ROAD NETWORK: RESOURCE MANAGEMENT FOR ITS MAINTENANCE

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Abstract

Reliable data and sound analysis are necessary to manage a road network in a cost-effective manner. Nowadays, adequate systems and equipment are available for gathering data and analysis. Grounded on sound analysis, properly financed road-improvement plans can be estimated. It is possible to outline different improvement scenarios on the basis of given priorities, say reduction of mortal accidents, and financial constraints. The process should blend the managerial and technical perspectives, as is shown with an empirical illustration from the road network of the Madrid region in Spain.

1. INTRODUCTION

For a long time, the resources management of network road conservation has been made using pavement management programs. These programs help the manager in the decision-making process considering the current and the theoretical evolution of the parameters that define the road network condition.

In 1990 the company GEOCISA (from the group Dragados y Constucciones, S.A) developed the pavement management program Gefirex and since then the company has maintained it active. This program was presented in the report "Roads database and inventory, Exploitation, conferences on investment strategies in conservation and pavement management", made by the Engineer Rafael Alvarez Loranca in Madrid in 1990. Later, the program improved due to the collaboration agreement signing, directed by the professor Fernando Varela Soto, between the company and the Politecnica de Madrid University. While this program continued growing in Spain, other similar programs started to grow all around the world.

The World Bank programs of pavement management called HDM III and HDM 4 were different. These programs affected in a stronger way the economic part of the management since their aim has been to guarantee the profitability of the investments making the programs more complex.

During the last years and in order to help the manager in the decision making process the need to integrate necessary information for road management has increased due to the overwhelming available data.

Following this line, RAUROS has been working since 2001, in close collaboration with GEOCISA and the department of Civil Engineering: Building Technology of the *Politecnica de Madrid* University, with the aim of continuing moving forward in the development of tools and allowing for the easy analysis of road condition, thus providing solutions for the civil engineering activity and at the same time considering the economic aspects that in short, give way to maintenance investment.

2. METHODS AND TECHNIQUES

Nowadays there are many reasons to intervene in a road: the main reason is the real or forecasted deterioration of the road, other may be an old or winding road with dangerous bends or narrow spaces. Moreover, an increase in the number of accidents may call for actions not only in the road, but also in the pavement.

In short, there are two approaches to the problem of management pavement and road. The first, the classical one, implies the allocation of the existent funds to strengthen pavements according to the state of functional and structural parameters that define pavement condition.

The second approach (which is an additional step) implies, after assigning the interventions in the first step, the analysis of other possible causes that may affect the pavement, and checking the analysis results to see if it is necessary to bring forward the actions planned for the subsequent years.

After the first analysis, and facing the new determining factors, a new study is performed with the pavement management system, to get a satisfactory result for the manager.

Below the used techniques and the applied methods for the road network analysis are described. The road covers 3,000 km divided in:

- Main road
- Secondary road
- Local road
- Slip roads
- Accesses

For the management of each one of them, a series of premises have been considered allowing to list the interventions in order of priority as well as its typology.

With regard to pavements, the parameters defining the intervention criteria are the following:

- Structural capacity: deflections and degradations (fissures and pothole)
- Superficial regularity: I.R.I
- Tyre-pavement grip: C.T.F

