The Design and Location Characteristics of Wildlife Overpasses in Hungary

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Abstract: Hungary's motorway network has developed significantly over the past twenty years. These developments have increased the length of fenced roads, which also means increased habitat fragmentation effects. Wildlife crossings have been built on new sections to reduce isolation caused by roads. This study examined 57 wildlife overpasses using satellite imagery. We determined the internal and overall widths of the crossings, their total length and the length of the noise barriers, as well as the width-to-length ratio. The crossings were classified according to ramp design, noise barrier material and noise barrier run-down. In addition, a surface cover map was used to examine landscape features within 500 m of the crossings and evaluate the crossings' placement. The median value of the inner width was 16.1. The median value of the width-to-length ratio was 0.13. Based on this, we concluded that the wildlife crossings in Hungary could be classified as narrow crossings. There was also considerable variation in design characteristics, with the crossings studied not being uniform in either ramp design or noise barrier characteristics. The results of the placement's landscape characterisation indicate that many overpasses in agricultural areas are particularly favourable for roe deer (*Capreolus capreolus*).

Introduction

Road networks are evolving strongly worldwide due to increased passenger and freight transport demands (Meijer et al. 2018). Investments are creating new networks and expanding existing ones to increase traffic capacity and speed. The most intensive traffic is on highways, which also carry significant transit traffic (Percoco 2015). It is often argued that road networks are significant threat to biodiversity (Bennett 2017; Ważna et al. 2020). This is due to the many impacts that roads have on the environment depending on their design (Forman and Alexander 1998). Habitat loss from construction and environmental pressures from traffic must be considered (Forman and Deblinger 2000). Roads can facilitate the spread of invasive species (Seabrook and Dettmann 1996). They also affect wildlife, influencing the diurnal and seasonal movements of different species: some species may avoid roads due to light and noise pollution, while others may be attracted to road environments (Fahring and Rytwinski 2009). Another significant impact of roads on wildlife is mortality from wildlife-vehicle collisions, an increased risk on highways (Hughes et al. 1996). These roads are often fenced to reduce wildlife-vehicle collisions (Clevenger et al. 2001). Fences increase habitat fragmentation, with varying degrees of separation of continuous habitats depending on road width, traffic volume and the presence of fencing (Reed et al. 1996). This reduces the potential for the free movement of species and limits access to resources. As reproductive opportunities become limited, population numbers and the free flow of genes may decrease (Keller and Largiadér 2003, Serieys et al. 2015). The persistence of a species is not threatened by isolation as long as the movement of individuals between isolated populations is possible, i.e. a viable metapopulation is established (Andrews 1990). Connectivity can be provided in various ways. On freely traversable roads, it can be provided by crossing individuals unaffected by wildlife-vehicle collisions. On fenced-ridden roads, the crossing of species can be facilitated by various transport structures, such as culverts (Dodd et al. 2003, Tari and Reinhoffer 2023) or wildlife crossings, which are purpose-built to reduce the fragmentation effects of roads (Bissonette 2007). The design of wildlife crossings has become increasingly important in recent decades and can be found on all continents (Brennan et al. 2022). The most commonly used types are underpasses (Clevenger and Huijser 2011) and overpasses (Ballók et al. 2010).

The length of highways and motorways in Hungary doubled between 2005 and 2020. While in 2005 there were 859 km of roadway, in 2020 there was 1774 km. Between 2020 and 2023, additional sections were completed, bringing the entire motorway network to nearly 1900 km. Further road upgrades are expected in the future. Because of such an increase in road mileage, habitat fragmentation must be considered, and wildlife crossings have been built on newly constructed sections. The study identified the design characteristics and site selection features of wildlife overpasses on Hungarian highways and motorways. The results are then compared with the existing normative / recommendations, and their effectiveness is discussed.

Material and methods

The study covered Hungary's fenced highway, motorway and main road networks. That covered approximately 2700 km of roads. Based on the data of the Hungarian Road Data Bank and the analysis of satellite images of the road network, a total of 57 wildlife overpasses were included in the study (Figure 1).

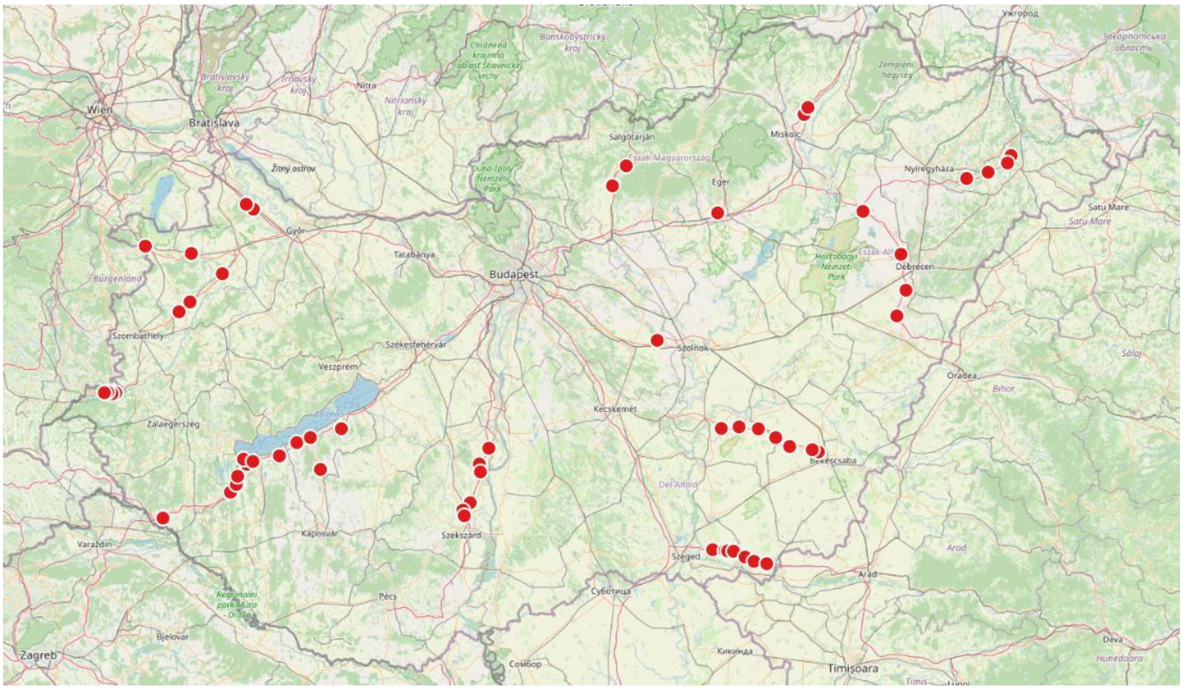

Figure 1 Location of the surveyed overpasses (Map data copyrighted OpenStreetMap contributors and available from https://www.openstreetmap.org)
1. ábra A vizsgált átjárók elhelyezkedése

