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Transport System Environmental Assessment of an Urban Agglomeration Integrated in a Coastal Wetland: Bay of Cadiz (Andalusia, Spain)

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Abstract

This report identifies and evaluates the environmental and social impacts of the transport system on the Bay of Cadiz, such a littoral space characterized by the coexistence of urban settlements and natural environments. Space occupation by transport ways has been utilized as an indicator to evaluate the system evolution and its territorial impacts, according to different strategies of mobility depending on the share of transportation modes. The results show that transport infrastructures represent the main responsible factor of the impact caused by the transport system over the Bay of Cadiz, affecting key elements of the littoral system such as hydrodynamics and sediment dynamics, and the most sensitive environments. Therefore the transport system must be considered as a fundamental factor in the conservation policies in the Bay of Cadiz. On the other hand, the Bay of Cadiz holds a great potentiality to reduce the current pressure of the transport system over the littoral environment, by means of an alternative transport model based on minimizing the infrastructure requirements.

1. INTRODUCTION

Environmental and social transport impacts are widely known and referenced in the specialized literature of the last two decades. In developed countries these impacts are due to or increased by the dominant transport model, based on private automobiles.

The most important environmental transport impacts are energetic consumption, affections to climate, atmospheric pollution, noise and land occupation and fragmentation (Estevan and Sanz 1996).

Amongst the social consequences the most important of these are traffic accidents, social discrimination due to only a part of society being motorized, spatial segregation, time consumption in displacements and health deterioration (Estevan and Sanz 1996).

In coastal areas, land transport impact is due to the effect that transport infrastructures have on the fragile littoral dynamics and from the activity in itself.

The aim of this report is to identify the impact of the transport system on the Bay of Cadiz, and to evaluate the influence of such a system on the evolution of the Bay's landscape. Therefore this study focuses on the territorial impacts of the transport system.

Finally, this study tries to characterize the possible evolution of mass transport share in the motorized mobility and its incidence on the generated territorial impacts.

2. STUDY AREA

The Bay of Cadiz constitutes an area of exceptional value characterised by the coexistence of urban and natural environments in the last 3,000 years. It comprises an area of sea-land space on which a polinuclear urban system is integrated forming a complex and diverse area (Figure 1).

The marine zone occupies 100 km^2 approximately and is constituted by an embayment-like external sector open to the Atlantic Ocean, and by a lagoon-like internal sector limited by sandy spits. The two sectors are connected by Puntales Strait through which water of the internal sector is renewed. In addition to this, there are more than 100 km^2 of intertidal zone formed by tidal flats, salt marshes, tidal creeks and *salinas*, which are very sensitive to environmental changes and of great ecological value. Besides, around 60 km^2 of intertidal zone have been dried up during the 20th century for agricultural and industrial purposes (Barragán Muñoz 1996).

Beaches, small cliffs and old dune systems stabilised by pinewoods complete the natural space. Salt marshes and coastal pinewoods are declared Natural Park and Special Protection Area for Birds (SPA). In addition, it will soon be included in the Ramsar Convention on Wetlands.

The sea-land landscape of the Bay and its dynamics are characterized by a horizontal component bringing about much frailty to the space.

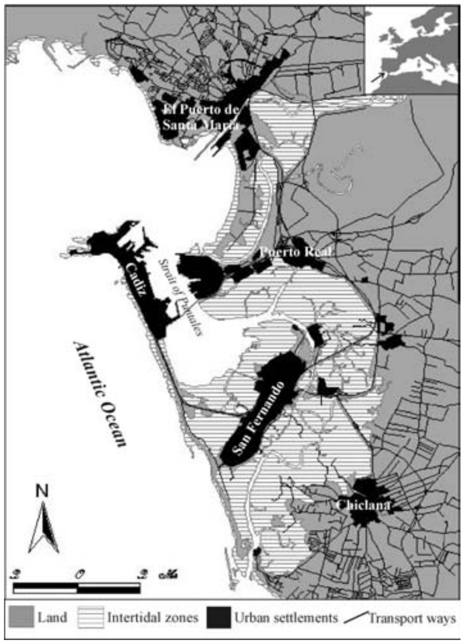

Figure 1: Situation map showing the urban settlements and network of transport infrastructures in the Bay of Cadiz.

This horizontal transport connecting land and sea is responsible for the maintenance of the salt marsh ecosystem, where natural transport of biological species, sediments, nutrients and organic matter is dominated by tide.