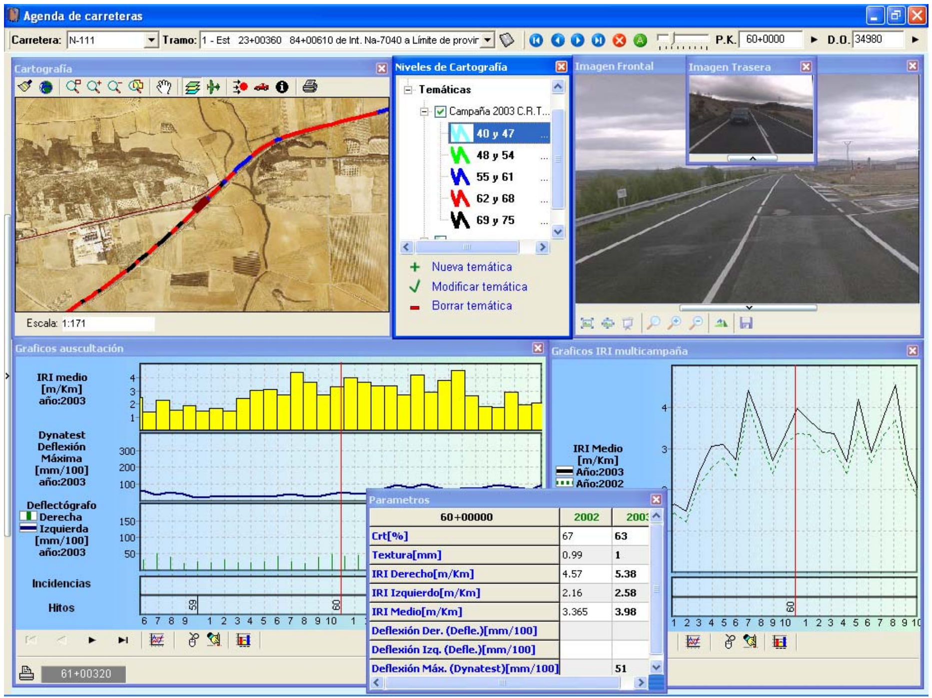


Figure 1. Data, images and maps showed by the program

Obviously, the pavements structure (kinds of layers and their thickness) constitutes fundamental information for pavement studies.

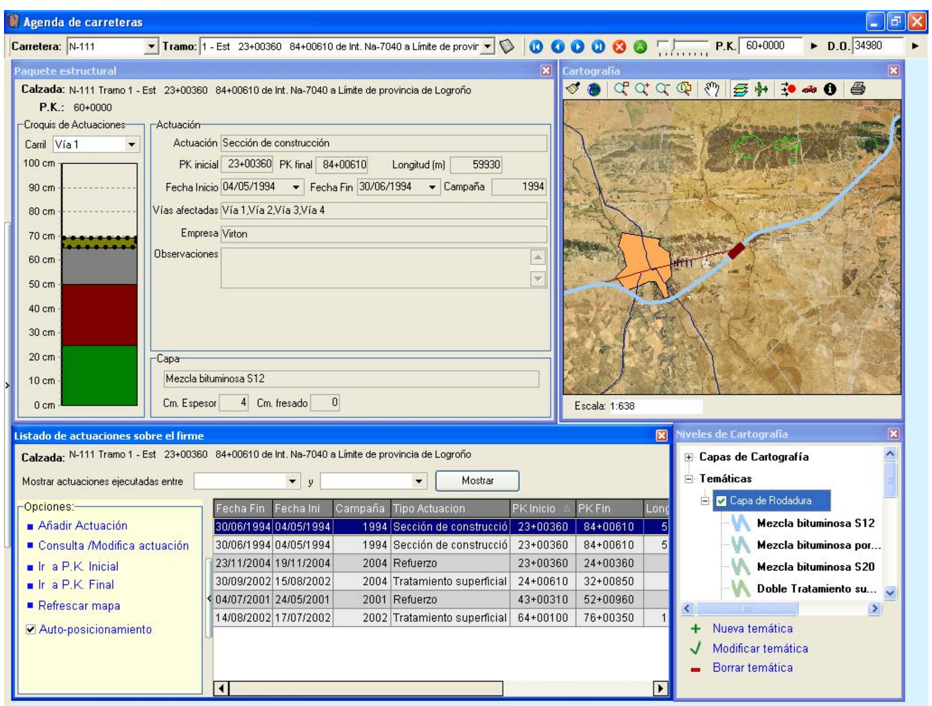


Figure 2. Graphic pavement structure, maps and existent interventions connections

As it is shown in Tables 1 to 8, the request for traffic information was considered to be a fundamental element for the setting of the intervention thresholds.

