TRAZADO ÓPTIMO DE RUTAS EN ESPACIOS NATURALES PROTEGIDOS:EL ENTORNO DE DOÑANA

GENERATING TOURISTIC PATHS IN DOÑANA UNDER ENVIRONMENTAL CRITERIA

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In recent years there has been an authentic blooming of touristic itineraries and routes over all corners of the planet (Briedenhann and Wikens, 2003). The touristic classical proposals, focused on a specific destination, have evolved towards interactive guides of travelling which highlight determined valuable aspects to be recognized by means of the visit to the country.

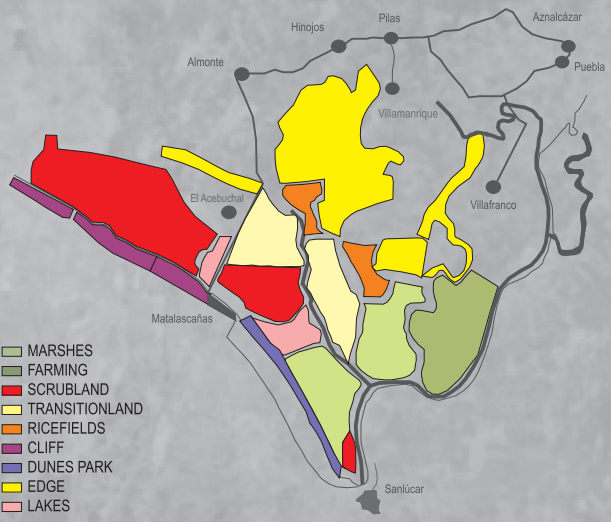
In the design and implementation of those routes, a journey in which predominates a specific heritage category (cultural, archaeological, historical, artistic or natural) is offered to visitors and, in order to become different from other proposals of the same segment, new attractions (natural monuments, literary heroes, movie sets, architectural paradigms, etc.) are incorporated along the itinerary (Hernandez-Ramirez, 2011).

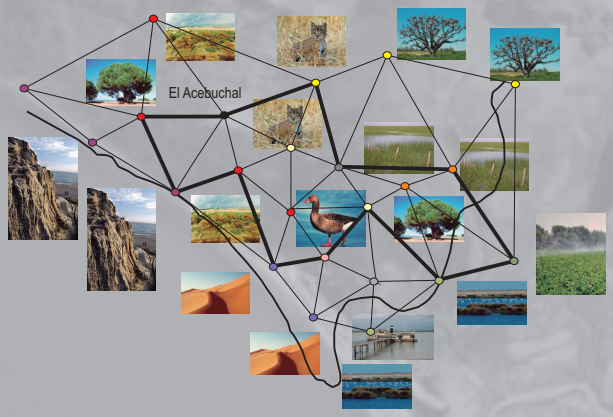
Ecotourism routes are possibly one of the best tools to achieve greater sensitivity and awareness in the population of environmental values. The circuits are commonly circular, starting and finishing in a center for the environmental interpretation. The path length should not exceed a certain length such that its progress doesn't represent a great effort for people nor the ecosystem becomes affected.

The route design should incorporate a high level of biodiversity. The optimal number of stops for including comments to the visitors is usually near to five and the duration of each stop should not exceed 10-15 minutes in order to maintain the attention. This time may be increased when people move on foot (and in silence) to reach a destination that can't be accessed using a motor vehicle.

The National Park of Doñana was recognized as Biosphere Reserve in 1981, Wetland of International Importance in 1982, Protected Area with European Diploma since 1985, Special Protection Area for Birds in 1988 and UNESCO World Heritage Site in 1994. Doñana receives more than 400,000 visitors annually, although less than 20% of them participate in paid tours inside the Park (Voth, 2006). The primary objective of those tours consists of offering facilities of environmental educational interpretation in situ, taking the existing biodiversity (marsh, forest, pasture, scrub, dunes, marshland, beach) into account

Assume that Delaunay triangulation has been established in the territory so that each triangular cell is visible from their own centroid or any vertex of its border.