On the other hand, the Bay of Cadiz comprises a system of medium and small cities that create a polinuclear urban agglomeration. Metropolitan relationships, although incipient, are nontheless under a strong development. It is a system of complete cities with services adequate for their sizes, far from the classic peripheral-centre model of metropolitan cities. The development of urban settlements in the Bay has been historically constrained by geographical conditions of the territory limiting those settlements to emerged areas and favouring vertical building and high population density in the cities. There are 400,000 inhabitants in the area that presents a population density of 6,324 inh/km^2 in urban locations (IEA 2002). The capital, Cadiz, has a relative important function as centre of leisure, cultural and official activities.

The independence of the cities allows for the number of daily displacements to be low, both on an urban scale and on foot (BB&J Consult 1995). However new metropolitan land uses and relationships, mainly developed throughout the last decades and promoted by the increase of motoring, have generated the rise of metropolitan mobility (Luna del Barco 2002).

The intensity of fluxes in the transport infrastructure main net presents a decentralised structure for mobility (Figure 2).

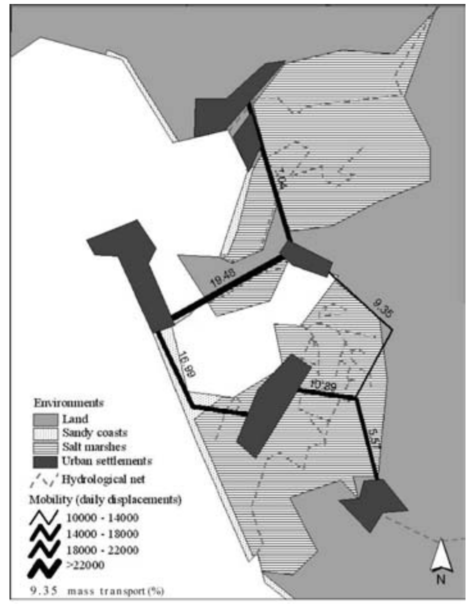

Figure 2: Metropolitan structure of mobility through the main transport network and kinds of environments in the Bay of Cadiz

In modal share of transport, private vehicles represent an 80% of motorized movement. Mass transport shows a decrease in usage due to its insufficient development. Additionally, transport planning and policies during the last decade have been based almost exclusively on building infrastructures for private vehicles and their access to the capital from the rest of the cities (Luna del Barco 2002).

3. METHODS

Impacts have been identified by land inspection, aerial photography and topographic cartography. The results have been classified and mapped dividing the study area in different zones according to geomorphological criteria and environmental sensitivity.

Different transport ways have been digitalized from aerial photographs and digital topographic cartography by means of a geographic information system. Therefore occupied surface for each transport way and environment has been calculated according to their length and their average width.

From a mobility inquiry (EPYPSA 1993), 18 transport zones have been distinguished in order to conform a basic level of mobility flux analysis. Mobility data has been analysed statistically according to mode transport and cause, and assigned to the main transport net.

According to the great differences in space requirements between the automobile and the mass transport, space occupation by transport ways has been utilized as an indicator to evaluate the system evolution and its territorial impacts, considering different strategies of mobility depending on the mass transport participation. From modal distribution of mobility for the main transport network (Fig 2) and the required space of each transport mode per passenger (Whitelegg 1993), the total space demand has been calculated in the current situation as well as in the projected strategies.

4. RESULTS

4.1 Impact inventory

Two impact groups, caused by transport infrastructures and by mobility, have been identified in 4 types of environments (urban settlements, salt marshes, sandy coasts and continental land) in which the study area has been divided.

Transport infrastructures cause salt marsh fragmentation, giving rise to the strangulation of tidal creeks, to the interruption and the modification of the water and sediment dynamics and to the differential filling or erosion processes. Also, the water regime interruption affects the water quality, impeding or making difficult water renovation, and causes a barrier effect for aquatic and intertidal fauna. On the other hand, the infrastructure building over the schorre causes destruction of vegetation and introduction of aloctonous species, encouraged by topography and soil type changes. The landscape impact over the salt marsh is mainly due to the contrast between the dendrite-like network of tidal creeks and the lineal network of transport ways. Impacts due to mobility in this zone are mainly acoustic pollution, which mainly affects birds, as well as water and soil pollution due to dry and humid deposition of atmospheric pollutants.

On the sandy coasts of the Bay, transport infrastructures mainly occupy dune systems. The destruction of the latter contributes to beach erosion due to the loss of sand reserves. Also, the transport ways produce the interruption of aeolian sediment dynamics and of sediment transference processes between the beach and the lagoon or salt marsh, such as overwashing or tidal deltas. They also produce the destruction of very valuable habitats and barrier effect for their fauna. The landscape impact in this zone is mainly due to the rupture of the transition between sandy spit and lagoon or salt marshes.

