Influence of highway construction on wild animals and protection measures

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ABSTRACT
With the development of the traffic construction in the west, the southwest and the sea area, the traffic network will gradually run through the densely animals-populated areas, even through the wildlife refuge, the criss-cross roads make the animal's habitat divided into blocks, easily resulting in the decrease in number of wild animals, population dispersion, habitat fragmentation and other adverse consequences. In order to ensure the stability of the ecosystem, the "eco-transportation" has gradually become the target of many national transportation constructions. Combining with engineering examples at home and abroad, the research analyzes the ill effects of highway construction on wildlife, and then expounds the preventive and remedial measures to be taken in the design, building and operation stages of traffic construction, in which emphasis is placed on the corridor for wildlife crossing on the road, including its common types, influencing factors and detail design. This paper can provide reference for the related engineering constructions and codes.

KEYWORDS: highway; wildlife; protective measures; animal corridor

1 INTRODUCTION
The 19th CPC National Congress puts forward the grand goal of becoming a powerful traffic country basically from 2020 to 2035, and comprehensively developing into a transportation power from 2035 to the middle of this century. With the rapid development of transportation in China, the traffic network will inevitably run through the densely animals-populated areas. A large number of cases have shown that road construction has brought many bad effects on wildlife: The famous Trans-Canada Highway across Canada's Banff National Park was dubbed "meat-eating Road" for running countless wildlife over(Wan, M., et al., 2005); In the Netherlands, interference from light significantly reduced the propagation of black-tailed Henan birds on both sides of the road(Molenaar J G D, et al.2006); Due to the animal's avoidance reaction on the road vehicles, the population density of Tibetan wild donkeys the density of the wild donkey in the 0~500m range of the Qinghai-Tibet highway is significantly lower than that of the 1000~2000m region (Yin, B. F., et al.2007); During the animal migration season, the heavy traffic in the Qinghai-Tibet highway makes it difficult for animals to travel through the roads to the breeding areas(Xi, L., et al.2002). The oil field highway in Liaohe Delta divided the habitat of the red-crowned cranes into blocks, and the decrease of the habitat area led to the occurrence of inbreeding among the red-crowned cranes.(Wan, D.M, et al.2002).

The protection, development and rational use of wildlife resources are of great significance in maintaining ecological balance, saving endangered species and carrying out scientific research(Li, Y. H., et al.2003). In order to protect wildlife effectively in traffic construction and coordinate these two aspects, researchers at home and abroad are actively exploring appropriate measures, among of which passages set for wild animals crossing the road are mainly adopted. As early as 1998, banff park in
Canada built 22 above-road and 2 down-road corridors in the Canadian Banff-Park’s Highway section which led to a decline in wildlife traffic mortality in Banff by 80% (Alexander S M, Waters N M. 2000). In Australia, the animal passages set on the Calder Expressway were used by 79 species of wild animals. Up to now, the total number of terrestrial wildlife corridors in North America has reached more than 684, of which nearly 70 passages has been assessed by 25 scientific research projects (Zhang, Y., Fei, S. J.2009). Based on scientific data, Europe and the United States have developed guidelines for the design of wildlife corridors.

The study of wildlife protection measures in current traffic construction in China started late but also bore fruit. Referring to the migration routes of Asian elephants, the Sixiao highway set up 23 bridges and 2 tunnels for elephants crossing roads, and according to the monitoring, 11 of those animal passages have been used (Li, Y. Q., Xing, S. H.2013); In the construction of Qinghai-Tibet Railway project, 12 wildlife passages were designed in main migration routes of Tibetan antelope in Kekexi and the utilization rate of which is over 80%; Wang Yun (2013) carried on the influence of the highway on animals, the utilization of animal channels, etc, directing at Tour Road of Changbai Mountain using the sample line and infrared camera monitor. Based on Arc-Gis platform and the datas of elevation, slope, vegetation in habitat, Gong minghao(2015), determined the locations of two giant panda corridors for the Yazikou section of the 306 provincial road in Sichuan province, at the same time, discussed and demonstrated how to optimize siting indexes and scientifically select locations. Li Shuai, et al(2018), with the guidance of niche theory, applying fuzzy comprehensive evaluation method and combining with GIS spatial data rendering, objectively evaluated the habitat suitability of ungulates wildlife along the expressway in construction period.

