PROPOSAL OF SECUNDARY ROAD MANAGEMENT SYSTEM (SRMS) IN DEVELOPING COUNTRY

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ABSTRACT

A visual evaluation method to know the conditions, in which a municipality network of Havana City is nowadays, has been applied since 1997. This method has led us to obtain technical criteria in order to establish priorities concerning network conservation as well as the cost of the necessary investments and the definition of the most suitable conservation strategies.

The systematic application of these evaluations, as well as the work methods that are derived from their application, have contributed to the elaboration of these practical suggestions, which are applicable to the integral management of a secondary network, when the municipality does not have enough resources.

This work states the basic principles to manage a network, in which the traffic volumes are low and consequently, the levels of fault evolve with smaller speed that in the main roads. Nevertheless, they have been accumulating wear during the years, because of a lack of resources in some cases, or the inadequate attention of the entities that are in charge of this activity. A proposal is made of how management should organize and work rationally this activity within these principles, defining possible short and medium term strategies and how the necessary resources can be used to organize better the activity.

Recommendations are based fundamentally on the result of the application of a method of visual evaluation that defines a condition indicator for each sector and road section in which the network is subdivided. This method is based on cost repairs, and it allows establishing the resources associated to these values.

In this article the basic principles for the integral management of a secondary network are proposed, considering a limited technology and scarce material resources. These suggestions can be useful to managers of future investments. They will be responsible for the introduction of the necessary changes in the developing countries.

1. INTRODUCTION

A great effort has been made in these years to maintain, under the best possible conditions, the main roads, in spite of the limitations imposed by economical situations in Cuba. Nevertheless, this has not been so in secondary roads that present a higher degree of fault. For this reason, only a low percentage of the secondary network is in good conditions. Pavements go deteriorating more and more if urgent solutions are not taken and management policies are not changed.

In 1997 the visual evaluation of pavements in an urban network of secondary roads, in one of the Municipalities of the capital of the country was carried out for the first time whose result was a technical approach to establish the priorities in the repairs. This evaluation offers advantages to the investors, from the point of view of the management of the network, to repeat the evaluation in a systematic way.

This proposal arises after successive evaluations and of actions guided to improve the administration work. Empirical work is changed for the introduction of an appropriate tool for the management of the conservation activity, achieving a more rational use of the scarce available resources, when establishing short and medium term strategies, with a more reliable technical base and consequently, with better results in the activity.

The starting point in management, is the evaluation of the road elements, by visual inspection, and in an objective way. The methods of visual inspection do not allow to evaluate the network in a short period. For this reason samples of road sections are selected randomly, to measure the existent faults and to calculate, using statistical techniques, the condition indicator of each sector in which the network is divided.

The proposed system intends to reorient the work form, to change the way a problem is focused and to solve it with the aid of technical criteria, presenting basic elements so that these changes can be successful. The proposals are the result of the experience in the management of an urban network. This does not mean that they can be also valid for a network of secondary highways.

2. FUNDAMENTAL PRINCIPLES FOR THE MANAGEMENT OF THE NETWORK

The management of the network needs a department for the planning, orientation and control (investor) of the secondary roads. This department maintains all the information up to date about the technical state of the roads, the need of conservation or rehabilitation, the plans to be carried out, the material, financial and human resources, as well as the investments that are planned in the underground networks. This department co-ordinates the works that are carried out in the underground networks with other investors of the territory, in order to guarantee that the workers restore the roads after the works, to its original state.

The management should be approached as a system that allows the manager to select the most appropriate performances according to the level of the existing fault and the repair costs, determining in this way the priorities of the works that will be carried out, considering the economic resources available.

Management, consequently, should use methods to rationalize those resources, as to guarantee the following general objectives:

1. To keep the functionality of the network with an appropriate quality, under the influence of the condition of the signal, the pavement and the sidewalk, as well as of the technical networks.
2. To establish conservation and medium term strategies of general character (3 to 5 years) and to plan the repair every three months according to those strategies.
3. To obtain the most economic options in the performance of the conservation works, from the point of view of the adopted solutions and optimize the movements of the workers that repair the networks to the desired places.
4. To reduce the affectations of the environment, selecting suitable materials and constructive systems.
5. To incorporate the investigation as part of the management system, giving the possibility to experience with new constructive techniques, low cost or recycled materials, in the conservation of pavements.

