than after sunset.

Besides evaluating the vehicle speeds, a complex road safety analysis was done using the PECA (PEdestrian Crossing Analyzer) application developed by KTI. The software rated the current level of safety and service at the pedestrian crossing and provided recommendations for improvement.

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<sup>1</sup> Katrakazas C., Michelaraki, E., Sekadakis, M., Yannis, G. (2020). A descriptive analysis of the effect of the COVID-19 pandemic on driving behavior and road safety. *Transportation Research Interdisciplinary Perspectives*, Volume 7, 100186. <https://doi.org/10.1016/j.trip.2020.100186>

Based on the results, an implementation-ready road layout concept plan has been developed in our Pilot Action aiming to improve the safety at the investigated pedestrian crossing.

The potential road safety related benefits of the proposed ITS device and other possible safety related interventions were then assessed based on the connections between the speed and accident risks/injury severity, and the PECA application. The first approach implied that the number of fatal accidents could be reduced by 33.4%, while the number of serious and slight injury accidents could be reduced by 22.7% and 10.3%, respectively, as a consequence of reduced speed. Furthermore, the risk of severe injury can be decreased to 37% from 47%, and the risk of death can be decreased to 15% from 20% at the specific location.

Besides this, the PECA application showed a great increase in the safety rating of the pedestrian crossing (from 6/10 stars to 9/10 stars) as a result of the implementation of the set of recommended interventions.

The results provide added value in the field of safe road infrastructure in the Danube area. The implementation and gathered results were done in a way to ensure maximum transferability and adaptability to similar situations in any other country of the Danube region and beyond.

Data along the implementation of the PA was collected, and all steps and results are described in detail in this document.

## 2 Introduction of the proposed ITS solution

Considering the significant potential in vehicle activated signs, a new ITS solution was developed in Hungary addressing speed issues at pedestrian crossings. Tackling the issue of speeding became especially important at the COVID pandemic period, while the increase of safety of vulnerable road users is a key area to be addressed. According to the Thematic Report<sup>2</sup> of project RADAR, the current observations in the aftermath of the COVID-19 pandemic shows at many countries that

- a comparatively higher share of vulnerable road user travel was noted on the urban and suburban system, and the number of cyclist (but usually not pedestrian) fatalities partly increased;
- average driving speeds increased slightly – whereas the share of extensive speed violations increased more substantially;
- the share of inadequate speed as prime causal crash factor increased, especially for fatal crashes.

### 2.1 Main parts of the device

The investigated vehicle activated ITS device consists of two main parts:

1. A pedestrian crossing warning sign with interior lighting and a LED text (Lassíts! – “Slow down!”) that should be placed 50-100m in front of the pedestrian crossing, complemented by a speed measuring radar (first radar) and WiFi transmitter

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<sup>2</sup> Effects of the COVID-19 pandemic on the status of road safety, (2021). Report on Thematic Area 5 (TA5): Transport Safety and COVID-19. RADAR project.





Figure 1: The pedestrian crossing warning sign with interior lighting, the LED text (Lassíts!), the first radar (looking at the same direction as the signs), and the WiFi transmitter (at the back of the pole)

The first radar of the device is a BX-946 microwave detector. The measurement principle of this detector is based on the Doppler effect. The detector unit is bouncing a microwave signal off to a desired target and analysing how the motion of the object has changed the frequency of the returned signal. Calculations of the Doppler effect accurately determine the velocity of the detected objects. This radar is able to detect arriving vehicles, and measure their speed within its range, which is about 20-25 meters (depending on weather and visibility conditions). This radar is not applicable for continuous data recording by tracking the vehicles.

2. A yellow blinker to be placed right near the pedestrian crossing, complemented by a speed measuring radar (second radar) and WiFi transmitter.



Figure 2: The yellow blinker, the second radar (above the blinker) and the WiFi transmitter (under the blinker)

The second radar of the device is a digital Falcon Plus II intelligent microwave detector, together with an ARM<sup>3</sup> based computer (self-developed by KTI's subcontractor). The measurement principle of this detector is also based on the Doppler effect. However, this unit has both a counting and tracking function. The equipment can also detect if the vehicle is arriving or leaving, therefore it is able to detect movement either uni- or bidirectional. During the measurement, the computer is recording the exact time and location of the measurement and the time vs. speed data continuously in microsecond intervals from the first moment the vehicle is within the range until it is detectable. Several speed samples are available for each vehicle, therefore speed vs. time or distance curves can be also generated. The radar unit is also equipped with a sophisticated communication module to provide the data remotely even during the measurement

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<sup>3</sup> ARM – a family of reduced instruction set computing (RISC) architectures for computer processors

real time or afterwards. The range of this radar is about 50 meters (depending on weather and visibility conditions).

During the measurements of the Pilot Action, the devices were powered by external batteries.

## **2.2 Method of operation**

The operation of the presented device was based on the arrival of vehicles to the pedestrian crossing.

The first radar detected incoming vehicles and measured their speed. When an incoming vehicle was detected, the interior lighting of the pedestrian crossing warning sign was turned on (regardless of the vehicle speed). If the vehicle arrived at a speed higher than the speed limit, the text “Lassíts” was also displayed. If no new vehicle has arrived, the lights turned off after 5 seconds.

When detecting an incoming vehicle, the first radar also activated the yellow blinker located on the column of the designated pedestrian crossing sign (regardless of speed). It switched off after 10 seconds without a new vehicle arriving.





Figure 3: Illustration of the operation of the ITS device (great differences of visibility of the warning sign can be observed in dark)

The speed data used for the analysis were provided by the Falcon radar, located on the column of the designated pedestrian crossing sign. By these data, the speed on a 50-meter-long section in front of the pedestrian crossing became analysable.

## 3 Determination of the effects of the proposed ITS solution at a pedestrian crossing

The aim of our Pilot Action was the investigation of the effects of the presented ITS solution at a pedestrian crossing. In the next chapter, the methodology of the evaluation (location, method of measurements, data processing) is presented in detail.

### 3.1 Information on the speed measurements

#### 3.1.1 Location of the measurements

In our Pilot Action, the speed measurements were carried out at a pedestrian crossing designated in urban area, close to the border of the city of Martonvásár in Hungary.

**Location:** 2462 Martonvásár, road 6204, 11+150 km section

**GPS:** 47.311269, 18.794216

**Type of area:** Urban

**AADT:** 5193 vehicle units/day (share of HGVs: 6.5%)<sup>4</sup>

**Speed limit:** 40 km/h

The measured direction was the one that leads out from the city, as presented in the next pictures.

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<sup>4</sup> Based on the data of the Hungarian Public Road Nonprofit Plc. (<https://internet.kozut.hu/kozerdeku-adatok/orszagos-kozuti-adatbank/forgalomszamlalas/>)



Figure 4: Measured section on road 6204

The investigated section is located in an urban area close to the border of Martonvásár city, on road 6204 at the 11+150 km section. The section is on a 2x1 lane road. Approaching the pedestrian crossing in the measured direction, there is a speed limit of 40 km/h, which ends at the intersection in which the pedestrian crossing is located. The speed limit sign is placed 350 meters in front of the crossing, after which the drivers have to pass in front of the gates of many houses, so the effect of this restriction can be assumed to be quite low at the pedestrian crossing. The operational speed is also negatively affected by the fact that after passing the pedestrian crossing, the drivers reach a road section with rural nature (with only bushes and trees near the road). The sign indicating the end of the settlement is located 400 meters after the pedestrian crossing.

In the measured direction, stopping on the right side of the road is prohibited by a sign on a 65-meter-long road section in front of the crossing. On the left side, cars can stop by pulling up on the gravel bench (see the picture below).





Figure 5: Prohibition of stopping in front of the pedestrian crossing

The pedestrian crossing sign is placed right near the pedestrian crossing. The distance between the pedestrian crossing, and the pedestrian crossing warning sign is exactly 50 meters<sup>5</sup>.

The location of the measurement was recommended by the road operator company. According to their observations, the attention of the drivers is not increased appropriately at this pedestrian crossing, especially at night or under poor visibility conditions. A street lighting column can be found only on the one side of the crossing, while the pedestrian crossing warning sign is shaded by a tree. No special elements for increasing the drivers' attention (prism, fluorescent yellow background for the pedestrian crossing sign, etc) can be found.

According to our observations during the measurements, the pedestrian traffic is not high. In the afternoon, 5-10 pedestrians cross here per hour, this number is even lower in the night. In the November of 2020, a pedestrian was hit (serious injury) at the pedestrian crossing at night, while in the July of 2019, a single vehicle accident occurred in the junction (a drunk moped driver fell because of the choice of inappropriate speed).

