

EFFECTIVENESS AND SUITABILITY OF DEFRAGMENTATION
AND FENCING FACILITIES ON STRUMA MOTORWAY, LOT 1
(Preliminary results)

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Abstract: Road constructions have a serious impact on environment, mainly through fragmentation and direct loss of habitats, collision mortality, barrier effect and general pollutions. Wildlife crossings and fences, which were introduced recently in motorway constructions, are only part of the measures to mitigate the negative effects. One of the newest motorway projects in Bulgaria – "Struma" also has an improved system for wildlife permeability and fences, reducing wildlife and human mortality.

The study is focused on the first stretch - Lot 1 (from km 305 + 220 to km 322 + 000) as it has various structures for wildlife protection and it has a long enough adaptation period, which is an important condition for reporting the facilities' effectiveness.

In addition, the study assessed the suitability and technical implementation of specialized and non-specialized facilities for mitigation of negative impact of road constructions. The main methods, used in the study include photographic capture by camera traps, animal tracks and excrement records, survey among the local population and analysis of the technical and natural features of the facilities.

The monitored facilities were: a large mammal ecoduct at km 314 + 070, a small and a middle mammalian subway at km 315 + 900, a non-specialized viaduct at km 314 + 400, bridges with dry paths, reptile and amphibian tube culverts. We also investigated the suitability of "rabbit fences" and guiding concrete fences for amphibians.

INTRODUCTION

The pressure of modern life demands various new constructions in previously undisturbed natural areas. Legal provisions nowadays require environmental impact assessment studies, prior to such interventions in nature, as well as monitoring of intervention effects (Kusak et al., 2008).

Modification of the animal's behavior (home range shifts, altered home range sizes, changed movement patterns and altered gene flow) is one of the ways in which roads affect terrestrial and aquatic ecosystems (Trombulak and Frissel, 2000; Coulon et al., 2004). Habitat fragmentation has been recognized as one of the most significant factors contributing to the decline of biodiversity in Europe (Damarad and Bekker, 2003). Large mammals and especially large carnivores are sensitive to habitat fragmentation and destruction, because of their low number, large ranges and direct chase by humans (Linnell et al., 1996; Noss et al., 1996).

Habitat fragmentation occurs when human-made barriers such as roads, railroads, channels, electric power lines and pipelines penetrate and divide wildlife habitat (Primack, 2006). Of these, roads have the most widespread and detrimental impact (Spellerberg, 1998).

For many years, ecologists and conservationists have documented the adverse relationship between roads and wildlife. Jaeger et al. (2005) identified four ways by which roads and traffic detrimentally impact on wildlife populations: "(1) they decrease habitat amount and quality, (2) they increase mortality due to wildlife-vehicle collisions (road kill), (3) they prevent access to resources on the other side of the road, and (4) they subdivide wildlife populations into smaller and more vulnerable sub-populations (fragmentation)". Bennett (1991) found that road kills do not pose a significant threat to healthy populations but can be devastating to small, shrinking, or threatened populations. Habitat fragmentation can lead to extinction or extirpation if a population's gene pool is restricted. In addition, habitat loss can be direct, if habitat is destroyed to make space for a road, or indirect, if habitat quality near roads is compromised due to emissions from the road (e.g. noise, light, runoff, pollution, etc.) (Jaeger et al. 2005). Finally, species that are unable to migrate across roads to reach resources such as food, shelter and mates experience reduced reproductive and survival rates, which can compromise population viability (Noss et al., 1996).

Preserving or restoring habitat continuity is recognized as one of the main tasks when the conservation of large mammals is the goal (Clevenger and Waltho, 2000; Chruszcz et al. 2003; Kaczensky et al., 2003). Construction of appropriate crossing structures on suitable and ecologically important places and other mitigation measures are necessary to minimize the negative effects of roads and highways (Clevenger and Waltho 2000; Kaczensky et al. 2003).

