Effect of Central Pedestrian Refuges on Calming of Traffic in Their Vicinity

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Abstract. Central pedestrian refuges are one of the traffic calming measures used in small towns and villages located on through routes. Their main function is to protect vulnerable road users from safety hazards and reduce the 85th percentile speed \( v_{85} \) before the island. In order to determine the efficiency of the central refuges in obtaining reduction of \( v_{85} \) speed to the desired level before the islands the authors measured the speeds both before and after the islands of different width in specific locations along the stretch i.e. in the entry, central and in the exit zones. The central refuges were typically 2 m wide, imposing a 1 m deflection of vehicles. Other deflections, namely by 2.5 m and 3 m were imposed by two of the analysed islands. In one case the vehicle path was not deflected, namely at the refuge/chicane combination located on the departure lane. The research covered in total ten different cases of crossings in villages on regional roads. Most of the analysed pedestrian islands were accompanied with hatched areas before and after the island with a conventional 1:5 taper. All the islands are located in a residential areas, yet with different types of adjacent developments. In all the analysed cases the maximum permitted speed during daytime was 50 km/h. Speed measurements were carried out with special traffic detection devices equipped with automatic traffic speed and volume recording function. The analyses considered free-flow average and \( v_{85} \) speeds. In a few cases buildings were located close to the roadway edge right after the central refuge. In the other cases the road was surrounded by a rural area or a forest. In two cases the island was followed by a horizontal curve affecting the sight line. The desired speed reduction or reduction down to the statutory speed for residential areas before the island was not obtained in all the analysed cases. In a few cases average speed under free-flow conditions of ca. 50 km/h and \( v_{85} \) speed of 55 km/h were obtained for the islands located in the village centres with houses located close to the road edge. Without residential buildings located close to the road edge before the island and with a restricted view on the further course of the road reduction of both speeds was obtained after the island. Smaller speeds were noted also on the road sections where greater horizontal deflections were imposed. The greatest speed reduction along the island was noted on the sections with reduced visibility or with residential buildings in close proximity. The degree of deflection was found to have a smaller effect.

1. Introduction

The economic growth entails an increase in the road traffic and growing problems related to ensuring the safety of traffic, including also the safety of pedestrians. These problems yet intensify on stretches of through routes within the boundaries of smaller towns and villages. As a countermeasure, central refuges for pedestrians are installed in many such places. In most cases, the main factor which has a
Direct bearing on both the number of road incidents and their severity are the speeds of travel. The various design guidelines, used in Poland [1, 2, 3, 4] or in other countries [5, 6, 7, 8, 9, 10] recommend installation of central refuges where it is necessary to obtain reduction of $v_{85}$ speed to below 50 km/h.

The respective national design guidelines approach the issue of designing the pedestrian islands in a different manner, specifying the requirements at different levels of detail. In the Polish publications and guidelines [1, 2, 3, 4] the emphasis is put on the geometry of the islands, the widths of the travel lanes and the sharpness of taper angles, depending on the location along the stretch of the road within the boundaries of the settlement. Conversely, such detailed geometrical requirements are not given, for example, in the Swedish guidelines [5]. However, various auxiliary treatments are recommended therein, depending on the volume of traffic. For smaller hourly volumes of traffic, elevating of the pavement surface is recommended to facilitate pedestrians travel. Where the hourly volume is high, protective fencing is recommended to be provided along the island access path to prevent illegal road crossing by pedestrians. The American guidelines [6] take a different approach, being quite specific about the geometrical requirements in the immediate vicinity of the pedestrian refuge islands. They require surrounding them with raised curbs and give detailed requirements for placement of marking/signage in their vicinity. The German guidelines [7], in turn, pay a lot of attention to the visibility issues. Special consideration is given to the width of central refuges which should be greater if a cycle path is planned parallel to the crossing. The requirements regarding the travel lane width to ensure traffic handling capacity appropriate to the local conditions are also given. The German guidelines are also quite specific about the location of pedestrian crossings depending on the shape of the central islands located in the entry zones of settlements. Finally, the relationship between the intervals of the subsequent traffic calming measures and the expected speed reduction was the subject of research described in [11].