### 3.1.2 Method of the measurements

The measuring equipment (Falcon radar) was already introduced in the previous chapter. The radar recorded the speed of arriving vehicles with a high frequency in the 50-meter-long section in front of the pedestrian crossing (approximately from the line of the pedestrian crossing warning sign).

Before and after measurements were performed, meaning that the measurements were done in the first week (2021.08.23-08.27) in the original condition of the environment of the pedestrian crossing. Then in the following week (2021.08.30-09.03), the ITS devices were installed and their effects were measured according to the same methodology as before.

The competent authorities (road operator, police) approved and supported the measurements.

### 3.1.3 Time of the measurements

Measurements have been done in the August of 2021, at weekdays. Based on the operational method of the ITS device (interior lighting), the greatest effects were expected in dark, so the measurements were carried out each day between 17:00 and 23:59. To be able to separately analyse the effects under different visual conditions, the exact time of sunset was summarized in the following table.

Table 1: Time of sunset on the days of the speed measurements

Date	Sunset
2021.08.23	19:42
2021.08.24	19:40
2021.08.25	19:38
2021.08.26	19:36
2021.08.27	19:35
2021.08.30	19:29

<sup>5</sup> The distance is in line with the Hungarian regulations (83/2004. (VI. 4.) GKM order)

2021.08.31	19:27
2021.09.01	19:25
2021.09.02	19:23
2021.09.03	19:21

During our analysis, the visual conditions were considered based on the above sunset times (daylight visual condition: before sunset, night light visual condition: after sunset).

### 3.1.4 Data processing

The maximum range of the measuring radar was 50 meters, but could vary according to the weather conditions, colour and size of the measured vehicles, etc. The equipment could detect vehicles almost up to its own location (line), therefore we considered the last measured point 1 meter away from the device, which was mounted on the pole of the pedestrian crossing sign.

Based on the recorded time and speed data, the elaborated data processing software was able to calculate the distance of the vehicles from the measuring equipment in case of each fixed measurement time moment. For the analysis, the vehicle speeds were determined for every integer meter value by linear interpolation, starting from 1 meter away from the line of the measuring equipment. Note that the measuring equipment was in line with the pedestrian crossing.

Due to the operating principle of the radar, the following difficulties had to be overcome:

- The equipment measured both traffic directions. However, the speeds in the different directions were recorded with different signs (arriving vehicles: positive; leaving vehicles: negative). This made it possible to remove unnecessary data measured in the undesired direction.
- The radar could not distinguish between vehicles moving close to each other in the same direction. Thus, it recorded the data in case of an arriving group of vehicles continuously, without interruption. We dealt this phenomenon using the counted distance values: in case of a close group of cars in the same direction, the distances calculated starting from the line of the equipment became high due to the large amount of continuously recorded data. As the maximum range of the instrument was 50 meters, data points calculated for a greater distance have been deleted. With this approach (assuming that the difference in speed within the close group of vehicles is minimal), we kept the data of the last vehicle of the group for each group of vehicles.

During the procession of the measurement data, further data filtering has been performed as follows:

- Measurements were deleted if the equipment did not “see” the vehicle at a distance of at least 20 meters.
- Measurements were deleted if the equipment did not record at least 10 measurement points (time moments) of a vehicle.

- Measurements were deleted if the distance between two adjacent measurement points for the same vehicle was higher than 5 meters. (In these cases, the coherent data probably belong to two different vehicles).
- Measurements were deleted if the speed of a vehicle was lower than 30 km/h at 10 meters in front of the pedestrian crossing, or lower than 30 km/h at the line of the pedestrian crossing. According to our observations, lower than 30 km/h speed data was observed only in those cases, when a vehicle intended to turn left before the pedestrian crossing or slowed down to give priority for a pedestrian.
- Measurements were deleted if the standard deviation of speed values of a vehicle was higher than 15% of the speed limit. (For some data sets, there was an unrealistic standard deviation due to measurement errors).

### **3.2 Results of the speed measurements**

Based on the results of the speed measurements, the following data have been calculated and presented both for the cases when the investigated ITS device were operating and non-operating:

- average speeds (calculated for every 5 meters, starting from 1 m away from the pedestrian crossing);
- v85 speeds (calculated for every 5 meters, starting from 1 m away from the pedestrian crossing);
- ratio of vehicles exceeding the speed limit (calculated at the following distances from the devices: -50 m, -25 m, -1 m);
- Ratio of vehicles reducing speed (in case of vehicles approaching the device - from first measured point to -1 m)
- Ratio of vehicles reducing speed by at least 10% of speed limit (in case of vehicles approaching the device - from first measured point to -1 m)

Besides the investigation of the aggregated data, the periods before and after sunset were also analysed separately.

To highlight the volume of deviation of the measurement data between the different measurement days, the following two figures show the daily average speeds. We illustrated the results of the first week (without ITS device) and the second week (with operating ITS device) separately. The number of the recorded vehicles was around 400 cars per day. In the first week, a total of 2099 vehicles, and in the second week, a total of 1986 vehicles were recorded (this applies to the 20-meter section in front of the pedestrian crossing, but the sample size was lower at more distant points due to the operational characteristics of the radar). In order to perform the further analyses using an appropriate sample size, our conclusions were drawn based on the aggregated results of the weekly measurements.

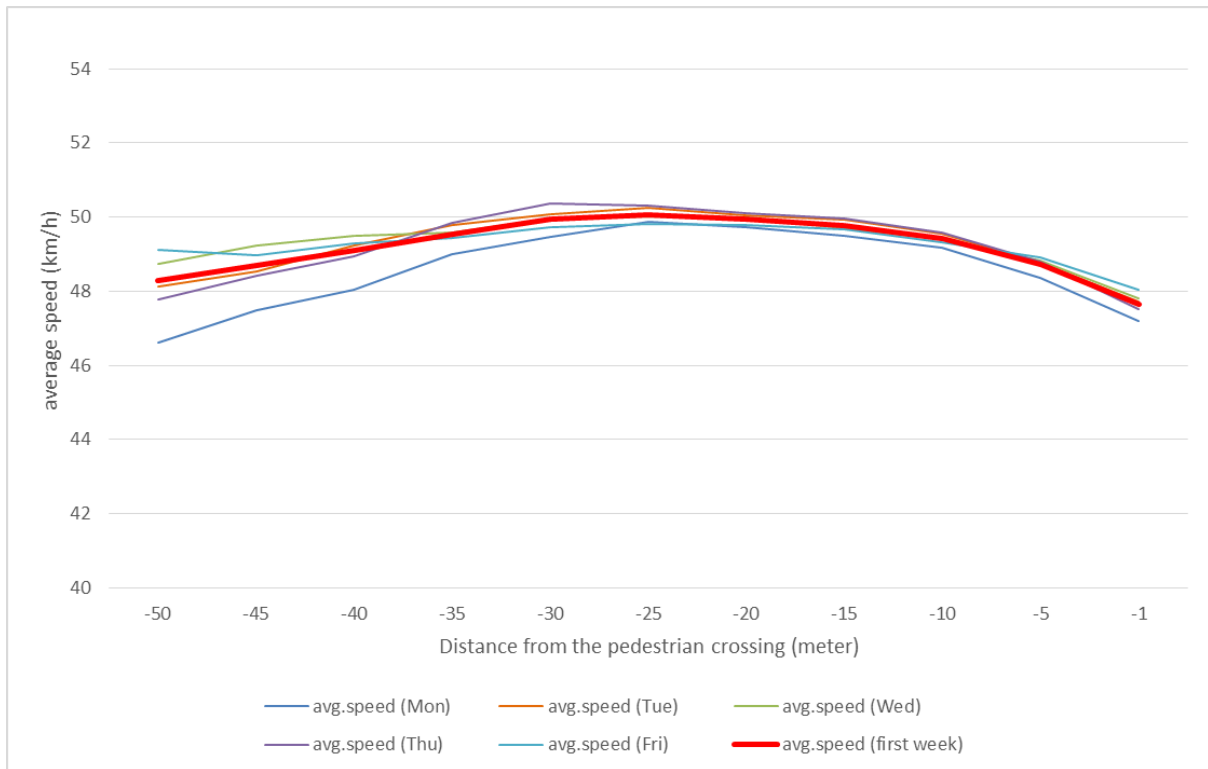


Figure 6: Average speed in front of the pedestrian crossing (first week - without ITS device)

