# Description and Implementation of RO.MA. for Urban Road and Highway Network Maintenance

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The RO.MA. pavement management system (PMS) developed for urban roads and highway networks in Italy is described and a short description of its elements is reported. Problems encountered in the implementation and start-up of the system, as well as the interaction with the users are detailed. Additionally, a review of the main information stored in the RO.MA. road data base and the criteria used for its design are discussed. Since 1988 the RO.MA. method has been successfully used for yearly maintenance planning of the entire Autovie Venete S.P.A. highway network, a north-east toll highway from Venice to Trieste, and a 1000-km provincial road network in Sardinia. Highlights of various PMS results during 1993 are reported. RO.MA. methodologies have been successfully applied in some municipalities in Northern Italy, and an example of urban road rehabilitation related to the municipality of Padua is discussed. For the Padua project, a multiannual rehabilitation program was applied and according to the available budget, a priority list of maintenance projects for the urban roads network was prepared.

For optimum results, public and private agencies will need to dedicate substantial investment toward the rehabilitation and maintenance of their road networks. Moreover, budgetary changes and constraints that cannot easily be foreseen, as well as political, economic, and administrative considerations, create the need for a comprehensive pavement management system (PMS) for roads.

The RO.MA. (Road Management System) methodology for urban and highway networks represents a powerful tool to assist agencies in improving the level of road service through the use of rehabilitation and preventive maintenance planning.

Moreover, the application of new technologies such as the nondestructive, high-performance systems used in RO.MA. for pavement evaluation can reduce the total cost and the time needed for determining the surface and structural characteristics of roads.

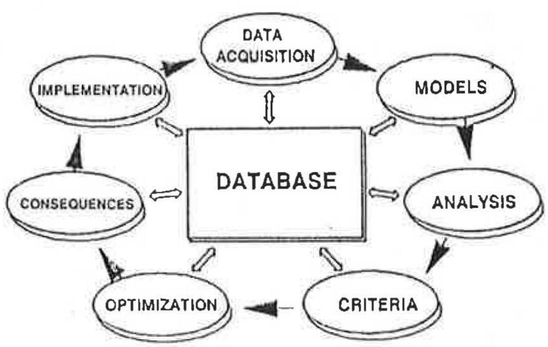
Substantial effort was spent using RO.MA. methods to produce a comprehensive and useful road data base as well as to set different maintenance alternatives according to budgetary changes and limitations.

Three examples of the application of the RO.MA. method will be discussed: (*a*) the maintenance planning of the entire toll Autovie Venete highway network in the north of Italy, (*b*) a 1000-km network of provincial roads in Cagliari (Sardinia), and (*c*) the rehabilitation of the main urban road network in the Padua municipality. In all cases, the interaction with users and the analysis of results generated by the application of the PMS were the most useful base for further adjustment of the RO.MA. method to improve its ability to handle users' requirements, political constraints, and economic decisions.

## Elements of RO.MA. PMS

The main components of the RO.MA. PMS are shown in Figure 1 (*top*) and can be summarized as follows:

1. Construction and rehabilitation history:
   a. Maintenance policy;
   b. Geometrical data on the pavements (thickness, layer composition, and number of lanes and their width);
   c. Survey of traffic data (volume and type);
   d. Physical constraints, especially for urban roads;
   e. Environmental conditions and types of maintenance allowed;
   f. Weather conditions (temperature, humidity, etc.); and
   g. Local cost of maintenance.
2. Pavement evaluation using new technologies such as nondestructive high-performance systems for measuring the condition of surfacing and structure of pavement:
   a. Surface distress;
   b. Evenness and the longitudinal and cross profiles of the road using a high-precision laser profilometer (Figure 1, *bottom*);
   c. Layer stratigraphy using radar technology;
   d. Bearing capacity using the falling-weight deflectometer (FWD); and
   e. Skid resistance.
3. The road data base, built according to user requirements: for successful application of the PMS, management of the data base by the users should be:
   a. User-friendly;
   b. Tailor made for users' needs;
   c. Presented in terms of homogeneous section subdivisions; and
   d. dynamic, allowing the user to easily update the information stored in the data base and to introduce modifications concerning economic models or analysis.
4. Different management systems are included for highways, provincial roads, and urban roads. Particular attention is paid to the different types of maintenance measures that have to be considered and to the functioning of user maintenance policy or physical or economic constraints.