Summing up, we can say that while the respective publications and guidelines cover the specific issues pertaining to the design of pedestrian islands in detail, the emphasis is put on different aspects depending on the country. This paper attempts to investigate how siting of the pedestrian refuges along the stretch of the road in the village is related to the obtained traffic calming. The objective is to determine the degrees of speed reduction after the islands located in different zones. With the island located in the entry, exist and village centre zones the authors analysed also the surrounding environment conditions. Also considered are the geometric parameters of the pedestrian refuges and the road layout before and after the island.

2. Research method and compilation of results

According to the data published in [8] in the case of the analysed road one should expect reduction of speed due to pedestrian islands in the region of 13–23%. Considering this, the authors set out to check if the speed reductions obtained in Poland correspond to the results published in [8]. To this end, a number of measurements were carried out in free or stable traffic flow situations in a few villages located on regional roads, where pedestrian islands were retrofitted in the period 2012–2016. All the analysed roads had pavements in good condition, new upright signs and pavement markings. The stretch of the road within the village boundaries was ca. 500–1000 m long. From the completion of retrofitting works some traffic incidents were noted on the analysed sections, yet they did not involve pedestrians. As such, the scope of this paper has been limited to investigating the speed reduction issue.

For all the test sections the speed measurements were taken between 10:00–15:00 hrs. in dry weather, including ca. 70 veh. in free-flow and up to 100 veh. in stable (more congested) flow conditions. The equipment used for testing were SR4 traffic detection devices with automatic speed recording. Additionally, traffic volumes were measured in each case, including determination of the percentage of heavy goods vehicles. The speed data were divided into traffic directions to calculate the 85th percentile and average speeds in free and stable flow conditions and the differences of speed before and after the pedestrian islands.
With most of analysed central refuges located in the settlement areas (figures 1–10), in two cases they are located in the entry zones and preceded by ghost islands (figure 1 and figure 9). The related pedestrian refuge islands are located quite close to the ghost island, namely ca. 170 m away. In one case, the bubble shaped ghost island is followed by a horizontal curve, obscuring the view on the further course of the road at the exit from the settlement area (figure 1). In the other case, the pedestrian refuge is followed by a symmetrical ghost island and good visibility of the road ahead is ensured, both in settlement entry and exist zones (figure 9).

Figure 1. Aerial view of the central refuge located after the village entry, bubble-shaped ghost island (test sections No. L1 and L2)

Figure 2. Skyline of settlement on one side of the road as seen by the driver entering the village near the pedestrian refuge (2 m wide platform; taper of 1:8 before and 1:6.5 after the island, heading to the village centre)

The two pedestrian refuges are located between the end of entry zone and the beginning of the central area of the settlement. The approach section in these cases is surrounded by farm fields (figure 6) or by a forest (figure 4). After the central refuge the settlement area starts, with nearby located residential buildings (figure 4).

One pedestrian refuge was installed in the central area of the village between two bus bays. This island is peculiar and has an asymmetric shape (figure 7 and figure 8) imposing 1 m deflection on one side and 3 m deflection on the other. In this case the peculiar feature of the island is that it is followed by an open bus bay which can be used by regular traffic.

Overall, the speed measurements were done in both directions of traffic near five pedestrian refuges having different geometries of platforms and sharpness of their end treatment markings. A few of them were located on a road stretch either with buildings located in close proximity to the road (figure 8) or only 80 m before the village centre (figure 4 and figure 6). Two other central refuges under analysis are located in a residential area with buildings located away from the roadway edge (figure 2 and figure 10). On a few test sections no houses were noted in the vicinity and the entry or exit section to the settlement was surrounded by a forest or farmland (test sections No. L2, L3, L4, L5 and L6). This said, all the analysed pedestrian refuges are located in a built-up area designated by D-42 entry signs. The B-33 speed limit sign was not found in any of the analysed cases.