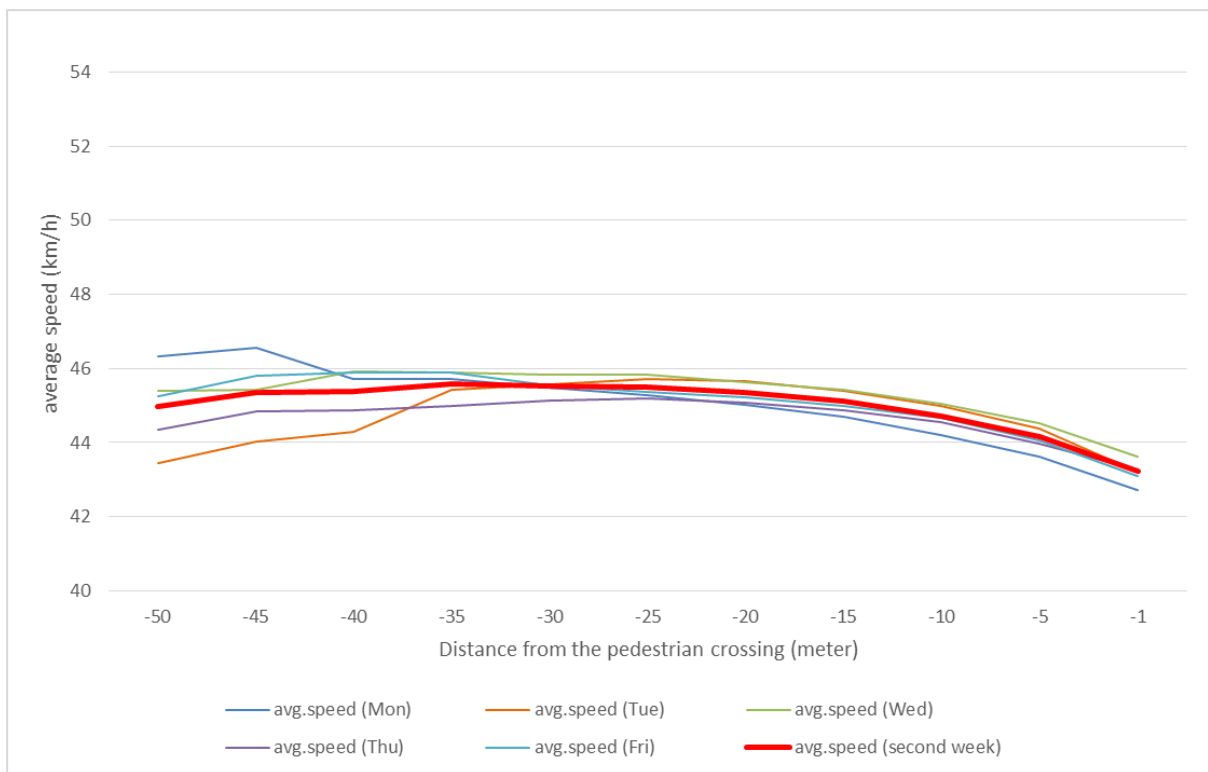


Figure 7: Average speed in front of the pedestrian crossing (second week - with ITS device)

The positive effects of the ITS device can already be seen based on the differences in the weekly average speeds. This will be analysed in detail later.

Based on the daily speed data, the speeds were lower than average on the first day of the first week. This suggests that although the measurement was not announced or indicated, the new “boxes” (small speed measurement devices) placed on the poles of the traffic signs prompted drivers to be somewhat “cautious”. This effect disappeared later as drivers got used to the presence of the devices.

At the 25-meter-long section in front of the pedestrian crossing, the results didn’t really differ depending on the days of the week. This was also the case in the second week. The larger deviations observed at the beginning of the measured road section (between -50 and -35 meters) may also be due to the fact that the measured sample size was much lower at these distances (e.g., in the second week, only 751 vehicles were recorded 50 meters away from the pedestrian crossing, out of the total 1986 vehicles).

**3.2.1 Analysis of aggregated data**

To evaluate the effects of the ITS device, weekly aggregated data were used. In addition to the average speeds, the v85 speeds were also shown in the figures below (this means the speed that 85% of drivers do not exceed, and 15% of drivers exceed).

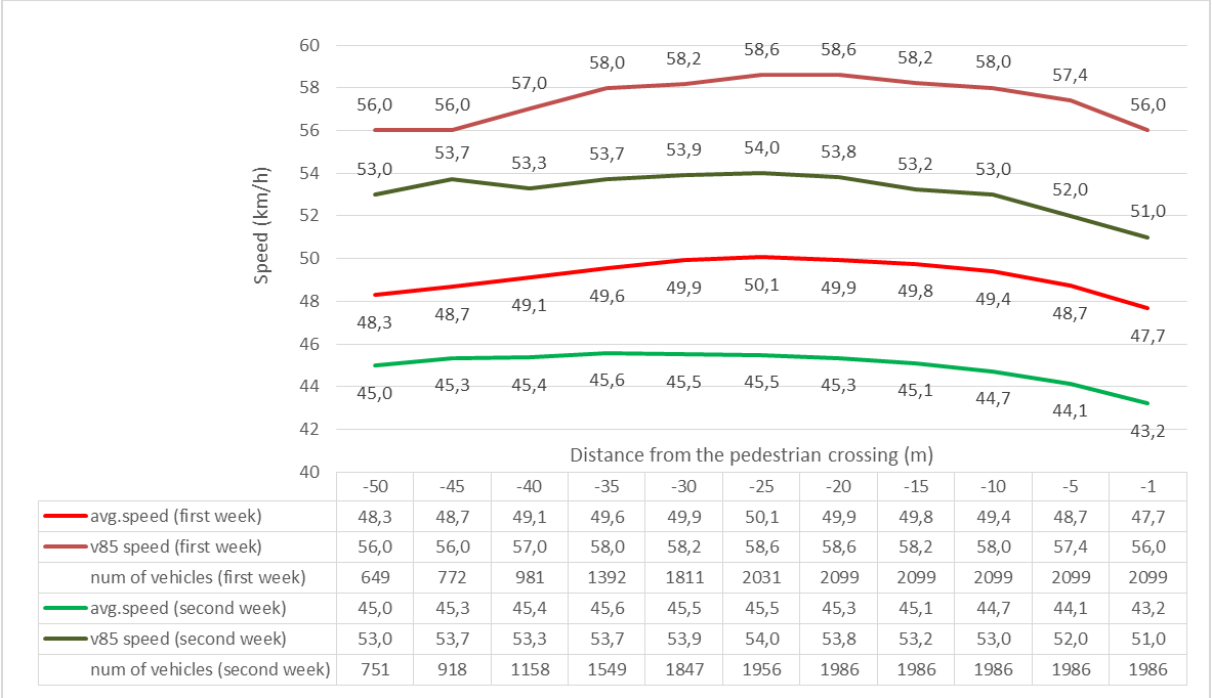


Figure 8: Average and v85 speeds in the different scenarios

First of all, it should be noted that in spite of the 40 km/h speed limit at the measured location, the average speeds were around 47-50 km/h, and the v85 speeds were around 56-59 km/h. This was presumably the consequence of the previously introduced characteristics of the location. This implies that dealing with speed management is highly justified at the area of the selected pedestrian crossing.

Based on the presented data, the deployed ITS device had a substantial positive effect on vehicle speeds. In the line of the pedestrian crossing warning sign (50 meters from the crossing), the average speed decreased by 6.9%, and the v85 speed decreased by 5.4%. The difference

got even higher as the vehicles approached the pedestrian crossing. In the line of the pedestrian crossing, the average speed was 9.3% and the v85 speed was 8.9% lower if the ITS device was operating. However, even in this case, the average speed was slightly above the allowed speed limit.

The shape of the curves shows that the drivers accelerated on the measured section by default (in the first week) since they were traveling out from the town and started to decrease their speed only about 20 meters from the pedestrian crossing. Contrary to this, the ITS device was able to achieve that the speed did not increase, or increased only very slightly from the line of the pedestrian crossing warning sign.

Besides the speed curves, several further parameters have been calculated as follows in Table 2.

Table 2: Value of indicators in the different scenarios

		First week (without scenario)	Second week (with ITS device)	Difference
Ratio of vehicles exceeding the speed limit	at -50 meter	88.0%	69.8%	-18.2%
	at -25 meter	89.4%	71.0%	-18.4%
	at -1 meter	79.1%	56.8%	-22.3%
Ratio of vehicles reducing speed (from first measured point to -1m):		78.4%	79.0%	+0.6%
Ratio of vehicles reducing speed by at least 4km/h (from first measured point to -1m)		28.3%	36.1%	+7.8%

In line with the lower average speeds, the share of vehicles exceeding the speed limit decreased significantly as a result of the presence of the ITS device. The difference was about 18% on the road section in front of the pedestrian crossing and 22% in the line of the crossing. However, even in the second week, the values were still high: more than half of the drivers was driving above the speed limit. This shows that in addition to strengthening the warning road signs, it would also be important to clearly indicate the expected behaviour (40 km/h speed limit) in the vicinity of the pedestrian crossing.