Tabla 1. TRÁFICO T0. Calzadas separadas	
Baches (%)	1
Fisuras (%)	1,5
I.R.I. (m/Km.)	1,5
Deflexión (Firme Flexible) (mm/100)	40
Deflexión (Firme Semirrígido) (mm/100)	35
C.R.T. (%)	50

Tabla 2. TRÁFICO T0. Calzada única	
Baches (%)	1
Fisuras (%)	1,5
I.R.I. (m/Km.)	1,5
Deflexión (Firme Flexible) (mm/100)	60
Deflexión (Firme Semirrígido) (mm/100)	40
C.R.T. (%)	50

Tabla 3. TRÁFICO T1. Calzadas separadas	
Baches (%)	1
Fisuras (%)	1,5
I.R.I. (m/Km.)	1,5
Deflexión (Firme Flexible) (mm/100)	60
Deflexión (Firme Semirrígido) (mm/100)	40
C.R.T. (%)	50

Tabla 4. TRÁFICO T1. Calzada única	
Baches (%)	1
Fisuras (%)	1,5
I.R.I. (m/Km.)	1,5
Deflexión (Firme Flexible) (mm/100)	80
Deflexión (Firme Semirrígido) (mm/100)	60
C.R.T. (%)	50

Tabla 5. TRÁFICO T2. Calzadas separadas	
Baches (%)	1
Fisuras (%)	1,5
I.R.I. (m/Km.)	1,5
Deflexión (Firme Flexible) (mm/100)	80
Deflexión (Firme Semirrígido) (mm/100)	60
C.R.T. (%)	50

Tabla 6. TRÁFICO T2. Calzada única	
Baches (%)	1
Fisuras (%)	1,5
I.R.I. (m/Km.)	1,5
Deflexión (Firme Flexible) (mm/100)	100
Deflexión (Firme Semirrígido) (mm/100)	80
C.R.T. (%)	50

Tabla 7. TRÁFICO T4. Calzada única	
Baches (%)	1
Fisuras (%)	1,5
I.R.I. (m/Km.)	1,5
Deflexión (Firme Flexible) (mm/100)	120
Deflexión (Firme Semirrígido) (mm/100)	100
C.R.T. (%)	50

Tabla 8. TRÁFICO T4. Calzada única	
Baches (%)	1
Fisuras (%)	1,5
I.R.I. (m/Km.)	1,5
Deflexión (Firme Flexible) (mm/100)	140
Deflexión (Firme Semirrígido) (mm/100)	120
C.R.T. (%)	50

Each one of the proposed limits has served to elaborate a hypothesis of a pavement situation throughout four years, considering such period a reasonable one to forecast the parameters evolution that describes the structural and functional condition of pavements.

Every time some of the parameters exceed the wanted thresholds in the evolution model, the system will detect a problem and analyse it, through a decision tree providing the most adequate to solve the failure. The calculation becomes difficult when the system forecasts the failure of two or more parameters at the same time. For all the possible failures there exists a response in the form of a flowchart that indicates, in each case, the most adequate conservation intervention regarding traffic, weather, etc

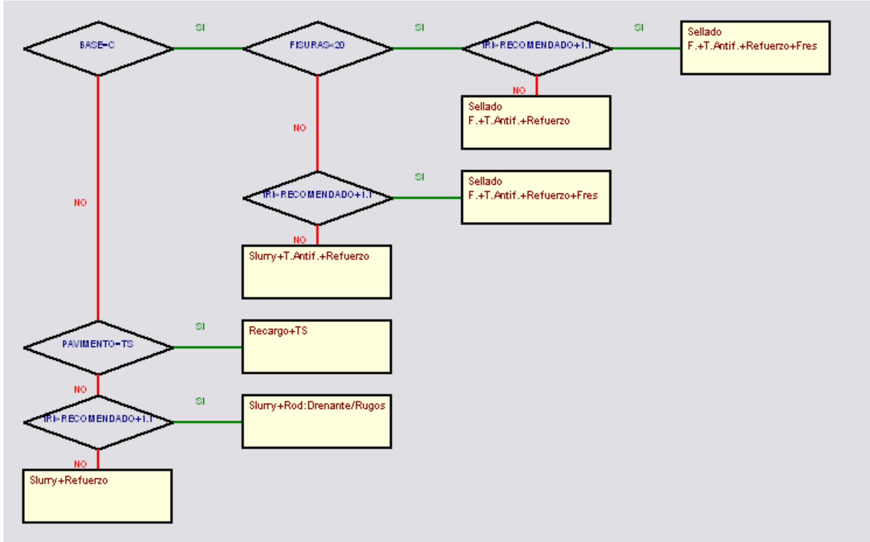


Figure 3. Organization chart of failure caused by fissures and I.RI.

