A MODEL APPLICABLE IN CASES OF ROAD IMPACTS ON HABITAT ENVIRONMENTS

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Abstract

Greece has many hydrotropic ecosystems offering plenty of beneficial services to both human and other organisms. Such services include the deposition and storage of water with improved quality standards, the enrichment of the water tables, the warrant of water supply and irrigation, protection from floods, production of fish catches, the offering of entertainment and exercise opportunities. Habitats are a space impacted by extended works made by human, like road systems. The integrated, complete system in computerized form presented in this work may assist the design of a road alignment and the analysis of environmental impacts on sensitive habitats caused by the design, construction and operation of a road. The method allows the dialogue between the user and the program. The computer programs and the calculations are standardized aiming to import new standard methods, algorithms, etc., at anytime, without changing the overall structure of the system.

Key words: *habitat, road, impact, assessment model, environment*

1. INTRODUCTION

Local environmental effects of roads may simultaneously exist with effects related to a large road network. In these effects, both biotic and abiotic components are included. The space occupied by the alignment of resource roads is directly lost. The direct loss of habitat and ecosystems (Daigle 2010) may be accompanied by the so called road-effect zone extending out from the road sides (Boarman & Sazaki 2006).

Ecosystem characteristics and species habitat needs and requirements are very different from place to place. Thus, the spatial effects of roads are also very diverse (Ahmed et al. 2013). It is clear that wildlife species with narrow ranges of mobility have a need for smaller habitats. On the other hand, mammals and birds are spread across wider living environments.

Wildlife populations are very often separated by human structures or other activities. Roads are very known example. Areas of habitat connecting such separated populations are called corridors (wildlife, green or habitat corridor). Corridors help prevent negative impacts like reduced diversity from a genetic point of view or inbreeding (Weeks et al. 2011). Fire and diseases have an effect on populations. Corridors can also help in restoring the previous state.

Referring to the negative impacts of roads from a time point of view, it can be stated that such impacts may occur both during the construction of the road project and subsequently during the use or maintenance of the road structure and its verges (Spellerberg & Morrison 1998).

An effort to resolve the discrepancy between universal models and a proposed road alignment is the Environmental Impact Assessment achieved by various systems. A system of sub-programs of this type has been developed in the Transport Engineering Laboratory of the Democritus University of Thrace in order to analyze the full geometric characteristics of a road project and assess the impact caused by both the construction and operation of roads to spatial ecological potential.

In the present paper, the part of the program relating to the impacts on the environment due to the operation of roads whose alignment passes through protected habitats will be analyzed. The goal is to highlight the dominant idea on which the software is based and the way the relationship between the user and the computer is interactively developed when data is imported as well as when the management of results is necessary.

Before analyzing the function of the proposed model, it is very useful to mention the laws protecting habitats of high value in Greece and give some features characteristic for each of the main habitats by which highways are nowadays running or going to be constructed.

2. TREATIES PROTECTING GREEK VALUABLE HABITATS

Protected areas are hosting unique, and thus valuable, elements of the natural wealth. They create a net of safety for the biodiversity of Greece which is one of the richest in the world regarding its forests, lakes, rivers, lagoons, mountains and of course sea. All important habitats are protected by the Greek legislation, mainly by the Ramsar and NATURA 2000 conventions.

The European Ecological Network NATURA 2000 had been founded in order to create a cohesive protected areas network in Europe. These areas include specific types of natural habitats, as well as species of flora and fauna which have significant priority on European level. The areas were initially divided in A (uniqueness of habitats and or species, regions of high value biodiversity), B (significant biodiversity but not uniqueness) and C (not enough information to access these areas to NATURA) categories. Areas are designated as protected under national law (Law 1650/86, as in force after its amendment by Law 3937/2011), conforming to the provisions of the 79/409/EEC directive. Any development in NATURA areas could be made on the precondition that the activities and the projects exercised in them they do not derogate from their particular ecologic features. The Network is comprised of two types of areas: the Special Protection Areas (SPA) for the avifauna and the Sites of Community Importance (SCI) based on the 92/43/EEC Directive “for the preservation of natural habitats and the wild fauna and flora. Figure 1 depicts all Special Protection Areas in Greece.



