

Ecological Infrastructures on Road Networks in and around Forested Areas

Sercan Gulci^{1*}, Abdullah E. Akay²

¹ Kahramanmaraş Sutcu Imam University, Faculty of Forestry, 46100 Kahramanmaraş, Turkey.

² Bursa Technical University, Faculty of Forestry, 16200 Bursa, Turkey.

Abstract

The road networks are located in and around forested areas to ensure sustainable management of forest resources. However, it is crucial to improve roads due to their habitat fragmentation and the barrier effects on forest ecosystems. Especially the wild animals, as one of the important components of ecosystem, are detrimentally affected by road networks due to degradation, alteration, conversion, and loss of their habitats. In recent years, ecological infrastructures have been developed to provide wild animals with transition zones between their habitats. In this study, ecological effects of road networks on wild animals were presented, functions of ecological infrastructures were indicated, and their types were described.

Keywords: Road networks, Ecological infrastructures, Road ecology

1. Introduction

In recent years, the amount of road networks in and around forested areas has been increased as a result of rapid urbanization and industrial developments. These road networks may cause serious habitat fragmentation problems on both flora and fauna ecosystems due to their barrier effects (Gulci and Akay, 2014). Particularly ecosystems of wild animal are subject to fragmentation, alteration, and conversion by road networks. The ecologic corridors, which provide wild animals with transition zone between their habitats, are crucial for sustainability of these species. However, the road sections constructed on the ecologic corridors negatively affect their vital needs and social behaviors (feeding, sheltering, breeding, immigration, etc.). These effects may threaten biodiversity of species and their existence in long run (Shanley and Pyare, 2011; Van der Ree et al., 2011).

Within the concept of road ecology, ecological infrastructures became important issues in order to provide wild animals with safe passages between their habitats and to reduce the risk of wild animal related traffic accidents. The various types of ecological infrastructures have been constructed in some of the countries in Europe and in North America, while road ecology can be considered as new subject in Turkey (Eker and Coban, 2010; Gulci, 2014). In this study, it was aimed to introduce these structures and indicate their importance for sustainability of wild animals. Different planning approaches have been used in many studies where optimum planning goals are considered

such as minimization of transportation cost, road distance, or travel time. In addition to this, goal programming like genetic algorithm and network analysis integrated with GIS have been used in some studies (Martin, et al., 2001; Greulich, 2002; Huang et al., 2006; Pentek et al., 2007).

2. Potential Ecological Effects of Road Networks

Improperly planned and constructed road networks may cause serious ecological effects on habitats of wild animals. These potential effects have emerged new approaches and techniques that aim to determine the ecological problems and provide strategic and engineering solutions (Trombulak and Frisell, 2000). Thus, the ecological effects of road networks on wild animals should be well understood considering ecologic, economic, and sociologic factors (Winkler, 1997).

The main ecological effects on habitats of wild animals due to road network are listed in six groups (Forman, 2006):

- Habitat losses during road construction stages
- Negative effects of roads on stream channels that leads to changes on runoff regime
- The loss of aquatic flora and fauna due to soil erosion and sediment yield to streams
- Changes on patterns of species
- Providing public access to remote areas may cause damages (illegal hunting, cutting, etc.) on habitats
- Road networks cause barrier effects between habitats

*Corresponding author: Tel: +90 3442801715 E-mail: sgulci@ksu.edu.tr

Received 25 April 2015; Accepted 3 June 2015

The ecological effects of road networks start at the construction stages where many bird, reptile, and mammal species can be subject to detrimental threats if proper environmentally friendly methods are not implemented. Besides, existing road networks negatively affect natural and social behaviors of the animals such as feeding, sheltering, breeding, and immigration (Coffin, 2007). The severity of these effects varies depending on road density and traffic volume (Forman et al., 1997; Spellerberg, 1998; Akay et al., 2011).

Because of road networks, wild animals have to share their habitats with human which then inevitably causes conflicts between human and wild animals. However, animals get involve traffic accidents while trying to escape from barrier effects of the roads (Gulci, 2014). These accidents can be deadly for both human and wild animals, and also result in serious injuries and economical losses. On road networks with heavy traffic, wild animals are divided into three groups: 1) species that are afraid of road surface, 2) species that are disturbed from traffic (noise, lights, etc.), and 3) species that stand still when they face a vehicle while crossing the road network (Jaeger et al., 2005). The animal behaviors and relationship between roads and wild

animal are studied by conducting species based ecological researches (Spellerberg, 1998; Coffin, 2007).

Stream sides are usually preferred areas for road locations due to favorable topographical and geological features; however, these roads may cause serious ecological effects on important ecosystems by interrupting transition between terrestrial ecosystems and riparian ecosystems. This leads to habitat fragmentation for both plants and wild animals and threats genetic diversities (Trombulak and Frisell, 2000).