The ratio of vehicles reducing speed was high due to the presence of the pedestrian crossing. However, the speed reduction mainly took place only right before the pedestrian crossing, as it has been shown by the previous figure. This ratio did not change significantly with the operation of the ITS device, but the accelerations were less typical in the second week. There was a 7.8% increase in the proportion of those who reduced their speed by at least 10% of the speed limit.

**3.2.2 Analysis of different periods (before/after sunset)**

Due to the operating principle of the device (interior lighting, light signals), it seemed to be reasonable to examine the effects separately under different visibility conditions. For this type of data splitting, the previously introduced times of sunsets were used (daylight visual condition: before sunset, night light visual condition: after sunset).

In Figure 9, the v85 and average speeds have been indicated with the same colours as in Figure 8 (red: first week, green: second week; darker: v85, lighter: average speed). The dotted lines show the periods before, and the dashed lines show the periods after sunset.

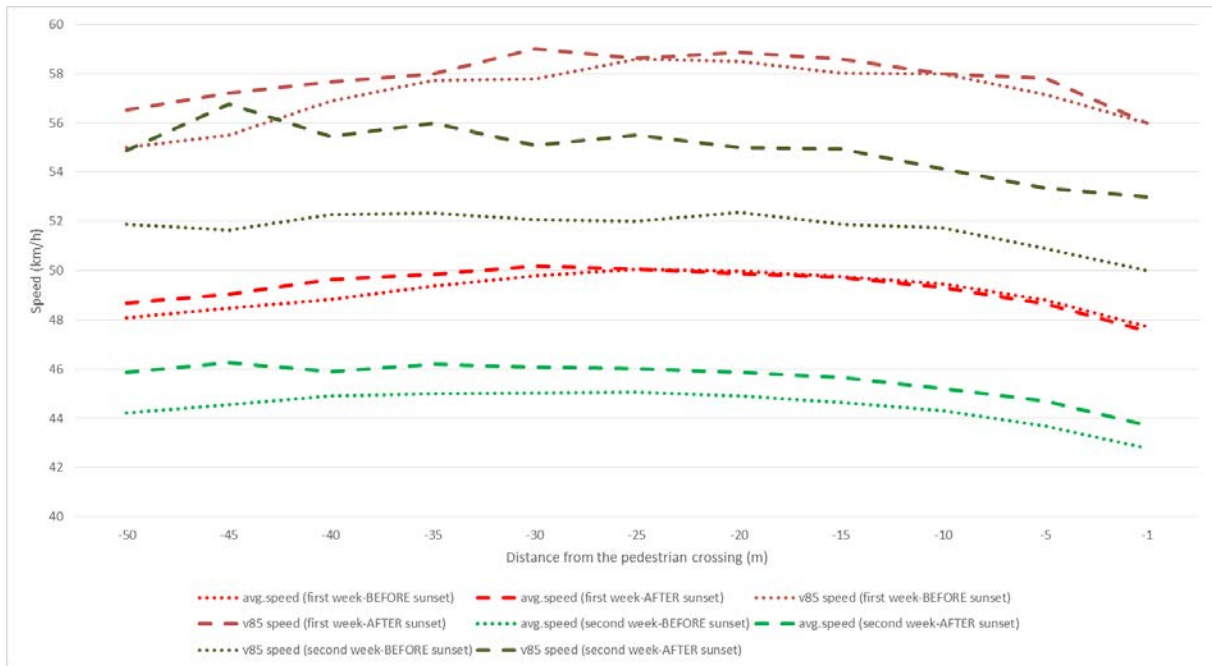


Figure 9: Average and v85 speeds of different periods in the different scenarios

According to the data from the first week (without the ITS device), there was no significant difference in the average speed, nor in the v85 speed in the periods before and after sunset. Typically, the speed values were only slightly lower, and only at the beginning of the measured section under daylight visual condition.

However, greater differences were observed in the second week. Contrary to the expectations, there was a higher decrease in speed before sunset. Thus, the ITS device achieved greater effects under daylight visual condition than after sunset. A possible explanation for this phenomenon can be that the drivers are less likely to expect pedestrians at the crossing at night. So, the warning by the pedestrian crossing warning sign seems to be given less importance in this period. However, a similar prediction of another hazard (e.g., a dangerous curve) might have the opposite effect. Investigating different type of locations and scenarios in this regard would be an interesting area for future research.

The other examined parameters of the different periods have been summarized in the next Table.

Table 3: Value of indicators of the different periods in the different scenarios

		First week (BEFORE sunset)	Second week (BEFORE sunset)	Diff.	First week (AFTER sunset)	Second week (AFTER sunset)	Diff.
Ratio of vehicles exceeding the speed limit	at -50 meter	88.2%	66.4%	-21.8%	87.6%	73.8%	-13.8%
	at -25 meter	90.0%	71.5%	-18.5%	88.5%	70.5%	-18.0%
	at -1 meter	80.7%	55.8%	-24.9%	76.5%	57.9%	-18.6%
Ratio of vehicles reducing speed (from first measured point to - 1m):		77.5%	79.3%	+1.8%	80.0%	78.5%	-1.5%
Ratio of vehicles reducing speed by at least 4km/h (from first measured point to -1m)		26.8%	36.5%	+9.7%	30.8%	35.5%	+4.7%

The values of the presented parameters also show greater beneficial effects in the period before sunset. In all three investigated cross-sections, there was a larger decrease in the proportion of speeders, and the proportion of speed reducers also changed in a more favourable direction before sunset.

### 3.2.1 Conclusions – Effects of the ITS device

According to the applied speed measurements, the main findings were the following:

- The investigated ITS device had a significant positive effect on vehicle speeds:
  - In the line of the pedestrian crossing warning sign (50 meters from the crossing), the average speed decreased by 6.9%, and the v85 speed decreased by 5.4%.
  - In the line of the pedestrian crossing, the average speed was 9.3% and the v85 speed was 8.9% lower if the ITS device was operating.
- The ITS device was able to achieve that the speed did not increase, or increased only very slightly from the line of the pedestrian crossing warning sign.
- The share of vehicles exceeding the speed limit decreased significantly as a result of the presence of the ITS device:
  - The difference was about 18% on the road section in front of the pedestrian crossing.
  - The difference was 22% in the line of the pedestrian crossing.
- Despite the speed reduction, the average speed was still higher than allowed and more than half of the drivers was driving above the speed limit. This shows that in addition to strengthening the warning road signs, it would also be important to clearly indicate the expected behaviour in the vicinity of the pedestrian crossing.
- There was a 7.8% increase in the proportion of those who reduced their speed by at least 10% of the speed limit.
- The ITS device achieved greater effects under daylight visual condition than after sunset.



Note that the presented measurements do not provide information on the long-term effects of the ITS device. The newly installed device can have more significant effects in its first period when road users encounter the situation for the first time. At the same time, we expect the effectiveness to be maintained in the longer term: regular commuters will know that they have to pay close attention at the specific location, while occasional commuters will continue to encounter a new signal. (E.g., vehicle activated speed/speed limit displays have been in operation in our country for a long time, but still have a positive effect based on measurements made under our previous Pilot Action in project RADAR).

## 4 Assessment of the current condition of the pedestrian crossing

After the investigation and quantification of the road safety benefits expected from the introduced ITS solution, the current condition of the pedestrian crossing was further analysed. The aim was to apply a complex road safety inspection procedure to be able to identify further potential safety related problems beyond the observations related to high vehicle speeds. Our aim was to focus on the widest range of existing safety related problems when elaborating the proposed interventions.

For the inspection, a web-based application (PECA-PEdestrian Crossing Analyzer) was developed by KTI in 2020 (access: <https://kti-peca.web.app/>).

