COMPUTER ASSISSTED METHODS FOR THE ASSESSMENT OF IMPACTS ON GEOMORPHOLOGICAL RESOURCES; APPLICATION TO A CASE STUDY IN NORTHERN SPAIN.

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ABSTRACT

The present contribution makes a proposal for the quantitative characterization of different types of consumable and non-consumable geomorphological resources, as a basis for impact assessment. These resources can be quite diverse in their nature, including for instance raw or construction materials, soils, sites of geomorphological interest or landscape resources. Accordingly, impacts can be expressed in quite different terms: lost monetary value in the case of resources with market value; lost productivity in the case of soils or geomorphological units which support productive ecosystems; area or population affected by losses in landscape quality; by means of non-dimensional numerical indices in the case of both landscape quality or sites of scientific, educational or recreational value.

Through a GIS, computer maps and associated databases can be prepared for the different types of geomorphological resources. The databases should include information on those parameters used for the characterization of each resource type. The computer overlay of proposed actions (road, railway, urban development, etc.) and resource maps enables the assessment of impacts, selection of least impacting alternatives and so on. The method proposed has been applied to assess the impacts of motorway construction in nothern Spain. Parameters used for describing existing resources, maps and databases, models for impact assessment and results obtained are presented.

1 INTRODUCTION

Gomorphological resources and assets are important for humankind because they fulfill a significant role with respect to some basic environmental functions, namely source of resources, support of activities and provider of services. (SCOPE, 1995; Cendrero, 1997). These resources are quite varied; they can be grouped into the following categories. (Rivas et al., 1997).

Consumable resources (Source): They include geomorphological deposits which can be used as raw, construction or energy materials, (clay, sand and gravel). These resources are widely exploited and have well known market values.

Non consumable resources or assets (Support / Services): These resources are important for a variety of activities; the use of them does not imply consumption in the strict sense of the term, but it could imply temporary or permanent damage. The following assets are considered here: sites of geomorphological interest, high natural value or high productivity units, units with high utilisation potential, and visual landscape.

Impacts on these resources depend, of course, on the nature of the resources themselves and on the kind of activity. In this paper impacts from construction activities are considered; in particular, the case study presented corresponds to the construction of a new motorway in northern Spain. (Fig. 1)
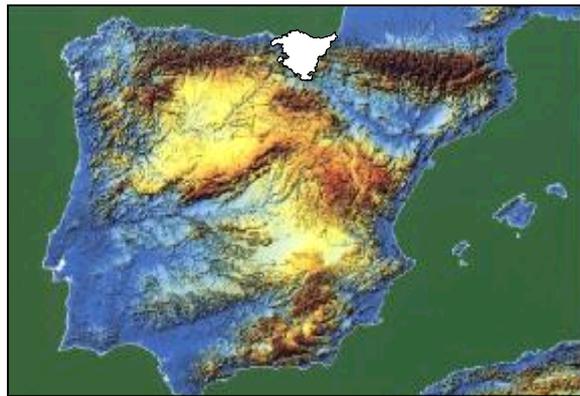
2 DESCRIPTION OF CASE STUDY AREA