3. Minimizing Ecological Effects of Road Networks

In order to minimize the ecological effects of road networks on wild animals, roads should be planned based on ecosystem based multiple use approaches and environmentally friendly strategies should be implemented in and around forested areas (Gulci, 2014). Since road networks provide important services to our daily life, activities that minimize ecological effects of roads on wild animals should involve public opinion in solution process. Public awareness is one of the key factors to minimize road effects in terms of protecting the habitat of wild animals (Figure 1) (Van der Ree et al., 2011).

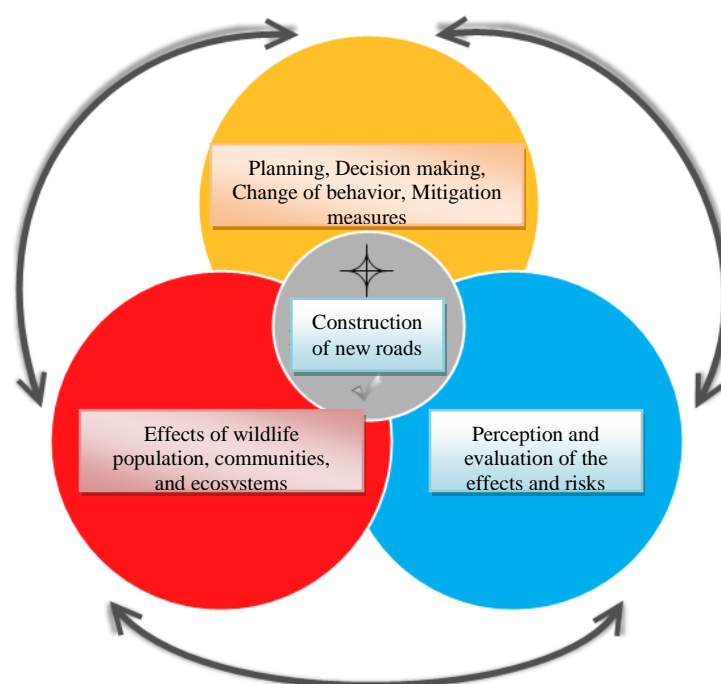


Figure 1. The process of reducing ecological effects of road networks

In order to ensure sustainability of wild animals and provide biological transitions between their habitats, road networks should be improved by mechanical and structural alternative approaches. The barrier effects of road networks can be prevented and other potential ecological effects can be reduced by implementing following approaches (Gulci and Akay, 2014):

- Minimizing road density and road widths, and locating road networks in and around forested areas by considering habitats of wild animals

- Preserving ecological corridors and passages for wild animals between habitats
- Determination of suitable passages with minimum ecological effects on wild animals
- Locating fences to direct wild animals to safe passages especially on roads with heavy and fast traffic
- Using warning signals for drivers
- Installing chemical and mechanical warning systems to keep wild animals away from the roads

- Constructing viaducts on important passages and directing wild animals to the underpass by using fences
- Constructing ecological infrastructures such as bridges and underpasses

After evaluating all the possible alternatives, one or more approaches listed above can be implemented by the road managers. Besides, animal behaviors and habitat needs should be well analyzed, and all of the available species in the study area should be taken into the consideration (Gulci, 2014).

4. Ecological Infrastructures

Road infrastructures are mainly designed for hydrological and geological purposes. Even if these road structures are not constructed for ecological purposes, some of the overpass and underpass type infrastructures can be used by wild animals. Figure 2 indicates an infrastructure that was first built to protect road against land sliding, and then it was covered by vegetation in time and wild animals started to use it as ecological bridges (Gulci, 2014). In recent years, road infrastructures solely for ecological purposes have been developed to provide wild animals with transition zones between their habitats. In fact there are numbers of ecological infrastructures developed within the concept of road ecology (Brudin, 2004). The ecological infrastructures are not only built on roads, but also they are built over railroads and rivers (Gulci and Akay, 2014).



Figure 2. An ecological infrastructure located in Mersin (Gülek), Turkey (Gulci, 2014)

4.1. Classification of Ecological Infrastructures

There are various types and sizes of infrastructures used for ecological purposes. The ecological infrastructures are classified based on sizes and habitat needs of the specified wild animals (Kintsch and Cramer, 2011).

Small size underpasses: Small size underpasses are generally 1.5 m wide passages that are made of metal, concrete, PVC, and wood material (Figure 3). These are culvert type structures and often used by small mammals (fox, beavers, etc.), amphibians, reptiles, and some medium mammals.



Figure 3. Small size underpass (Gulci, 2014)

Medium size underpasses: The width of the medium size underpasses are between 1.5 m and 2.4 m, and its maximum height is 2.4 m (Figure 4). These structures are usually preferred by medium size wild animals (i.e. jackal), small size animals, and species with short moving distances (snakes, turtles, etc.), and some ground birds.