In this study, measurements were taken using Google Earth Pro 7.3.6.9345 (64-bit) software (Harrington et al. 2017), a program capable of analysing the dimensional parameters of wildlife crossings with the accuracy required (Brennan et al. 2022). Four measurable parameters were recorded for each crossing. These were: A.) - Inner width (meter), the internal width of the crossing that is suitable for animals (movement corridor, not including screens or fencing) B.) - Total crossing width (meter), the distance between the two outer edges of the construction. C.) - Total length of the crossing (meter), in the longitudinal axis of the crossing, based on the distance between the start of the access ramps. D.) - Length of side screens/noise barrier (meter), measured along the longitudinal axis of the passage from the start to the end of the screening (screening aims to reduce the disturbance of animals by light or noise). The width-to-length ratio was also determined using the internal width and the length of the screens (A/D) (Figure 2).

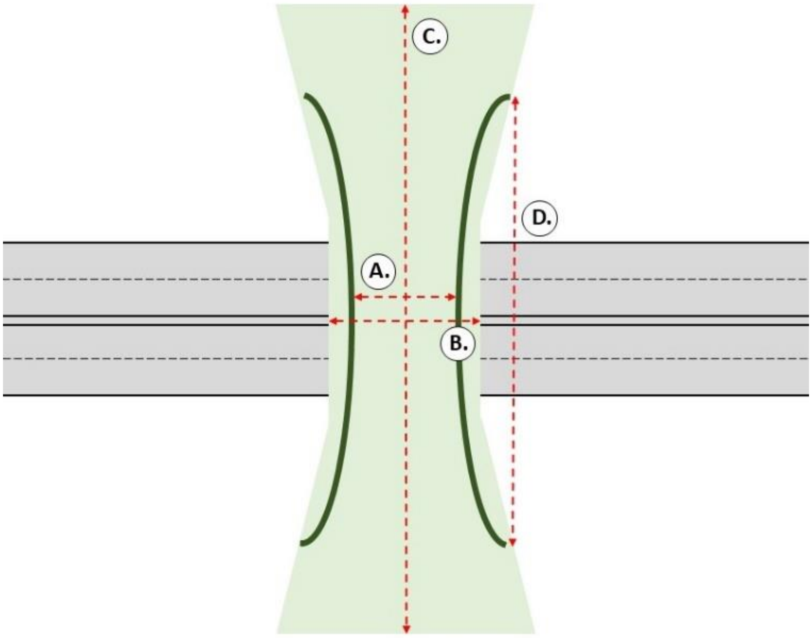

Figure 2 Measurement sites at the overpass (Brennan et al. 2022) (A.: Inner width, B.: Total width, C.: Total length of the crossing, D.: Length of screen/noise barrier)
2. ábra Mérési helyek elhelyezkedése az átjárón (A.: Belső (közlekedő folyosó) szélessége, B.: Teljes szélesség, C.: Átjáró teljes hossza, D.: Zajvédő fal hossza)

In addition to the measured parameters, the design characteristics of the crossings and their occurrence concerning the total number of crossings were determined. According to the shape of the access ramps, two groups could be differentiated: those with a straight design (**a.**) and those with a parabolic shape design (b.) (hourglass shape (b.1), semi-hill shape (b.2)) (Figure 3).

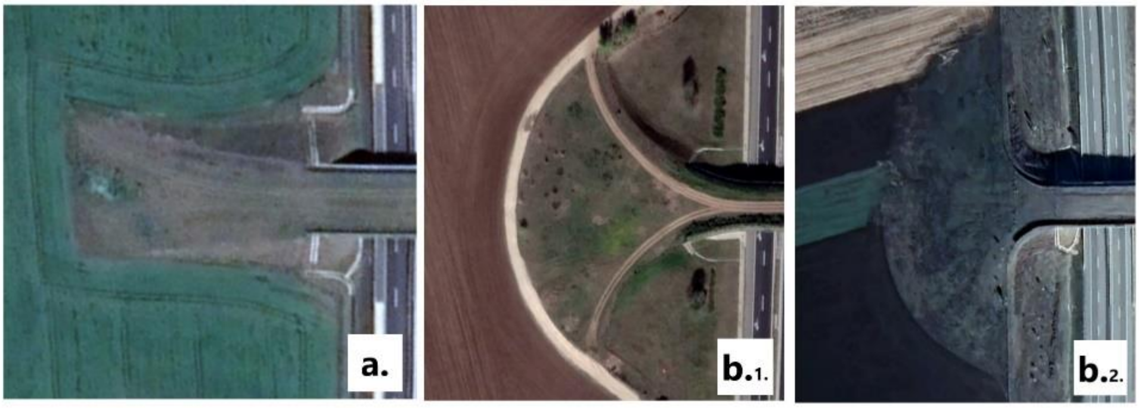

Figure 3 Shape of the access ramps (a.: straight design, b.: parabolic shape design (b.1.: hourglass shape, b.2.: semi-hill shape)
3. ábra Rámpa kialakítás (a.: egyenes, b.: parabolika (b.1.: homokóra forma, b.2. féldomb forma))

Four noise barrier/screening design variations were observed regarding the choice of materials. These were: a.) vegetation (Hedge-like structures) only, b.) wood pile and vegetation, c.) wood pile only and d.) panels (Figure 4).