Figure 1. Location map

The study area (Fig.1) corresponds to the middle valley of river Deva (Guipzcoa, northern Spain) and covers approximately 190 Km^2. It is a densely populated (80,000 inhabitants) industrial area, with pronounced relief (100-700 m) and temperate, humid climate (average annual temperature 14 °C; rainfall 1400 mm). Materials which represent geomorphological resources are limited to alluvial sand and gravel and silty-gravelly colluvial deposits. Sites of geological-geomorphological interest are scarce in the study area. They correspond mainly to good outcrops of significant structures or rock types, or good sedimentary sequences. The natural landscape has been intensely transformed, with an almost complete substitution of the original land cover. Cultivated grasslands and pine forests dominate the rural landscape. Therefore, valuable natural units are scarce, limited to a few protected areas. However, the visual landscape outside the urban-industrial core is still quite pleasant, as it retains a rural character. The proposed motorway, meant to provide a faster and more efficient link between Vitoria and San Sebastin, through Eibar, has raised several environmental concerns; these are mainly traffic increase through and at either end of the new transportation axis, introduction of a barrier between the two sides of the valley, visual impact of the new infrastructure modification of infiltration/runoff related processes, and damage to natural resources or assets. A conceptual model representing the potential impacts of the different actions related to motorway construction and operation is shown in figure 2.
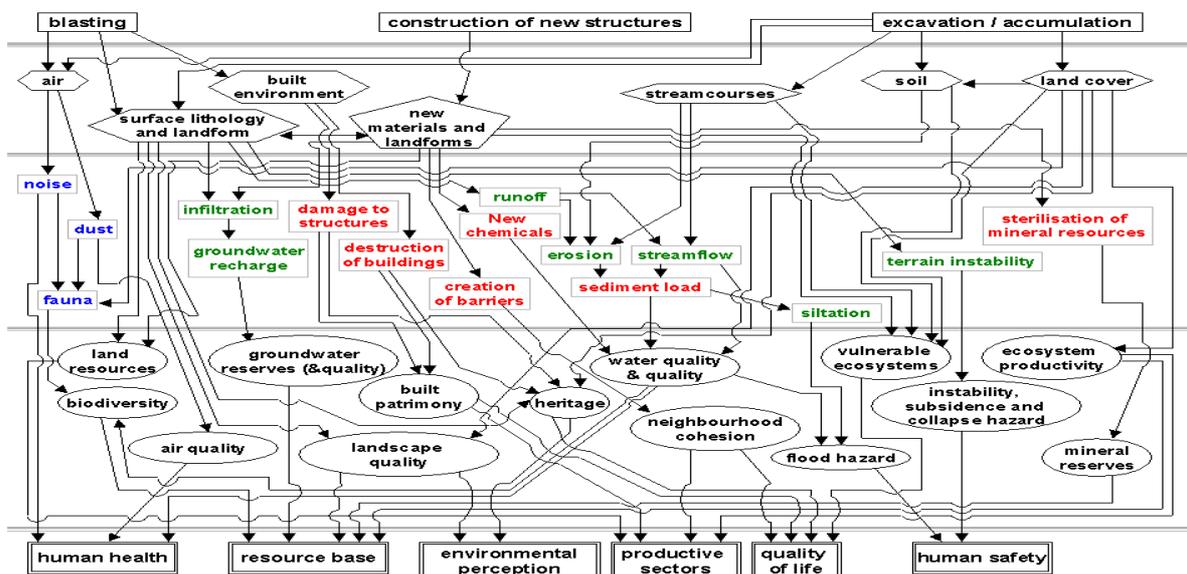

Figure 2. Conceptual model for impacts during the construction phase.

3 NATURE AND SIGNIFICANCE OF IMPACTS

3.1 Consumable resources

The nature of impacts a motorway can produce on consumable geomorphological resources is essentially of an economic nature. Although these materials have a low unitary value and are usually abundant, in certain areas they may be scarce. If they are destroyed or sterilised, supply from alternative, distant sources may be necessary, with the consequent cost increase. In the case of widely used materials, such as sand and gravel, this could represent an increase of costs for all construction activities, for many years to come. The overall impact could thus be considerable.

3.2 Sites of geomorphological interest

These sites are part of the natural and cultural heritage (Poli, 1999); they contain essential information for the interpretation of geomorphological processes and history and have a potential for scientific, educational or tourism use. They can be totally destroyed or partly damaged by motorway construction.

3.3 Valuable natural units

Certain land units present a combination of geomorphological (landform, deposits, processes, soil) and other characteristics (land cover, heritage sites) that confers them a high natural value. In other cases their interest is due to a high natural or potential productivity (wetlands, high quality soils). Again, these units can be damaged or destroyed during motorway construction.

3.4 Land units with high utilisation potential

Some land units have geomorphological (landform, deposits, absence of hazards) and other characteristics (location) which make them especially suitable for intensive uses. The occupation of these units by a motorway represents the loss of a resource which may be scarce, as is the case in the study area.

3.5 Visual landscape

Visual quality (intrinsic merit of a unit from a perceptual point of view) and fragility (sensitivity to visual intrusion from human activities) of landscape are determined mainly by three groups of factors: geomorphology (relief, shape, rock type), vegetation, and land use (especially impacting elements such as prominent constructions); presence of water is also important. The introduction of new large structures such as a motorway represents a visual intrusion which may reduce visual quality. This reduction (intensity of the impact) is related to the degree of modification; that is, contrast in size, shape, colour and texture between the structure and the pre-existing landscape. The magnitude of the impact can be considered to depend on the number of people and/or extent of the area affected.