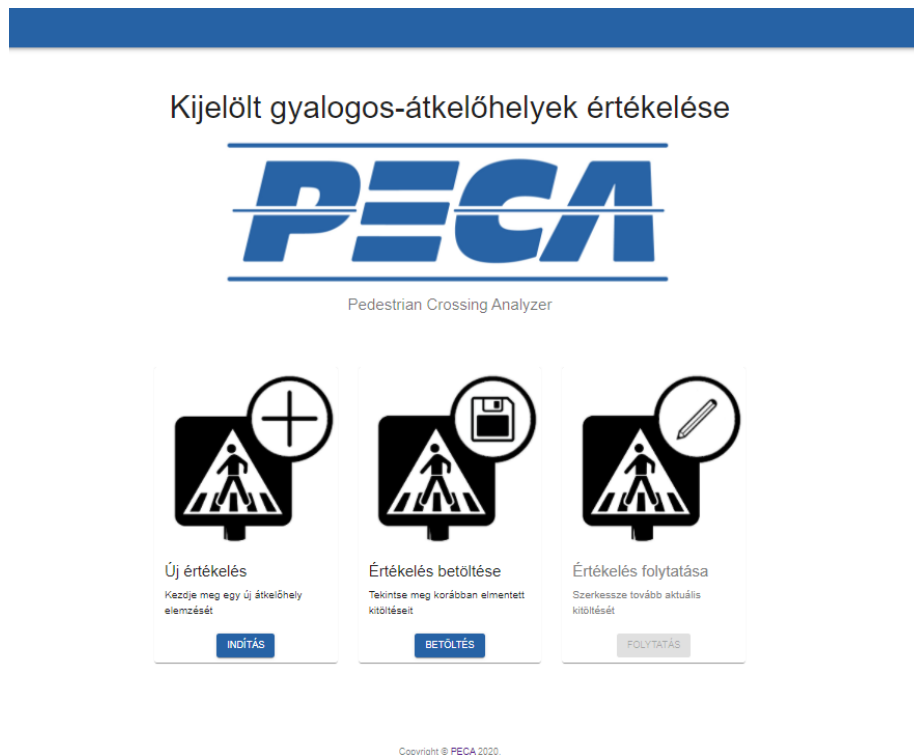


Figure 10: Main menu of the PECA (PEdestrian Crossing Analyzer) web-based application

The PECA software is applicable for the complex evaluation of the road safety and service level of designated pedestrian crossings within urban areas. It is also able to provide automatic recommendations to improve safety based on the coded parameters and results of the analysis.

During the evaluation (similarly to the process of the iRAP methodology) it is necessary to record and code the parameters characterizing the pedestrian crossing and its environment. The assessment is then performed by the application based on the risks assigned to the attributes.

As a result of the analysis, the application provides the aggregated rating of safety and service level on a scale of 1 to 10 (star rating), as well as a rating according to each predefined criteria groups, in each direction.

Besides this, the PECA application is also able to automatically generate recommendations aiming to improve the safety and service level of the investigated pedestrian crossing. These are

usually general measures and traffic engineering tools which might be applied on the specific location. Each suggestion is recommended based on predefined functions using the risks assigned to the different criteria.

The coded parameters related to the investigated pedestrian crossing have been summarized in the following tables, by directions. Note, that the previously introduced and measured direction was identified as direction 2.

Table 4: Value of parameters independent of direction

Parameter	Value
Crossing width, transverse direction (meters)	= < 7
Ensure the shortest possible passage	Yes
Presence of refuge island	No
Distance of pedestrian crossing from the real conflict area of the intersection (meters)	> 4; = < 8
The built-up of one side	Normal
The built-up of the other side	Sparse
Public transport stop in the environment of the crossing	No
Road section involved in coordinated traffic management	No
Distance from the nearest traffic light intersection (meters)	> 200
Ensure full crossing of the road	Yes
Condition of the road marking signing the pedestrian crossing	Medium
Other, awareness-raising element on the road surface at the pedestrian crossing	No
Distraction object in the vicinity of the crossing	No
Longitudinal width of the pedestrian crossing	Insufficient
Solid pavement connection on both sides	Yes
Size and accessibility of pedestrian stands	Appropriate on both sides
Irregular crossings near the pedestrian crossings	Not typical
Tactile pavement signs at the pedestrian stands – two sides of the crossing	No, neither side
Other, different looking surfaces at the pedestrian stands – two sides of the crossing	Yes, on one side

Amount of pedestrian traffic at peak hours (ped/h)	< = 100
Higher than average presence of children and elderly	No
Peak hour vehicle traffic (veh/h)	601-800
Share of heavy motor traffic	6-10%

Table 5: Value of parameters in direction 1 (towards the city – opposite to the measured direction)

Parameter	Value
Road surface condition	Perfect
Outline of the road section in front of the pedestrian crossing	Straight
Crossing more than one lane in the same direction	No
Crossing a separate turning/accelerating/receiving lane	No
Speed limit (km/h)	50
Other, speed reducing intervention	No
Prohibition of overtaking by a solid centre line	No
Possible turning directions of the arriving vehicle traffic	Only from left turning
Other, awareness-raising element on the road surface in front of the pedestrian crossing	No
“Pedestrian crossing” road sign in front of the pedestrian crossing	Yes
“Pedestrian crossing” road sign condition and recognisability	Appropriate
“Designated pedestrian crossing” traffic sign - on the right side	Yes
Position of “Designated pedestrian crossing” traffic sign on the right side	In accordance with the law
“Designated pedestrian crossing” traffic sign - on the left side (or above the road)	No
“Designated pedestrian crossing” traffic sign-visibility from 50 meters - daytime	Yes
“Designated pedestrian crossing” traffic sign-visibility from 50 meters – at night/ under poor visibility conditions	Yes

Any other unauthorized traffic sign on the same pole with the “Designated pedestrian crossing”	No
Any other awareness-raising solution on the “Designated pedestrian crossing” traffic sign	No
“Pedestrian crossing warning sign” in front of the pedestrian crossing	Yes
Visibility and recognisability of the “Pedestrian crossing warning sign”	Appropriate
Other warning signs for pedestrian crossing	No
Impaired detection because of the condition and track alignment of the road	Not obstructed on either side
Impaired detection because of installed, covering effect physical element	Not obstructed on either side
Impaired detection because of temporary covering effect	Not obstructed on either side
Attention-distracting traffic manoeuvre needed in front of/after the pedestrian crossing	No
Detection of the crossing for drivers arriving from the left curve	Not difficult
Any solution highlighting the lighting of the pedestrian crossing on the route	No
Adequacy of public lighting in the vicinity of the pedestrian crossing	Appropriate only on one side
Operational speed in front of the crossing (km/h)	51 - 60

Table 6: Value of parameters in direction 2 (out from the city – in the measured direction)

Parameter	Value
Road surface condition	Perfect
Outline of the road section in front of the pedestrian crossing	Straight
Crossing more than one lane in the same direction	No
Crossing a separate turning/accelerating/receiving lane	No
Speed limit (km/h)	40
Other, speed reducing intervention	No
Possible turning directions of the arriving vehicle traffic	Only from left turning
Another crossed pedestrian crossing in the same junction – going straight	No

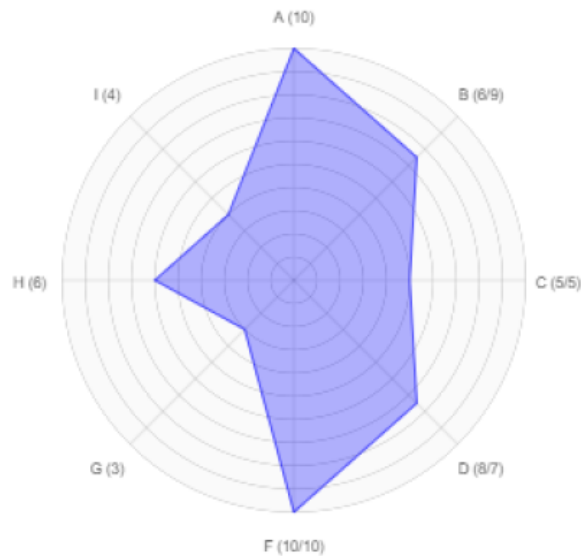
Other, awareness-raising element on the road surface in front of the pedestrian crossing	No
“Pedestrian crossing” road sign in front of the pedestrian crossing	Yes
“Pedestrian crossing” road sign condition and recognisability	Appropriate
“Designated pedestrian crossing” traffic sign - on the right side	Yes
Position of “Designated pedestrian crossing” traffic sign on the right side	In accordance with the law
“Designated pedestrian crossing” traffic sign - on the left side (or above the road)	No
“Designated pedestrian crossing” traffic sign-visibility from 50 meters - daytime	Yes
“Designated pedestrian crossing” traffic sign-visibility from 50 meters – at night/ under poor visibility conditions	Yes
Any other unauthorized traffic sign on the same pole with the “Designated pedestrian crossing”	No
Any other awareness-raising solution on the “Designated pedestrian crossing” traffic sign	No
“Pedestrian crossing warning sign” in front of the pedestrian crossing	Yes
Visibility and recognisability of the “Pedestrian crossing warning sign”	Inadequate
Other warning signs for pedestrian crossing	No
Impaired detection because of the condition and track alignment of the road	Not obstructed on either side
Impaired detection because of installed, covering effect physical element	Not obstructed on either side
Impaired detection because of temporary covering effect	Not obstructed on either side
Attention-distracting traffic manoeuvre needed in front of/after the pedestrian crossing	No
Detection of the crossing for drivers arriving from the left curve	Not difficult
Any solution highlighting the lighting of the pedestrian crossing on the route	No
Adequacy of public lighting in the vicinity of the pedestrian crossing	Appropriate only on one side
Operational speed in front of the crossing (km/h)	51 - 60