Figure 4. Medium size underpass (URL-1)

Large size underpasses: The large size underpasses are generally used by deer species and they provide effective passage for any species with long or short moving distances. These structures do not meet the requirements of the regular bridges. The heights and widths of these structures are 2.4-3.1 m and 3.1-6.1 m, respectively (Figure 5).

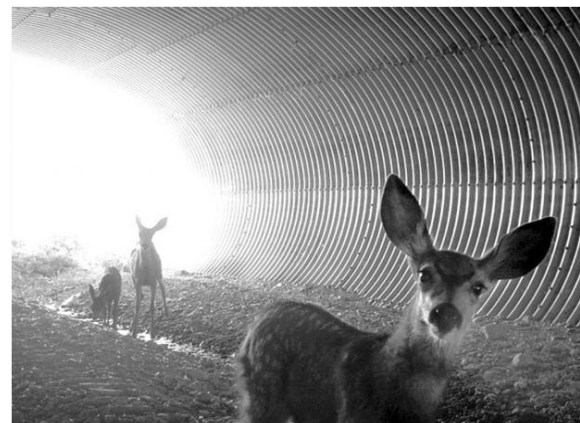


Figure 5. Large size underpass (URL-2)

Viaducts (Ecoducts): The viaducts are bridge like structures that are used to connect high road sections (e.g. minimum 4.6 m high from the ground) and provide transportation for automobiles, trucks, trains. The wild animals can pass underneath the viaducts to reach their habitats (Figure 6).



Figure 6. Viaducts as ecological infrastructures (URL-3)

Ecological bridges: The ecological bridges, which are also called as wildlife bridges, ecosystem bridges, green bridges, wildlife overpasses, are used by most of the wild animals (Figure 7). Ecological bridges are constructed over linear transportation alignments such as highways and railroads in order to overcome their barrier effects on wild animals. The surface of these infrastructures is covered by suitable vegetation depending on the habitat needs of the species.



Figure 7. Ecological bridges on state highway (Gulci, 2014)

Special passages: The special infrastructures are usually built for small terrestrial mammals, reptiles, and ground bird (Figure 8). Within these infrastructures, some of the factors such as water, humidity, temperatures, light, and dry surface can be adjusted when it is needed. The special passages are generally built for species under protection.



Figure 8. Special infrastructures (FHWA, 2014)

Arboreal bridges (Drawbridges): The arboreal bridges are designed for small species (i.e. reptiles, mammals, and birds) that stay off the ground and move over tree canopies. They are small size structures, which are made of ropes or iron poles. The arboreal bridges provide connections between tree canopies from both sides of the roads (Figure 9).

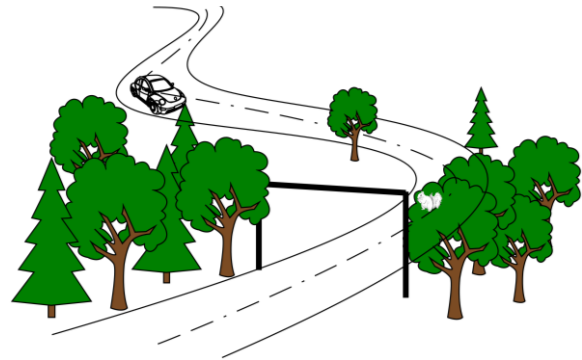


Figure 9. The arboreal bridges types structures (Gulci, 2014)

4. Conclusion

The ecological infrastructures are built to minimize the ecological effects of road networks on wild animals. These infrastructures provide animals with safe and easy access to their habitats. Their locations as well as sizes and types are determined based on the habitat needs of the species and available ecological corridors in the region. It is crucial to locate ecological infrastructures along the road networks especially in and around forested areas in order to ensure sustainability of wild animals. Besides, wild animals may cause serious traffic accidents while trying to cross the road networks. These accidents can be deadly for both human and wild animals, and also result in serious injuries and economical losses. Especially large mammals such as deer species, wild boars, and foxes threat the road safety in all over the world.

References

- Akay, A.E., Inac, S., Yildirim, I.C., 2011. Monitoring the Local Distribution of Striped Hyenas (*Hyaena hyaena* L.) in the Eastern Mediterranean Region of Turkey (Hatay) by Using GIS and Remote Sensing Technologies. *Environmental Monitoring and Assessment* 181 (1-4): 445-455.
- Brudin, C.O., 2004. Wildlife use of existing culverts and bridges in North Central Pennsylvania. IN: Proceedings of the 2003 International Conference on Ecology and Transportation, Eds. Irwin CL, Garrett P, McDermott KP. Center for Transportation and the Environment, North Carolina State University, Raleigh, NC: 344-352.
- Coffin, A.W., 2007. From Road Kill to Road Ecology: A Review of the Ecological Effects of Roads. *Journal of Transport Geography*, 15, 396-406.
- Eker, M. and Coban, O.H., 2010. Impact of Road Network on the Structure of a Multifunctional Forest Landscape Unit in Southern Turkey. *Journal of Environmental Biology*, (31):157-168.
- FHWA, 2014. <http://www.fhwa.dot.gov> URL (Accessed: 21.04.2014).
- Forman, R.T.T., Friedman, D.S., Fitzhenry, D., Martin, J.D., Chen, A.S. and Alexander, L.E., 1997. Ecological Effects of Roads: Towards Three summary Indices and an Overview for North