An efficient road management system, according to global criteria, must comprise cross calculation models, i.e. these models must be based on previous experiences with structures similar to the ones of the present study, and at the same time it must allow for the modification of these modules in order to adapt them to the new condition of each network at any moment of the process. With regard to the system described in this paper, it counts with those developmental models published by the World Bank. Notwithstanding, its skilled-learning characteristic enables the user to modify these models at the same time new structural or functional measures are added. Besides, the correction proposed by the system does not apply for the developmental models in the whole network, but in each homogeneous section. Hence, the prediction of failures should be much more accurate. Besides, not only should “positive” developmental models (models that consider material cracks and make characteristics worse over time) be applied, but also “negative” ones. The second ones being responsible for predicting the final condition of the parametres that shall determine the pavement condition once the conservation intervention has been done. Like in the previous case, the working procedure for this study allows for the dynamic adjustment of these models at the same time results yielded by trial are added; both before and after a conservation intervention has been done.

From the user’s point of view, conservation works are annoying. This is why it is essential to consider other factors, and not only exclusively technical, when a comprehensive conservation plan is designed for a specific period of time. Primarily, the repetition works in the same sector should be avoided, i.e. interventions should be performed only once in each sector over the four years of study.

For those management systems that apply only for road network conservation, other factors (and not only those parameters that determine the pavement condition) have been taken into account. At this present moment, whem Road Safety is a hot issue among public administration officials and when there is an increasing concern about death-toll rates in traffic accidents, it seems vital considering accidents as a critical factor for conservation investment plans. Following this idea, and thanks to a highly-efficient management tool, the aspects related to the accident causes have been identified: road network geometry (elevation map, horizontal alignment, and banks), road safety elements (pavement-tyre friction, road signs, signalling lights), etc.

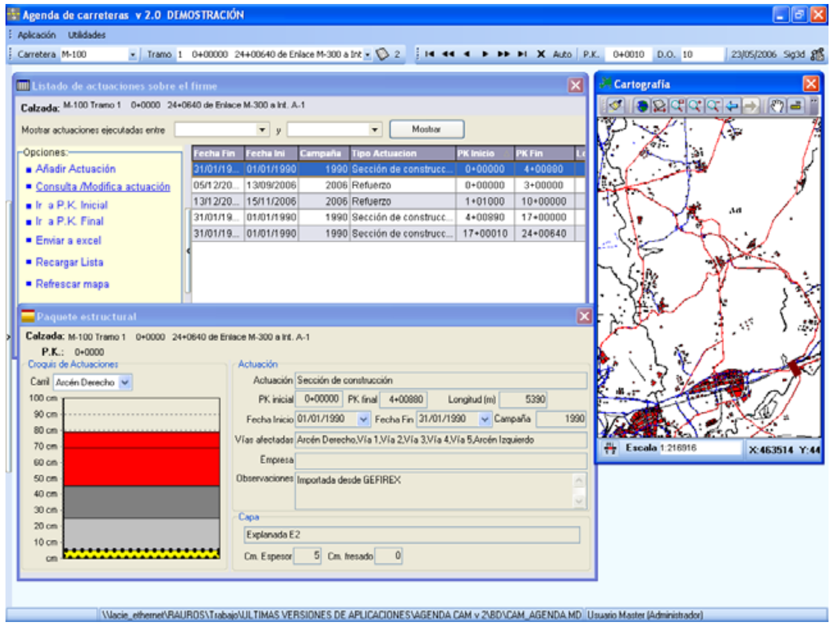


Figure 4. This is a sample of the road security aspects considered in the application: Geometry, Road Signing, Accidents, Accident Hotspot Sections, and thematic Maps

However, studying these purely technical aspects is not enough. It is also recommendable to have a computerized tool that enables the user to revise and compare the results yielded by a road network study. This is the reason why this system comprises a visual database with a picture of every 10-meter section of each road; as well as a tool to locate any desired position, in any of the studied areas, using UTM coordinates.