At present, the traffic in China is extending to the densely animals-populated areas such as the West, the Southwest and the sea, therefore, "ecological transportation" will certainly become the goal of our country's traffic construction. The influence of traffic on animal community and the corresponding repair measures are the most concerned core parts of ecological construction research, and this paper will carry on the concrete research on these two parts. As there is no guide to the design of the wild animal passages in our country, for which this article can provide reference.

2 THE IMPACT OF TRAFFIC CONSTRUCTION ON WILDLIFE

2.1 Habitat destruction

Traffic construction directly affects the size and quality of habitat along road. For instance, the traffic noise pollution caused by mountain blasting and operation of large-scale equipment during construction stage can lead to communication distortion among birds, then have a direct impact on their mating. High-speed vehicles make it difficult for animals to cross the other side of the road, so their habitat is separated. Whatsmore, large mammals active avoidance response away from road in a certain distance, so that the living area is further smaller (Bliss-Ketchum L L,2016). Ding Hong et.(2008) studied the scope of the influence by roads on the living environment of different animals, and concluded with Fig. 1.
2.2 Deaths from traffic accidents

Owing to migration, predation and reproduction, animals often travel through roads, resulting in a huge number of animal deaths in car accidents. According to the relevant monitoring results, since the 20th century, about 159,000 mammals died in traffic accidents in the Netherlands, while about 5.48 million frogs and reptiles in Australia annually. Astoundingly, as the most developed country of highway construction, this figure was as high as nearly 1 million annually (Guan, L., Wang, Y. 2016). The continuous expansion of traffic network has seriously affected the population of wild animals.

2.3 Traffic blocking effect

Traffic structures are often banded that hinder the communication of animal on both sides. More than that, expanded traffic reticular will lead to the fragmentation of the animal habitat, then the original stable animal population is divided into some small and isolated populations, which is more prone to fluctuations, and even completely disappear (Cuperus R, et al. 1999, Zhang, H. B., 2002, Mader H J. 1984). Not only that, the migration of animals will be affected. Many species, such as wolves, grizzly bears and antelope, try to avoid crossing the road for foraging or mating activities, which results in inbreeding and genetic variants of offspring. Reh W (1990) found out that the average number of alleles on each enzyme of frogs in a pond near the highway is 2.23, and the number of the frogs in the undisturbed ponds far away from the highway is 2.5. The long-term effects of this barrier effect on animals are no less than the direct injury to animals caused by traffic accidents (Hou, X., et al. 2011).

2.4 Impact on ecosystem balance

The change in quantity or habit of one kind of organisms in an ecosystem will affect other, and form a new ecological pattern. If the original ecosystem is advanced, traffic construction is very likely to destroy the ecological balance. While if the original system belonged to the inferior level ecosystem, the alien species invasion caused by the construction, may increase in biological diversity. As the consequences of biological invasion are often unpredictable, it is the primary choice to preserve the original ecological landscape as much as possible.

3 MEASURES TO PROTECT ANIMALS IN ECO-TRANSPORTATION

3.1 Design phase

3.1.1 Reasonable choice of path

Before planning and design, we should carry out environmental and wildlife resources survey in the area, so as to keep the route far away from species-rich habitats, high-density animal communities, complex landscape areas, etc.