Fig 1. The 263 NATURA 2000 sites in Greece (source: Minister of Environment and Energy)

The Ramsar Convention was signed on February 2nd, 1971 in the Iranian city of the same name and entered into force on December 21st, 1975. Greece was the 7th country to sign and ratify this treaty by virtue of the Presidential Decree 191/74 establishing 10 protected wetlands which are included in the list of Ramsar Wetlands of International Importance. 7 out of the 10 Ramsar sites are located in the vicinity of the Egnatia Motorway, Northern Greece. Areas protected by the Ramsar Convention are listed in Tables 1, 2, 3 and 4 for the Western Greece Territory, the northern (Western and Central Macedonia parts) Greece, and Thrace, respectively

Table 1. Ramsar protected areas in southern Greece

Characteristic ecosystems	**Description**
Kotychi Lagoon and Strofylia Forest	
Wetlands and the surrounding flooded areas, The *Pinus pinea* forest, Sand dunes, Limestone hills	Kotychi is the largest lagoon in the Peloponnese with an area of approximately 750 hectares and an average depth of 0.40–1.0 meters. Located near the lagoon, the Strofylia pine forest covers a coastal forest strip 15 km long and 0.5-3.5 km wide.
Messolonghi Lagoon	
Aquatic ecosystem The basic ecologic characteristic of the area is not only the 150.000 acres lagoon, but the multiformity of formations and the diversity of habitats which implies great biodiversity respectively	The Messolonghi Lagoon is one of the most important wetlands of Europe. Birds of prey, amphibians, reptiles, swamp and sea turtles are some of its inhabitants.
Amvrakikos Gulf	
Semi closed eutrophic A coastal inlet connected to the sea. The area supports a rich reptile and amphibian fauna, is important for breeding, staging and wintering numerous species of water birds, and provides important feeding grounds for nesting raptors. Nesting species include globally threatened *Pelecanus crispus*.	The extensive delta of two rivers including freshwater marsh with the largest reed beds in Greece, wet meadows and seasonally inundated land, lagoons, barrier spits, a major salt marsh, and some of the most extensive tracts of riparian forest remaining in Greece. Aitoloakarnania, Preveza, and Arta Territorial Unities are covered. It was added to the Montreux Record, July 4th 1990 because numerous human activities like traditional fishing, intensive fish farming, livestock grazing, and (illegal) housing construction have modified the water balance, and the demand for irrigation water has led to increasing salinity levels.

Table 2. Ramsar protected areas in northern Greece (West Macedonia)

Characteristic ecosystems	**Description**
Small Prespa Lake	
Wetland ecosystem favoring breeding and feeding of rare water bird species. It hosts the world‘s largest breeding colony of the Dalmatian pelican (*Pelecanus crispus*). The flora in the region is composed of more than 1,500 plant species of which 146 endemic species in the Lake Ohrid and 39 endemic species from the Prespa Lakes.	Small Prespa Lake was added to Ramsar list in December 21st 1975. In 1999 the Society for the Protection of Prespa received the Ramsar Wetland Conservation Award for its conservation efforts.
Axios River Delta - Loudias River - Aliakmon River and Kitros Salt Pit	
The wetland with more than 295 bird species, 27 mammal species and 27 reptile and amphibian species is not uniform, composed by individual habitats having special features each. Plant societies adapted to sand, plants resistant to salt, grassland with rushes reed beds, aquatic plants and riparian bowery vegetation have been created.	It’s a National Park. An important role in these areas being found between the land and the sea is played by water (underground, surface, permanent, seasonal) as well as by its salinity.

Table 3. Ramsar protected areas in northern Greece (Central Macedonia)

Koronia and Volvi Lakes, Rentina Straits (Macedonian Tempi)	
The two lakes compose the wetland complex. Part of this system is the lakeside forest of Apollonia, on the south bank of Lake Volvi, a kingdom of grey herons (*Ardea cinerea*), since is the only area in Greece where mixed colonies of grey herons and white storks (*Ciconia ciconia*) are hosted. Rare predators have been recorded. Richios River crosses the Rentina Straits, characterized by their fauna wealth and protected plant species. A part of the wetland is a significant area for the birds.	Lake Volvi is located at a distance of 39 km east of Thessaloniki and at the west of Strymonikos Gulf the Koronia or Lagkada or Agios Vasilios Lake. The whole area covers 43,000 acres. Rentina's Straits are characterized as Special Protected Area of Mediterranean Importance.
Kerkini Lake	
Many mammals (*Canis aureus L., Canis Lupus, Felis silvestris*, *Lutra lutra*, *Mustela nivalis*, C*apreolus capreolus*, *Lepus europaeus Sus scrofa* etc) 10 amphibian species and about 20 reptile species. 30 fish species, mainly eels – *Conger conger*. Among the about 300 bird species, *Pelcanus crispus* and *Phalacrocorax pygmeus* are unique in the world.	It is an artificial lake constructed in order to restrain the flooding waters of Strymonas River. It has been declared a National Park. Many rare predators like *Aquila chrysaetos, Aquila heliaca*, *Falco peregrinus*

