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Application of network method as a tool for integrating biodiversity values in Environmental Impact Assessment

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Abstract Highway construction or expansion projects are among major activities of economic development especially in developing countries. However, road development consistently can lead to major damages to the environment, including habitat fragmentation and ecological instabilities and a considerable threat to fauna and flora. At this point, Environmental Impact Assessment (EIA) in road developments is needed to address and evaluate the ecological issues in decision-making. The object of this study is to strengthen the consideration of ecological issues, i.e., biodiversity in the existing EIA tools. This paper regards a network method as a means to make informed planning decisions by the lessons from a case study. The results indicate that network method is well suited to be applied in ecological impacts assessment. However, some limitations such as complexity and time consumed make casual networks unpopular. Also, impact of traffic noise on acoustic communication (wildlife and human) was performed. It has been shown that sound level for human is much higher than admissible standards. Finally, the study expresses some mitigation measures to improve the acquisition for environmental impact assessment process.

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Introduction

Integrating environmental considerations with economic one in the policy-making process is generally accepted as a principle means of helping to deliver sustainable development (Parkhurst and Richardson 2002; Pearce 1993). Although there are various international efforts into measuring sustainability, only a few of them have an integral approach taking into account environmental, economic, and social aspects (Singh et al. 2009). Infrastructures as one of the most important economic development policies reflect public and scientific concerns about the environmental consequences. Furthermore, performance of Environmental Impact Assessment (EIA) for any proposed development actions such as infrastructures is required. But the variety of methodologies available and the constraints on resources sometimes make it difficult to select the appropriate assessment tools. EIA methods range from simple to complex, requiring different kinds of data, various data formats, and variant levels of expertise and technological sophistication for the interpretation.

Casual networks in EIA have been assigned predominantly to impact identification, prediction, and assessment (Canter 1996). They consist of linked impacts, including chained multiple effects and feedbacks (Barthwal 2002; Gilliland and Risser 1977; Lavine 1978; Sorensen 1971, 1972). Network diagrams provide a means for displaying first, secondary, tertiary, and higher order impacts of projects. However, the separate analysis required for each environmental condition could result in a complex assessment. The main advantage of using network and systems analysis is that it makes explicit the multiple and often complicated nature of impacts resulting from a project (European Commission 1999). This method is considered to be best applied to ecological impacts, i.e., biodiversity and difficult to apply to socioeconomic impacts (Barrow 1997; Perdicoulis and Glasson 2006).

Recent decisions by the Conferences of the Parties to the CBD have recognized the need to better integrate biodiversity in impact assessments (Slootweg and Kolhoff 2003). Impact assessment as a potentially powerful tool ensures the objectives of the CBD which are integrated into decision-making process. This component is concerned with predicting and managing the impacts of proposed developments, i.e., linear infrastructures on both ecological patterns and processes and more broadly with biodiversity (Wegner et al. 2005).

Linear infrastructures such as roads are among the main threats to natural habitat worldwide and are characterized by a series of common impacts, such as habitat fragmentation (Forman 2003; Geneletti 2006; Gontier 2007). This results in both habitat loss and isolation and often also causes habitat degradation (Fahrig 1997; Gontier et al. 2006; Mörtberg et al. 2007; Opdam and Wiens 2002). Fragmentation and habitat loss by roads leads to loss of biodiversity at genetic, species, and ecosystem levels that are levels which should take into account in Environmental Impact Assessment. However, reviews of biodiversity impact assessments in different countries revealed that explicit treatment of biodiversity impacts is often poor (i.e., Byron 2000; Söderman 2005). Consideration of biodiversity issues has been demonstrated to be only partial, with assessments mainly focusing on some species and direct impacts. They ignore indirect and cumulative impacts and lack full treatment of biodiversity combining knowledge on the affected components (Söderman 2006).

Roads represent one of the most widespread forms of modification of the landscape that occurred during the past century and particularly after World War II (Trombulak and Frissell 2000). Roads not only create a barrier between natures on both sides, i.e., fragmentation but also add to pollution, disturbance, and traffic mortality (Verbooma et al. 2007). For example, noise pollution impacts are a relevant health burden from transportation but gives little insights into the assessment scheme (Hofstetter and Müller-Wenk 2005). For several decades, noises produced by human technologies have destructed many natural habitats and increased the natural noise sources. While noise is considered as a problem for human's life, this problem has been neglected in conservation biology (Lengagne 2008).

The main object of this study is to propose a network method to supplement the existing EIA tools. For this purpose, this study evaluates the environmental impacts by emphasizing the biodiversity aspects. Then, in "Result and discussion," monitoring of noise emissions was carried out to evaluate the impacts on biodiversity. This study was carried out from January 2008 to February 2009 in Fars Province, Iran.