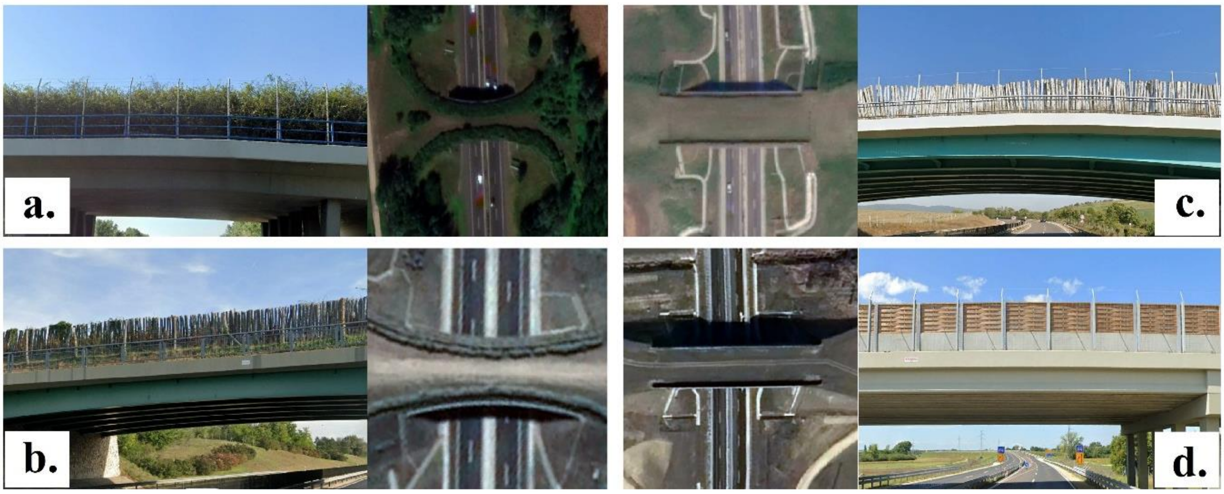

Figure 4 The noise barrier/screening design variations (a.: vegetation only, b.: wood pile and vegetation, c.: wood pile only, d.: panels)
4. ábra Zajvédőfalak típusai (a.: csak növényzet, b.: fa cölöpfal és növényzet, c.: csak fa cölöpfal, d.: panel)

Four different noise barrier/screening designs were observed in regard to the way they run-down the ramp: a.) right-angled (turns 90 degrees end of the ramp to continue parallel to the roadway), b.) straight, c.) curved (following the curve of the ramp at the hourglass and semi-dome design), d.) cut (noise barrier/screening present only on movement corridor) (Figure 5).

Figure 5 Noise barrier/screening designs (a.: right-angled, b.: straight, c.: curved, d.: cut)
5. ábra Zajvédőfal lefutásának típusai (a.: derékszögű, b.: egyenes, c.: íves, d.: levágott/nincs lefutás)

The measured parameters of the groups were compared by the Kruskal-Wallis test, and differences between groups were analysed using the Mann-Whitney pairwise method. To analyse the landscape characteristics of overpasses placement, buffers with a 500-meter radius were established around the overpasses (Schmidt et al. 2021). Within these buffers, the habitat was surveyed using a 20x20 meter resolution raster layer "Hungarian Ecosystem Atlas Map" (Ministry of Agriculture 2019), using QGIS software (QGIS Development Team 2023). Seven habitat types were identified: Urban, Roads and railways, Croplands, Grasslands, Forests and woodlands, Wetlands, Rivers and lakes. Based on the habitat type composition within the buffers, overpasses were clustered using Cluster analysis (Nagy et al. 2021), with Ward's methods. The average percentage of landscape cover was determined for each of the separate clusters. PAST4 software was used for statistical analyses (Hammer et al. 2001). Normality tests of the data were performed (Shapiro-Wilk test). The parameters of the overpasses were not found to be normally distributed, so non-parametric tests were performed (Kruskal-Wallis test, Mann-Whitney U-test). For the medians, the 25th and 75th quartiles are given in parentheses. For information purposes, mean values and standard deviations are shown in the supplementary material.

Results

Characteristics of overpasses

As a first step in the study, 57 wildlife crossings were categorised according to their design characteristics. 56.1% ($n = 32$) were of the straight ramp design type, while 43.9% ($n = 25$) were of the hourglass or semi-hill design type. In terms of noise barrier (screening) design, 47.4% ($n = 27$) had wood piles only, 35.1% ($n = 20$) had wood piles and vegetation, and 15.1% ($n = 9$) had vegetation only, with only 1 case of panel protection. In terms of the run-down of the noise barrier, the straight type was observed in 38.6% ($n = 22$) of the overpasses, the curved design was observed in 31.6% ($n = 18$), the cut noise barrier was observed in 26.3% ($n=15$), while right-angled occurred in 3.5% ($n = 2$). As can be seen, significant variation in design occurred, which also affected dimensional characteristics. The median value of the inner width was 16.1 (9.6–18.7) meters (min: 5.7, max: 20.2). The median value for the total width was 23.2 (19.9–24.4) meters (min: 19.1, max: 27.9). The difference between the two values was significant (Mann-Whitney U-test; $U = 60.5$, $p < 0.001$). For the total length of the overpasses, the median value was 148.5 (124.7–171) meters (min: 89.4, max: 288.4). For the length of the noise barriers, the median value was 93.1 (77.2–114.8) meters (min: 50.7, max: 265.3). The difference between the two values was verifiable (Mann-Whitney U-test; $U = 426.5$, $p < 0.001$). The median value of the width-to-length ratio was 0.13 (0.11–0.22) (Figure 6).

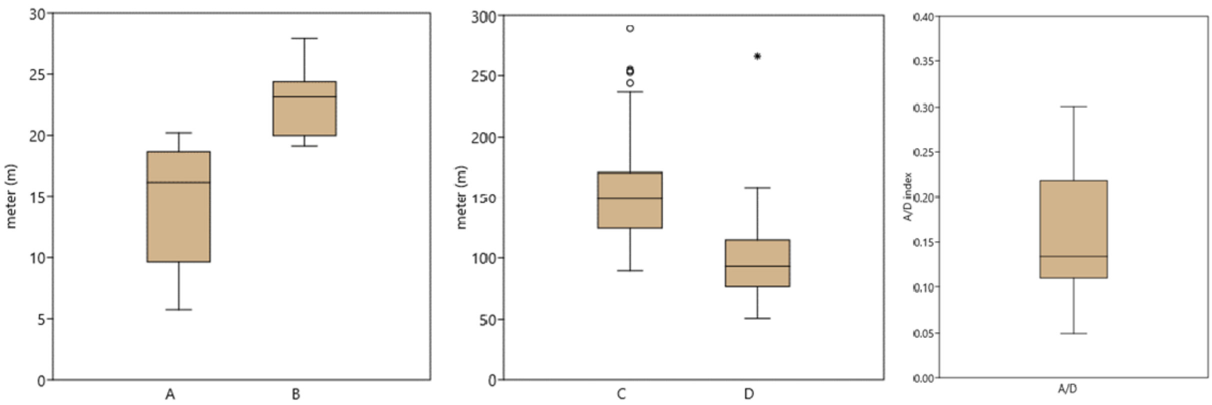

Figure 6 Dimensioning characteristics of overpasses (A.: inner width, B.: total width, C.: total length of the crossing, D.: length of screen/noise barrier, A/D.: width-to-length ratio)
6. ábra Átjárók méretezési jellemzői (A.: belső (közlekedő folyosó) szélessége, B.: teljes szélesség, C.: átjáró teljes hossza, D.: zajvédő fal hossza, A/D.: közlekedőszélesség/zajvédőfal hosszának aránya)

The median value with 25th quartile (Q1) and 75th quartile (Q3) value of each parameter for each design variations are reported in Table 1, to present the significant differences between different designs and the impact of the design on dimensioning of the overpasses.