Based on the coded parameters, the following results were observed:

## Összesített biztonsági, szolgáltatási szint

6 / 10

### Szempon-t-csoportonkénti értékelés



#### Jelmagyarázat

A: Környezeti adottságok, elhelyezés, B: Forgalmi rend, C: Horizontális jelzésrendszer, D: Vertikális jelzésrendszer, E: Jelzőlámpás irányítás, F: Gyalogosok és járművezetők egymást történő észlelése, G: Észlelés éjszaka, közvilágítás, H: Gyalogos felállóhelyek, várakozási terület, I: Forgalom jellemzői

Figure 11: Results of the analysis by the PECA application

That is, the:

- Aggregated rating of safety and service level: 6/10
- The evaluation by criteria groups:
  - A: Location, environmental conditions: 10
  - B: Traffic management: 6 (direction 1); 9 (direction 2)
  - C: Horizontal traffic sign system: 5 (direction 1); 5 (direction 2)
  - D: Vertical traffic sign system: 8 (direction 1); 7 (direction 2)
  - E: Traffic light control (not relevant in this case)
  - F: Mutual detection of pedestrians and drivers: 10 (direction 1); 10 (direction 2)
  - G: Detection at night, public lighting: 3
  - H: Pedestrian stands, waiting area: 6
  - I: Traffic characteristics: 4

In its current state, the pedestrian crossing has received a medium rating (6 stars out of 10). It is favourable that the design of the site is simple, the road is in a good condition (criteria group A), the mutual detection of pedestrians and drivers is not hindered by the alignment of the road or any covering effects (criteria group F).

However, there are great potentials for improvement according to several criteria. For example, the intensity of the lighting is currently weak, there is a street lighting column only at the south side of the crossing (criteria group D). As previously presented, vehicle speeds are high, especially in light of the allowed speed limit (criteria group I). Road markings and pedestrian stands should also be improved (criteria groups C and H).

The most relevant road safety measures provided automatically by the application were the following.

Related to parameters independent of direction:

- Improvement of the condition of the road marking signing the pedestrian crossing
- Increase of the longitudinal width of the pedestrian crossing to 4.5 meters
- Provision of tactile pavement signs at the pedestrian stands on both sides

Related to parameters in direction 1:

- Improvement of the intensity of public lighting
- Reduction of vehicle speeds
- Application of solid centre line in front of the pedestrian crossing to avoid overtaking manoeuvres

Related to parameters in direction 2:

- Improvement of the intensity of public lighting
- Reduction of vehicle speeds
- Improvement of the visibility and recognisability of the pedestrian crossing warning sign



## 5 Design of the implementation-ready road layout concept plan

The presented ITS device was deployed temporarily for the duration of the speed measurements carried out as part of our Pilot Action, with the support of the road operator company. The location was selected based on the recommendation of the road operator. Their experiences, the previously happened two accidents and the results of our speed measurements also showed the need to reduce the road safety risks at the site.

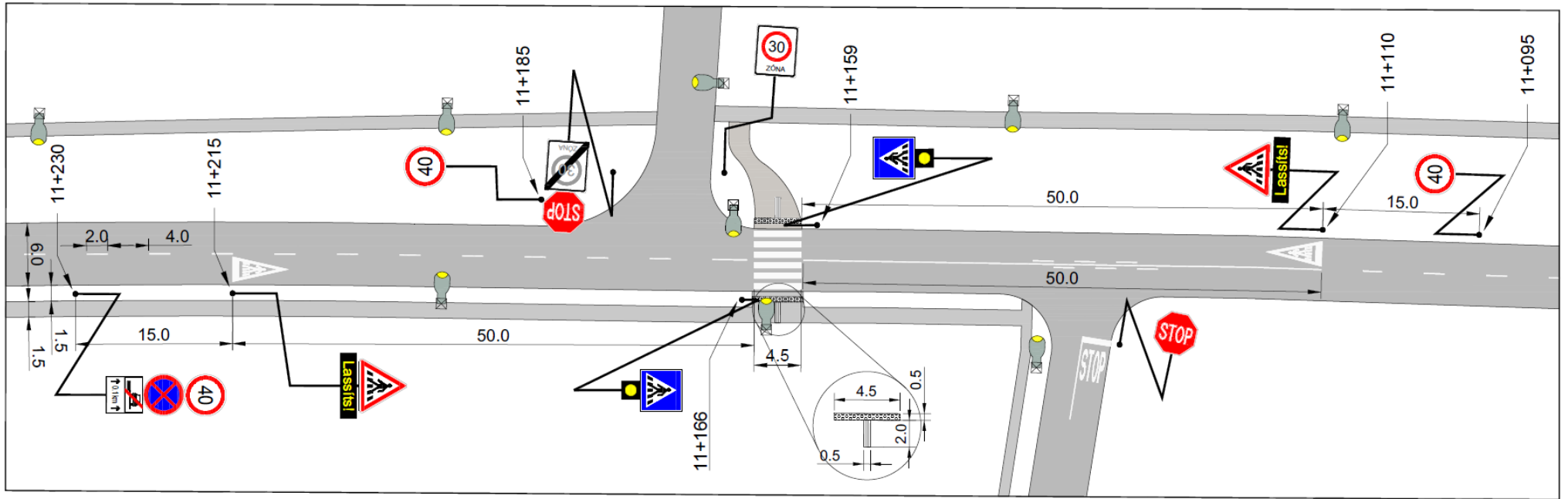
The PECA application rated the current level of road safety and service as medium by 6 stars out of 10 and also identified possible effective tools of reducing risks.

In accordance with these results, an implementation-ready road layout concept plan has been developed in our Pilot Action aiming to improve the safety at the investigated pedestrian crossing. The proposed measures were based on our speed measurement results and the additional risks identified during the road safety inspection:

- During our previous Pilot Action, we found that road signs activated by vehicles are effective in the field of speed management.
- During the current Pilot Action, we have shown that the prediction of danger (by warning signs) based on the above-mentioned operating principle has significantly reduced the average speed of the vehicles (by almost 10% in the line of the pedestrian crossing).
- However, we also found that in addition to warning, clarifying the expected behaviour is also a necessary task.
- With the help of the PECA software we identified the parameters and criteria with the greatest potential for improvement.

In line with the findings, the proposed interventions were the following:

- deployment of the proposed ITS device in both directions:
  - installation of a yellow blinker on the column of the designated pedestrian crossing sign
  - installation of the pedestrian crossing warning sign with interior lighting and “Lassíts!” LED text replacing the current, traditional warning sign
  - Operation of the device according to the previously presented operating principles (vehicle activated, depending on speed)
- Repetition of the 40 km/h speed limit in the measured direction (direction 2) 65 meters in front of the pedestrian crossing
- Introduction of a 40 km/h speed limit in direction 1, 65 meters in front of the pedestrian crossing
- Installation of a public lighting column on the north side of the pedestrian crossing
- Application of solid centre line in front of the pedestrian crossing in direction 1, in a length of 50 meters
- Increase of the longitudinal width of the pedestrian crossing to 4.5 meters
- Provision of tactile pavement signs at the pedestrian stands on both sides
- Improvement of the condition of the road marking signing the pedestrian crossing



## 6 Determining the potential effects of the Pilot Action

The investigation of the potential road safety related benefits of the proposed ITS device and other possible safety related interventions was based on two different approaches:

- First, the international literature was studied to determine the connection between the speed and accident risks/injury severity, especially focusing on pedestrian hits.
- Second, the previously introduced PECA application was used to code those parameters that are to be modified by the proposed interventions. The assessment was again performed using the new values and the results were compared.

### 6.1 Results based on the connection between speed and accident risks/injury severity

Driving at a high speed increases the odds of getting involved in an accident, and it also increases the severity of the injuries. Drivers need time to detect a potentially risky situation, make a decision about what to do, and react. At higher speeds, there is less time for all of these. In addition, at a higher speed, more energy is released when colliding with another vehicle, road user or obstacle.<sup>6</sup>

According to recent studies, a 1% increase of the speed leads to 3% increase in the number of road accidents. This depends also on the initial speed. The larger the increase in speed, the steeper the increase in accident risk. This relationship is true only in general, the exact connection between speed and accidents is affected by initial speed and the characteristics of the road also. Individual speed differences can be also relevant, faster drivers have higher accident risks.<sup>6</sup>

Some studies found that the rate of accidents increases faster with the increase of speed on minor roads than on major roads. The main characteristics that count are lane width, junction density and traffic flow, these had impact on speed-accident relationship.<sup>7</sup>

Nilsson, a Swedish researcher, has created a Model<sup>8</sup> for the relationship of speed and accident risk. It is called the Power Model. The theory is based on kinetic principles and empirical data. According to the theory, the change of the number of the accidents can be predicted from the change of speed with the help of a set of power functions. Accordingly, based on the work by Nilsson and applying the empirical update of Elvik et al.<sup>9</sup>, a 1 km/h increase of speed on a 120 km/h road increases the rate of accidents by 2%, on a 50 km/h road, by 3%.