The following models represent some variants which can be used in order to assess the generation of routes in the National Park of Doñana. Problems 1 and 2 belong to a visibility setting, whereas Problem 3 turns out to be useful for designing cyclical paths which collect one instance at least of the existing ecosystems.

DESIGNING A HAMILTONIAN ROUTE IN A GRAPH (NOT NECESSARILY CYCLICAL):

PROBLEM 1: The zookeeper's route problem (Chin and Ntafos, 1992): Given a simple polygon P (the zoo) with a set C(P) of disjoint convex polygons (the cages) inside it, find a shortest route inside P that visits (without entering) each polygon in C(P). In some sense, the zookeeper's route problem looks like our Tourist's Tour Problem if we consider cages as environmental units.

PROBLEM 2: The safari route problem (Ntafos, 1992): Given a simple polygon P and a set C(P) of disjoint convex polygons inside P, find a shortest path inside P that visits each polygon in C(P). One may consider the safari route problem as the tour made by the rangers (or the scientific researchers) whose objective is to supervising all the environmental units (polygons) while minimizing the total travel distance.

PROBLEM 3: The Generalized Traveling Salesman Problem (Laporte and Y. Nobert, 1983): Given a vertex set V, partitioned into m disjoint clusters $V=V_1 \cup V_2 \cup \dots \cup V_m$ find a minimum cost tour containing at least one vertex from each cluster.

The tour in the figure is of minimum cost and contains at least one vertex from each cluster (different nodes have been assigned to the same cluster if they are instances that correspond to the same ecosystem).

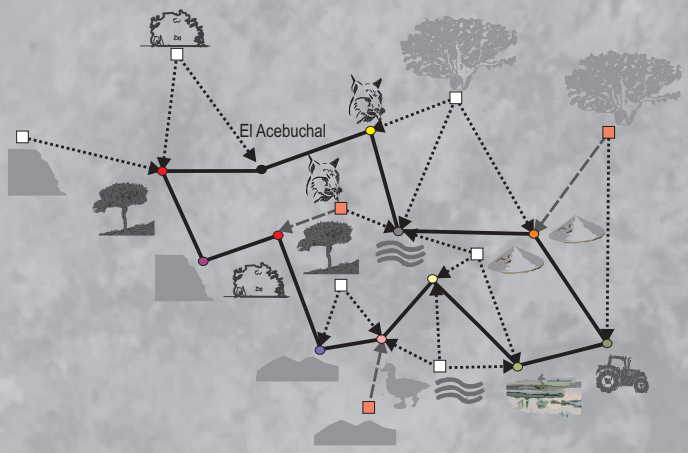
Problems 4 and 5 can be used in order to extend the optimal cycle by adding connections to other singular locations with limited accessibility (hiking in silence). Problem 5 rounds off the model since it provides a guarantee of biodiversity.

DESIGNING A BIMODAL NETWORK OF ROUTES IN A GRAPH (MULTICRITERIA SETTING):

PROBLEM 4: The Ring Star Problem (RSP) (Labbé et al., 2004): Given a vertex set U, composed of two subsets V and W, determine a solution where the sum of the ring costs of all edges on the cycle inside V and the assignment costs associated to arcs connecting nodes of W to the cycle is minimized.

PROBLEM 5: The Generalized Covering Tour Problem (GCTP): Given a vertex set U, composed of two subsets V and W, determine a cycle, not necessarily Hamiltonian over subset $V=V_1 \cup V_2 \cup \dots \cup V_m$ of minimum cost such that the tour contains at least one vertex from each cluster and, moreover, a number of vertices of W can be covered in the sense of they lie within a given distance r from a vertex on the tour.

The tour in the figure is motorized and of minimum length, while satisfying the biodiversity constraint. Moreover, three walking excursions are feasible to carry out in spite of spatial and time limitations.



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