The speed distribution parameters calculated from the measurement data and the parameters of the pedestrian refuge islands are compiled in Table 1.
Figure 3. Aerial view of the refuge/chicane combination on the village entry section (test sections No. L3 and No. L4)

Figure 4. Skyline of the village as seen by the driver entering the village near the refuge/chicane combination (2 m wide platform; 1:5 taper)

Figure 5. Aerial view of the pedestrian refuge on the village entry section (test sections No. L5 and No. L6)

Figure 6. Skyline of the village as seen by the driver entering the village (2 m wide platform; 1:5 taper)

Figure 7. Aerial view of the pedestrian refuge in the village centre area between two bus bays (test sections No. L7 and No. L8)

Figure 8. Driver’s view of the road after the pedestrian refuge (4 m wide platform; taper of 1:5 at the side imposing 3 m and 1:15 at the other side imposing 1 m deflection)
### Table 1. Compilation of measurement data.

| No. | Test section | Siting                        | Deflection, m | Speed before refuge $v_{85}^{before}$ | Speed before refuge $v_{av}^{before}$ | Speed before refuge $v_{pp}^{before}$ | Speed after refuge $v_{85}^{after}$ | Speed after refuge $v_{av}^{after}$ | Speed after refuge $v_{pp}^{after}$ |
|-----|--------------|-------------------------------|---------------|----------------------------------------|----------------------------------------|----------------------------------------|--------------------------------------|--------------------------------------|--------------------------------------|
| 1   | L1           | Entry zone                    | 1.0           | 64                                     | 55                                     | 55                                     | 71                                   | 61                                   | 61                                   |
| 2   | L2           | Exit zone                     | 1.0           | 71                                     | 63                                     | 63                                     | 64                                   | 58                                   | 58                                   |
| 3   | L3           | Entry zone – central area      | 2.5           | 76                                     | 68                                     | 67                                     | 53                                   | 48                                   | 47                                   |
| 4   | L4           | Central area – exit zone       | 0.0           | 53                                     | 48                                     | 47                                     | 68                                   | 59                                   | 58                                   |
| 5   | L5           | Entry zone – central area      | 1.0           | 76                                     | 65                                     | 64                                     | 65                                   | 58                                   | 57                                   |
| 6   | L6           | Central area – exit zone       | 1.0           | 58                                     | 51                                     | 51                                     | 64                                   | 57                                   | 57                                   |
| 7   | L7           | Central area                   | 1.0           | 57                                     | 52                                     | 52                                     | 54                                   | 48                                   | 47                                   |
| 8   | L8           | Central area                   | 3.0           | 56                                     | 45                                     | 44                                     | 63                                   | 54                                   | 54                                   |
| 9   | L9           | Entry zone                     | 1.0           | 64                                     | 56                                     | 54                                     | 67                                   | 57                                   | 55                                   |
| 10  | L10          | Exit zone                      | 1.0           | 59                                     | 52                                     | 51                                     | 63                                   | 54                                   | 51                                   |

### 3. Results and discussions

Considering the diversity of the speed data and speed reduction values the authors decided to establish relationships between the measured data, ordering them depending on the speed reduction index for the entry section and village centre area and separately for the exit section. In addition, all the measurement speeds are related to the 85th percentile speed $v_{85}$ in figure 11 and to the average free-flow speed in figure 12.

The analysis of the $v_{85}$ values presented in figure 11 showed that pedestrian refuges have no significant speed-reducing effect. Speed reduction after the pedestrian refuge was obtained only in four cases, by ca. 5–14% in three and by ca. 30% in one case. Siting of the pedestrian refuge between the...
end of entry zone and the beginning of the central area before a horizontal curve obstructing the view down the road with residential buildings in close proximity had a significant effect on the obtained speed reduction. Note that in each case speed reduction was obtained in a differently sited location. As an example, at the village entry preceded by a curve to the left and with visible residential buildings located close to the roadway a 14% speed reduction was recorded after the pedestrian refuge (figure 6 and test section No. L5).