Table 4. Ramsar protected areas in Thrace, Northern Greece

Characteristic ecosystems	**Description**
Nestos River Delta	
Brackish lagoons, salt marsh and undisturbed *Ammophila arenaria* dunes with an endemic plant association of *Cyperus capitatus*, *Pancratium maritimum* and *Eryngium maritimum*. Kotza Orman Forest is the largest expanse of riparian woodland in the southern Balkans (dominated by *Populus alba*, *Salix acutifolia* and *Platanus orientalis*). The area supports the most important population of spur-winged plovers *Holopterus spinosus* in Europe.	Important for the conservation of sand dune plants and animals hoping the encroaching development from Keramoti will have minimal impact on the fauna, the area (125,000 acres) is proposed as National Park, with three Special Protection Areas for bird conservation.
Vistonis Lake, Porto Lagos and Lafra-Lafrouda Lagoons	
Artificial landscapes and 75% wetland (coastal lagoons; mud and sand flats; rivers and streams; salt marshes; sand dunes and beaches; standing brackish and salt water; standing freshwater; tidal rivers; enclosed tidal waters) Important area for breeding, passage and wintering of water birds and raptors, and breeding species associated with reed beds (*Branta ruficollis*, *Haliaeetus albicilla*, *Aquila clanga*, *Aquila heliaca*, *Falco naumanni*).	The whole wetland complex includes two NATURA 2000 sites and a Specially Protected Area. The area has been declared as the National Park of East Macedonia and Thrace Coastal lagoons surrounded by salt-marsh lie between Vistonis lake and the sea.
Ismarida (Mitrikou) Lake and Thrace lagoons complex	
Coastal wetland complex. Species of global	Mitrikou Lake, it has inflow from the river

conservation concern: *Haliaeetus albicilla*, *Branta ruficollis*, *Oxyura leucocephala*, *Aquila heliaca*, *Falco naumanni*, *Larus audouinii*. 20,000 water birds (*Tadorna tadorna*; *Anas penelope*; *Anas platyrhynchos; Recurvirostra avosetta*; *Larus ridibundus; Anas crecca*) are hold in winter.	Filiouris, and the lagoons Lafri-Lafrouda, Valtos, Elos, Ptelea, Alyki, Karatza, Xirolimni, and Porto Lagos, presenting high salinity.
Evros River Delta	
Wetland - 316 bird species (very large number compared to the total of 425 species in Greece) *Pelecanus onocrotalus*, *Plegadis falcinellus*, *Platalea leucorodia*, *Pelecanus crispus*, *Larus minutus* and *Chlidonias niger* are passing from the Delta.	Important wetland for the wintering of *Cygnus columbianus* in Europe. The presence of the *Numenius tenuirostris* one of the scarcer birds all over the world. Area: 200 km^2.

3. PARTIAL MODEL OF ROAD IMPACTS IN REGIONS OF ENVIRONMENT THAT DESERVE PROTECTION (HABITATS).

This model researches the effects of a road under construction or in use in habitat regions. Habitats are mainly important natural environments of flora and fauna. Environmentally sensitive area can be described as an area in which plant or animal life or their habitats are either rare or especially valuable because of their special nature or role in an ecosystem and which could be easily disturbed or degraded by human activities and developments (road building, forest clearing, suburban development etc.). Habitats that are very sensitive to human interventions should be protected. Hiscock (1996) has defined sensitivity as the "intolerance of a habitat, community or individual of a species to damage or death from an external factor". It is appropriate to make a distinction between intolerance which causes death or reduces a specific population to unrecoverable levels and intolerance to damage which can be repaired (possible recovery and survival). Tillin and Tyler-Walters (2014) have similarly defined sensitivity as the "likelihood of change when a pressure is applied to a feature (receptor) and its function of the ability of the feature to tolerate or resist change (resistance) and its ability to recover from impact (resilience)". The following types of habitats are very sensitive:

- Habitats that very seldom turn up (unique habitats).
- Habitats that never revive, or regenerate after many years.
- Habitat systems, where particular biotopes, even very small are connected between each other.