3.1.2 Establishment of wildlife passage

The wildlife corridor is the main content of the ecological transportation construction, and is also the main way that the animals cross the roads safely. In the past several decades of highway construction in China, some areas take advantage of culverts and viaducts to provide some passages for wild animals through, such as Tibetan antelope corridors of Qinghai-Tibet railway, Asian elephant corridors of the Sixiao railway and animal corridors of the Changbai Mountain Tour Road, etc. However, compared to Chinese rich wildlife resources and the traffic network that runs through it, wildlife passage is rare. The use of the Tibetan antelope corridors in Golmud section of the Qinghai-Tibet Railway is shown in Fig. 2 (Li, Y. Z., et al. 2008).
The wildlife passages are divided into the large one and the small one according to the size, and according to the location of the structure, which also can be divided into above-road one and down-road one (Zhang, Y., Fei, S. J., 2009). The specific classification can be referred to Table 1.

<table>
<thead>
<tr>
<th>Passage type</th>
<th>Above the road</th>
<th>Under the road</th>
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<tbody>
<tr>
<td>Large passage</td>
<td>“Green Bridge”</td>
<td>Underpass of viaduct, Animal tunnel, Eco-culvert</td>
</tr>
<tr>
<td>Small passage</td>
<td>Suspension cable, footbridge</td>
<td>pipe culvert</td>
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1) Above-road passage

The "Green Bridge" passage is usually set above road when the road is across vast natural vegetation belt, and usually imitates the natural state on its surface with plants so that called "Green Bridge", as shown in figure 3. The width of it is generally set to 30-50m. Compared with other passages, the advantages of "Green Bridge" are more prominent: Firstly, its environment is consistent with the natural environment, in which animals have no sense of strangeness. Secondly, the plants on the passage can reduce the vehicle noise and block animals’ sight to cars, so animals are less disturbed by vehicles below. The third is that the passage can satisfy hoofed animals in habits that they prefer to climb up rather than drill holes.

The suspension cable and footbridge are mainly set for endemic species, so the specific form and size should be determined according to their living habits. For example, the Xi-han highway set up a sling passage for golden monkeys (Kou, X. Y., et al., 2015). The Australian Christmas island set up a bridge over the road to ensure the safe migration of red crabs (Liu, X. Q., 2015), as shown in figure 4.
2) Under-road passage

The underpass of viaduct can be used as an animal passage in the construction of mountain railway. Because of its environmental continuity of both sides, it is suitable for large mammals to use, which is the main form of animal passage in Qinghai-Tibet railway, as shown in Fig. 5. The utilization of such passages is positively correlated with its length, height, open rate (open rate = length × Height/width), and negatively correlated with the channel width. Generally, this kind of corridor is supposed to meet values of the open rate ≥5, length ≥6m, height ≥4m (Wang, Y., et al., 2017), as shown in Figure 6. At present, the viaduct is widely used in the mountainous road in China due to the geological requirements and architectural aesthetics, for another, the viaduct arch can be used as an animal passageway under the condition of satisfying the size requirement, so that this kind of passage is more economical and practical.

An animal tunnel is a short-distance underpass built for small mammals in hilly areas or high embankments, with width of 3-5 m. Culvert and pipe culvert are the drainage channels under the subgrade. The culvert span is 3-5m, while the diameter of the pipe culvert is less than 2m. These two can be used as animal corridors separately for small and medium animals. In development, compared with original culvert, the eco-culvert has platforms on both sides of the cave, which are higher than the water level, so that the land animals can pass the culvert when rainy season comes. The culvert diagram is shown in figure 7. As the necessary drainage facilities for the road, culvert, pipe culvert can also be used for an animal corridor, therefore more economical. However, due to its close to the road and then vehicle interference, some of large mammals will voluntarily avoid it, but it is basically suitable for small mammals, reptiles and amphibians.
In general, animals will take several years to adapt to these passages. The factors that affect the use of the animal passage mainly include the size, location, type, surrounding landscape characteristics and the extent of human interference nearby. Li Shuai (2018) studied the factors that cause the ungulates to adapt to Mengxin highway animal passages, and found that the order of elements according to the influence was: the distance of drinking water point > population distance > the number of drinking water points > the distance from road. Zhang Hongfeng (2016) detected by monitoring that the corridor utilization rate was positively correlated with passage openness and height, and the above-road corridor can be adapted to almost all animals. Therefore, in order to make the animal corridors achieve its best use effect, relevant departments must to carry out local wildlife survey before design, and determine the species, quantity, life habits, activity path of animals along the way, so as to correctly select the location, type and number of corridors (Liang, J. C., et al, 2016). In addition, the detailed optimization design will also enhance the use of animal channels. The optimal design of the channel will also enhance the use of animal channels. For example, planting vegetation same as surrounding on the surface of passage can reduce animals’ sense of crisis, and then improve the frequency of use of passage; and it can also be used to attract animals by planting animals' favorite vegetation and set special smell they love (Wei, F. W., Feng, Z. J. 1998); furthermore, reasonable setting of fences outside the channel can guide animals to enter in, and then improve the use of animal passages.