On the land, an intensification of roads is observed, and is associated to the expansion of urban settlements. Consequently, an intense fragmentation of the landscape and an important loss of natural assets have taken place. The network of transport infrastructures causes changes on superficial hydrology, interrupting the surface drainage to the coast and the contribution of fresh water to the salt marshes. On a social level, the biggest infrastructures produce a barrier effect for people that provokes access problems in some places.

In urban areas, atmospheric and acoustic pollution are intensified, although the values of atmospheric pollution are lower than those of other cities in the region (CMA 1997), because of their small size. The urban space occupation by motorized transport is considerable due to the high density of the urban network. The social impacts are also intensified in urban areas. The incommunication of the cities, the lack of an efficient transport and the increase of displacement distances generate a spatial segregation in the population of the Bay (Luna del Barco 2002), characterized by low economical indicators in the European context. Considering that 29.5 % of families do not own a car and 48% of the population does not have a driving license (66% of women) (IEA 2002), the lack of an adequate transport system produces social discrimination in this sector of the population. The new infrastructures built in the last decades have introduced important changes in the dynamics of the cities, altering land uses, favouring the expansion of urban settlements and inducing a motorization and traffic increase (Luna del Barco 2002).

4.2 Space occupation by transport infrastructure

Occupied surface has been used as a quantitative indicator of the impact due to transport infrastructures in the Bay of Cadiz. The main transport network, which supports the metropolitan mobility, represents 28.5 % of the total surface assigned to roads. Among the types of transport ways (Table 1), motorways stand out occupying one third of total space assigned to non-urban roads, being the roads with the greatest environmental and social impact (due to the high fragmentation they produce). Furthermore, the 31.5 % of the total distance covered by motorways is built over the most sensitive environments of the littoral space (i.e. salt marshes and sandy spits).

Among the types of environments, sandy coasts represent the highest road occupation (Table 2), mainly due to their density over the Cadiz isthmus (see Figure 1). Land and salt marsh environments present a great difference in road occupation. Continental land presents a high road density, yet with a heterogeneous spatial distribution.

Table 1: Total length, average width and total occupied surface by transport infrastructures according to their type.

Type of transport way	Length (km)	Average width (m)	Occupied surface (km^2)	% total ways
Motorways	76.5	50	3.8	33.54
Main road	48.1	25	1.2	10.54
Secondary road	78.2	15	1.2	10.28
Local road	535.9	8	4.3	37.57
Railway	46.1	20	0.9	8.07
Main network	*100.6*		*3.25*	*28.51*
Total	*784.8*		*11.4*	*100*

Hence the highest road density is found in urban spread zones (see Figure 1). Few transport ways cross the active or dried up intertidal zones, although these are of great size (motorways, main roads…). However, the affected extension of salt marshes is wider than the surface occupied by roads. The strangulation of tidal creeks in their intersections with transport network produces changes in the hydrodynamic regime, affecting the creeks' total flooding surface.

Table 2: Space occupation by transport ways according to type of environment

Type of environment	Transport way surface (km^2)	Occupation (%)
Land	8.33	4.18
Salt marsh	2.01	1.90
Sandy coast	0.48	5.96
Total non-urban roads	*11.4*	*3.22*
Urban settlements	15.4	40.00
Total	*26.8*	*7.56*

4.3 Mobility strategies and future scenarios

The space occupied by the main transport network (Fig 2) has been evaluated in the current situation, and for two different mobility strategies depending on the mass transport share (Table 3). The Collective Strategy is based on the generalized use of mass transport for motorized displacements, whose extreme scenario would be a mass transport share of 100 %. On the opposite side of the spectrum, the Individual Strategy is based on the generalized use of the private vehicle, whose extreme scenario would be a mass transport share of 0 %. These projections show the variation margin of the transport system's pressure over the littoral.

Table 3: Space occupation by the main road network in the current situation and projected scenarios.

	Space demand (km2)	Space occupation (km2)	Increase (%)
Current situation	3.34	3.25	-
Individual Strategy	3.51	3.42	5.1
Collective Strategy	2.28	2.22	-31.7

The Individual Strategy projection shows that the current situation is close to the most unfavourable, since the suppression of the metropolitan mass transport would only require extending the roads in a 5 % to satisfy the current mobility. This increase varies from 1.99 to 7.32 % according to the inter-city relations (see Fig 2). The current projects to extend the roads in the Bay, which would mainly affect the inter-city relation of higher increase (7.32%) (such as some road duplications or the construction of a new bridge over the Bay), might mean the completion of that mobility scenario.