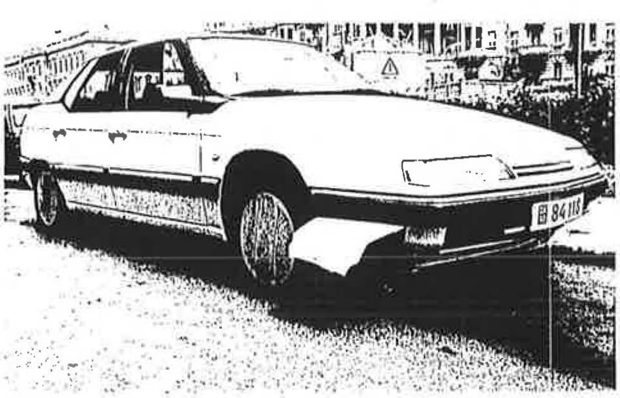



**FIGURE 1** ***Top:*** **elements of a pavement management system;** ***bottom:*** **laser profilometer for measuring evenness and longitudinal and cross profiles of road.**

The PMS has to provide cost/benefit analysis in terms of single projects as well as network levels. The modern electronic data collection equipment available today produces a lot of data. For this reason it is essential that the PMS provide meaningful results and presentations to make the interpretation of data easier for the user to understand.

## Implementation of RO.MA. for Urban Roads

In April 1992 a PMS study was conducted for the rehabilitation of the main urban roads in the municipality of Padua. The test included over 40 km of roads, most of it around the center of Padua, and they were subjected to a heavy traffic volume.

The scope of work was to develop a PMS for maintenance rehabilitation over a 2-year period, and the related amount of available budget was fixed by the administration. Before starting, a great deal of time was spent with the users to set the correct design for each of the following elements of the project:

- Maintenance policy;
- Alternative measures for each road, depending on the location, the presence of sidewalks, the possibility of the use of scarification measures, and so on;
- Pavement evaluation, that is which types of data to collect and the interpretation of the data defining the level of the pavement performance expected in term of evenness, bearing capacity, skid resistance, and so on; and
- Drainage characteristics and their impact on the rehabilitation costs.

## Pavement Evaluation

The following high-performance systems were employed for the pavement evaluation of the municipality of Padua:

- FWD for pavement bearing capacity evaluation;
- Laser profilometer for evenness pavement condition in term of International Roughness Index (IRI);
- SCRIM system to determine skid resistance;
- Distress analysis of seven types and three severity levels.

## Models

A number of different models were used to prepare final data for the economic evaluation:

- Deflection-value interpretation by the Road Moduli Evaluation (RO.M.E.) program. The modulus evaluation is carried out using basically Boussinesq equations for strain and stress calculations and Odemark/Kirk modifications known as the method of equivalent thicknesses. Besides modulus evaluation, RO.M.E. is able to calculate the remaining fatigue life of the pavement and the overlay needed to sustain the expected traffic.
- Road homogeneous subsection division using the ISO program. Based on field data acquisition and external constraints, the program provides homogeneous sections for the whole network. This is a very important step to provide a good PMS for urban roads, because as the number of physical constraints or political and administrative considerations to take into account is very high.
- Economic models including analysis of uneven roads, vehicle operating cost, environmental conditions, and pavement forecasting conditions in terms of benefit/cost analysis of the different maintenance alternatives proposed.
- Models to prepare a priority list for maintenance.