Moreover, the Management System also allows the user to make a representation of **thematic** maps in several formats: dotted or solid lines, in accordance with the previously established thresholds. Furthermore, the system allows the user to obtain different types of graphs, or information previously specified. Figure number five shows the possible visualizations of Geometry module (image, thematic maps, alphanumeric parametres and their graphical representation).

Figure 5. Sample of a front image, thematic maps, and geometry

These modules, as well as the rest of the modules, show a complete interactivity among different data (alphanumeric data, images, maps, etc.), so that whenever the kilometric point changes, the information changes according to it.

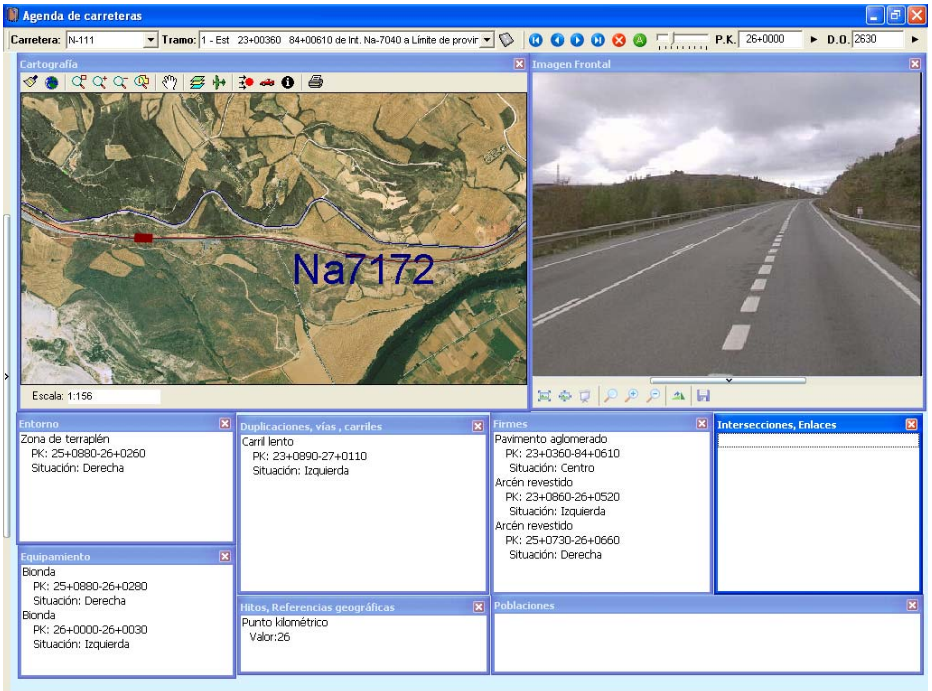


Figure 6. Inventory

3. RESULTS

Next is shown the four-year studies of the complete Madrid Road Network.

Three studies were carried out:

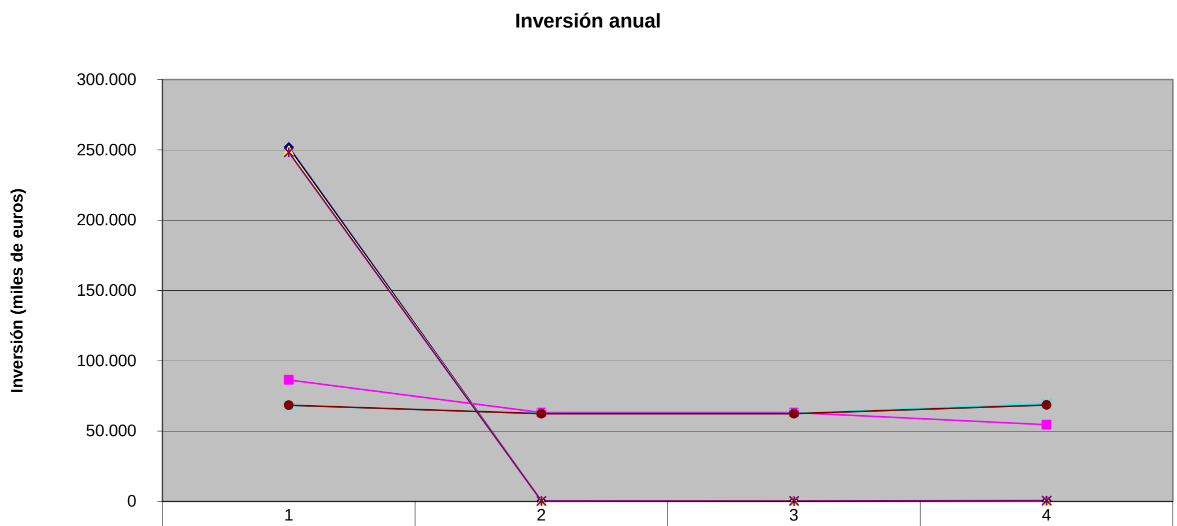
- Study A, considering previously specified thresholds.
- Study B, 10 % decrease in the demand (10% increase in the threshold levels)
- Study C, 20 % decrease in the demand (20% increase in the threshold levels)