The present research looks on the negative influence of motorway constructions and monitoring of the mitigation measures, applied on the Struma motorway in Southwestern Bulgaria. The main objectives of the study are focused on the technical and landscape state qualification. We also report effectiveness assessment of the fences and crossing structures, wildlife obstruction and barrier effects (slopes, erosion, waste, anthropogenic activity), reducing the efficiency of the facilities.

MATERIALS AND METHODS

Study area

The survey object is a section of Struma motorway, one of the first Bulgarian road projects with serious reducing fragmentation measures. “Struma” motorway connects “Lyulin” highway via “Daskalovo” junction at Pernik and provides a motorway link from the capital Sofia to the Greece border checkpoint “Kulata”. The highway link is also part of the European Road E-79, connecting the cities of Kosice in the south-eastern part of Slovakia and Thessaloniki to the Greek coast of the Aegean Sea.

Our study is focused on a section of Struma motorway, named “Lot 1”. This section has a variety of wildlife structures and has been in operation long enough (since 2013). In many publications the long-term adaptation period is mentioned as the main condition for higher efficiency of facilities (American transport department, 2008).

Lot 1 of Struma represents section of the motorway from km 305 + 220 to km 322 + 000 with a total length of 16.780 km.

Lot 1 is located in the “Dupnitsa” valley, drained by the Struma River and its tributaries. Lot 1 intersects important ecological corridors between “Verila” mountain and “Milevsko-Koniavska” mountain group (Figure 1).

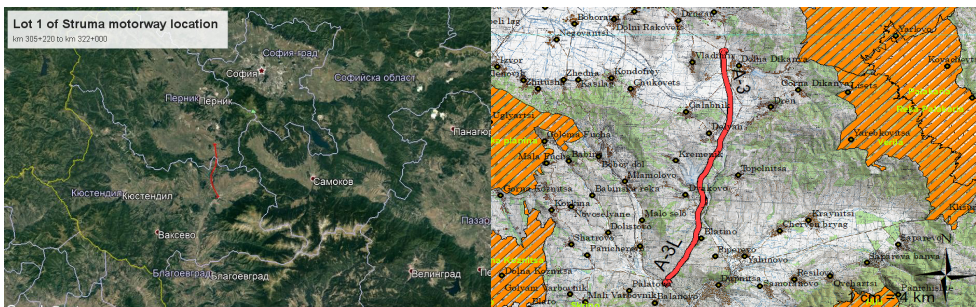


Fig. 1. Lot 1 of Struma motorway location

In Lot 1 range, there are 15 large facilities, among which an overpass for large mammals and a subway for medium and small mammals. The bridges are specialized with dry paths and there are also 31 concrete drainages, designed as passages for amphibians.

For noise disturbance mitigation noise-protecting walls were installed. As mortality reducing measures, the so-called "rabbit fences and guiding amphibian concrete fences were set up.

Two specialized passages for wild animals and one non-specialized passage were selected for the monitoring as follows (Figure 2):

Overpass for large mammals at km 314+070. The facility is the first specialized eoduct with such dimensions on the territory of the country (10 m wide and 80 m long). The facility has a 70 cm embankment and a noise barrier.

Its maximal slope is 30 degrees in order to be suitable by as many species as possible. The perimeter of the facility is equipped with containers for camera traps.

Subway for medium and small mammals at km 315+900. The facility is 4 meters high and 15 meters long and paved with fine sand along the passage. At the entrance of the passage there is a wet habitat and artificial pond.

Viaduct at km 314 + 400 (to overcome the activation of a landslide) The facility consists of two separate axle structures for each platform with a length of the individual openings of 27.55 m. Because of its technical characteristics, the facility is suitable for passage of animal species.