Figure 2 shows typical output of some pavement evaluation results. Included are

- Distress analysis (seven types of distress were considered at three different severity levels),
- IRI value (mm/meter),
- Skid resistance value, and
- Summarized outputs of RO.M.E. (moduli of asphalt layers—granular base and subgrade layers—remaining pavement life in terms of equivalent standard axles, and needed reinforcement).

## Pavement Priorities and Management

On the basis of the average condition of the homogeneous pavement sections and on physical and political considerations, a cost/benefit ratio analysis was carried out for individual projects as well as for the network level. The effect of an optimized rehabilitation strategy on the future condition of the road network was then analyzed according to the budget constraints, and a multiannual rehabilitation program (over 2 years) was proposed. The following rehabilitation alternatives were considered: 3 to 4 cm of reinforcement, 3 to 4 cm of scarification and reinforcement with binder and surface course, surface treatment, and rehabilitation with full reconstruction (18-cm depth).

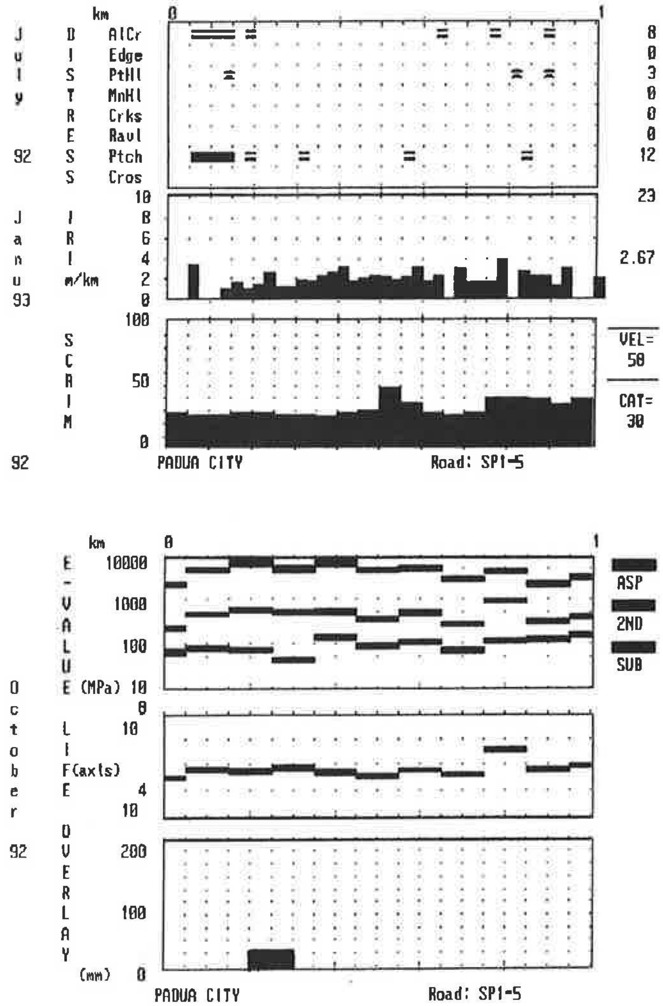



**FIGURE 2 Typical output of RO.MA. pavement evaluation.**

Table 1 shows an example of the rehabilitation program for 1993 as reported for each homogeneous section, including name of the road, initial and final homogeneous sections and chainage, area, IRI value (unevenness values greater than 3 mm/m are considered bad); distress per kilometer (low distress value, 0 to 20; medium distress, 20 to 40; high distress, over 40), reinforcement in millimeters, CAT (skid resistance) values lower than 40 are bad, rehabilitation proposed, and cost in millions of lire.