- America. In 'Habitat Fragmentation and Infrastructure.' Ed. K. Canters (Ministry of Transport, Public Works and Water Management: Maastricht and The Hague, Netherlands). 40-54.
- Forman, R.T.T., 2006. Good and Bad Places for Roads: Effects of Varying Road and Natural Pattern on Habitat Loss, Degradation, and Fragmentation. IN: Proceedings of the 2005 International Conference on Ecology and Transportation, (Eds. Irwin C.L., Garrett P, McDermott, K.P.) Center for Transportation and the Environment, North Carolina State University, Raleigh, NC. pp. 164-174.
- Greulich, F., 2002. Transportation networks in forest harvesting: early development of the theory. In: Yoshimura T (eds) Proceedings of International Seminar on New Roles of Plantation Forestry Requiring Appropriate Tending and Harvesting Operations held at Tokyo, Japan, pp. 57-65.
- Gulci, S., 2014. Research to Ecological Infrastructure for Road Networks in and around Forest Edges. Phd thesis, Kahramanmaraş Sütçü İmam University, Faculty of Forestry, Kahramanmaraş, Turkey. 204 p.
- Gulci, S. and Akay, A.E., 2014. Evaluating Ecological Functions of Road Structures within and around Forested Areas. The 2nd Mediterranean Environment and Forest Symposium, 22-24 October 2014, Isparta, Turkey.
- Huang, B., Yao, L., Raguraman, K., 2006. Bi-level GA and GIS for multiobjective TSP route planning. *Transportation Planning and Technology*. 29: 105-124.
- Jaeger, J.A.G., Bowman, J., Brennan, J. Fahrig, L., Bert, D., Bouchard, J., Charbonneau, N., Frank, K., Gruber, B., and Tluk von Toschanowitz, K., 2005. Predicting When Animal Populations are at Risk from Roads: an Interactive Model of Road Avoidance Behavior. *Ecological Modelling*, 185(2-): 329-348.
- Kintsch, J. and Cramer, P.C., 2011. Permeability of Existing Structures for Terrestrial Wildlife: A Passage Assessment System. Report to the Washington State Department of Transportation Research Report No. WA-RD 777.1. Washington State Department of Transportation, Olympia, WA. 84s.
- Seiler, A. 2001. Ecological Effects of Roads. Department of Conservation Biology, SLU, Uppsalla, Sweden. *Introductory Research Essay*, 9: 1-40.
- Martin, A.M., Owende, P.M.O., Holden, N.M., Ward, S.M., O'Mahony, M.J., 2001. Designation of timber extraction routes in a GIS using road maintenance cost data. *Forest Products Journal*. 51: 32-38.
- Pentek, T., Picman, D., Potocnik, I., Dvorscak, P., Nevecerel, H., 2007. Analysis of an existing forest road network. *Croatian Journal of Forest Engineering*. 26: 39-50.
- Shanley, C.S. and Pyare, S., 2011. Evaluating the Road-effect Zone on Wildlife Distribution in a *Rural Landscape*. *Ecosphere*, 2(2): 1-16.
- Spellerberg, I.F., 1998. Ecological Effects Of Roads And Traffic: A Literature Review. *Global Ecology and Biogeography Letters*, 7 (5): 317-333.
- Toumboulak, S.C. and Frisell, C.A., 2000. Review of Ecological Effects of Roads on Terrestrial and Aquatic Communities. *Conservation Biology*, 14 (1): 18-30.
- Van der Ree, R., J., Jaeger, A.G., Van Der Grift, E.A. and Clevenger, A.P., 2011. Effects of Roads and Traffic on Wildlife Populations and Landscape Function: Road Ecology is Moving Towards Larger Scales. ISSN 1708-3087. *Ecology and Society*, 16(1): 48.
- Winkler, N., 1997. Environmentally Sound Forest Harvesting. Testing the Applicability of FAO Model Code in the Amazon in Brazil, FOPH Publication. Italy. 84s.
- Url-1. 2014. <http://nhinfrastructure.blogspot.com.tr> (Accessed on: 04.10.2014)
- Url-2. 2014. <http://mtstandard.com> (Accessed: 04.10.2014)
- Url-3. 2014. <http://arc-solutions.org> (Accessed: 04.10.2014)