Materials and methods

The study area and scenario

The study area includes Arjan–Parishan biosphere reserve located in southern Iran (29°26′ N, 51°42′ E). It covers about 59,000 ha in Fars Province between Shiraz and Kazerun. Parishan Lake and Arjan wetland with exclusive biodiversity level increase the importance of the region. Arjan–Parishan has been on the international wetlands list since 1975 (Darvish Sefat 2007). The region's location and its mountains produce a wide range of climate conditions that are largely responsible for the great diversity of plants and animals. The ecological characteristics of the region also influenced the cultural history and economic development. Elevation ranges from around 800 m in the southeastern part of Parishan zone, and the highest mountain peaks reach over 3,020 m in Arjan zone. Figure 1 shows the location of Fars Province in Iran and a simplified map of Arjan–Parishan biosphere reserve.

To reduce the mortality rate in this area and to increase the quality of life of the inhabitants of the villages, the provincial authorities have decided to strengthen the existing road network by constructing a new motorway. Two alternatives routes among the many proposed by the appointed engineers were considered in this study. The first alternative is widening of existing road, and the other one is construction of a new road namely Dashtearjan–Poleabgineh (Fig. 2).

The approximate length of alignment 1 is about 40 km, but for Dashtearjan–Poleabgineh is about 62 km. Dashtearjan–Poleabgineh road takes almost a similar route as Alignment 1. It generally follows Alignment 1 until it reaches the core area of Arjan–Parishan biosphere reserve where it curves southward around the core area and then it returns to Alignment 1. The numbers of tunnels for the first and second routes are, respectively, 1 and 6. Each alternative is designed to be partly two-laned and partly three-laned. The mentioned routes which cross Arjan–Parishan biosphere reserve have been compared to decrease the eventual accident of previous road.

Network method

In fact, a number of techniques or methodologies are available for EIA which one of the major types is casual network. The network technique developed by Sorensen is regarded as one of the best known methods for investigating higher order impacts (Shopley and Fuggle 1984; Lohani et al. 1997). Networks are diagrams that demonstrate casual relations between their elements. In causal

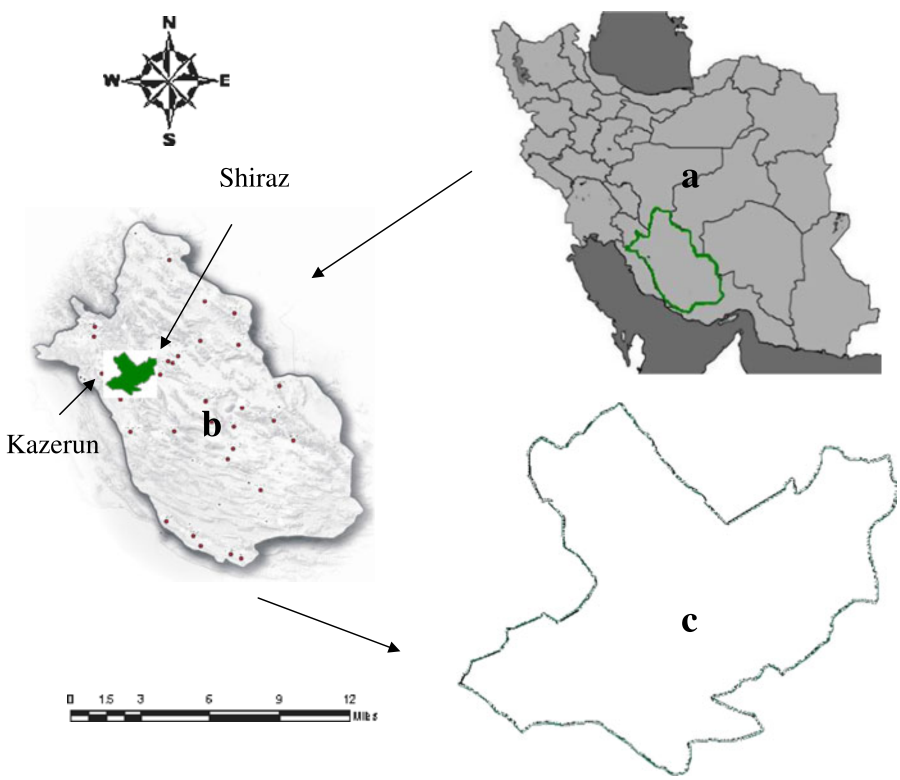

Fig. 1 Location of the study area: **a** Iran, **b** Fars Province, **c** Arjan–Parishan Biosphere Reserve