Table 1 Dimensioning different designs (A.: inner width, B.: total width, C.: total length of the crossing, D.: length of screen/noise barrier, A/D.: width-to-length ratio)

1. táblázat Különböző kialakítási típusú átjárók átlagos méretjellemzői (A.: belső (közlekedő folyosó) szélessége, B.: teljes szélesség, C.: átjáró teljes hossza, D.: zajvédő fal hossza, A/D.: közlekedőszélesség/zajvédőfal hosszának aránya)

CHARACTERISTIC OF ACCESS RAMPS	A$^{N.S.}$		B$^{N.S.}$		C$^{N.S.}$		D**		A/D$^{N.S.}$	
	med[1]	Q1-Q3	med[1]	Q1-Q3	med[1]	Q1-Q3	med[1]	Q1-Q3	med[1]	Q1-Q3
parabolic shape design	12.4	9.5-18-6	20.3	19.7-24.4	145.2	119.1-182.3	81.9	73.7-95.5	0.18	0.11-0.23
straight design	16.6	10.6-18-6	23.5	20.4-24.3	151	128.4-167.9	105.7	89,3-146.6	0.13	0.09-0.19

SCREENING MATERIALS	A**		B**		C$^{N.S.}$		D$^{N.S.}$		A/D**	
	median	Q1-Q3	median	Q1-Q3	median	Q1-Q3	median	Q1-Q3	median	Q1-Q3
wood pile only	18.6	16.9-19.5	23.9	23.2-24.5	158.5	127.1-172.1	97.7	72.8-119.9	0.18	0.14-0.24
vegetation only	6.9	6.4-7.4	19.9	19.7-20.7	128.3	116.9-135.5	98.4	92.8-122.7	0.06	0.06-0.08
wood pile and vegetation	11.9	9.6-17.4	20.3	19.8-24.3	155	126.7-217.9	84.8	75.1-110.6	0.12	0.11-0.21

SCREENING RUN-DOWN DESIGN	A$^{N.S.}$		B*		C**		D**		A/D**	
	median	Q1-Q3	median	Q1-Q3	median	Q1-Q3	median	Q1-Q3	median	Q1-Q3
cut or *right-angled*	12.3	9.6-18.1	20.2	19.7-23.7	170	148.6-220.5	77.3	67.4-89.9	0.18	0.12-0.23
straight	15.3	8.5-19.1	23.5	20.1-24.3	142.3	121.1-160.9	113.9	92.9-150.7	0.12	0.07-0.14
curved	18.4	10-19.1	23.9	20.2-25.3	127.9	115.2-170.4	87.3	74.1-109.7	0.18	0.11-0.24

For data pairs: Mann-Whitney U test, for data triples: Kruskall-Wallis test: N.S. – non-significant, * $0.01<p<0.05$, ** $p<0.01$

[1] median

It can be concluded that the ramp design showed a verifiable difference only for the length of the noise barriers after performing the Mann-Whitney U-test ($p=0.001$), with the straight design having a higher mean length value of 34.8%.

For the design of the noise barriers, the Kruskal-Wallis test showed a difference in three of the five tested parameters ($p<0.001$). For the inner width, the paired comparison showed that all three types differed. Overpasses with vegetation only had the smallest inner width diameter, followed by overpasses with a combination of wood pile and vegetation, and overpasses with wood pile had the widest movement corridor. For the case of total width, the paired comparison showed that the wood pile crossings were wider, while there was no demonstrable difference between the other two types. All three types differed for the width/length ratio, with the highest value for the wood pile-only screening, followed by the wood pile with vegetation type, and the lowest value for the vegetation-only screening.

Looking at the classification of the noise barrier by run-down, the Kruskal-Wallis test did not confirm a difference in the inner width ($p = 0.473$), while in the other cases, it did (B: $p = 0.028$, C: $p = 0.006$, D: $p < 0.001$, A/D: $p = 0.004$). In the paired comparisons for total width, only the curved design differed from the other two types ($p = 0.012$). For total length, overpasses with cut or right-angled break screening were demonstrably longer than straight type ($p = 0.007$) or curved type ($p = 0.005$). The latter two types did not differ from each other ($p = 0.653$). For the length of the noise barrier, all three paired comparisons demonstrated a difference ($p < 0.001$). The shortest noise barriers were those with a cut or right-angled break, with a higher value for those with a curved design, and the most extended noise barriers were those with a straight type. For the width-to-length ratio, the curved design did not differ from the cut ($p = 0.908$), while the mean value of the straight screening was demonstrably lower than the others ($p = 0.002$, $p = 0.011$).

Landscape characteristics of overpasses

After examining the design features, the landscape characteristics of the location of the gateways were assessed. The landscape composition in the 500 m vicinity of the crossings and its occurrence concerning the total number of crossings were as follows: Urban (average cover ratio: 4.2%, occurrence: 84.2%), Roads and railways (average cover ratio: 3.7%, occurrence: 98.2%), Cropland (average cover ratio: 58.9%, occurrence: 94.7%), Grassland (average cover ratio: 4.7%, occurrence: 93%), Forests and woodland (average cover ratio: 24.8%, occurrence: 94.7%), Wetlands (average cover ratio: 3.4%, occurrence: 64.9%), Rivers and lakes (average cover ratio: 0.4%, occurrence: 19.3%). The cover values for each landscape element show a wide variation between the studied overpasses (Figure 7).