In order to complete these objectives it is necessary to have a detailed information of the characteristics of the network and of their technical conditions, as well as the necessary parameters in decision making. The conditions of the network are obtained by means of visual evaluation whose results can be employed to establish strategies and priorities, but also to project the rehabilitation of a specific road.

The information is stored in a database, where you access through a code to introduce new data or to update the existent ones and it is the basis for the analysis of alternatives that allow the manager to select, with certain restrictions, the best variant.

3. PARTS COMPONENTS, RECOMMENDATIONS FOR THE MANAGEMENT

3.1 Organization of the network; Road sections and code

When the network is extensive it can be divided into sectors. You can use the division that has the government of the territory as criteria. In the case of a rural network, it is convenient that these sectors are the highways that form part of this network.

Each sector of the network is divided in streets and these in road sections, identifying each one with a code. These road sections will be the basic unit for the observation and

maintenance in the network. In urban roads the experience has carried to that these road sections coincide approximately with the blocks that are the divisions of our streets and avenues, of 100m long. In highway segments 100m are also considered.

By means of a code system you can access to the requested road section in the computer programs in a quick way, and it should be composed by digits that identifies the sector to which it belongs and the serial one within the sector.

3.2. Information about the network; Database

Right decisions depend on the information that one has of the network. That is why it is necessary to know and to update the following data:

- About the component elements:

1. Physical inventory: dimensions of the roadway, sidewalks, kerbs and location of the drainage devices.
2. Pavement characteristics: Type (rigid or flexible), thickness of layers and materials that compose the structures.
3. Results of visual evaluations carried out and resistant parameters of the structures, in the event of auscultation with equipment.
4. Constructive history: Performed conservation works, projected and performed rehabilitation in each road section.
5. Signing: Location of the signs, types and conditions.

- About decision making:

1. Defined conservation strategies for each type of structure.
2. Qualification criteria of the road sections.
3. Criteria to establish the priorities of performance of the conservation in the network.
4. Condition indicator of each road section and street of the network. They are obtained by statistical inference starting from the visual evaluation of a representative sample of the network.

The existence of a database facilitates that the information is organized in the way the management demands and it can be consulted and accessed by the specialists in any moment, by means of the codes.

3.3. Data of the traffic

The traffic in the secondary roads is not a decisive element, since the volumes are low. However, it is sometimes necessary a temporary diversion of traffic towards the secondary roads for repairs in the main roads, thus circulating heavy vehicles, especially buses that can be of excessive load for axis for these pavements. For this reason it is necessary to use a procedure to know the loads of the traffic in order to determine which roads will be

used to deviate the vehicles and during what time, or to know the additional expenses that can be generated.

Through an amount of vehicles classified by silhouette it is possible in an economic way to have information on the magnitudes of the loads for axis that circulate. You can obtain the percentage of heavy vehicles and a PAIDT approach[1].

3.4 Technical evaluation of the pavements and sidewalks

Once the roads are used they begin the progressive fault of their elements; due mainly to the quality of the repairs, affectations to the roads for courts to repair underground networks, water outlet towards or on the streets or inappropriate use of the streets for deposit of materials.

It is necessary to carry out evaluations systematically, to know the condition of the network, maintaining the database updated. The evaluations are carried out at three levels:

1. Preliminary evaluation, with a method quick enough to obtain the general condition of all the road sections, with the objective of carrying out general plans of detailed inspections.
2. Detailed evaluation that is carried out starting from a sample, to make decisions and to establish strategies and priorities in the network.
3. Evaluation for rehabilitation project, taking information of the conditions of each road section, and analyzing the different causes.

3.4.1 Preliminary evaluation; Abbreviated method

The abbreviated method is used to have a criterion on the state of the network in a preliminary way in order to make plans of global character, and not to take decisions in the conservation. It is a quick evaluation, carried out by a specialist, travelling all the road sections and conferring a qualification among 0-10 according to the level of fault. Road section qualifications are shown in table 1 and the necessary criteria given to it. The results of this method define the proportion of qualifications that present the network of a sector or of a street.

[1] In Cuba an approximate method is used for the determination of the loads of the traffic, based on the amount by silhouettes. When distinguishing during the count the load condition (full, half or empty) can be considered for statistical procedures, the spectrum of loads, the characteristic load and the factor truck-axis.