**TABLE 1 Padua Urban Roads: Maintenance Measures for 1993**

| Num | Street | From | To | Area | IRI | Distr | Rein | Cat | Maint Measures | Price |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ACQUAPI | 0 | 0.325 | 2275 | 3.85 | 52 | 48 | 42 | Reinforce 3+3cm. | 22.7 |
| 2 | ACQUAPI | .325 | .85 | 3675 | 3.41 | 52 | 67 | 41 | Reinforce 3+3cm. | 36.7 |
| 3 | BEZZECC1 | 0 | .525 | 3675 | 5.42 | 63 | 3 | 42 | Scar.3cm+Reinforce 4 cm | 39.8 |
| 4 | BEZZECC1 | .525 | 1.35 | 5775 | 4.67 | 46 | 127 | 45 | Reconstruction 18 cm (9+5+4) | 242.0 |
| 5 | PIOVESE1 | 0 | .3 | 2100 | 4.11 | 23 | 9 | 54 | Nothing | 0 |
| 6 | PIOVESE1 | .3 | .675 | 2625 | 5.71 | 37 | 83 | 52 | Scar.4cm + Reinforce 3+3 | 40.1 |
| 7 | PIOVESE1 | .675 | 1.2 | 3675 | 4.54 | 55 | 5 | 36 | Scar. 3cm +Rein-force 4 cm | 39.8 |
| 8 | PLEBIS1 | 0 | .3 | 1050 | 3.43 | 40 | 32 | 50 | Reinforce 3 cm. | 5.78 |
| 9 | PLEBIS1 | .3 | .6 | 1050 | 2.94 | 10 | 19 | 49 | Nothing | 0 |
| 10 | PLEBIS1 | .6 | 1.225 | 2188 | 2.8 | 50 | 18 | 51 | Reinforce 3+3 cm. | 21.8 |
| 11 | PLEBIS1 | 1.225 | 1.75 | 1837 | 3.78 | 25 | 14 | 46 | Nothing | 0 |

All the information collected was loaded into the data base with the other collected data. Particular attention was paid to the software design of the data base according to the needs of the user. Highlights of the user needs included the possibility of full interaction between users and the data base, modifications and updating of the data base, forecasting models of future pavement condition, and searching program to produce a priority list of the roads according to user inputs such as listing of the worst homogeneous sections based on evenness or skid resistance conditions.

Furthermore, the user is allowed to modify the type and cost of the different rehabilitation measures. The maintenance planning for the Padua municipality is summarized as follows:

| *Year* | *Area (mq)* | *Cost (lira millions)* |
|---|---|---|
| 1993 | 158 000 | 3210 |
| 1994 | 146 000 | 2270 |
| | 304 000 | 5480 |

## PMS 1993 for Autovie Venete Toll Highway Network

Since 1988 the RO.DE.CO. group has been involved in preparing the Autovie Venete toll highway network rehabilitation program. The application of the RO.MA. method during this period and interactions with the users have allowed quality improvements to be made. The results of the PMS were used to determine the best economic solution.

For example, the change in the evenness equipment survey from using PSR (or PSI) values to a new laser profilometer system allowed the possibility of a full analysis of the longitudinal and cross profiles and rutting, with a substantial improvement in PMS quality results. Using a laser profilometer, one can identify, for example, aquaplaning sections or incorrect cross profiles.

Filtering IRI values in terms of APL values (short and medium wave lengths), it is possible to recognize the type and the cause of uneven pavement conditions. The data base can be used to suggest which type of improvement should be made in order to provide better management.

For the pavement evaluation of the PMS for 1993, the following pavement characteristics were evaluated (on slow and fast lanes) on more than 126 km of highway:

- Longitudinal and cross profile (IRI-APL values),
- Rutting,
- Skid resistance, and
- Distress analysis.

Figure 3 shows the typical output of the laser profilometer measurements. For safety reasons, particular attention was paid to skid resistance values. The 1993 pavement evaluation data were compared with the data stored in the data base for 1992 in order to note and explain the change in pavement conditions.

This work, conducted over a 5- to 6-year period, allowed the RO.MA. method to improve its capability to foresee future pavement conditions with a more tailored decay law for skid resistance values, IRI values, and so on.