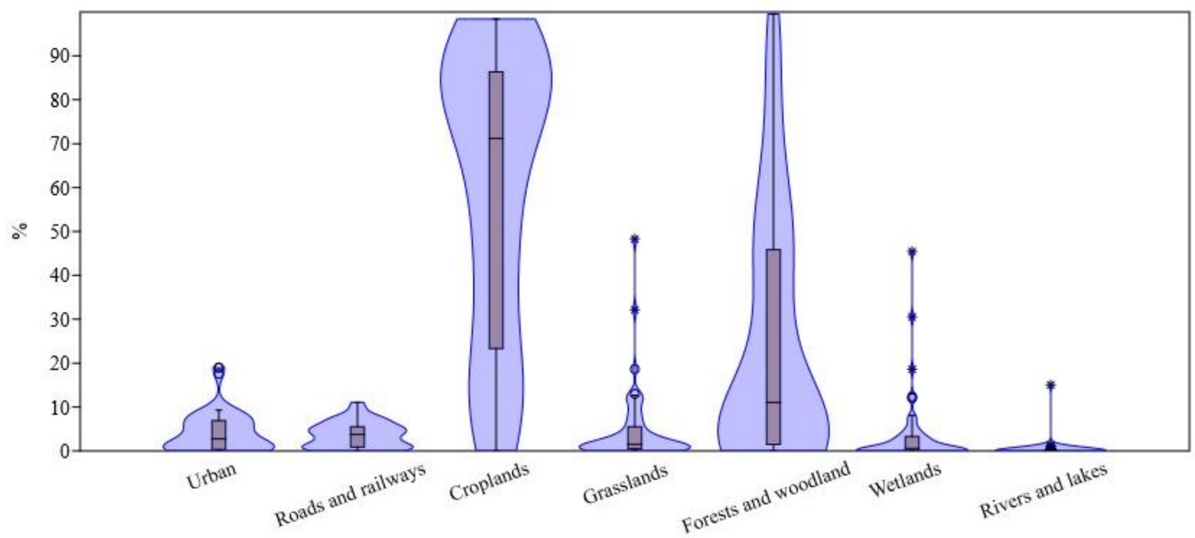

Figure 7 Distribution of cover values of habitat types
7. ábra Élőhelytípusok borítási értékeinek eloszlása (épített környezet, mesterséges vonalas létesítmények, agrárterületek, gyepterületek, erdők és egyéb fásszárú vegetáció, vizes élőhelyek, felszíni vizek)

Due to the high variance, it was necessary to classify the overpasses according to habitat characteristics in order to evaluate the location selection. For this purpose, cluster analysis was performed, two main groups and three to three subgroups per main group were separated based on the landscape elements surrounding the overpasses (Figure 8).

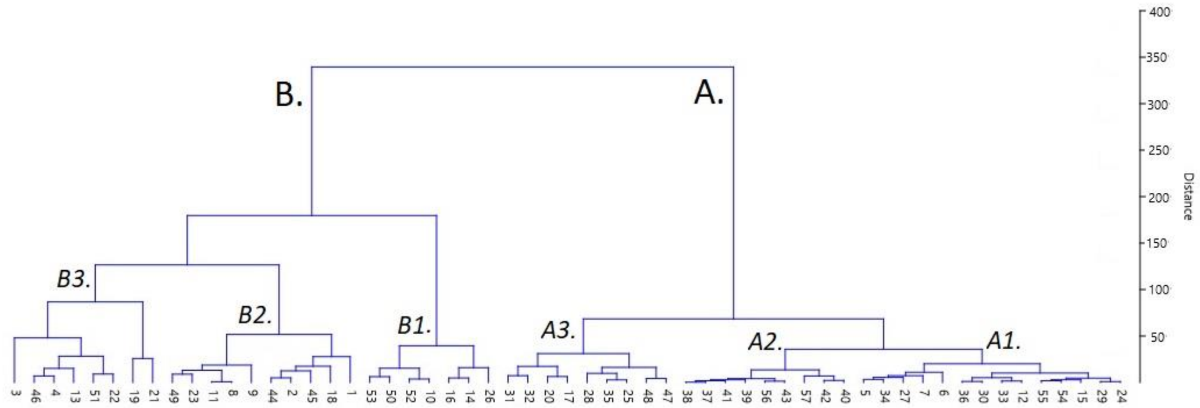

Figure 8 Grouping of gateways by habitat cover values
8. ábra Átjárók csoportosítása élőhelyek borítási értékei alapján (2 főcsoport A. és B., 3-3 alcsoporttal)

Dominant habitat types can characterise distinct main groups. Main group A. includes overpasses (n = 32) with an average of 84.4% of Cropland in their vicinity, which can be considered as "Cropland overpasses". While for the remaining overpasses B. (n = 25), the dominant landscape type is Forest and woodlands vegetation, with a proportion of 50.6%; these can be classified as "Forest overpasses".

The two main groups can be further subdivided into three subgroups, depending on the habitat types that are more important in addition to the dominant landscape type (Figure 9).

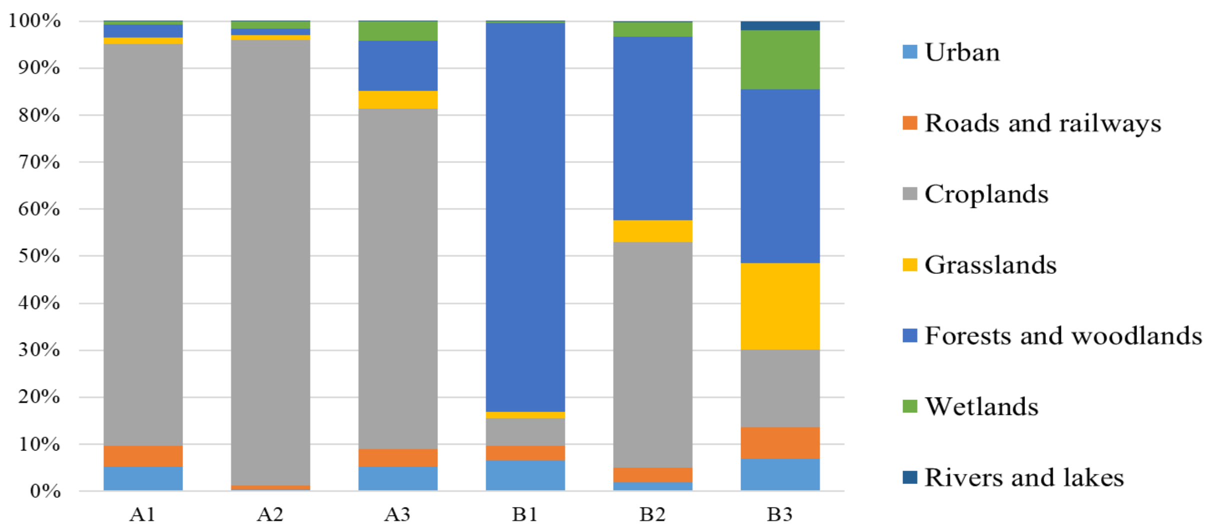

Figure 9 Landscape characteristics of the subgroups
9. ábra Alcsoportok táji jellemzői (épített környezet, mesterséges vonalas létesítmények, agrárterületek, gyepterületek, erdők és egyéb fásszárú vegetáció, vizes élőhelyek, felszíni vizek)