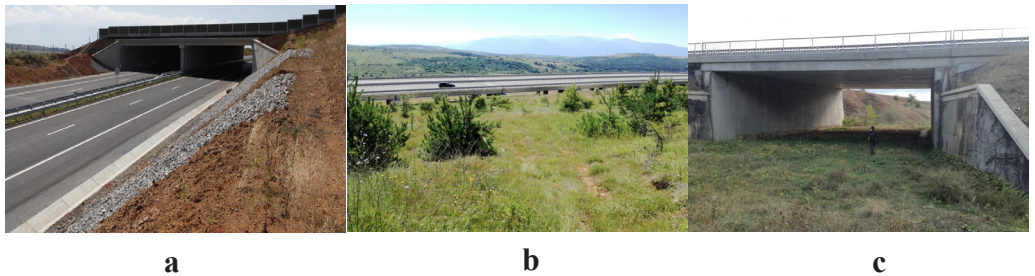


Fig. 2. Photos of the monitored facilities (**a** – overpass; **b** – viaduct **c** – underpass)

Camera trapping

Camera trapping is one of the most commonly used methods for studies on ecology field- detection of rare species, estimation of population size and species richness, as well as research on habitat use and occupation of human-built structures (Swann at al., 2010). Cameras are also the most commonly used methodology in evaluating the efficiency of wildlife crossing structures.

In our study we used “Browning” (BTC-8F-HD) camera traps with motion sensors and infrared flash. The cameras were placed on the three large facilities.

The entire perimeter of the facility was covered only in the underpass, while the lack of the possibility of covering a larger perimeter of the viaduct resulted in the lack of sufficient data.

The overpass is equipped with containers for the cameras, but they are unsuitable to be used (see results). Because of the dangers of theft and vandalism (Foster at all, 1995), the cameras were located very cautiously and the entire perimeter of the overpass was also not covered. We changed 3 and 4 different locations, respectively for the viaduct and the ecoduct.

Camera traps were set to take 3 consecutive pictures, 15 seconds apart upon activation, with the video feature turned off. The camera traps were checked once a month to replace batteries and memory cards. A standard form was filled for each camera location, including information about every specific habitat.

The cameras were set up in the summer (June, July, August, September), as this is the most active season for mammals and the most suitable for their study (Mata et al, 2003, Yanes et al, 1995), but due to location determination difficulties of the specialized subway, it was studied later (October, November, December, January).

Tracks registration

Most data for passages were documented by footprints in the mud. The substrate under the large facilities is suitable for tracking. Each track was photographed, measured and identified. Tracks on the overpass were difficult to document, due to the dense vegetation. Track counts were reported once a month and the most passes were recorded on the subway for medium and small mammals. When passes were recorded by tracks, and this information was also confirmed by camera traps data, they were counted as 1 pass.

Track pads

Tracking pads were the first method employed to assess the use of wildlife crossing structures (Yanes et al, 1995, Rodriguez et al, 1997). They represent furrows of fine material, most commonly sand, spread along the midline of each crossing structure, encompassing its entire parameter and perpendicular to the direction of animal movement (Bider, 1968). The tracking pads have to be levelled over and the new tracks were recorded periodically. This method provides information about the number of animals that have passed, and often their species. One track bed is installed on the overpass for large mammals, but the lack of maintenance hinders the possibilities for effective use of the pad.

Polls

Polls have been conducted on only 5 people, due to the local's unwillingness to participate. The numerous poachers in the area are a possible cause. All model species were presented to the respondents with a possible option "yes" or "not". The results are summed up and presented in Table 1.

Suitability and adaptation analysis, structure implementation and behavior preferences evaluation

We tried to evaluate all the accompanying factors that potentially influence the efficiency of the facilities. For each facility a technical-landscape inspection has been carried out. We described the characteristics, all discrepancies against good practices, legal requirements and the EIA (Environment impact assessment) Decision.

We took into account the long adaptation period, learning curve and the differences between the species (Clevenger et al, 2009). Clevenger, Norman and others explored the use of crossings by design type and they prove that there are strong preferences (i.e., selection) for design types of wildlife crossing structures and they are consistent over time (Clevenger et al, 2009, Norman, 2012). Many scientists (Norman et al, 1998; Clevenger and Waltho, 2000; Van Manen, 2001; Hlavac and Andel, 2002; Brudin III, 2003) were looking for a correlation between the openings and sections of the facilities, according to the preferences of the species, but it is difficult to compare with the local species, as even species of similar size and those of the same taxonomic groups have different requirements for wildlife crossings.