The cost/benefit analysis for Autovie Venete was carried out considering the client's four types of maintenance rehabilitation methodologies:

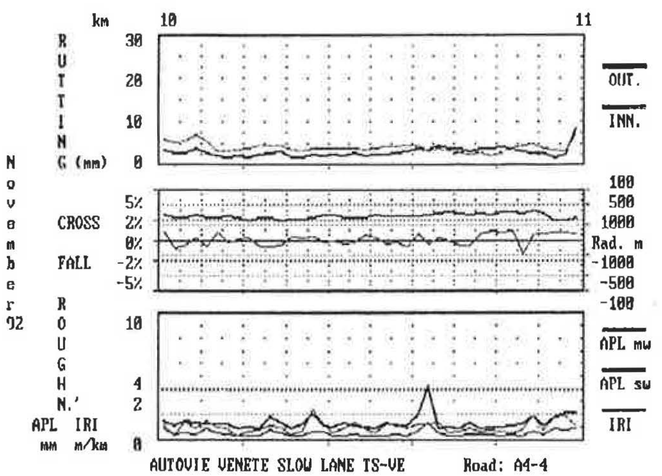



**FIGURE 3 Typical output of laser profilometer.**

- Surface treatment (slurry seal),
- Scarification and reconstruction of 4 cm of asphalt layer (this measure has the advantage of being performed on one lane only),
- Reinforcement with special draining mixes with modified asphalts (3 cm), and
- Reconstruction (45 cm) with subbase stabilization by hydraulic binders.

The optimization program analyzes the different maintenance alternatives taking into account that for a cost/benefit analysis, some of them have to be extended on both the slow and fast lanes.

Table 2 shows a partial output of the PMS for the slow lane of Autovie Venete in terms of homogeneous sections. The following data are given:

- Indication of the highway lane,
- Year of the last maintenance on the homogeneous section,
- Chainage (initial to final) of homogeneous sections,
- IRI value (a good IRI value for newly paved road is lower than 2 mm/m),
- Surface life in years,
- Distress per kilometer,
- Skid resistance (CAT) values,
- Maintenance type, and
- Cost.

The total budget available from the agency for highway network maintenance (650 lane-km) was approximately 10 billion lire (U.S. $6 million). According to the RO.MA. PMS results, this budget is sufficient to increase the general functional and structural conditions of the road network.

Figure 4 shows the improvement in pavement performance in terms of IRI values from 1989 to 1992, using the RO.MA. PMS for maintenance planning. It should be noted that the number of road sections with insufficient IRI values has been reduced by more than 50 percent in 4 years.

## PMS 1993 FOR CAGLIARI PROVINCIAL ROAD NETWORK

During 1993, a full PMS study was completed of 1000 km of provincial roads in Cagliari, Sardinia. The functional and structural pavement condition was evaluated using the following systems:

- Longitudinal pavement profile by laser profilometer and skid resistance by SCRIM system,
- Pavement bearing capacity by FWD,
- Distress analysis, and
- Ground penetrating radar system (GPRS) to determine the thicknesses and composition of the different pavement layers.

The use of GPRS was essential to provide accurate and reliable data for use in the road Modulus evaluation step.

The pavement management study included over 150 provincial roads, and a multiannual maintenance program was prepared considering both free budget and fixed budget cases as suggested by the user. For both cases examined, a maintenance priority list was prepared based on cost/benefit analyses of the alternative measures.

Table 3 is an example of the maintenance priority list for a fixed budget. The total cost proposed for the whole network provincial road was more than 19 billion lire.

A complete road data base was prepared and implemented on the user's personal computer. After a few days of training, the user was able to manage the data base alone. The data base is a powerful tool for administrations to use annually in managing and preparing the proper maintenance rehabilitation program for their roads. According to the PMS results, a priority list provides the administration with appropriate information as to which roads need attention and which type of maintenance is necessary based on the available annual budget.

In the case of the Cagliari provincial road network, special software was prepared to associate the graphic and alphanumeric information of the road data base. The graphic representation made the interpretation of the data easier for the user to understand because a great deal of data was collected for the analysis.