Table 1: Scale of qualification. Abbreviated method.

PUNCTUATION	CONDITION OF THE ROAD SECTION
0	Excellent, without fault.
1-5	The faults can be solved with isolated repairs, predominantly with superficial patching, but they occupy less than 50% of the area.
6	It requires retread. More than 50% of the faults requires superficial patching.
7-9	The faults can be solved with isolated repairs, predominantly with deep patching, but they occupy less than 50% of the area.
10	It requires reconstruction. More than 50% of faults requires deep patching.

With this procedure the distribution of qualifications is determined in the network. This distribution is basic to obtain representative and necessary samples in the detailed evaluation, extracting from the population, as many road sections for qualification as they exist in the preliminary distribution. In the preliminary evaluation those areas are detected where bigger faults exist or those where repair is not required. These elements are useful to plan the detailed evaluation.

A correlation has been carried out between this quick method and the detailed evaluation procedure of the network that is presented in the following section, evaluating this way this coincidence. The correlations have been used to adjust the detailed method according to the criteria of the specialists and to define the performance thresholds. Figure 1 shows one of these correlations.

The methodology applied in a systematic way, gives way to experiences that accumulate and they improve the methodology itself. This application gives the engineers better criteria when they evaluate the seriousness of the faults. For that reason this form of correlation has been used to control the work of the appraiser and to adjust their results.