We also assessed the location and landscaping of the facilities and how this affects their efficiency.

Target species

Brown bear (*Ursus arctos*), Golden jackal (*Canis aureus*), Grey wolf (*Canis lupus*), Red fox (*Vulpes vulpes*), Wild cat (*Felis silvestris*), Roe deer (*Capreolus capreolus*), Wild boar (*Sus scrofa*), Beech marten (*Martes foina*), European badger (*Meles meles*) and European hare (*Lepus europeus*) were selected as target species. The species are typical for the region, but the theoretical range of the target species is bigger than the realistic one. The focus on one or two species is mentioned as a weak side in a number of studies (Clevenger and Waltho, 2005) in view of the importance of protecting the whole ecosystem. A major focus is placed on medium and large mammals as they are most affected by fragmentation processes, because of their larger individual territories, later and slow reproduction and migration (Alexander et al, 2005).

Carnivores are especially important for the study, in the position of the so-called “umbrella species”, the presence or absence of which would give us more information about the interrelations of many other species (Roberge et al., 2004).

RESULTS AND DISCUSSION

Technical characteristics and suitability of the facilities

Prior to commencement of the monitoring work, all available large and small facilities were surveyed for their technical suitability for wildlife crossings and the suitability for installing camera traps. Thus, the previously planned dry paths (under bridge facilities) were excluded as a subject of the study, because of the bad implementation. Continuity of the “rabbit fence” makes the bridges and the dry paths completely unusable for animals (Figure 3a). This can be considered as a serious omission in the overall wildlife linkage system



Fig. 3: a) bad implementation of the “rabbit fences” at the bridges; **b)** good implementation of culvert with guiding fences;

Due to the lack of time and resources, the culverts for amphibians and reptiles were also excluded for monitoring, but they were examined from a technical point of view. The entrances and exits of the facilities are situated at the elevation of the surrounding terrain, with smooth passing of the culvert into guiding concrete fences (Figure 3b). Their frequency is appropriate for the length of the area, with 31 specialized culverts (approximately every 0.5 kilometer). The drainages are without siltation. The only observed disadvantage was the lack of substrate spread along the length of the facilities.

The large mammal overpass is located in a very conflict point of two overlapping roadways, one railroad and in the same time, in the center of ecological corridor, near a large water reservoir. The overpass is technically well-implemented, but without landscaping and lack of any maintenance. There are also missing shelters. These omissions have a very negative impact on the efficiency of the facility. The facility is without sufficient visibility which further extends the adaptation period and learning curve. Containers for cameras and tracks pads are completely unusable, due to the high vegetation, impossibility of cameras attachment and the danger of theft and vandalism (Figure 4).



a



b

Fig. 3: a) bad implementation of the “rabbit fences” at the bridges; **b)** good implementation of culvert with guiding fences;

The subway for medium and small mammals is technically well-implemented and well-naturally soundproofed. At the entrance of the facility, there is an artificial pond in order to attract more wild animals, but the surface water runoff is discharged into it. This results in pollution with solid waste, common dusts, oxides and persistent organic pollutants. Location of the facility is appropriate with enough shelters near the subway, but there are no special sets for reptiles and amphibians.

The Viaduct, although a non-specialized facility, has the technical possibility to be a passage for animals. The lack of appropriate landscape shaping, shelter for small animals and noise insulation significantly affects its effectiveness as a

crossing structure. Although the facility has been monitored, its large perimeter made this extremely difficult to perform.

All facilities are in close proximity to the first-class road, which is appropriate for the monitoring, but extremely unfavorable by the additional overlapping barrier effect and the danger of theft and vandalism.

Efficiency of the wildlife crossings

In the range of lot 1, there are 57 culverts, 31 of which are specialized for reptiles and amphibians, 15 large facilities, 9 of which are with technical possibilities for crossings and 2 specialized for wildlife crossings. Monitoring was carried out for 3 large facilities - 2 specialized and 1 non-specialized.