The new software (Road Information System) consists of

- A geographic data base for displaying the cartography of the territory and geographically localizing relevant information and elements,

TABLE 2 Maintenance and Rehabilitation Measures on A4-1 (Slow Lane)

| High Way ID | Year Last Maint. | From | To | Area | IRI | VSS | Distress | SCRIM | Maintenance Measures | Price |
|---|---|---|---|---|---|---|---|---|---|---|
| A4-1 | 92 | 0 | 0.5 | 2100 | 3.13 | 4 | 0 | 52 | Nothing | 0 |
| A4-1 | 90 | 0.5 | 1.825 | 5565 | 1.83 | 6 | 0 | 51 | Nothing | 0 |
| A4-1 | 80 | 1.825 | 2.9 | 4515 | 2.18 | 4 | 17 | 45 | Nothing | 0 |
| A4-1 | 92 | 2.9 | 3.9 | 4200 | 1.38 | 7 | 0 | 65 | Nothing | 0 |
| A4-1 | 86 | 3.9 | 6.125 | 9345 | 1.04 | 5 | 2 | 46 | Nothing | 0 |
| A4-1 | 86 | 6.125 | 6.75 | 2625 | 1.36 | 3 | 35 | 48 | Nothing | 0 |
| A4-1 | 86 | 6.75 | 8 | 5250 | 0.87 | 5 | 2 | 46 | Nothing | 0 |
| A4-1 | 92 | 8 | 11.65 | 15330 | 1.19 | 8 | 1 | 67 | Nothing | 0 |
| A4-1 | 88 | 11.65 | 13.8 | 9030 | 1.98 | 6 | 0 | 53 | Nothing | 0 |
| A4-1 | 89 to 91 | 13.8 | 26.8 | 54600 | 1.79 | 6 | 1 | 51 | Nothing | 0 |
| A4-1 | 80 | 26.8 | 34.5 | 32340 | 1.28 | 3 | 28 | 43 | Nothing | 0 |
| A4-1 | 80 | 34.5 | 36.95 | 13965 | 1.56 | 4 | 11 | 40 | Drain. Asph. | 361.7 |
| A4-1 | 89 | 36.965 | 39.8 | 11970 | 1.57 | 5 | 4 | 48 | Nothing | 0 |
| A4-1 | 80 | 39.8 | 41.55 | 7350 | 1.29 | 5 | 1 | 43 | Nothing | 0 |
| A4-1 | 91 | 41.55 | 42.05 | 2100 | 2.29 | 6 | 0 | 55 | Nothing | 0 |
| A4-1 | 86 | 42.05 | 43.15 | 6270 | 1.61 | 4 | 5 | 37 | Drain.Asph. | 162.4 |
| A4-1 | 91 | 43.15 | 53.05 | 41580 | 1.46 | 6 | 3 | 50 | Nothing | 0 |
| A4-1 | 86 | 53.05 | 57 | 16590 | 1.83 | 4 | 27 | 46 | Nothing | 0 |
| A4-1 | 80 | 57 | 59.3 | 9660 | 1.49 | 3 | 28 | 45 | Nothing | 0 |
| A4-1 | 86 | 59.3 | 59.8 | 2100 | 1.4 | 5 | 8 | 45 | Nothing | 0 |
| A4-1 | 86 | 59.8 | 60.5 | 2940 | 1.39 | 4 | 24 | 47 | Nothing | 0 |
| A4-1 | 86 | 60.5 | 61.175 | 2835 | 1.37 | 4 | 9 | 44 | Nothing | 0 |
| A4-1 | 86 | 61.175 | 61.825 | 2730 | 1.26 | 3 | 31 | 45 | Nothing | 0 |
| A4-1 | 86 | 61.825 | 67.125 | 22260 | 1.59 | 4 | 9 | 44 | Nothing | 0 |
| A4-1 | 78 | 67.125 | 68.7 | 6615 | 1.97 | 4 | 13 | 44 | Nothing | 0 |
| A4-1 | 91 | 68.7 | 69.675 | 4095 | 2.05 | 5 | 3 | 46 | Nothing | 0 |
| A4-1 | 84 | 69.675 | 71.4 | 7245 | 1.52 | 4 | 31 | 49 | Slurryseal | 78.7 |
| A4-1 | 78 | 71.4 | 74.25 | 11970 | 1.49 | 4 | 25 | 55 | Slurryseal | 130 |
| A4-1 | 88 | 74.25 | 79.6 | 22470 | 1.37 | 6 | 3 | 55 | Nothing | 0 |
| A4-1 | 92 | 79.6 | 81.6 | 8400 | 1.71 | 7 | 0 | 55 | Nothing | 0 |
| A4-1 | 82 | 81.6 | 82.9 | 5460 | 1.52 | 6 | 0 | 51 | Nothing | 0 |
| A4-1 | 84 | 82.9 | 83.55 | 2730 | 3.01 | 3 | 26 | 50 | Nothing | 0 |
| A4-1 | 88 | 83.55 | 88.1 | 19110 | 2.02 | 6 | 5 | 53 | Nothing | 0 |
| A4-1 | 89 | 88.1 | 93.5 | 22680 | 1.6 | 6 | 0 | 52 | Nothing | 0 |
| A4-1 | 91 | 93.5 | 95.95 | 10290 | 0.92 | 6 | 1 | 47 | Nothing | 0 |
| A4-1 | 88 | 95.95 | 99 | 12810 | 0.92 | 5 | 1 | 40 | Scar.4+Rein 4cm | 182.54 |
| A4-1 | 79 | 99 | 109.7 | 44940 | 1.14 | 5 | 1 | 41 | Scar.4+Rein 4cm | 640.39 |
| A4-1 | 91 | 109.7 | 119 | 39060 | 1.14 | 5 | 0 | 47 | Nothing | 0 |
| A4-1 | 74 | 119 | 121.35 | 9870 | 1.7 | 5 | 6 | 45 | Nothing | 0 |
| A4-1 | 92 | 121.35 | 123.9 | 10710 | 1.45 | 8 | 0 | 69 | Nothing | 0 |
| A4-1 | 91 | 123.9 | 126 | 8820 | 1.77 | 7 | 4 | 60 | Nothing | 0 |