In the case of cropland overpasses, subclass A1. is dominated by Croplands (85.5%), followed by Urban environment (5.1%) and Roads and railways elements (4.1%). For A2. the dominance of Cropland is even higher (94.9%). While in subgroup A3. the proportion of Cropland is slightly reduced (72.2%), with the presence of Forests and woodlands (10.6%) and Urban (5.1%). Forest overpasses, subgroup B1. have the highest Forest and woodland cover (82.7%), with Urban (6.5%) and Croplands (5.8%). In the main subgroup B2. the presence of Forests and woodland decreases (39%) and becomes dominated by Croplands (47.9%). In the last subgroup B3. the proportion of Forests and woodlands decreases somewhat further (37%), with the highest proportion of Grasslands (18.5%), followed by Croplands (16.5%) and the highest presence of Wetlands (12.4%). Overall, this is considered the group with the most diverse habitat.

Discussion

After examining the 57 overpasses included in the research, significant differences can be observed in the design of the overpasses in Hungary. Regarding the total width of the crossings, it can be established that the median value for the total width was 23.2 (19.9–24.4) meters. This value is in line with the previously effective (from 12.01.2007 to 05.2019) e-ÚT_2-1.304:2007 "Ecological Passages" Road Technical Regulation, which recommends a width of at least 20 meters. However, the value falls short of e-ÚT_03.07.53:2019, which came into force on 15.05.2019, and e-ÚT_03.07.53:2019/M1:2021, which was amended on 15.09.2021, "Ecological gateways and protective fences construction next to public roads" from those specified in the Road Technical Regulations. This document already foresees a width of 25 meters for the movement corridor. The total width of the crossings completed after 2019 approaches this value, but the internal width does not reach it. If crossings are built in the future, an increase in width can be expected. Much more significant differences can be observed in the case of the inner width. It was proven that the solutions used for noise barriers (screenings) influenced the internal dimensions. The narrowest movement corridor occurred at those overpasses where only vegetation was planted as a noise barrier. The presence of natural vegetation has been proven to help the use of overpass (Sołowczuk 2020), but noise barriers cannot be passed through, so they do not fulfil this role. No bushes or woody vegetation could be observed in the traffic corridor of the examined crossings; in all cases, it was covered with grass. The combination of the wood pile and the vegetation provides a wider movement corridor; the presence of a single row of shrubs is typical. The widest movement corridor was provided by the overpasses with only wood pile screening. The median value of the inner width was 16.1 (9.6–18.7) meters, which is well below other European (38 meters) and American (33 meters) examples (Brennan et al. 2022). Small-width overpasses can be less effective than those with a wide design (Clevenger and Waltho 1997); 50-meter-wide overpasses are considered the most optimal (Clevenger and Huijser 2011). In addition to the width, the length of the crossings and the length of the noise barrier, which determines the size of the traffic corridor, are important features that affect use. Regarding both, the sizing values of the overpasses in Hungary exceed the region's values (Brennan et al. 2022). As a result, the median width/length ratio (0.13) falls short of the optimal value of 0.8 (Iuell et al. 2003). The intensity of use can be influenced by the design of the access ramp, with long or steep-sided ramp types making it difficult for some species to cross (Clevenger and Huijser 2011). 56.1% of the access ramps included in the study had a straight ramp, while the more optimally designed hourglass or semi-hill-shaped ramps were found in 43.9%. The use of crossings is influenced mainly by traffic volume (Singer and Doherty 1985), noise barriers are protection against disturbance, but their layout can also affect game movement. In several cases, a straight run type was observed on the ramp, which may impede the use of the ramp by animals coming from the side. The three other types (curved, cut and right-angled), which occurred in 61.4% of cases, were more optimal.

In addition to design, the use of crossings is strongly influenced by their location (Ng et al. 2004). Sharp habitat differences between the two sides of a crossing can reduce crossing use (Clevenger and Waltho 2003). The presence of human habitat and other linear facilities can also negatively affect crossing use (Iuell et al. 2003). Based on the results of the habitat characterisation studies, the presence of human disturbance near the overpasses is a common phenomenon in Hungarian overpasses. It was also observed that fourteen overpasses (subgroups B2. and B3.) showed a highly mosaic composition, with sharp separation between the two sites. For the remaining overpasses, three sub-groups (A1., A2., A3.) were dominated by cropland habitats, while only one sub-group was dominated by forest habitats (B1.). This distribution is not considered optimal because the overpasses are mainly designed for large ungulate species, which prefer this crossing type (Kusak et al. 2009). In Hungary, these large mammals include the red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*), wild boar (*Sus scrofa*), fallow deer (*Dama dama*) and mouflon (*Ovis gmelini musimon*). Of these species, the red deer and mouflon are found mainly in forested areas. Wild boar and fallow deer may also be present in mosaic agricultural areas with forest patches and forested areas as well. Roe deer is the dominant species in low forest cover croplands (Csányi et al. 2022). Based on the space and habitat use characteristics of these species (Náhlik et al. 2009, Heffenträger et al. 2014, Tari et al. 2014, Náhlik et al. 2022, Tóth et al. 2014) and the landscape characteristics of the overpasses, it can be concluded that the placement of overpasses in Hungary is mainly favourable for roe deer. As the construction of overpasses is very costly (McGuire and Morrall 2000), it is preferable to locate them in areas where they provide access for as many of the above species as possible. In order to meet the needs of red deer and wild boar, the overpasses should be placed so that it connects directly with forest areas. In agricultural areas, the role of combined underpasses can be important for deer (van der Ree and van der Grift 2015).

Overall, it can be concluded that the design of overpasses in Hungary cannot be considered fully uniform. In several cases, there are design features that may reduce the efficiency of the overpasses. In addition, some features were observed in the location of some overpasses which may reduce the efficiency of use for certain species.

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References

Andrews, A. 1990: Fragmentation of Habitat by Roads and Utility Corridors: A Review. Australian Zoologist, 26(3-4):130–141. DOI: https://doi.org/10.7882/AZ.1990.005

Ballók, Zs., Náhlik, A., Tari, T. 2010: Effects of building a highway and wildlife crossings in a red deer (Cervus elaphus) habitat in Hungary, Acta Silvatica Lignaria Hungarica, 6: 67–74

Bennett, V.J. 2017: Effects of Road Density and Pattern on the Conservation of Species and Biodiversity. Current Landscape Ecology Reports 2:1–11. DOI: https://doi.org/10.1007/s40823-017-0020-6

Bissonette, J. A. 2007: Evaluation of the use and effectiveness of wildlife crossings. National Cooperative Highway Research Program (NCHRP) 25-27. Final report. Trans. Research Board, Washington DC.