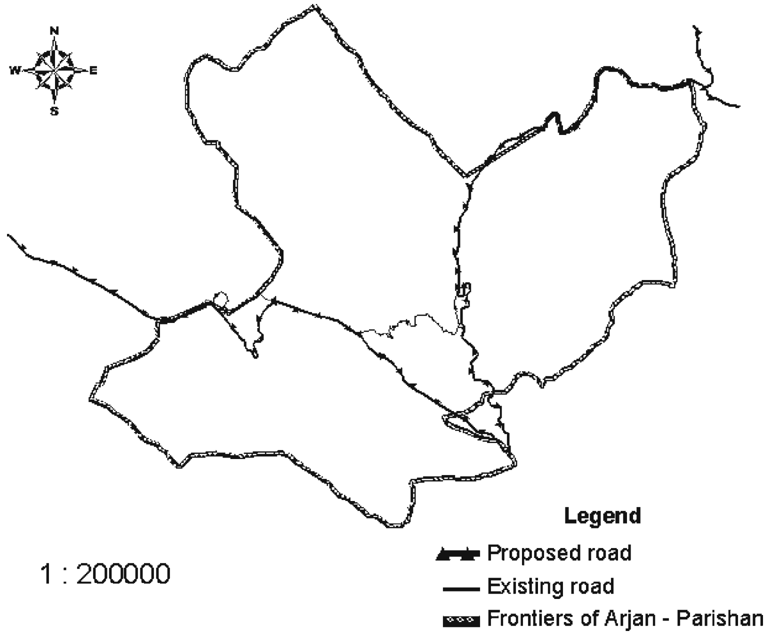

Fig. 2 The two routes proposed to link kazerun and Shiraz

networks, the process of interpreting results is even more complicated. Hence, the significance of the overall impact may be difficult to estimate. Since network method applies a holistic approach to impact assessment, it has the potential to require a slightly higher time or cost input.

For this case study, the application of a network method was chosen as an appropriate methodology. It is based on casual networks which come from an EU Guidance Document (European Commission 1999). In this method, a series of flow diagrams were prepared which illustrated the impact relationships between the effects of various activities of the project and each element of the receiving environment. The network showed a very complex system, which was useful in identifying indirect impacts and also interactions between the impacts (Fig. 3).

This network diagram is a directed graph with elements which are stated textually in various shapes. The network of impacts is initiated by one action of the project process. The process was subsequently repeated with each of the actions on the left of the diagram. As shown in Fig. 3, primary impacts and secondary impacts are defined respectively by rectangle and circle shapes and also their relationship are marked by unidirectional arrows. The directions with same color and shape indicate that there are links between individual elements of the environment and activity. The magnitude of the interaction (extent or scale) is described by assigning a value ranging from 1 (for small magnitudes) to 5 (for large magnitudes). This method could identify beneficial, as well as harmful impacts using appropriate designators (Fig. 4). In both cases of primary and secondary impacts, simple shapes (rectangle and circle) show negative impacts of the project while the double shapes represent positive impacts. Also, the activities which cause irretrievable impacts on the

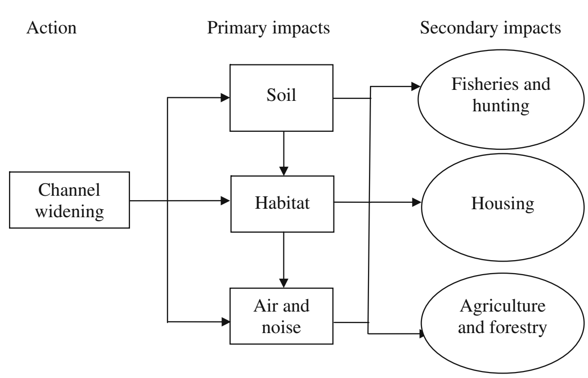

Fig. 3 Sample of the diagram used in the European Commission (European Commission 1999)

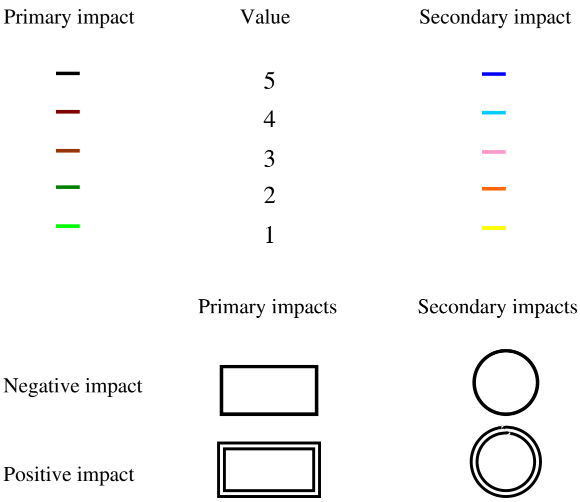

Fig. 4 Legend of impact score for the network-based method

environment are shown by colored boxes. When the cause-and-effect impact in feature of chains was prepared, each action and its potential for impacting each environmental item is to be considered. Scoring can be used to give an overall total score for the project or alternative options. The total number of specified actions and environmental items may increase or decrease depending on the nature. Following this approach, a comparison is made between the alternative routes in terms of their degree of impacts in order to select the least impact route. Note that all the interactions between elements is presented in EIA report in both text and diagram formats.

Result and discussion

Evaluation and comparison of the alternatives

The large number of interaction paths shown between the elements demonstrates that an impact on one of the key elements has a high potential to cause major change in an overall system (European Commission 1999). Network diagrams are one of the best ways of representing these casual chains. A sample of cause-and-effect diagram in Fig. 5 illustrates the network of impacts initiated by one action of the road operation phase (the effect of transportation). As it was mentioned earlier in this paper, the lines in same color demonstrate that changes in one element imply related changes in other elements. For example, where the air would be affected by transportation of the proposed road, this would in turn impact upon water quality. These changes would affect flora and fauna of the area which in turn would influence the food chain. Food chain then interacts with a highly complex diversity change. Changes in the relative size of diversity will decrease the rate of ecotourism. Thus, it can be seen that an impact on one of the key elements has a high potential to cause major change in an overall ecosystem.