**Total Cost (Lira): 1.5557E+09**

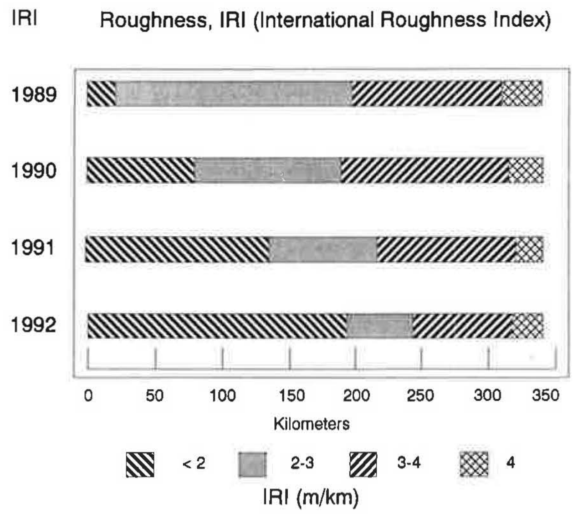



**FIGURE 4 Pavement performance improvement using RO.MA. PMS: Autovie Venete (slow lanes only).**

- Alphanumeric data base containing detailed information on the road network (structural and function pavement conditions), and
- Image data base containing photographic images and drawings.

The Road Information System represents a powerful tool for managing information and was built in such a way as to allow the user to add new elements to the road network, such as bridges, structures, ancillary work, and other equipment.

## CONCLUSIONS

Three examples of the use of the RO.MA. PMS were presented for urban, provincial, and highway networks. In all the cases examined, a brief description of the pavement evaluation and PMS phases of the RO.MA. method were given. The appropriateness of the proposed method has been discussed in terms of technical and economic aspects.