3.1.3 Installation of ancillary facilities

The installation of protective fences on both sides of fill or flat roadbed can prevent ungulates animals from entering in. The traffic accident is significantly reduced after the use of fences in Banff Park Roads in Canada (Alexander S M, Waters N M. 2000). The fence needs to be higher than the snow level on both sides of road and is usually 2.6-2.8 m, the top of which should be provided with barbed wire to prevent animals from climbing in; in addition, amphibians and reptiles, once fell into ditches or drains, are easily drowned because of inability to climb out, and therefore in wetlands and water-rich areas, ditches should be set up slopes or filled in appropriate coarse gravel to facilitate the animals climb out.

3.2 Construction stage

Field construction tends to output serious noise pollution, occupy a large area of space and have more human activities. Dai Qiang, et al (2006) found the high-density area of black lip pika during the construction is farther away from road than the running time. In the construction stage, the preventive measures are adopted, such as avoiding night construction, adopting directional clustering and shading; during the peak period of wildlife migration, the number of construction times should be reduced or stopped; it is also critical to reduce machinery noise, temporary road, life garbage, material pollution and construction sewage. The new Hong Kong-Zhuhai-Macau Bridge, which uses the steel-tube artificial island seawall and the immersed tunnel, effectively avoids massive silt filling and excavation; and in order to reduce the influence of the engineering on white dolphins as far as possible, the construction repeatedly to be stopped, which may provide reference for other marine engineering (Chen, W., et al, 2015).
3.3 Operation period.

The protection measures for wildlife during operation mainly include that: warning signs are placed nearby the main wild passages (it contains the species and distribution of animals, speed limits and forbidden signs, etc.), as shown in Figure 8; timely maintain or repair wildlife passages; during the period of animal concentration, the department should take reasonable measures to control traffic volume and speed of vehicles; in addition, during the operation, animal passages should be monitored for a long time, according to which the staff can analyze the usage of corridor and the adaptive capacity of animals to corridor, and then optimize it based on the animals’ living habits. The common monitoring methods are foot monitoring, automatic photography, direct counting, camera monitoring, radio telemetry and marking recapture.

Fig. 8 Sign of animal passage for Qinghai-Tibet Highway

4 CONCLUSION

China's modern traffic construction started late, but the has rapidly developed, which results in that the existing network is scarce in ecological concept. At present, the industry has gradually paid attention to ecological environment, not only traffic efficiency. This paper first analyzes the adverse effects of traffic construction on wildlife, and then puts forward the precautions and remedial measures in view of it, in which the role and types of wildlife passages are emphatically expounded. The conclusions are as follows:

(1) The adverse effects of traffic construction on wildlife include habitat destruction, traffic death, barrier effect and ecosystem destruction.

(2) The corresponding animal protection measures should be taken in the process of traffic construction, which can effectively reduce the adverse effects of road construction on animals.

(3) The establishment of wildlife passage (including common types, influencing factors and detail design) is presented in combination with engineering examples at home and abroad in order to provide reference value for related engineering construction.

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