Damages in habitat areas in case of road construction are divided into three categories: (a) total loss of habitat surfaces, (b) serious degrade of the development and (c) long-term and late damages.

In the model, the following data, in the form of thematic maps, are used as input:

- Habitats deserving protection (habitat classification according to the degree of ecological importance and variety or threat).
- Water surfaces.

Moreover, the following results from the model of road alignment are required:

- Embankments- road cuts.
- Road carriage lane.
- Impact of road cuts on underground waters.
- Road drainage.
- Polluted areas.

3.1. Total loss of habitat surfaces

The area required by the road alignment destroys existing habitats and subdivides untouched (virgin) areas (Kallimanis et al. 2008).

As shown in the flowchart in Figure 2, the total area required by the road alignment is formed as the union of the "road pavement surface", the "surface of road cuts", and the "embankments surface". The intersection of this result and the "habitat surfaces deserving protection" provides the "lost habitat areas". The rest represents the "remaining habitat areas". These are used to calculate the degree of "segmentation" of former virgin areas. The "segmentation" threatens the great mobility of wildlife. Moreover, animal crossing of the road endangers the animals themselves as well as it lowers the safety on the road.

The capital letter symbols used in Fig 2 have the following meaning: A=habitat surfaces; B=total surface needed for the alignment; C=surface area of carriageway lane, D=A∩B; T= wetland surfaces; V=total surface area required by the road, V=A∪B∪C; and R=remaining habitat surfaces, R=B\A.

3.2. Serious degradation of vegetation growth

Some habitats are particularly sensitive to human interference (e.g. wet habitats will be completely destroyed by construction measures that lower the water table).

The surfaces are calculated in the following steps:

- The “wet habitats” are selected as a subset of “remaining habitats”; i.e. indicator A in the flow diagram and then intersect with the “effect of road cuts to groundwater”. The result of this intersection gives wet habitats that are damaged or destroyed, due to the lowering of the water table, that is, the result of “potential loss of habitat due to lowering of aquatic horizon” Habitats can also be damaged with the deprivation or the increase of surface water inflow.
- Artificial drainage, diverting and pumping of the water will result in dramatic changes in the physical structure of the habitat. Such changes have their greatest effects on aquatic ecosystems which are cleaved from their own source of water (atmospheric precipitation, runoff).