In turn, they took into account:

- Only technical criteria for the maintenance interventions during the required quantity of years (Study 1).
- Technical and economic criteria and the distribution of the necessary interventions throughout the four-year study, periodizing costs (Study 2).

Hence, the result is six conservation studies: A1, A2, B1, B2, C1 y C2, with the purpose of comparing their results.

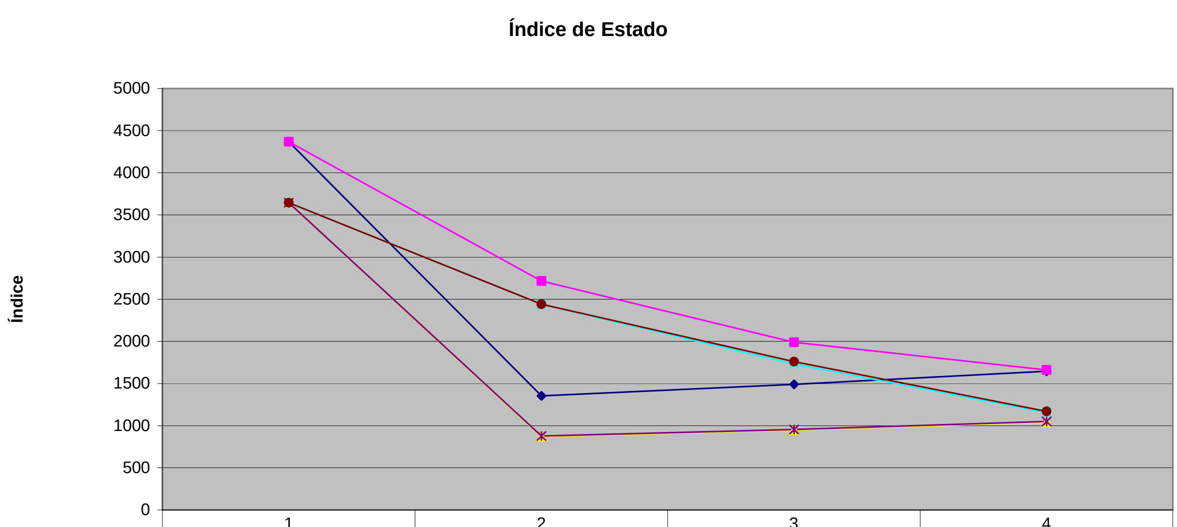
Figures 10, 11 and 12 show the results:



	1	2	3	4
Estudio A1	251.993	180	191	338
Estudio A2	86.427	63.175	63.176	54.564
Estudio B1	249.676	166	463	172
Estudio B2	68.226	62.619	62.618	69.564
Estudio C1	248.261	265	291	537
Estudio C2	68.505	62.338	62.338	68.581