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<sup>6</sup> European Commission, Speed and Speed Management, European Commission, Directorate General for Transport, February 2018.

[https://ec.europa.eu/transport/road\\_safety/sites/roadsafety/files/pdf/ersosynthesis2018-speedspeedmanagement.pdf#page=28&zoom=100,78,104](https://ec.europa.eu/transport/road_safety/sites/roadsafety/files/pdf/ersosynthesis2018-speedspeedmanagement.pdf#page=28&zoom=100,78,104)

<sup>7</sup> Aarts, L., & van Schagen, I. (2006) Driving speed and the risk of road crashes: A review Accident Analysis & Prevention Volume 38, Issue 2, March 2006, Pages 215-224

<sup>8</sup> Nilsson, G. (2004) Traffic safety dimensions and the power model to describe the effect of speed on safety. Bulletin 221, Lund Institute of Technology, Lund.

<sup>9</sup> Elvik, R., Høye, A., Vaa, T. & Sorensen, M. (2009) The handbook of road safety measures, 2nd edition. Amsterdam [etc.], Elsevier

The Power Model's formula for relationship between speed and accident risk is the following:

$$A_2 = A_1 \left( \frac{v_2}{v_1} \right)^2$$

In words: the number of the accidents after speed change ( $A_2$ ) equals the number of the accidents before the speed change ( $A_1$ ) multiplied by the new mean speed ( $v_2$ ) divided by the former mean speed ( $v_1$ ), raised to the square power.

There are similar results of British studies<sup>10,11</sup> where a 1 km/h speed change increased the number of accidents by 1-4% on urban roads, and 2.5-5.5% on rural roads. The lower numbers belonged to higher quality roads. The relationship between speed and accidents depends largely on characteristics of the road and traffic, and also on the behaviour and characteristics of drivers using the roads, like gender, age, drink driving and seat belt wearing.

Elvik and colleagues made a systematic literature research and meta-analysis of 96 studies that made 460 estimations about relationship of speed and accidents in order to inspect the validity of the Power Model's formula.<sup>12</sup> Their results confirmed the Power Model with small modifications. In a later report<sup>13</sup>, Elvik has established the following exponents for rural roads in case of each type of accidents:

Table 7: Proposed exponents for Power Model in case of different type of accidents on urban roads<sup>13</sup>

Accident or injury severity	Exponent	95% confidence interval
Fatalities	3.0	(-0.5, 6.5)
Seriously injured road user	2.0	(0.8, 3.2)
Slightly injured road user	1.1	(0.9, 1.3)
All injured road users (severity not stated)	1.4	(0.4, 2.4)
Fatal accidents	2.6	(0.3, 4.9)
Serious injury accidents	1.5	(0.9, 2.1)
Slight injury accidents	1.0	(0.6, 1.4)
All injury accidents (severity not stated)	1.2	(0.7, 1.7)
Property-damage-only accidents	0.8	(0.1, 1.5)

<sup>10</sup> Taylor, M., Lynam, D.A. & Baruya, A. (2000) The effect of drivers' speed on the frequency of accidents. TRL Report TRL421. Transport Research Laboratory, Crowthorne.

<sup>11</sup> Taylor, M., Baruya, A., & Kennedy, J.V. (2002) The relationship between speed and accidents on rural single carriageway roads. TRL Report TRL511. Transport Research Laboratory, Crowthorne.

<sup>12</sup> Elvik, R., Christensen, P., & Amundsen, A (2004). Speed and road accidents: an evaluation of the Power Model. TØI report 740/2004. Oslo.

<sup>13</sup> Elvik, R. (2009). The Power Model of the relationship between speed and road safety. Update and new analyses. TØI report 1034/2009. Oslo.

The results verified that there is a strong connection between speed and accident risk. The statistical connection does not necessarily mean that there is a causal relationship between the two components, but there are several proofs that the connection is causal:

- There is strong statistical connection between speed and accidents there are no other factors that can be assumed to be connected so strongly to accidents.
- When speed changes there is also a change in the number of accidents, it is a consistent relationship.
- There are several studies that verified the causal relationship between the two. The observed changes were independent from any other environmental characteristics.
- Also, the physical regularities support the causal connection.<sup>1112</sup>

In our example, the investigated ITS device was able to decrease the average speed at the pedestrian crossing from 47.7 km/h to 43.2 km/h. Thus, using the Power Model's formula with the proposed exponents, the number of fatal accidents could be reduced by 22.7%, while the number of serious and slight injury accidents could be reduced by 13.8% and 9.4%, respectively, as a consequence of reduced speed.

Besides the accident risk, the speed also influences the severity of injuries. Higher driving speeds lead to higher collision speeds and thus to severer injury. At collision speeds below 30 km/h, collisions between motorised vehicles and pedestrians are much less likely and if they do happen, they do not usually result in a fatality.<sup>14</sup> The injury severity of the road users involved in a crash is not only determined by the collision speed, but also by the mass difference between the participants and by the vulnerability of them. Vulnerable road users like pedestrians are more likely injured in a crash than car occupants.<sup>15</sup> The relation between the speed and the injury severity is more direct and less complicated than between speed and accident risk.<sup>15</sup>

The higher the impact speed, the higher the accident severity. When a car and a pedestrian crash, the survival rate of the latter dramatically decrease by the impact speed of the car. According to studies<sup>16</sup>, at a collision speed of 20 km/h nearly all pedestrians survive a crash with a passenger car; about 90% survive at a collision speed of 40 km/h, at a collision speed of 80 km/h the number of survivors is less than 50%, and at a collision speed of 100 km/h only 10% of the pedestrians survive.<sup>15</sup>

Other results<sup>17</sup> indicated that only 5 percent of pedestrians would die when hit by a vehicle traveling at 30 km per hour or less. This compares with fatality rates of 40, 80, and nearly 100 percent for striking speeds of 50, 65, and 80 km per hour or more respectively. Pasanen

<sup>14</sup> European Road Safety Observatory Road Safety Thematic Report – Pedestrians 2021 [https://ec.europa.eu/transport/road\\_safety/sites/default/files/road\\_safety\\_thematic\\_report\\_pedestrians\\_tc\\_final.pdf](https://ec.europa.eu/transport/road_safety/sites/default/files/road_safety_thematic_report_pedestrians_tc_final.pdf)

<sup>15</sup> SWOV Fact Sheet. The relation between speed and crashes. 2012. <https://www.littlerock.gov/media/2484/the-relation-between-speed-and-crashes.pdf>

<sup>16</sup> Rosén, E., Stigson, H. & Sander, U. (2011). Literature review of pedestrian fatality risk as a function of car impact speed. In: Accident Analysis and Prevention, vol. 43, nr. 1, p. 25-33.

<sup>17</sup> W.A. Leaf and D.F. (1999) Preusser Literature Review on Vehicle Travel Speeds and Pedestrian Injuries. <https://one.nhtsa.gov/people/injury/research/pub/hs809012.html>

(1993)<sup>18</sup> and Anderson et al. (1997)<sup>19</sup> examined specific crashes and both determined that reducing vehicle speeds would have reduced pedestrian injuries in two ways: by eliminating some crashes altogether, and by reducing injury severities in the others.

Richards (2010)<sup>20</sup> observed a gradual rise of risk of fatality up to impact speeds of around 50 km/h. Above 50 km/h the risk increases more rapidly with the speed: the risk increases 3.5 – 4.5 times from 50 to 65 km/h. Another study<sup>21</sup> saw that over 60% of pedestrian fatalities occurred in an area where the speed limit was 50 km/h or lower. Although the risk of pedestrian fatality may seem relatively low at 50 km/h, the large number of pedestrian accidents at these speeds leads to a lot of pedestrian fatalities at 50 km/h or less.

Of course, there are several other factors that influence the fatality rate of a pedestrian hit by a car beside the impact speed. These are: victim age, victim height and weight, victim gender, victim body mass index (BMI), vehicle type, vehicle curb weight, and vehicle bumper height.<sup>22</sup>

To quantify the effects of the proposed Pilot Action on possible injury severity, the diagram published by Tefft (2011)<sup>22</sup> was used. In the diagram, the risk of severe injury (left) and death (right) was determined in relation to impact speed (by averaging data from 422 pedestrian hits).