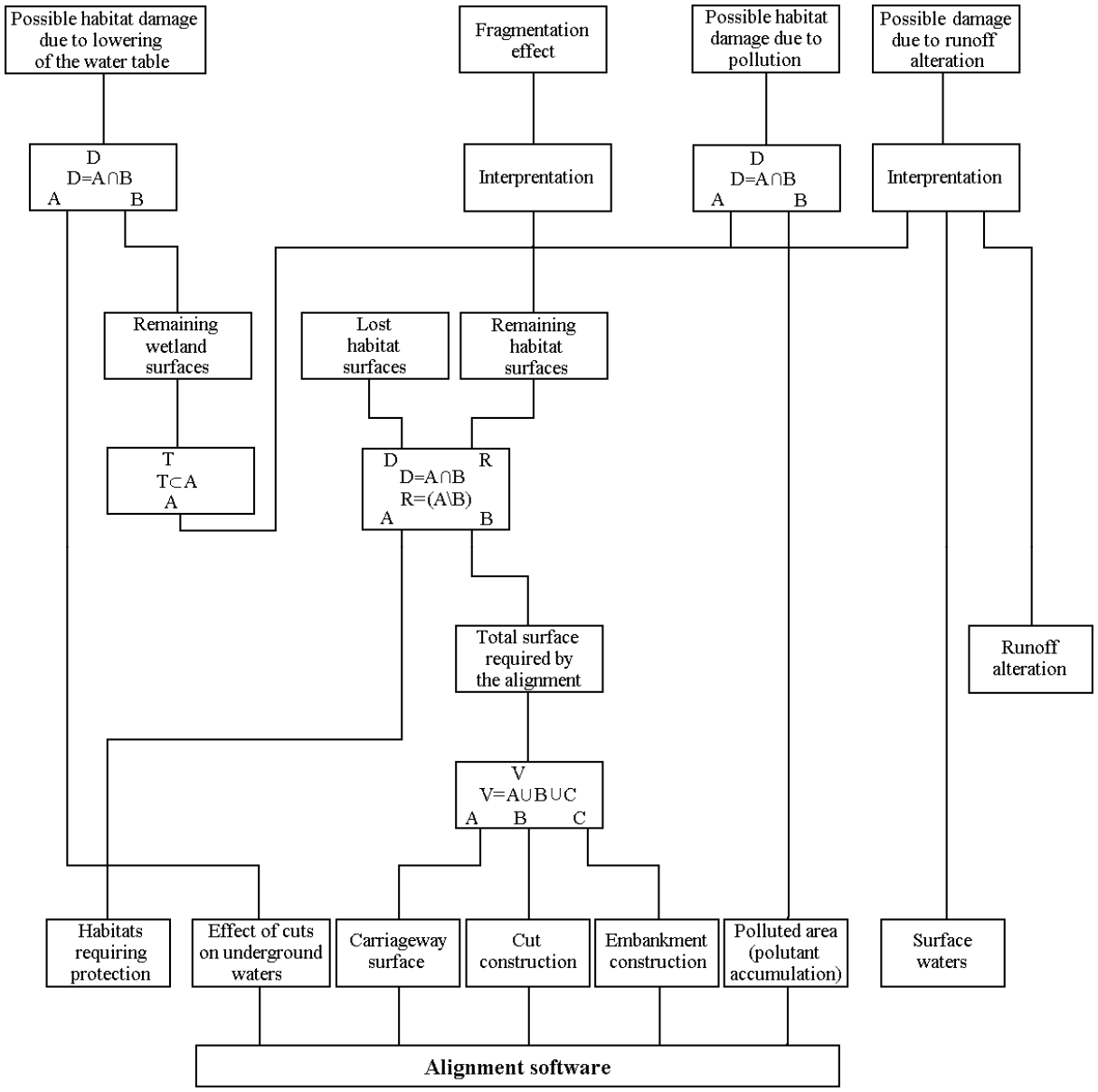


Fig 2. Flowchart for the assessment of road impacts on sensitive habitats

In the following design stages, the amount of water flowing to the recipients (streams, etc.) after rain is estimated. If the amount of water exceeds a certain percentage, potential damage will appear to shores, otherwise, the recipients should be extended. Both cases (damage and extensions) result in the destruction of existing streams and riverbanks.

In the beginning, the three data are drawn together as follows: (a) "Surface water", (b) "Remaining areas", and (c) "Runoff change" (surface water sub-program). It follows an interpretation of the yielded findings.

The habitat of the bank of a river is classified as degraded, when the drainage of the new road pollutes the water. The degree of contamination is obtained from the Table 5 referring mainly to surface water model. The result of the interpretation is stored as "possible habitat loss by the surface water".

Table 5. Impacts due to increased water runoff

% Change	**Diverse impact grade**
Up to 1%	None
1% to 5%	Small
6% to 10%	Large
More than 10%	In excess

3.3. Long-term and delayed damages

Road traffic emissions degrade perennials and habitat wildlife (Bell et al. 2011). As the plants on habitats are immobile, they are contaminated by exhaust fumes and with time contaminants accumulate. If these plants are used to feed the wild animals, the food chain is contaminated after a certain period of time. In contaminated areas of habitat is a permanent risk to the flora and fauna. Existing species die and completely new species are formed. Thus, the structure of the habitat is completely altered. Contaminated habitat surfaces are calculated by the intersection of the "remaining habitats" with "contaminated surfaces" and the result is "possible damage to habitats from pollution".

4. CONCLUSIONS

It is globally recognized that the ecosystem characteristics and species habitat needs and requirements differ largely not only from territory to territory but from adjacent sites as well. This leads to diverse spatial effects of roads and to the need for different countermeasures. In addition to causing direct mortality, roads can have a number of indirect impacts such as habitat fragmentation. Wildlife species within narrow mobility ranges need smaller habitats, while mammals and birds are spread across wider living environments.

Greece is very wealthy in habitats where scarce wildlife is found. To protect these valuable natural features a series of laws and codes have been put in act. The most strict of them are the Ramsar convention and the NATURA 2000 treaty.

The integrated, complete system in computerized form presented in this work may assist the design of a road alignment and the analysis of environmental impacts on sensitive habitats caused by the design, construction and operation of a road. The method allows the dialogue between the user and the program. It must be noted that, for a part of the calculations, it is not possible to find simple algorithms. The computer programs and the calculations are standardized aiming to import new standard methods, algorithms, etc., at anytime, without changing the overall structure of the system.

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