10 model species were studied, of which 6 were recorded in the field. The camera traps were active for 69 days on the Viaduct, 84 days on the overpass and 26 days on the subway. This is a total of 189 camera trap days with 18 registrations by a camera trap and 34 recorded tracks (Figure 5).

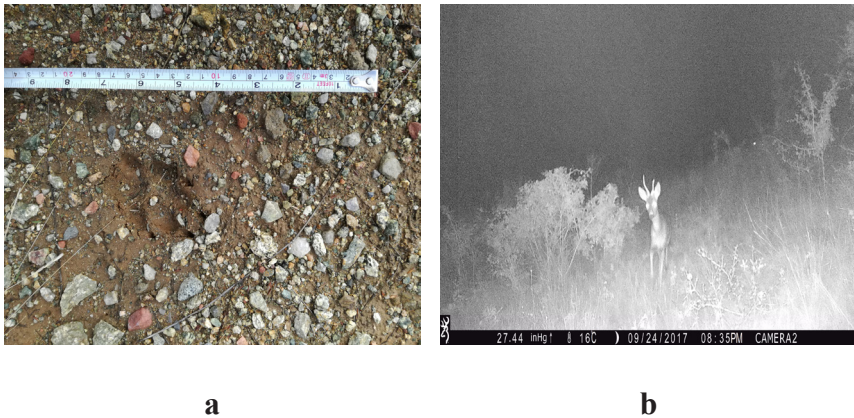


Fig. 5: a) data, documented by tracks, **b)** data documented by camera traps

The survey covers 7 months (between June and November 2017) and one control study in September 2016. The survey encompasses 3 seasons, with no data on the winter season, which is the most suitable for tracking. The monitoring data is presented in Tables 1, 2 and 3.

Table 1: Type of data collected for each model species

Species	Footprints	Excrements	Camera traps	Polls
Brown bear (<i>Ursus arctos</i>)	No	No	No	No
Golden jackal (<i>Canis aureus</i>)	Yes	Yes	Yes	Yes
Grey wolf (<i>Canis lupus</i>)	No	No	No	No
Red fox (<i>Vulpes vulpes</i>)	Yes	Yes	Yes	Yes
Wild cat (<i>Felis silvestris</i>)	No	No	No	No
Roe deer (<i>Capreolus capreolus</i>)	Yes	No	Yes	Yes
Wild boar (<i>Sus scrofa</i>)	No	No	No	Yes
Beech marten (<i>Martes foina</i>)	Yes	No	Yes	Yes
European badger (<i>Meles meles</i>)	Yes	No	No	Yes
European hare (<i>Lepus europeus</i>)	No	No	No	Yes

Table 2. Total number of registrations by species distributed by facilities

Species	Overpass at km 314+070	Viaduct at km 314+400	Subway at km 315+900	total number of passes
Brown bear (<i>Ursus arctos</i>)				0
Golden jackal (<i>Canis aureus</i>)			6	6
Grey wolf (<i>Canis lupus</i>)				0
Red fox (<i>Vulpes vulpes</i>)	3	5	4	12
Wild cat (<i>Felis silvestris</i>)				0
Roe deer (<i>Capreolus capreolus</i>)	5			5
Wild boar (<i>Sus scrofa</i>)				0
Beech marten (<i>Martes foina</i>)	1	2	2	5
European badger (<i>Meles meles</i>)		2	2	4
European hare (<i>Lepus europeus</i>)			1	1
Total number of passes	9	9	15	33

Table3: Tracks distributed by species and date of visit

Species	Overpass	Viaduct	Subway
Brown bear (<i>Ursus arctos</i>)			
Golden jackal (<i>Canis aureus</i>)			sep.2016; oct. 2017; nov.2017;
Wolf (<i>Canis lupus</i>)			
Fox (<i>Vulpes vulpes</i>)	sep.2016; sep 2017	june 2017; july 2017; aug 2017; sep. 2017	sep.2016, oct. 2017,nov.2017
Wildcat (<i>Felis silvestris</i>)			
Deer (<i>Capreolus capreolus</i>)	sep.2017		avoidance-nov. 2017
Wild boar (<i>Sus scrofa</i>)			
The beech marten (<i>Martes foina</i>)		aug 2017; aug 2017	sep.2016; oct.2017; nov. 2017
The European badger (<i>Meles meles</i>)		july 2017; june 2017	sep.2016, nov.2017
The European hare (<i>Lepus europeus</i>)			oct.2017