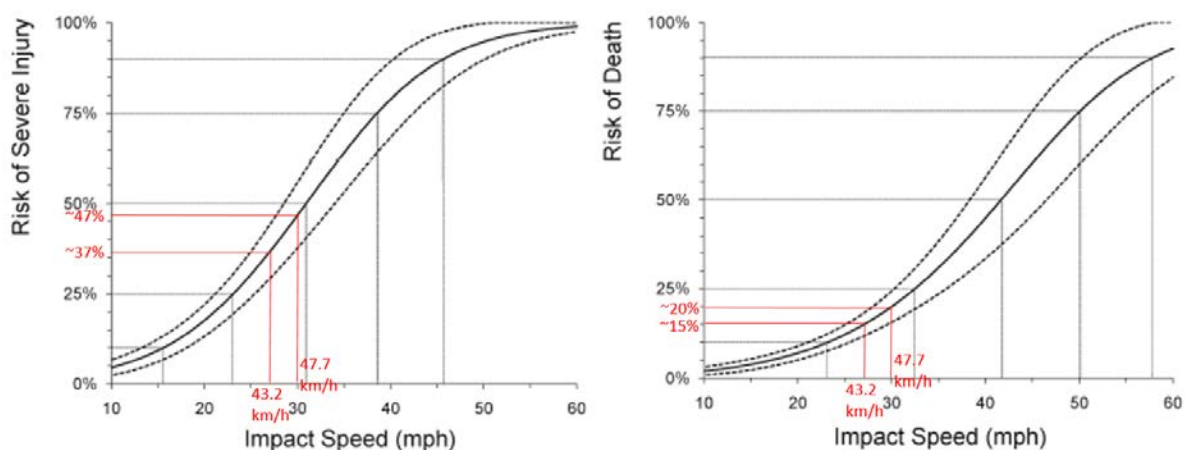


Figure 12: Change of the risks of severe injury and death<sup>22</sup>

<sup>18</sup> Pasanen, E. (1993). The video recording of traffic accidents. Report No. 1993:4, March 1993, Helsinki Finland City Planning Department, 11 pp.

<sup>19</sup> Anderson, R.W.G., McLean, A.J., Farmer, M.J.B., Lee, B.H., & Brooks, G.B. (1997). Vehicle travel speeds and the incidence of fatal pedestrian crashes. *Accident Analysis and Prevention*, 29(5), pp. 667-674, 1997.

<sup>20</sup> Richards, D. C. (2010) Relationship between Speed and Risk of Fatal Injury: Pedestrians and Car Occupants. Transport Research Laboratory. Department for Transport: London. [https://nacto.org/docs/usdg/relationship\\_between\\_speed\\_risk\\_fatal\\_injury\\_pedestrians\\_and\\_car\\_occupants\\_richards.pdf](https://nacto.org/docs/usdg/relationship_between_speed_risk_fatal_injury_pedestrians_and_car_occupants_richards.pdf)

<sup>21</sup> Crinson, L., Cuerden, R. and Vandrevalla, T. (2009) Review of Pedestrian Fatal Road Traffic Accidents. TRL Client Project Report CPR103. Prepared for the Department for Transport Project Record T501V. Crowthorne: TRL.

<sup>22</sup> Tefft, B.C. (2011). Impact Speed and a Pedestrian's Risk of Severe Injury or Death (Technical Report). Washington, D.C.: AAA Foundation for Traffic Safety.

As a result of the reduced speed due to the proposed ITS solution, the risk of severe injury decreases to 37% from 47%, and the risk of death decreases to 15% from 20%. Note, that the decrease can be even higher, since several other interventions were proposed in our Pilot Action besides the ITS device that can achieve an even greater decrease in speed.

## 6.2 Results based on the PECA application

In chapter 4, the safety and service level of the pedestrian crossing was assessed in its current condition, using the PECA application. Based on the proposed interventions of our Pilot Action, several parameters can be improved. In order to determine the impact of these measures related to the rating of the pedestrian crossing, the assessment was again performed using the new values and the results were compared.

In the following table, only those parameters have been summarized, the value of which are to be changed as a result of the proposed road safety interventions.

Table 8: New value of parameters after the implementation of the proposed interventions

<b>Parameters independent of direction</b>	
Condition of the road marking signing the pedestrian crossing	Good
Longitudinal width of the pedestrian crossing	Appropriate
Tactile pavement signs at the pedestrian stands – two sides of the crossing	Yes, on both sides
<b>Parameters in direction 1</b>	
Speed limit (km/h)	40
Other, speed reducing intervention	Yes (Slow down!)
Prohibition of overtaking by a solid centre line	Yes, in a length of at least 30 meters
Other warning signs for pedestrian crossing	Yes, yellow blinker
Adequacy of public lighting in the vicinity of the pedestrian crossing	Appropriate on both sides
Operational speed in front of the crossing (km/h)	41 - 50
<b>Parameters in direction 1</b>	
Other, speed reducing intervention	Yes (Slow down!)
Visibility and recognisability of the “Pedestrian crossing warning sign”	Adequate
Other warning signs for pedestrian crossing	Yes, yellow blinker

Adequacy of public lighting in the vicinity of the pedestrian crossing	Appropriate on both sides
Operational speed in front of the crossing (km/h)	41 - 50

When quantifying the potential effect, we assumed that the set of interventions could move the operational speed to the range of 41-50 km/h (in both directions). This was a reasonable assumption considering that the presence of the ITS device alone was able to decrease the v85 speed to 51-54 km/h from 56-59 km/h in direction 2.

Based on the PECA analysis, the following results were obtained in the improved scenario.

### Összesített biztonsági, szolgáltatási szint



### Szemponc-csoportonkénti értékelés

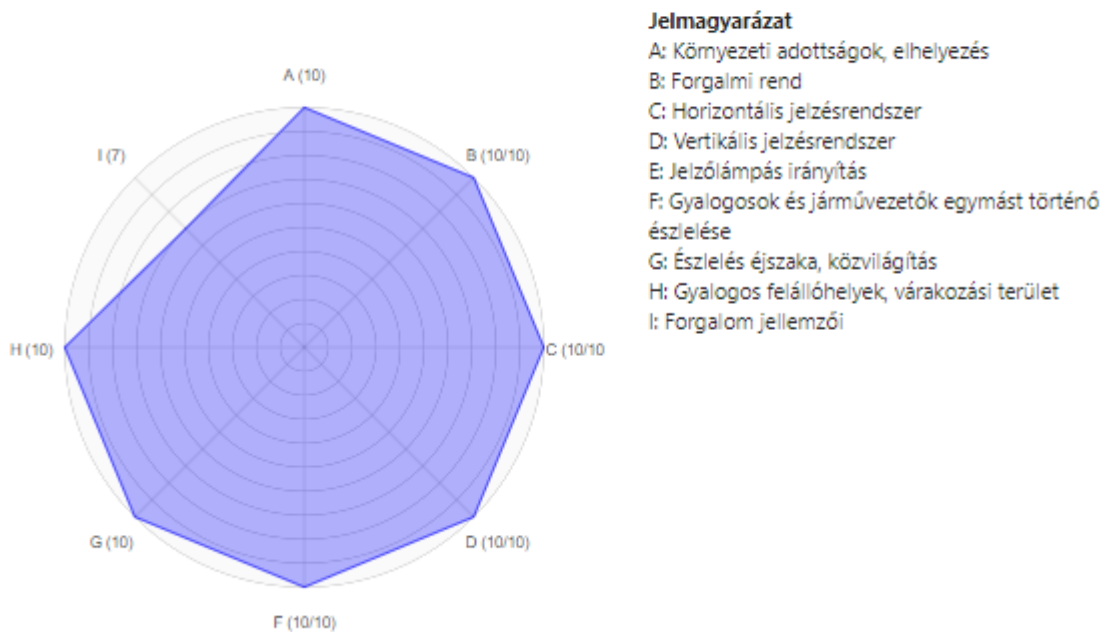


Figure 13: Results of the analysis by the PECA application after implementation of interventions

That is, the:

- Aggregated rating of safety and service level: 9/10
- The evaluation by criteria groups:
  - A: Location, environmental conditions: 10
  - B: Traffic management: 10 (direction 1); 10 (direction 2)
  - C: Horizontal traffic sign system: 10 (direction 1); 10 (direction 2)
  - D: Vertical traffic sign system: 10 (direction 1); 10 (direction 2)
  - E: Traffic light control (not relevant in this case)



- F: Mutual detection of pedestrians and drivers: 10 (direction 1); 10 (direction 2)
- G: Detection at night, public lighting: 10
- H: Pedestrian stands, waiting area: 10
- I: Traffic characteristics: 7

As a result of the proposed interventions, the level of road safety and service at the investigated pedestrian crossing could increase to an excellent 9/10 rating. Only the traffic characteristics criteria group did not receive a perfect rating, as the operating speeds were still assumed to be in the range above the speed limit of 40 km/h. If the proposed measures resulted in a greater reduction in speed, this value could also be changed to 10.