In another case, in the exit zone with a curve to the right and without residential buildings in close proximity, both before and after the refuge island, 10% speed reduction was obtained (test section No. L2). The greatest reduction of 30% was obtained for the pedestrian refuge located between the end of entry zone and beginning of the village centre area (figure 4 – test section No. L3, figure 11 – exception No. 4). In this case the approach section is surrounded by a forest and the horizontal deflection ends at a bridge with residential buildings situated close to the roadway edge. The bridge is followed by a curve to the right, that obscures view down the road. The last of the analysed cases was an asymmetric pedestrian refuge located on a straight road section in the village centre with residential buildings in close proximity to the roadway edge and very good view down the road (figure 8 – test section No. L7, figure 11 – exceptions No. L1 and No. L3). In this case reduction of speed by 5% was noted. In the other cases the pedestrian refuges were installed on straight sections giving the driver very good visibility of the road ahead. The surrounding environment includes residential buildings, either in close proximity or more distant from the road, farm fields or forest groves. The above factors had a different effect on the perception of the drivers who, in the absence of obstacles deflecting the vehicles and being sure of safe passage along the pedestrian refuge did not reduce their operating speed.

The thick dashed line in figure 11 represents the probable speed variation tendencies in the entry zone and in the village centre area and, separately, in the exit zone. Higher approach speeds yielded a greater, proportional reduction of the departure speed after the island. The one and only exception to that was the asymmetric pedestrian refuge located in the village centre area with buildings in a close proximity. The smallest speed values both before and after the island were recorded at the side deflecting the vehicles by 1 m. On the other side, deflecting the vehicles by 3 m the travel lane continues into an open bus bay and 12% increase of speed was noted after the refuge there. This anomaly is attributed to the passable bus bay area, lack of nearby buildings and location close to the village exit. Similar proportions of changes of the analysed parameters were noted in the exit zone, where the speed change after the island was proportional to the level of the approach speed. The factors influencing the speed variation at the pedestrian refuges included larger distance to the nearest buildings, lack of indications of probable pedestrian traffic and forest or open rural area visible right after the pedestrian refuge.

Considering the obtained, high values of $v_85$ the authors carried out the same compilation of average free-flow speeds. According to the official definition, in the free-flow a driver has a clear view down the road as it not obstructed by any preceding vehicle. Small hourly traffic volume on the regional roads under analysis resulted in small differences, i.e. ca. 1 km/h between the free-flow and stable-flow speeds. Accordingly, the data in figure 12 are limited to free-flow traffic, since in this situation the operating speed could be influenced by visibility of the road ahead or features of the surrounding environment seen by the driver after the island, including nearby or distant houses. Conversely, in a stable traffic flow, the driver’s visual field is partly reduced by the outline of the preceding vehicle.

The analysis of the average speeds presented in figure 12 showed that approach speeds in excess of 60 km/h were noted only in three cases (tests sections No. L2, L3 and L5). Higher approach speeds are attributed to the surrounding environment, i.e. forest (test section No. L3) or farm fields and lack of any buildings in the proximity of the pedestrian refuge (test sections No. L2 and L5). In the other cases the average approach speeds were smaller than 55 km/h. Moreover, in two cases values smaller than 50 km/h were obtained (test sections No. L4 and L8). The pedestrian refuges in question are completely
different from each other in terms of design, the common feature being the approach section location which was in the village centre. In one case, residential buildings are situated close to the island and there is a side obstacle in view, namely a bridge located right before the island (test section No. L4). In the other case, with no buildings in proximity of the road on the approach section, the asymmetric shape of island imposes the greatest horizontal deflection of all (test section No. L8). The analysis showed that in most cases the average departure speeds did not exceed 60 km/h. Conversely, the previously mentioned pedestrian refuges where the smallest approach speeds were noted did not make the drivers slow down and, instead, they tended to accelerate after passing the island, which is attributed to very good visibility conditions and lack of nearby houses in both cases.