Developing a network or system analysis will be depending upon a number of activities. Hence, as the same way, the other activities which are associated with the road development would be considered. The impact of the alternatives on each component is subsequently assessed and scored, and then the scores are normally assembled (Table 1).

As Table 1 shows, total weighted impact score for the first alternative is −608 which imply that on the whole, it is more beneficial than the other one. But, because of the following reasons compared with widening of existing road, construction of a new road is approved:

- Presence of more irretrievable impacts of existing road to proposed road such as fragmentation, ecosystem loss,...
- Nonexistence of any extra alternative from developer viewpoint because of mountainous area

It is critically important to precise any assessment to those things that specifically and coherently address the focal question of the assessment (e.g., biodiversity, sustainable economic development). The choice of an alternative in EIA which minimizes the environmental impact of the action should be an important determinant of any decision to proceed.

The review of literature of EIS case studies in UK and Wales (Perdicoulis and Glasson 2006) revealed that the use of casual networks by practitioners in the determination significant impacts is extremely low, at the order of 3% or less. The search in the EIS projects in Iran also indicates

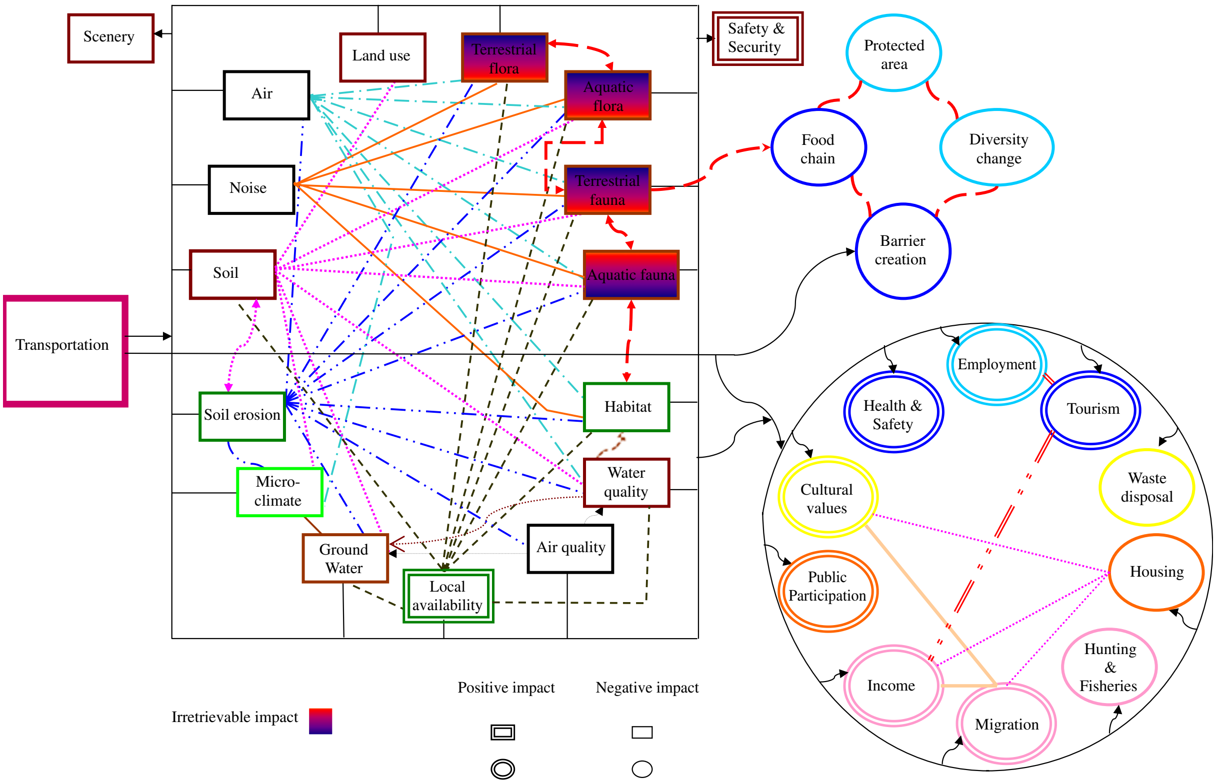

Fig. 5 The impacts of operation phase for proposed road

the same findings. It can be explained by the two drawbacks of this method (time consumed and complexity). It is suggested that when casual relationship appears too complex, people tend to either simplify in their own way or ignore the casual model altogether (Perdicoulis and Glasson 2006). However, it seems that highlighting the chains and impacts by color makes explicit mechanisms of cause and effect and understanding impacts. In other words, visual representation of network method enables the decision maker's, i.e., managers to understand the nature and made an informed decision. From this context, in this study, network analysis is applied because particular principles of networks such as transparency and integration make it to be appropriate in ecological impact assessment. This finding was consistent with past studies as was the finding that this methodology provides a good understanding of the effects of the scheme on the receiving environment (European Commission 1999; Perdicoulis and Glasson 2006).