The implementation of a road data base on the user's PC containing PE and PMS data allows and forces the user to prepare more realistic annual maintenance budgets based on a scientific approach to maintenance rehabilitation problems.

Moreover, the use of new software for graphic representations on a PC of the cartography of the territory increases the information available for the agency to manage its road network in terms of efficiency and economy, and the graphic presentation of the data allows the user to easily understand the results of the RO.MA. analysis.

**TABLE 3 Maintenance Priority List for Cagliari Provincial Road Network**

| Num | Street | From | To | IRI(m/km) | Distr | Maint Measure | Price |
|---|---|---|---|---|---|---|---|
| 1 | SP1-10 | 0 | 0.5 | 6.58 | 0 | Reinf. 5 cm binder | 19.5 |
| 2 | SP1-10 | 0.5 | 1.35 | 2.28 | 79 | Reinf 6 cm. binder | 38.25 |
| 3 | SP1-10 | 1.35 | 1.9 | 2.7 | 25 | Slurryseal | 13.2 |
| 4 | SP1-10 | 1.9 | 2.8 | 7.63 | 26 | Reinf. 6 cm binder | 40.5 |
| 5 | SP1-10 | 2.8 | 3.325 | 4.56 | 63 | Reinf 5 cm binder | 20.48 |
| 6 | SP1-10 | 3.325 | 4 | 6.07 | 41 | Reinf 5 cm binder | 26.33 |
| 1 | SP1-18 | 0 | 0.55 | 2.59 | 42 | Reinf 3 cm | 15.73 |
| 2 | SP1-18 | 0.55 | 4.95 | 2.74 | 80 | Reinf 6 cm binder | 181.5 |
| 3 | SP1-18 | 4.95 | 5.475 | 2.91 | 32 | Reinf 3 cm | 15.02 |
| 4 | SP1-18 | 5.475 | 7.1 | 2.76 | 100 | Reinf 6 cm binder | 67.03 |
| 5 | SP1-18 | 7.1 | 8.1 | 2.97 | 29 | Reinf 3 cm | 28.6 |
| 6 | SP1-18 | 8.1 | 8.65 | 3.16 | 71 | Reinf 5 cm binder | 19.66 |
| 1 | SP1-23 | 0 | 7.9 | 3.7 | 89 | Reinf 6 cm binder | 325.88 |
| 2 | SP1-23 | 7.9 | 8.85 | 2.63 | 41 | Reinf 3 cm | 27.17 |
| 1 | SP1-29 | 0 | 0.5 | 2.53 | 52 | Reinf 4 cm | 21.13 |
| 2 | SP1-29 | 0.5 | 5.025 | 2.99 | 83 | Reinf 6 cm binder | 220.6 |
| 3 | SP1-29 | 5.025 | 5.8 | 4.45 | 44 | Reinf 4 cm | 32.75 |
| 1 | SP2-2 | 0 | 4.825 | 5.62 | 115 | Reinf 6 cm binder | 212.17 |
| 2 | SP2-2 | 4.825 | 5.4 | 4.05 | 19 | Reinf 3 cm | 17.94 |
| 3 | SP2-2 | 5.4 | 6.05 | 5.79 | 98 | Reinf 6 cm binder | 29.25 |
| 4 | SP2-2 | 6.05 | 6.8 | 2.81 | 1 | Nothing | 0 |

The use of the RO.MA. system in all three cases presented in this paper resulted in optimization of the maintenance budgets for all three agencies. This was accomplished through the use of RO.MA. techniques to identify specific areas of the roadway that are in need of maintenance. Similarly, RO.MA. identified areas of the roadway that did not need maintenance. The users benefitted from this analysis by knowing exactly where to implement maintenance techniques as well as what those techniques should be. By identifying the problem areas of the roadway, the users' maintenance budget was optimized.