Figure 11. Calculated free-flow $v_{f5}$ values and speed reduction index for passage along the pedestrian refuge

Exceptions:
1 and 3 – pedestrian refuge islands located in the village centre, with residential buildings in close proximity, between two bus bays, speeds before and after the pedestrian refuge are close to the speed limit in residential areas,
2 – pedestrian refuge islands located in the entry, the road is surrounded by distant buildings before the pedestrian refuge and farm fields after it, resulting in the operating speeds exceeding the 50 km/h speed limit in residential areas,
4 – pedestrian refuge island located between the end of entry zone and the beginning of the village centre area with a forest surrounding the road before the island, resulting in high approach speeds, which become reduced to the speed limit in residential areas after it due to a large horizontal deflection.

Smaller departure speeds (<50 km/h) were noted in two cases, and these featured pedestrian refuges with completely different engineering (test sections No. L3 and No. L7). In the first case, the island is located in the village centre with residential buildings situated in close proximity to the road and imposes a typical horizontal deflection by 1 m (test section No. L7). The refuge is located on a straight section, giving the driver very good visibility of the road ahead. The second of the two pedestrian refuges is located between the end of entry zone surrounded by a forest and the beginning of the village centre.
with residential buildings situated in close proximity. It is followed directly by a bridge being a major roadside obstacle (test section No. L3). The existing trees adjacent to the roadway edge largely obscure the driver’s field of view to the right. In both cases, the lower departure speeds were caused by the presence in view of roadside features, including nearby buildings, bridge parapets and existing vegetation.

Figure 12. Calculated stable flow $v_{85}$ values and speed reduction index for passage along the pedestrian refuge

Exceptions: designated same as in Figure 11.

The thick dashed line in figure 12, same as in the previous analysis, represents the probable speed variation tendencies in the entry zone and in the village centre area and, separately, in the exit zone. Higher speeds before the island yielded a greater, proportional reduction of the departure speed $s$. Four departures from this pattern did occur, same as previously, which are marked in figure 12.

It must be clearly stated that when the average speeds are considered, the pedestrian refuge islands do have a speed reducing effect in their vicinity. However, in a majority of the analysed test sections the average free-flow speeds exceeded the statutory speed limit for residential areas in Poland. The surrounding environment was analysed to show that the factors relevant to the level of operating speeds are the buildings and visibility conditions in the immediate vicinity of the pedestrian refuge, influencing the driver’s perception of the surroundings and alerting the driver of probable pedestrian traffic.

4. Conclusions

The analyses of $v_{85}$ carried out under this research showed that only in four cases the pedestrian refuges had a speed reducing effect, including only one case where the departure speed was close to the speed limit in residential areas in Poland. Siting had a decisive bearing on the speed reduction obtained in this
case, namely location between the end of entry zone and the beginning of the centre area with the built-up area infrastructure in view. These conditions, accompanied with the width of the platform of the refuge/chicane combination determining the amount of horizontal deflection and reduced visibility of the road ahead by the curve to the right, starting after the bridge, resulted in such a big, i.e. by over 20 km/h reduction of the operating speeds of vehicles. Moreover, locations in the entry zones, devoid of residential buildings in close proximity feature high speeds of vehicles on the section leading to the pedestrian refuges, close to the speeds of travel outside settlements. Conversely, much smaller approach speeds were noted on the test sections located in the village centre areas, which were close to the 50 km/h speed limit in residential areas and, as a result, smaller were also the amounts of speed reduction.

Similar relationships were noted for average free-flow speeds and their values were much closer to the speed limit in residential areas.

The authors believe that speed reducing effect of the pedestrian refuges depends, to a large extent, on their siting. The relevant external stimuli at the pedestrian refuge location, including nearby buildings, clear signs/markers and, last but foremost, limited view down the road impose on the driver a conservative behaviour, having a desired effect on their driving speed at the pedestrian refuge islands. Also relevant is the pedestrian refuge geometry, namely sharpness of approach taper and the amount of the imposed horizontal deflection. Although not conclusively demonstrated by this research, most probably due to location of an open bus bay after the pedestrian refuge imposing the greatest horizontal deflection, this parameter, together with the sharpness of approach taper and also the siting of the refuge and presence of stimuli affecting driver’s perception can have a significant bearing on the degree of the obtained speed reduction.

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