Table 1 Summary in construction and operation phase for two alternatives

Scenarios	Positive impact	Negative impact	Total
Alternative 1 (widening the existing road)	144	752	−608
Alternative 2 (construction of a new road)	143	861	−718

Monitoring

Consideration of boundaries, natural and anthropogenic is very important in monitoring any assessment. Hence, decisions must be able to deal with widely differing situations and promote good-quality development.

Since the proposed road has more disadvantages, monitoring of the noise levels has been carried in first year of operation phase at nearby road. Sound measurement at different sites was done in operation phase in order to assess the environmental impact of noise on human and biodiversity. A total of five stations throughout the mentioned road were selected for monitoring noise. Measurements were carried out two times at each station, and each time was divided into working day and vacation day (Fig. 6). At a distance of 5, 10, 50, 100 m from the road in summer, the sites were selected based on land use and geomorphology types. Since, summer is a holiday season in Iran, the travels would be increased. Hence, recognition of noise impacts in this season could exactly be accomplished. Noise measurements were conducted in the mentioned sites using sound level meter type 2236 from Bruel and Kjaer. There are different sound level values, but for the purpose of this study, $L_{\max}$, s_{pl}, and L_{eq} were the used values. The result of the noise measurement in five points is shown in Table 2.

The noise standards for different category of areas are based on the weighted equivalent noise level (L_{eq}). For this stage, the obtained average L_{eq} on the road limits (the closest point to Dashtearjan–Poleabgineh road) up to 100 m from the road (the most far point to the road) with noise standard should be compared. Iran, similar to several countries, has enacted laws to regulate ambient noise levels. Table 3 shows the noise standard in Iran. From this stage, it could be concluded that for residential areas, the noise levels recorded at all points are higher than prescribed permissible levels. In addition, during operational phase, the maximum L_{eq} and $L_{\max}$ were in the closest point of fifth station, and the minimum was at a distance of 100 m from the third station. Placement in sharp slope, speed decrease of vehicles, and increase in noise engine are the reasons why station 5 has a significant impact on existing ambient noise levels.

Noise pollution, as it affects humans, has been a recognized problem for wildlife. Many researches have worked on the effect of noise on wildlife (e.g., Barnass 1985; Luckenbach and Bury 1983). They agree that noise can affect the animal's physiology and behavior. In some cases, wildlife