4 IMPACT MEASUREMENT AND EVALUATION

The procedure to assess impacts on these resources rests on the application of a GIS-based database consisting of a number of thematic layers that represent natural and human characteristics of the study area. The following steps are involved:

- Identification of suitable impact indicators
- Establishment of the procedure to measure and/or predict the effects of the new motorway on those indicators
- Determination of data input necessary for measurement/prediction
- Selection, modification or creation of the necessary thematic layers in the GIS-based database
- Implementation of procedure
- Translation of the initial indicators into terms that are significant for comparisons and impact evaluation.

These steps are briefly presented below for the different types of geomorphological resources considered.

4.1 Consumable resources

Indicators used to express impacts are the volume and value of the material lost or sterilised. The geomorphological deposits map and associated database provide the information to determine volume and value of the individual deposits affected (Fig.3; Table 1).

	Dep type	Deposit description	Mtwy alt. 1	No. Pixels	Area (m²)	Depth (m)	Volume (m³)	Price (€/m³)	Maximum Value (€)	D	A	Corrected value (€)
Z + Mtwy	Z	Nil surface deposit	Mtwy	79	179,500	2	359,000	0	0	-	-	-
Z + no	Z	Nil surface deposit	No	12641	31,602,500	2	63,205,000	0	0	-	-	-
Csm + Mtwy	Csm	Silty sands	Mtwy	3	7,500	3	22,500	23.92	538,200	0.5	0.04	10,764
Csm + no	Csm	Silty sands	No	625	162,500	3	487,500	23.92	11,661,000	-	-	-
Cgp + Mtwy	Cgp	Gravel	Mtwy	3	7,500	4	30,000	10,37	311,100	0.5	0.02	3,111
Cgp + no	Cgp	Gravel	no	132	330,000	4	1,320,000	10,37	13,688,400	-	-	-
R + no	R	Mixed spoil	no	17	42,500	3.5	148,750	0	0	-	-	-

Table 1. Example of theapplication of the deposits database to impact calculation.

Impacts for deposit i :

$$I_i = \text{Volume} \times \text{price} \times A \times D \times H \times R$$

where:

A; coefficient depending on relative abundance (0 - 1)
D; coefficient depending on the distance to nearest road (0-1)
H; coefficient depending on the population in the surroundings (0-1)
R; coefficient which depends on the reversibility of action (0 -1)

$$\text{Total Impact} = \Sigma I_i$$

The maximum potential value and the corrected value for the area in the map, on the basis of A and D are shown in table 1. H and R are constant for the study area or dependent on the type of action. Evaluation of the significance of impacts can be made by means of a comparison with the price increase for supply from alternative sources.
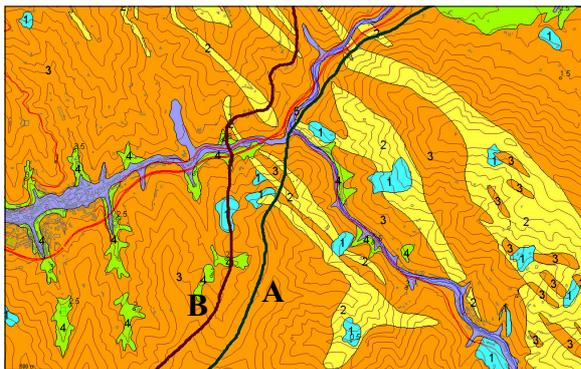

Figure 3. Map obtained crossing surface deposits, regolith thicknes and alternatives maps. **A**) alternative 1; **B**) alternative 2.
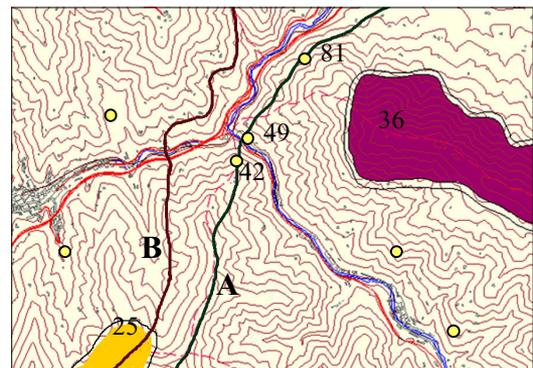

Figure 4. Map obtained crossing map of high natural value units, SGIs map and alternatives map. SGIs; 81: folded structure, 49: pillow lava, 42: terrace sequence. High-natural value units; 25: protected area Udalaitz ; 36: protected area Valle de Haranerreka .