Brennan, L., Chow, E., Lamb, C. 2022: Wildlife overpass structure size, distribution, effectiveness, and adherence to expert design recommendations. PeerJ. DOI: https://doi.org/10.7717/peerj.14371

Clevenger, A.P., Waltho, N. 2003: Long-term, year-round monitoring of wildlife crossing structures and the importance of temporal and spatial variability in performance studies, Proceedings of the International Conference on Ecology and Transportation, 293–302.

Clevenger, A.P., Waltho, N. 2005: Performance indices to identify attributes of highway crossing structures facilitating movement of large mammals. Biological Conservation, 121(3): 453–464. DOI: https://doi.org/10.1016/j.biocon.2004.04.025

Clevenger, A. P., Huijser, M. P. 2011: Wildlife crossing structure handbook design and evaluation in North America. Western Transportation Institute. Final Report FHWA-CFL/TD-11-003; p. 224.

Clevenger, A. P., Chruszcz, B., Gunson, K. E. 2001: Highway mitigation fencing reduces wildlife-vehicle collisions. Wildlife Society Bulletin, 29: 646–653.

Csányi S. Márton M., Bőti Sz., Schally G. 2022: Vadgazdálkodási Adattár - 2021/2022. vadászati év. Országos Vadgazdálkodási Adattár, Gödöllő, p. 70.

Dodd, C. K., Barichivich, W. J., Smith, L.L. 2004: Effectiveness of a barrier wall and culverts in reducing wildlife mortality on a heavily traveled highway in Florida. Biological Conservation, 118: 619–631. DOI: https://doi.org/10.1016/j.biocon.2003.10.011

Fahrig, L., Rytwinski, T. 2009: Effects of Roads on Animal Abundance: an Empirical Review and Synthesis. Ecology and Society, 14(1): 21

Forman, R. T. T., Alexander L.E. 1998: Roads and their major ecological effects. Annual Review of Ecology and Systematics 29(1): 207–231. DOI: https://doi.org/10.1146/annurev.ecolsys.29.1.207

Forman, R. T. T., Deblinger, R.D. 2000: The Ecological Road-Effect Zone of a Massachusetts (U.S.A.) Suburban Highway. Conservation Biology, 14: 36–46.

Hammer, Ø., Harper, D. A. T., Ryan, P. D. 2001: PAST: Paleontological statistics software package for education and data analysis. Palaeontol Electron, 4(1): 9.

Harrington, S., Teitelman, J., Rummel, E., Morse, B., Chen, P., Eisentraut, D., McDonough, D. 2017: Validating google earth pro as a scientific utility for use in accident reconstruction. SAE International Journal of Transportation Safety, 5(2): 135–166. DOI: https://doi.org/10.4271/2017-01-9750

Heffenträger G., Sándor Gy., Tari T., Náhlik A. 2014: Dámszarvas (*Dama dama*) mezei- és erdei élőhely-preferenciájának vizsgálata, In: Bidló A. Horváth A. Szűcs P. (szerk.): IV. Kari Tudományos Konferencia: Konferencia kiadvány, Sopron, pp. 255–260.

Hughes, W. E., Saremi, A. R., Paniati, J. F. 1996: Vehicle-animal crashes: an increasing safety problem. Institute of Transportation Engineers Journal, 66: 24–28.

Iuell, B., Bekker, H., Cuperus, R., Dufek, J., Fry, G., Hicks, C., Hlavac, V., Keller, V., Rosell, C., Sangwine, T., Torslov, N., Wandall, B. M. 2003: COST 341 habitat fragmentation due to transportation infrastructure.

Wildlife and traffic: a European handbook for identifying conflicts and designing solutions. Brussels: European Co-operation in the Field of Scientific and Technical Research, p. 172.

Keller, I., Largiad`er, C. R. 2003: Recent habitat fragmentation caused by major roads leads to reduction of gene flow and loss of genetic variability in ground beetles. Proceedings of the Royal Society of London Series B, 270: 417–423. DOI: https://doi.org/10.1098/rspb.2002.2247

Kusak, J., Huber, D., Gomerčić, T., Schwaderer, G., Gužvica, G. 2009: The permeability of highway in Gorski kotar (Croatia) for large mammals. European Journal of Wildlife Research, 55(1): 7–21. DOI: https://doi.org/10.1007/s10344-008-0208-5

McGuire, T., Morrall, J. 2000: Strategic highway improvements to minimize environmental impacts within the Canadian Rocky Mountain National Parks. Canadian Journal of Civil Engineering, 27(3): 523–532. DOI: https://doi.org/10.1139/l99-096

Meijer, J. R., Huijbregts, M. A., Schotten, K. C. G. J., Schipper, A. M. 2018: Global patterns of current and future road infrastructure, Environmental Research Letters, 13(6): 064006 DOI: https://doi.org/10.1088/1748-9326/aabd42

Nagy, E., Benedek, I., Zsolnai, A., Halász, T., Csivincsik, Á., Ács, V., Nagy, G., Tari, T. 2021: Habitat Characteristics as Potential Drivers of the Angiostrongylus daskalovi Infection in European Badger (*Meles meles*) Populations. Pathogens, 10(6): 715. DOI: https://doi.org/10.3390/pathogens10060715

Náhlik, A., Farkas, A., Tari, T. 2022: First hungarian GPS telemetry results on mouflon home-range evaulation and habitat use. Abstracts of the 8th World Conference on Mountain Ungulates, p. 65.

Náhlik, A., Sándor, Gy., Tari, T., Király, G. 2009: Space use and activity patterns of red deer in a highly forested and in a patchy forest-agricultural habitat. Acta Silvatica Lignaria Hungarica, 5: 109–118.

Ng, S. J., Dole, J. W., Sauvajot, R. M., Riley, S. P. D., Valone, T.J. 2004: Use of highway undercrossings by wildlife in southern California. Biological Conservation, 115: 499–507. DOI: https://doi.org/10.1016/S0006-3207(03)00166-6

Percoco, M. 2016: Highways, local economic structure and urban development. Journal of Economic Geography, 16(5): 1035–1054. DOI: https://doi.org/10.1093/jeg/lbv031

QGIS Development Team. 2023: QGIS Geographic Information System. Open Source Geospatial Foundation Project.