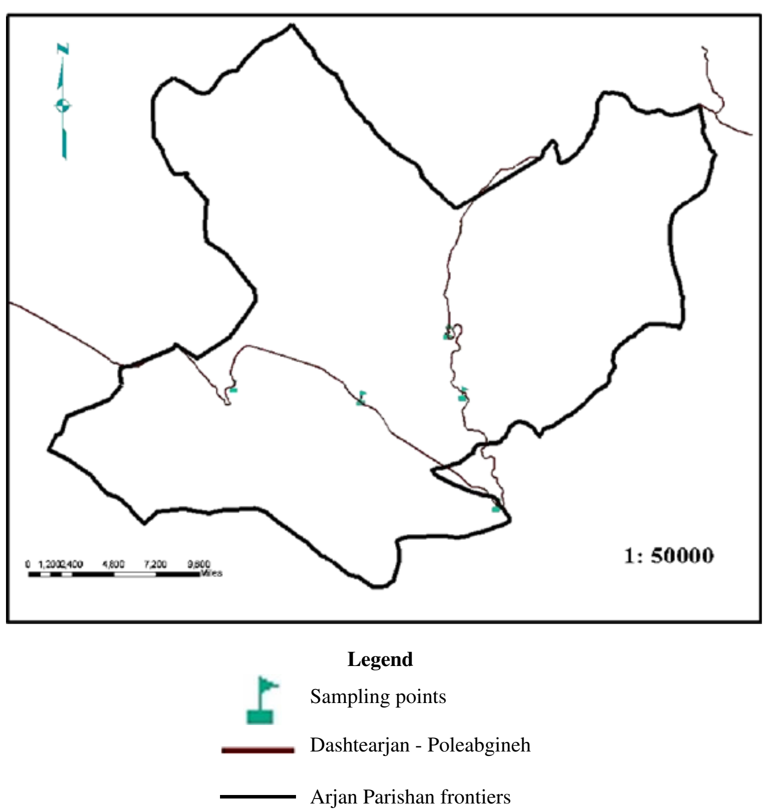

Fig. 6 Sampling locations of noise in the study area

Table 2 Result of noise measurement at Stations 1, 2, 3, 4, and 5

		spl	L_{eq}	L_{max}
Station 1				
Vacation day	At the edge of the road	63.3	71.3	87.6
		65.9	69.3	90.1
Working day		73.2	73.1	87.4
		65	76.6	84.9
Vacation day	5 m far from the road	62.4	70.1	87.6
		59.9	68.4	78.3
Working day		57.2	71.4	87.2
		52.1	68.8	84.9
Vacation day	10 m far from the road	61.6	68.9	87.6
		57.6	66.8	78.1
Working day		56.3	70.2	87
		54.1	67.3	84.9
Vacation day	50 m far from the road	46.8	67.7	87.6
		54.1	56.1	69.9
Working day		54.9	69.5	86.4
		50.7	65.9	84.6
Vacation day	100 m far from the road	44.6	48	60
		43.2	49	59.1
Working day		52.5	68.8	86.2
		49.8	65.4	83.9
Station 2				
Vacation day	At the edge of the road	62.9	65.2	82.2
		66.3	68.1	85.8
Working day		66.4	69.2	87.2
		69.2	72.2	89.9
Vacation day	5 m far from the road	55	59.8	75.5
		57.8	60	78.1
Working day		65.3	69	87.2
		58.2	62.7	78.4
Vacation day	10 m far from the road	52.7	57.5	73
		55.4	58.1	75.6
Working day		63.9	68.7	87.1
		57.4	61.2	78.2
Station 3				
Vacation day	At the edge of the road	68.8	72.7	90
		67.3	72.6	92
Working day		76.2	70.7	86.3
		71.1	72.8	86.1
Vacation day	5 m far from the road	61.4	66.9	83.5
		60.8	66.8	81.4
Working day		62.6	65.9	80.1
		59.1	66.1	80.1
Vacation day	10 m far from the road	62.6	65.6	83.5
		59.1	63.3	77.8
Working day		59.7	64.2	78.6
		58.1	65.9	78.4
Vacation day	50 m far from the road	52.7	58.9	67.5
		56.2	55.7	67.9
Working day		51.1	59.8	66
		52.3	60.4	67
Vacation day	100 m far from the road	43.2	51/2	54.3
		49.4	53.3	36.6

Table 2 (continued)

		spl	L_{eq}	L_{max}
Working day		48.6	50.1	61.9
		48	54.3	62
Station 4				
Vacation day	At the edge of the road	72.5	74.5	92.8
		74.3	75.3	101.2
Working day		68.3	70.7	87.6
		70	73.8	90.4
Vacation day	5 m far from the road	68.8	73.5	92.8
		71.9	74.3	98.6
Working day		67.1	70.7	87.2
		71.4	72.9	90.4
Vacation day	10 m far from the road	68.3	70.5	79.6
		70.2	73.1	83.2
Working day		60.3	66.6	83.8
		66.8	70.3	89.2
Vacation day	50 m far from the road	49.8	52.8	69.5
		53.4	54.7	71.2
Working day		50.8	56.2	96.6
		55.4	67.4	89.1
Vacation day	100 m far from the road	50.3	52.6	65
		50.9	52.3	65.6
Working day		43.6	50.6	62.4
		56.3	65.2	89
Station 5				
Vacation day	At the edge of the road	71.9	77.6	103.7
		69.2	78.4	105.1
Working day		65.3	68.1	86.8
		70.9	73.3	89.9
Vacation day	5 m far from the road	63.1	64.7	82.6
		60	63.3	84.7
Working day		44.7	65.3	83.9
		63.1	66.3	92.7
Vacation day	10 m far from the road	58.2	61.9	81.6
		62.2	64.8	83.8
Working day		58.3	63.1	83
		62.9	68.7	91.8

In stations 2 and 5, consideration of mountainous area, some sampling was not performed

falls into noise pollution and changes their routine activities. But birds and other animals that are connected with sound signals would be disturbed in the limits of the road (Bialek and de Ruyter van Steveninck 2005; Niven et al. 2003; Sornborger and Adams 2008). However, understanding species' ability to adapt their communicative systems to cope with human-made noise constitutes an important contribution to wildlife conservation (Lengagne 2008).

Table 3 Ambient noise standards in Iran (Monavai 2001)

Category of zones	L_{eq} in dB (A)	
	Day	Night
Residential	50	30
Residential and commercial	60	50
Commercial	65	55
Residential and industrial	70	60
Industrial	75	65

[a]Day time (7:00 A.M.–10:00 P.M.)
[b]Night time (10:00 P.M.–7:00 A.M.)

For this study, in order to measure the sound intensity, the closest animal habitat of Arjan–Parishan biosphere reserve from Dashtearjan–Poleabgineh road has been calculated (Table 4). It should be mentioned that Dashtearjan–Poleabgineh road passes through *Ursus arctos*, *Capra aegagrus*, *Gazella subgutturosa*, *Herpestes*

Table 4 Nearest distance of Arjan-Parishan biosphere reserve habitats from the road

	Habitat	Closest distance of each species to Dashtearjan–Poleabgineh
1	*Hyla savignyi*	594
2	*Bufo viridis arabicus*	902
3	*Rana ridibunda ridibunda*	775
4	*Uromastyx asmussi*	303
5	*Walterinnesia aegyptia*	876
6	*Macrovipera lebetina*	3,318
7	*Natrix tesselata tesselata*	211
8	*Mauremys caspica ventrimaculata*	1,958
9	*Testudo graeca zarudnyi*	620
10	*Francolinus francolinus*	2,872
11	*Pelecanus crispus*	1,880
12	*Oxyura leucocephala*	2,254
13	*Ovis Orientalis Laristanica*	260
14	*Panthera Pardos*	2,262
15	*Dama Mespotamica*	1,200

edwardsii, *Varanus griseus*, *Branta ruficollis*, *Grus grus* habitats.