4.2 High-productivity and high-natural value units

Destruction of, or damage to these units (Fig. 4) directly reduces the natural capital and biodiversity of an area. Impacts are measured on the basis of total and relative area affected. The significance of this reduction can be

established by comparison with the total extent of protected areas in the province. Data input for this assessment comes from the maps of protected areas and of integrated morphodynamic units.

Fig. 4 shows that alternative 2 affects 5,000 m^2 of protected area. This represents 0.12 % of all protected area in the province. If fragmentation is considered, it can be assumed that the total of this protected area will be damaged; this would represent 0.36 % of the total for the province.

4.3 Sites of gomorphological interest

The value of these sites can be expressed using different methods and criteria (Dur n, 1998; Poli, 1999). Impacts on SGIs have a quantitative (number of sites affected) and a qualitative (value of the site and degree of damage) aspect. A series of parameters (Table 2) are used to establish the value of a site, before and after construction of the motorway. Details on the precise method of calculation of impacts are given by Rivas et al. (1997).

Impact for one SGI (i):

$$I_{SGI\,i} = V_{SGI\,i\,(post)} - V_{SGI\,i\,(pre)}$$

Total impact on SGI s = $\sum I_{SGI\,i}$

Where: V represents the value of the SGI and n represent the number of SGIs affected by the motorway.

SGI	Type	C	A	E	K	Ex	D	Ac	O	S	H	Acc.	Q	P	V$_{SGI}$
81 pre	Folded structure	4	2	2	1	0	0	0	4	0	3	4	5	14	2
81 post	Folded structure	2	2	1	1	0	0	0	2	4	3	4	4	12	0.83
49 pre	Pillow Lava	3	3	3	1	0	0	0	4	2	3	4	7	14	1.75
49 post	Pillow lava	1	3	2	1	0	0	0	2	4	3	4	6	12	0.5
42 pre	Terrace	4	3	2	1	2	1	1	4	3	3	4	9	15	2.75
42 post	Terrace	2	3	0	1	0	0	0	0	3	3	4	4	10	0.75

C: state of conservation; A: relative abundance; E: extent; K: degree of knowledge; Ex: good example of processes; D: diversity; Ac: activities; O: conditions of observation; S: availability of services; H: number of inhabitants (constant); Acc: accessibility; Q: quality of the SGI; P: potential for use; V$_{SGI}$: value of SGI (V$_{SGI}$ = C (2Q + P) / 48).

Table 2. Example of application of SGIs database to impact calculation.

Alternative 1: no sites affected.
Alternative 2: $V_{81(post)} + V_{49(post)} + V_{42(post)} - V_{81(pre)} - V_{49(pre)} - V_{42(pre)} = -4.41$

It is obvious that in the example shown the least impacting route corresponds to alternative 1. The significance of impacts on SGI is not easy to express in other terms; comparison of the impact values obtained with those corresponding to the destruction of well-known geological-geomorphological landmarks or sites in the region is considered an appropriate procedure.

4.4 Land units with high utilisation potential

The loss of land resources can be best expressed in terms of absolute and relative area of such units occupied or degraded by the motorway. Utilisation potential of homogeneous morphodynamic units (Cendrero et al., 1993) is established on the basis of: slope gradient, size and shape of units, potential hazards and geotechnical conditions, location with respect to roads and inhabited areas. Figure 5 shows the distribution of morphodynamic units; only units with the optimum conditions for the criteria indicated above have been highlighted. Land units within the service perimeter of the motorway (25m on each side of the axis) are totally lost for other uses. An additional 50m on each side of the road are considered to be affected by a 50% reduction of their potential.
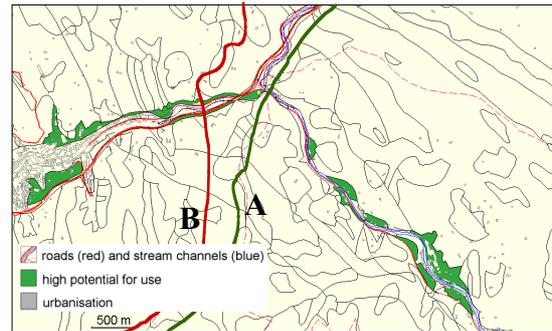

Figure 5. Map of homogeneous land units. For greater clarity the colour code has been eliminated, except for units with high potential for use.

Impacts can easily expressed as area destroyed or affected or by means of the equivalent monetary value (Table 3).