Reed, R. A., Johnson-Barnard, J., Baker, W. L. 1996: Contribution of roads to forest fragmentation in the rocky mountains. Conservation Biology, 10: 1098–1106. DOI: https://www.jstor.org/stable/2387146

Schmidt, G. M., Lewison, R.L., Swarts, H. M. 2021: Pairing long-term population monitoring and wildlife crossing structure interaction data to evaluate road mitigation effectiveness. Biological Conservation, 257: 109085 DOI: https://doi.org/10.1016/j.biocon.2021.109085

Seabrook, W., Dettmann, E. B. 1996: Roads as activity corridors for cane toads in Australia. Journal of Wildlife Management, 60: 363–368. DOI: https://doi.org/10.2307/3802236

Serieys, L. E. K., Lea, A., Pollinger, J. P., Riley, S. P. D., Wayne, R. K. 2015: Disease and freeways drive genetic change in urban bobcat populations. Evolutionary Applications, 8: 75–92. DOI: https://doi.org/10.1111/eva.12226

Sołowczuk, A. 2020: Effect of Landscape Elements and Structures on the Acoustic Environment on Wildlife Overpasses Located in Rural Areas. Sustainability, 12(19): 7866 DOI: https://doi.org/10.3390/su12197866

Tari T., Reinhoffer I. 2023: Közúti műtárgyak szerepe az autópályák átjárhatóságában szőrmés ragadozófajok esetében. Magyar Apróvad Közlemények, 15: 1–9. DOI: https://doi.org/10.17243/mavk.2023.001

Tari T., Sándor Gy., Heffentrager G., Pócza G., Náhlik A. 2014: A vaddisznó területhasználata és aktivitása egy síkvidéki élőhelyen In: Lipák, L. (szerk.): Alföldi Erdőkért Egyesület Kutatói Nap XXII: Tudományos eredmények a gyakorlatban, p. 29–36.

Tóth B., Bleier N., Schally G., Lehoczki R., Csányi S. 2014: Otthonterület-becslési módszerek összehasonlítása az őz (*Capreolus capreolus*) területhasználatának elemzésében. Vadbiológia, 16: 51–62.

van der Ree, R., van der Grift, E. A. 2015: Recreational co-use of wildlife crossing structures. In: van der Ree, R., Smith, D.J., Grilo, C. (Eds.): Handbook of Road Ecology. John Wiley & Sons, Oxford, p. 184–189.

Ważna, A, Kaźmierczak, A, Cichocki, J, Bojarski, J, Gabryś G 2020: Use of underpasses by animals on a fenced expressway in a suburban area in western Poland. Nature Conservation, 39: 1–18. DOI: https://doi.org/10.3897/natureconservation.39.33967

Útpálya feletti vadátjárók kialakítási és elhelyezési jellemzői Magyarországon

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Kulcsszavak: élőhely-fragmentáció, nagytestű patások, zajvédelem, közlekedés, elszigetelődés

Absztrakt: Magyarország gyorsforgalmi úthálózata jelentősen fejlődött az elmúlt 20 évben. A fejlesztéseknek köszönhetően emelkedett a kerítéssel ellátott utak hossza, ami az élőhelyfragmentációs hatások erősödését is jelenti. Az utak okozta izoláció mérséklése érdekében vadátjárók épültek az új szakaszokon. A kutatásban 57 útpálya fölött kialakított vadátjárót vizsgáltunk meg műholdfelvételek felhasználásával. Meghatároztuk az átjárók belső és teljes szélességét, teljes hosszukat és a zajvédőfalak hosszát, valamint a szélesség/hosszúság arányt. Osztályoztuk az átjárókat: rámpa kialakítás szerint, zajvédőfalak anyaga szerint valamint a zajvédőfalak lefutása szerint. Továbbá felszínborítási térkép segítségével az átjárók 500 méteres körzetében vizsgáltuk a táji jellemzőket és értékeltük az átjárók elhelyezését. Eredményeink alapján megállapítható, hogy a felüljárók közlekedési folyosójának szélessége a median értéket figyelembevéve 16,1 méter volt. A szélesség-hosszúság arány pedig 0,13. Ez alapján megálapítottuk, hogy a magyarországi vadátjárók a keskeny átjárók közé sorolhatók. A kialakítási jellemzőkben szintén jelentős variancia volt megfigyelhető, a vizsgált átjárók nem voltak egységesek sem a rámpa kialakításában sem pedig a zajvédőfalak jellemzőiben. Az elhelyezés táji jellemzőinek vizsgálati eredményei alapján megállapítható, hogy magas az agrárterületeken kialakított átjárók száma, ami elsősorban az őz (*Capreolus capreolus*) számára kedvez.

Appendix 1 Dimensioning of overpasses, mean and ±SD (A.: inner width (meter), B.: total width (meter), C.: total length of the crossing (meter), D.: length of screen/noise barrier (meter), A/D.: width-to-length ratio)

1. Melléklet Átjárók méretjellemzői kialakítás szerint átlag- és szórás értékekkel (A.: belső (közlekedő folyosó) szélessége (méter), B.: teljes szélesség (méter) , C.: átjáró teljes hossza (méter), D.: zajvédő fal hossza (méter), A/D.: közlekedőszélesség/zajvédőfal hosszának aránya, (méter))

MEAN CHARACTERISTIC	A	B	C	D	A/D
overall	14±4.8	22.2±2.4	156.8±44.6	101.3±35.8	0.16±0.06

CHARACTERISTIC OF ACCESS RAMPS	A	B	C	D	A/D
parabolic shape design	14±5	22.3±2.8	157.7±47.5	84.7±14.9	0.17±0.1
straight design	14.7±4.7	22.5±2	156±43	114.3±41.9	0.143±0.1

SCREENING MATERIALS	A	B	C	D	A/D
wood pile only	17.6±2.7	23.6±1.8	156.6±41.7	100.5±29.7	0.188±0.1
vegetation only	7.0±0.9	20.1±0.5	126.4±13.3	106.2±23.2	0.068±0.09
wood pile and vegetation	13.1±3.8	21.9±2.7	170.1±52.7	100.9±48.3	0.147±0.1

SCREENING RUNDOWN DESIGN	A	B		D	A/D
cut or right-angled	13.7±4	21.3±2	181.6±40.9	77.3±15.6	0.185±0.1
straight	14.1±5.1	22.4±2.2	148.2±43.4	127.3±41.1	0.115±0.09
curved	15.4±5.3	23.3±2.6	143.7±42	92.2±19.4	0.176±0.1