Afterwards, average of obtained spl from all stations was computed. Therefore, with the following expression, reduction of noise pressure would be estimated as follows (Barthwal 2002):

$$\mathrm{spl}_2 = 10 \text{ Log }_{10} \frac{R}{r} \qquad (1)$$

Sound level at R distance $= \mathrm{spl}_1 - \mathrm{spl}_2$

R Distance of the habitat to limit of the road
r Meters from the limits of the road (5, 10, 50, and 100 m)
spl_1 Mean of sound level at (selected as 5, 10, 50, and 100 m) based on dB
spl_2 Reduction of noise pressure based on dB

In view of the experimental conditions in the present study, sound level pressure in habitat species of Table 4 is not more than the admissible standards. The quantity fluctuates between 33.47 to 45.86 dB which shows decrease in spl values. Although pressure to environment would be abated during reach of habitat, it is not appropriate for wildlife. Also, as mentioned earlier, noise pollution impacts as the proximity of other species habitat to the road would not be declined.

Traffic noise and other forms of anthropogenic noise can impact wildlife in different ways. The first involves noise as source of disturbance (Frid and Dill 2002; Lengagne 2008). Since insulated traffic noise would harm animals and in a real ecosystem, interaction of various factors would result in long-term impacts for different levels; thus, in order to protect the wildlife from the adverse impacts, it is necessary to apply mitigation measures. Control of noise at the source, i.e., tree plantings and earth berms, propagation of noise in the atmosphere by putting noise barrier, and noise control at the receivers end, are some measures that could be taken to reduce noise pollution.

Conclusions

Human activities such as road construction can alter fundamental ecological process, including the balance of water, energy, noise, air, etc. which can in turn influence other aspects of the environment. On the other hand, since infrastructures may reduce other actions or secondary impacts such as land development or change social and economic patterns. Thus, network method is the best one to assess the impacts. A wide variety of information must be used in a network method, and it is also time-consuming and costly method, but simple and comprehensible representation of project impacts makes it functional. Generally, a disadvantage of network analysis is that it may not be quantitative. However, as shown in this paper, it is possible to include irretrievable, direct, and indirect impacts in the network diagram using quantitative measurements.

Consequently, the results of the scenario analysis reveal that Dashtearjan–Poleabgineh road is more desirable. However, as a result of the importance of Arjan–Parishan biosphere reserve as a unique biodiversity and nonexistence of any extra alternative, Dasht Arjan Poleabgineh road was constructed. An experimental approach of noise along Dashtearjan–Poleabgineh road in the first year of operation phase shows that sound level is much higher than admissible standard. Thus, in order to decrease any noise pollution, a strong control program such as tree planting and erecting earth berms especially in core area of the study area is essential for adverse impacts of vehicles.

References

Barnass, A. N. (1985). *The effects of highway traffic noise on the phonotactic and associated reproductive behavior of selected anurans*. Nashville: Vanderbilt Univ.

Barrow, C. J. (1997). *Environmental and social impact assessment—An introduction*. London: Arnold.

Barthwal, R. R. (2002). *Environmental impact assessment*. New Delhi: New Age.

Bialek, W., & de Ruyter van Steveninck, R. R. (2005). *Features and dimensions: Motion estimation in fly vision*. arXiv:q-bio.NC/0505003.

Byron, H. (2000). *Biodiversity and environmental impact assessment: A good practice guide for road schemes*. The RSPB, WWFUK, English Nature and Wildlife Trusts, Sandy, Beds.

Canter, L. W. (1996). *Environmental impact assessment*. New York: Mc Graw–Hill.

Darvish Sefat, A. A. (2007). *Atlas of protected areas of Iran*. Tehran: Tehran University Publication, ISBN: 964039114.

European Commission (1999). *Guideline for the assessment of indirect and cumulative impacts as well as impact interactions*. Luxemborg: Office for Official Publications of the European Communities.

Fahrig, L. (1997). Relative effects of habitat loss and fragmentation on population extinction. *Journal of Wildlife Management, 61*, 603–10.

Forman, R. T. T. (2003). *Road ecology: Science and solutions*. Washington: Island.

Frid, A., & Dill, L. (2002). Human-caused disturbance stimuli as a form of predation risk. *Conservation Ecology, 6*, 11.

Gilliland, M. W., & Risser, P. G. (1977). The use of systems diagrams for environmental impact assessment. *Ecological Modeling, 3*, 188–209.