Años

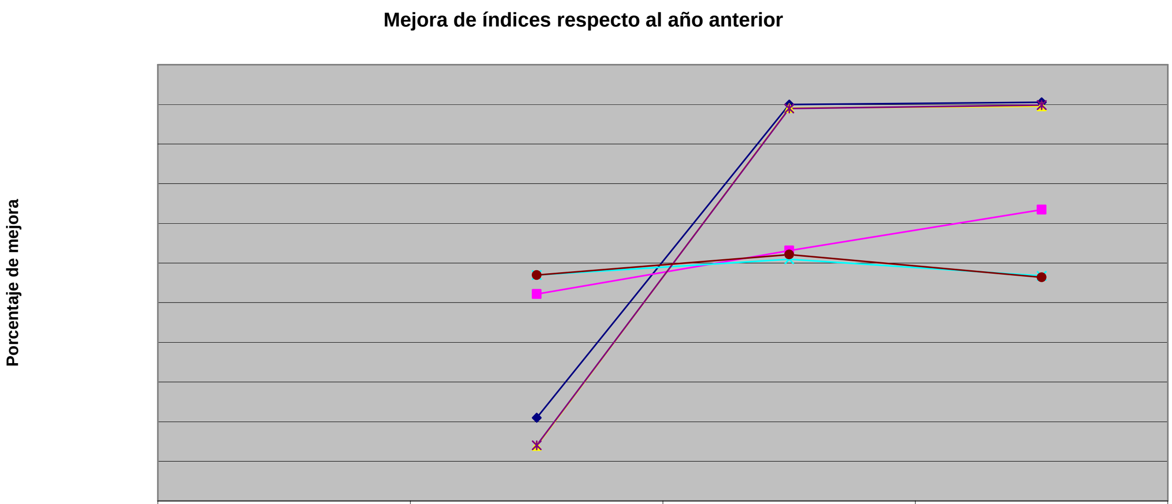
Figure 7. Annual investment (thousands of euros)



	1	2	3	4
Estudio A1	4368	1354	1489	1646
Estudio A2	4368	2717	1988	1660
Estudio B1	3644	870	949	1040
Estudio B2	3644	2440	1731	1156
Estudio C1	3644	876	954	1048
Estudio C2	3644	2440	1760	1169

Años

Figure 8. Condition Index



	1	2	3	4
Estudio A1		-69%	10%	11%
Estudio A2		-38%	-27%	-17%
Estudio B1		-76%	9%	10%
Estudio B2		-33%	-29%	-33%
Estudio C1		-76%	9%	10%
Estudio C2		-33%	-28%	-34%

Años

Figure 9. Percentage of annual improvement, compared to the previous index

In the case of studies number 2, the improvement of road surface condition is homogeneous, and so is the spending incurred.
Nevertheless, in the case of the first studies, evidently the first year (main year for investments) sees a considerable index improvement, but in turn, there is a decline in the index in the remaining years, due to the lack of interventions.

In both cases, starting with the same data but taking into account different economic criteria for the conservation study, the final result with periodized expenditure is better, let alone the evident advantage of a periodized-spending depending on the available budget.

4. CONCLUSIONS

The Expert Road Management has been developed for the grader operator of a road network, whose job is the performance of maintenance works, to ensure the best possible conservation and economic optimisation. This simple task calls for a process of analysis, which must consider several factors at the same time.

The conclusion of this analysis is, undoubtely, the choice of interventions, which will have to be adapted to the available budget.

This process will require:

- to list the parametres characterizing the road condition, whether functional or structural,
- to collect the data of these parametres through a systematic process,

- to establish the evolution models of the parametres,
- to define the maximum levels of the parametres for each category (type of road),
- to describe conservation interventions and new road data collection,
- to plan the most convenient intervention for each road section, the most appropriate moment to carry them out and their cost,
- to establish annual budget funds allocated to the road conservation; depending on these, the system shall propose to postpone or put forward the interventions, always considering the technical criteria to maintain the network in the best possible and homogeneous condition,
- And to avoid interventions in immediately following years due to the harm to the user.

To conclude, this system, integrated in a computer application, as well as those similar, are a breakthrough in pavement and road management, since they allow for the addition of a detailed assessment of other factors that may influence the plan of conservation interventions performed in a road network. In order to have a successful resource management it is necessary to have access to a huge amount of data, calculation models to estimate conditions, to obtain easily interpretable and manageable data both for the experts in road conservation area and economic managers.

It is not enough to have a great deal of data. What is interesting is to get through them some knowledge about reality.

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