Alternative	Area lost (m^2)	%	Value (€/m^2)	Total value (€)	Area affected (m^2)	%	Value (€/m^2)	Total value (€)	Total impact (€)
1	-	-	-		-	-	-	-	-
2	5,125	1.51	54,57	279,671.25	5,125	1.51	27,29	139,861.25	419,532.50

Table 3. Example of application of SGIs database to impact calculation.
(EURO values are conservative estimates and do not intend to reflect actual land prices).

In the example considered, only alternative 2 produces an impact on this resource and it is not very significant.

4.5 Visual landscape

Indicators of impact magnitude can be the total area from which the new structure (or individual sectors of it) can be seen or the number of people affected. A measure of intensity can be obtained by defining the level of visual intrusion in sensitive units (those with high visual quality or fragility) on the basis of different degrees of contrast with the new structure, presented by means of photographs or images. The procedure to follow for assessing visual impacts starts with the definition of landscape units directly affected by the new road. Visual quality of units can be assessed on the basis of: relief (difference between maximum and minimum altitude); general shape (convexity, concavity, etc); landform (irregularity, ruggedness); geomorphological diversity (No. of geomorphological elements in unit); vegetation (rank of vegetation type); land use (intensity of human modification); water bodies/courses.
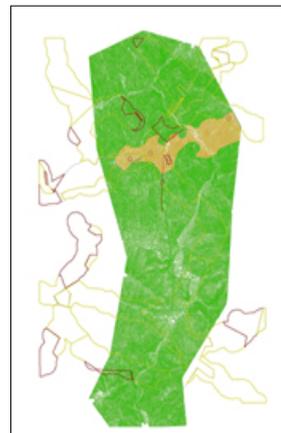

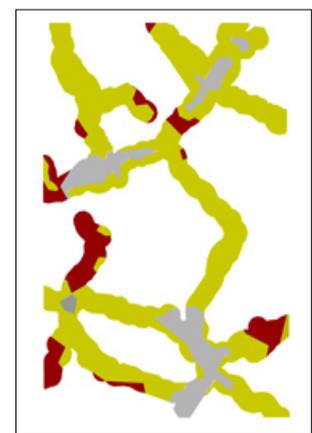Figure 6a. Visual basin.

Figure 6b. Areas of great visual effect

The magnitude of impacts is expressed as the intersection (Fig. 6c) between visual basins of individual motorway sectors (Fig. 6a) and areas of   great visual effect or buffers around population centers and main roads (Fig. 6b).
This can be performed using standard GIS tools. Realistic views (RV, Fig. 7) are then simulated for each motorway sector.
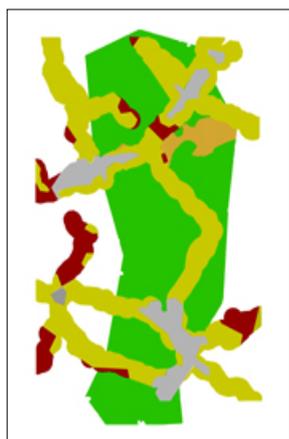
Figure 6c. Areas of significant visual impact in visual basin.

Intensity of visual intrusion is determined quantitatively (% of view occupied by the new structure) and qualitatively (generation of a series of RV with different levels of visual intrusion, to define a rank).
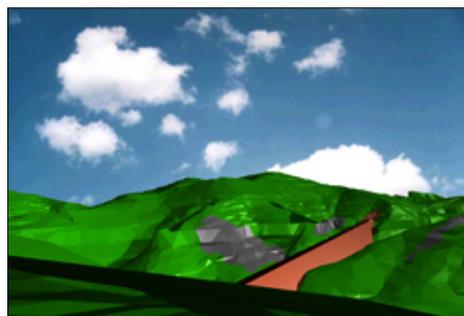

Figure 7. Simulation realistic of views.

The numerical values obtained (area, %) can then be modified using a coefficient which depends on the visual quality of the units affected. As in the case of SGI, the relevance of visual impacts can be established through comparisons with well-known examples of visual intrusion in the region.

5. CONCLUSIONS

The method presented provides a clearly defined and easy to apply means of measuring and evaluating impacts on very different types of geomorphological resources. Implementation of the method through a GIS is fast (as long as the necessary digital database is available). The assessment of impacts is carried out on the basis of quantitative indicators or qualitative but replicable evaluations. That is, the process is transparent and any operator would obtain similar results on the basis of a given data set. A similar approach could be useful to assess impacts on other types of static environmental components.

ACKNOWLEDGEMENTS

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