Geneletti, D. (2006). Some common shortcomings in the treatment of impacts of linear infrastructures on natural habitat. *Environmental Impact Assessment Review, 26*, 257–226.

Gontier, M., Balfors, B., & Mörtberg, U. (2006). Biodiversity in environmental assessment-current practice and tools for prediction. *Environmental Impact Assessment Review, 26*, 268–286.

Gontier, M. (2007). Scale issues in the assessment of ecological impacts using a GIS-based habitat model — A case study for the Stockholm region. *Environmental Impact Assessment Review, 27*, 440–459.

Hofstetter, P., & Müller-Wenk, R. (2005). Monetization of health damages from road noise with implications for monetizing health impacts in life cycle assessment. *Journal of Cleaner Production, 13*, 1235–1245.

Lavine, M. J. (1978). *Bridging the gap between economic and environmental concerns in environmental impact assessment. Environmental Monitoring and Assessment Review 2*. New York: Elsevier.

Lengagne, T. (2008). Traffic noise affects communication behavior in a breeding anuran, *Hyla arborea*. *Biological Conservation, 141*, 2023–2031.

Lohani, B., Evans, J. W., Ludwig, H., Everitt, R. R., Carpenter, R. A., & Tu, S. L. (1997). *Environmental Impact Assessment for developing countries in Asia 1*. Overview, 356. Available at: http://www.adb.org/Documents/Books/Environment_Impact/chap3.pdf.

Luckenbach, R. A., & Bury, R. B. (1983). Effects of off-road vehicles on the biota of Algodones Dunes, Imperial County, California. *Journal of Applied Ecology, 20*, 265–286.

Monavai, S. M. (2001). *A guide to environmental impact assessment of highways*. Joint publication of Iran DOE and UNDP; 40.

Mörtberg, U. M., Balfors, B., & Knol, W. C. (2007). Landscape ecological assessment: A tool for integrating biodiversity issues in strategic environmental assessment and planning. *Journal of Environmental Management, 82*, 457–470.

Niven, J. E., Vahasoyrinki, M., Kauranen, M., Hardie, R. C., Juusola, M., & Weckstrom, M. (2003). The contribution of Shaker Kþ channels to the information capacity of Drosophila photoreceptors. *Nature, 421*, 630–634.

Opdam, P., & Wiens, J. A. (2002). Fragmentation, habitat loss and landscape management. In K. Norris & D. J. Pain (Eds.), *Conserving bird biodiversity general principles and their application*. Cambridge: Cambridge University.

Parkhurst, G., & Richardson, J. (2002). Modal integration of bus and car in UK local transport policy: The case for strategic environmental assessment. *Journal of Transport Geography, 10*, 195–206.

Pearce, D. (1993). *Blueprint 3: Measuring sustainable development*. London: Earthscan.

Perdicoulis, A., & Glasson, J. (2006). Causal networks in EIA. *Environmental Impact Assessment Review, 26*, 553–569.

Singh, R. K., Murty, H. R., Gupta, S. K., & Dikshit, A. K. (2009). An overview of sustainability assessment methodologies. *Ecological Indicators, 9*, 189–212.

Slootweg, R., & Kolhoff, A. (2003). A generic approach to integrate biodiversity considerations in screening and scoping for EIA. *Environmental Impact Assessment Review, 23*, 657–681.

Söderman, T. (2005). Treatment of biodiversity issues in Finnish environmental impact assessment. *Impact Assess Project Appraisal, 22*(2), 87–99.

Söderman, T. (2006). Treatment of biodiversity issues in impact assessment of electricity power transmission lines: A Finnish case review. *Environmental Impact Assessment Review, 26*, 319–338.

Sorensen, J. (1971). *A framework for identification and control of resource degradation and conflict in the multiple use of the coastal zone*. Berkeley: University of California, Department of landscape Architecture.

Sorensen, J. (1972). Some procedures and programs for environmental impact assessment. In R. B. Ditton & T. L. Goodale (Eds.), *Environmental impact analysis: Philosophy and methods*. Madison: University of Wisconsin.

Sornborger, A. T., & Adams, M. R. (2008). The evolution of fidelity in sensory systems. *Journal of Theoretical Biology, 253*, 142–150.

Shopley, J. B., & Fuggle, R. F. (1984). A comprehensive review of current environmental impact assessment methods and techniques. *Journal of Environmental Management, 18*, 25–47.

Trombulak, S. C., & Frissell, C. A. (2000). Review of ecological effects of roads on terrestrial and aquatic communities. *Conservation Biology, 14*(1), 18–30.

Verbooma, J., Alkemadeb, R., Klijna, J., Metzgerc, M. J., & Reijnena, R. (2007). Combining biodiversity modeling with political and economic development scenarios for 25 EU countries. *Ecological Indicators, 62*, 267–276.

Wegner, A., Moore, S. A., & Bailey, J. (2005). Consideration of biodiversity in environmental impact assessment in Western Australia: Practitioner perceptions. *Environmental Impact Assessment Review, 25*, 143–162.