Clevenger and Waltho have found that the most limiting factors for the use of highway underpasses by large mammals are structural openness, followed by the distance to an urban area (Clevenger and Waltho, 2000). The first factor (structural openness) does apply only for the underpass (because of the large size of the viaduct). The distance to the nearest town was measured for the monitored objects and used in evaluation of possible differences in crossing structure use. Performance data confirms that the farthest passage is also the most usable, although the differences for the three facilities are negligible



Fig. 6: Distance of the facilities to nearest settlement
a) the underpass **b)** the overpass and the viaduct

Ungulates, wolves and bears are the most consistent species in terms of usage of crossing structures (Clevenger et al., 2009). The ungulates avoid variations of subways, which was fully supported by our study (Norman et al., 1998). There were freshly discovered tracks of ungulates (mostly roe deer) on a path leading to the underpass, but there were no photos of passing wild ungulates in the underpass. There was also no data on human presence and passages of livestock in the subway. Clevenger and Waltho defined structural openness as a limiting factor for the use by large mammals. In support of this statement, it is appropriate to take into account the traces of roe deer reaching near the facility (Clevenger and Waltho, 2000).

The jackals and foxes have no particular preference for the type of the crossings (Mata et al., 2003). Rodriguez also described this tendency only for the red fox (Rodriguez, et al, 1996). We can also confirm this as a trend by registration of the fox on all of the three large facilities.

The data about the jackal definitely showed a preference of the subway, confirmed by 6 traces and camera trap registrations only there.

In a long-term study of the effectiveness of wildlife crossings, there is a large difference between the adaptation period for carnivores and ungulates (Clevenger

et al, 2009). The average monitoring period of 18 studies reporting on wildlife crossing structure use by mammals was 17 months (Clevenger and Huijser, 2009), but high efficiency has been reached in four to six years for carnivores and two to three-year period for ungulates. For bears this period is even longer (Clevenger et al., 2009). Only 4 years have passed, since the commissioning of the facilities, which means that efficiency can be studied only for the medium and small mammals, but not for the designed target species (wolves and bears).

CONCLUSIONS

In conclusion, we would add that, despite the statistical and comparative nature of some analysis in the study, the facilities couldn't be compared in their efficiency as they represent a common system for wildlife crossing, they are not interchangeable, but together they ensure the passing of much more species.

As an integral barrier for wildlife, motorways sections require a comprehensive approach for limiting the strong fragmentation effect. The crossing facilities on Lot 1 can't be considered an integrated mammalian crossing system, reducing the fragmentation effect, because they are concentrated in one small section. It should be taken into account that this stretch is indeed the most urgent for mitigation measures, because it is a conflict point of two overlapping roadways and one railroad.

Despite of the limited available data we have detected crossings of carnivores on all of the large facilities, which is important flag for crossing structure use, as their position of flagship species.

Although well located and specialized, with clear evidence of carnivore persistence, the wildlife crossing structures are not enough to ensure the successful connection between Verila Mountain and the Milevsko-Koniavska Mountain group. Therefore, we recommend the construction of two more specialized wildlife passes, right after the Dyakovo Dam. We highly recommend equipping the bridges to serve as wildlife crossings. The frequency, design and performance of the culverts is good enough, specifying that the structure must be covered with an appropriate substrate. Effectiveness monitoring should be carried out for them.

In the area of the facilities there is active grazing, poaching, and passing of motor vehicles. Restricting them would have a positive impact on crossings efficiency. This is confirmed by the fact, that for the most efficient facility – subway for small and medium mammals, there was no evidence of human presence. The factors determining its high efficiency are complex - good location, the wet habitat, the appropriate shelters and the largest distance from settlements.

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