On the other hand, the Collective Strategy projection shows a greater profit due to the liberation of space with the increase of mass transport participation (Table 3).

In this strategy, the decrease of transport infrastructure pressure over the littoral exceeds a 30 % in all inter-city relations. These values show the potential of disoccupation and restoration of environmentally valuable zones, affected by transport infrastructures.

This projection does not consider the eventual increase of mass transport occupation (i.e. number of passengers per trip), which would be expected with a growing demand of mass transport. Neither does this consider a greater participation of the railway in mass transport, whose space requirement is smaller than that of the bus (Whitelegg 1993). Both aspects could significantly increase the profitability from space liberation.

In addition, the establishment of a maritime transport system among the cities of the Bay would decrease the space demand in the land. The maritime way is possible in 6 of the 10 inter-city relations of the Bay.

Other environmental indicators have been assessed in previous studies (Luna del Barco 2002; Luna del Barco *et al.* 1998) for the same mobility scenarios, showing the potential of environmental improvement of the transport systems. The assessed indicators (Table 4) show different variation margins, due to their respective saturation degree.

Table 4: Environmental impact indicators of transport system in the Bay of Cadiz in the current and projected situations.

	ENERGY CONSUMPTION (TEP/DAY)	NOISE LEVEL (DBA)	AVERAGE SHOPPING DISTANCE (KM)
Current situation	196.7	72	2.27
Individual Strategy	216.8	75	5.74
Collective Strategy	80.7	58	1.67
Variation margin (%)	10.2 / -59.0	4.2 / -19.4	152.9 / -26.4

The energy consumption is the best indicator of transport global effects (greenhouse effect, climate change, marine pollution due to oil transport, global economy…). The current energy consumption is close to the one which would be reached in the extreme scenario of the Individual Strategy and would suffer a strong decrease applying the Collective Strategy. This shows the inefficient character of the current strategy of mobility and the great potential of transport system, which would contribute, for example, to reaching the international agreements for the reduction of greenhouse gases emissions.

The noise level, which is a good indicator of urban environmental quality, also presents a current value close to the most unfavourable and shows a considerable potential to improve the urban environment, going deeply into the Collective Strategy.

The average distance of shopping displacements is an indicator of the metropolization degree of the Bay's city systems. The values of this indicator show a high degree of functional independence among the urban settlements of the Bay for the present situation. On the contrary, this indicator shows an important increase of metropolitan relationships consequent to the increase of car use in the shopping displacements. This increase would reflect on the demand of transport infrastructure, which would raise the projected value of space occupation in the Individual Strategy.

5. CONCLUSIONS

The impact caused by the transport system over the littoral environment on the Bay of Cadiz is mainly due to the transport infrastructures and may be considered very high. These infrastructures affect key elements of the littoral system, such as hydrodynamics and sediment dynamics. Therefore the transport system must be considered as a fundamental factor in the conservation policies in the Bay of Cadiz.

The transport infrastructures built in the Bay of Cadiz the last decades have provoked deep changes both in the dynamics of the cities and in the Bay's landscape.

Both environmental and social components of the system are similarly affected by negative impacts of transport and both are benefited from the reduction of those effects. Therefore, there is no interest conflict between conservation and population requirements. On the contrary, environmental and social vectors go in the same direction.

Space occupation and fragmentation are the main impacts caused by transport infrastructure. The most sensitive areas, salt marshes and beaches, also support a greater pressure from the transport system, because of the high occupation index in some of them and because of the presence of infrastructures with the greatest impacts on others.

Due to the space frailty and the shortage of useful soil in the Bay of Cadiz, space occupation presents a high environmental and social cost. This justifies the priority of measures focused on minimizing soil occupation, such as those to reduce the space assigned to transport infrastructures.

The Bay of Cadiz presents a great potential to reduce the current pressure of the transport systems over the littoral environment, given the high environmental profitability due to the increase of mass transport participation in the daily mobility, and given the high potential to develop a transport system minimizing the infrastructure requirements, based on the train, maritime transport and non-motorized transport modes.

However, the current and potential metropolitan processes of the Bay's city systems may involve a considerable increase in the demand of metropolitan transport infrastructure, and, consequently, a pressure increase over the natural space of the Bay.

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