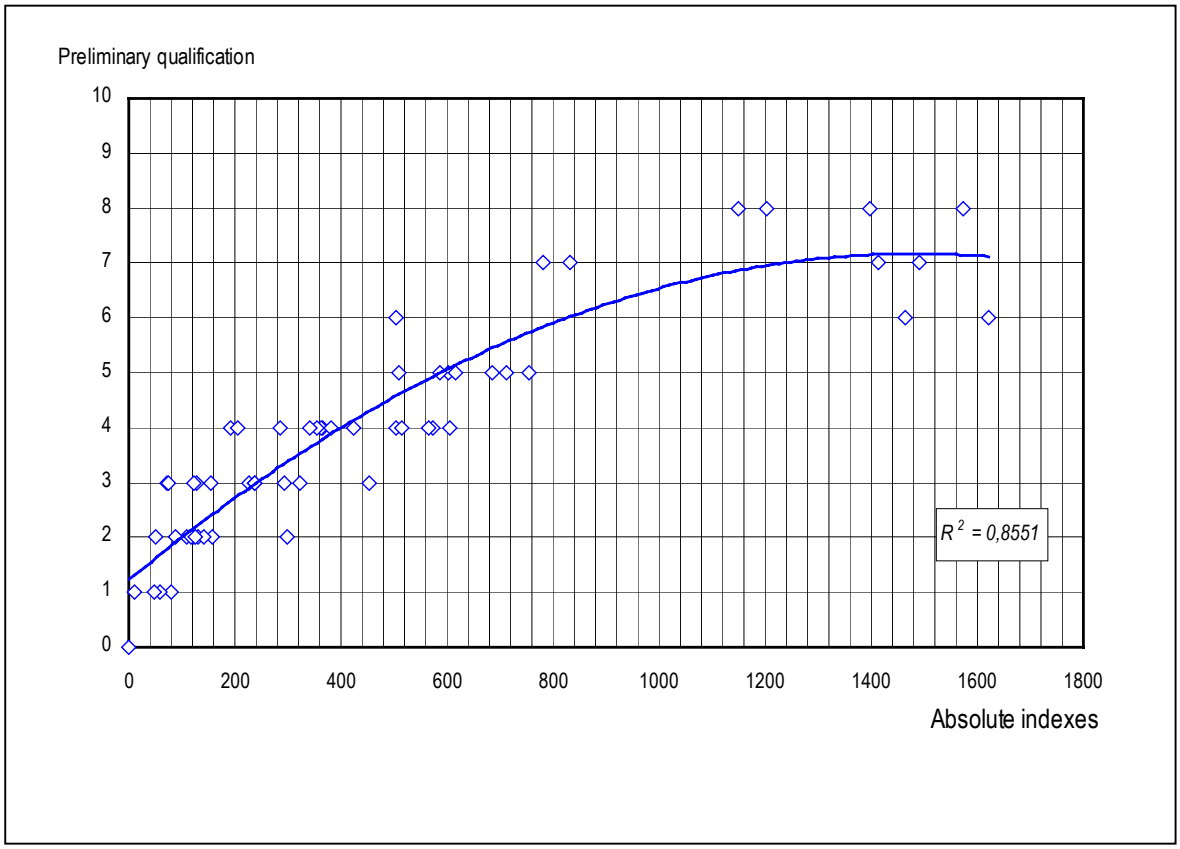


Figure 1: Correlation among the preliminary and detailed evaluation, carried out in a sector of the secondary network of the Municipality Playa (Popular Council of Cubanacán).

3.4.2 Detailed visual evaluation

There are different procedures of visual evaluation and the great variety of possible faults that may be found complicates the field work.. The work of the appraiser is considerably simplified, in the proposed method because the condition indicator is considered starting from the corrections. These several faults can be corrected with the same performances, and so unnecessary definitions of faults may be avoided.

In some cases it is not possible for the extension of the network, to evaluate all the road sections in a detailed form. For this reason a selected sample is evaluated. First, the number of road sections to evaluate the selected sample is defined in each sector, to fulfil a preset error and then, those road sections that will be selected to form the sample in an random way.

The degree of representation is guaranteed by selecting a number of road sections for qualification that satisfies the distribution of qualifications already obtained during the preliminary evaluation. Then, each road section of the sample is evaluated visually, including the pavement, the sidewalks, the kerbs and the signing.

The possible road sections to be evaluated in the network are located in a territory layout, and by some random procedure those road sections that belong to the selected sample are marked considering the following recommendations:

1. To cover all the areas of the territory, so that in the sample a quantity of road sections in each sector is proportional to the total number of road sections that the territory contains.
2. To evaluate at least one point for each avenue or street with the aim of establishing priorities.
3. To select in each sample from each qualification a quantity of proportional road sections to those that were obtained during the preliminary evaluation.

When the road section is evaluated in this method, the affected area is not only defined, but it is also identified with the proposed solution. The appraiser will receive training, to value when a pavement is damaged superficially or when a problem concerns the whole structure.

The evaluation pattern is a draft of the road section, where the faults are represented according to certain symbols. The inventory of the elements of highways is also included

The road section should be first evaluated before the repair of the faults and their unitary costs is established, according to the standard prices in construction. Two types of evaluation indexes are established: Absolute, that represents the necessary total cost and that of State, that represents the cost divided by width, to compare streets of different cross section.

The information processed and picked up in the evaluation allows the manager to calculate the indexes of condition of each evaluated road section, and to infer, for statistical procedures that of each street, sector and that of the network. Consequently, the following is obtained:

- The Indexes of State and Absolute of each street or avenue of the network.
- The Index of State and Absolute of each sector.
- The distribution of qualifications that exists in the network.
- The necessary investments in each case.

To calculate the indexes, first it is necessary to establish certain approaches or performance thresholds. Two types of corrections are established: isolated and generalized. The first one will require a punctual, located repair that can be corrected by means of patching, the other one requires a resurfacing of the whole road section due to the degree of generalization in the surface. Therefore, when the necessary isolated corrections overcome a certain percentage of the total area, a widespread correction will be cheaper. Otherwise, the cost will be the sum of the isolated corrections corrected by means of patching. This is a valid point for the superficial corrections as well as deep ones.

Thus, the absolute costs of each road section, can present three variants:

1. Superficial isolated corrections + deep isolated corrections.
2. Superficial generalized corrections + deep isolated corrections.
3. Deep generalized corrections (reconstruction, with reinforcement possibility).

In table 2 the approaches are shown to qualify the network keeping in mind the value of the Index of State. The correspondence with the preliminary evaluation is also shown.

Table 2: Road section qualifications

QUALIFICATION	INDEX OF STATE	PRELIMINARY QUALIFICATION
Very good	0	0
Good	0 - 300	1-3
Fair	301 - 500	4-5
Bad	501 - 700	6-8
Very bad	Bigger than 700	9-10

Figure 2 represents a result obtained with this method, where the state indexes and absolute calculated for each sector of the network is shown. The differences can be appreciated among the sectors.

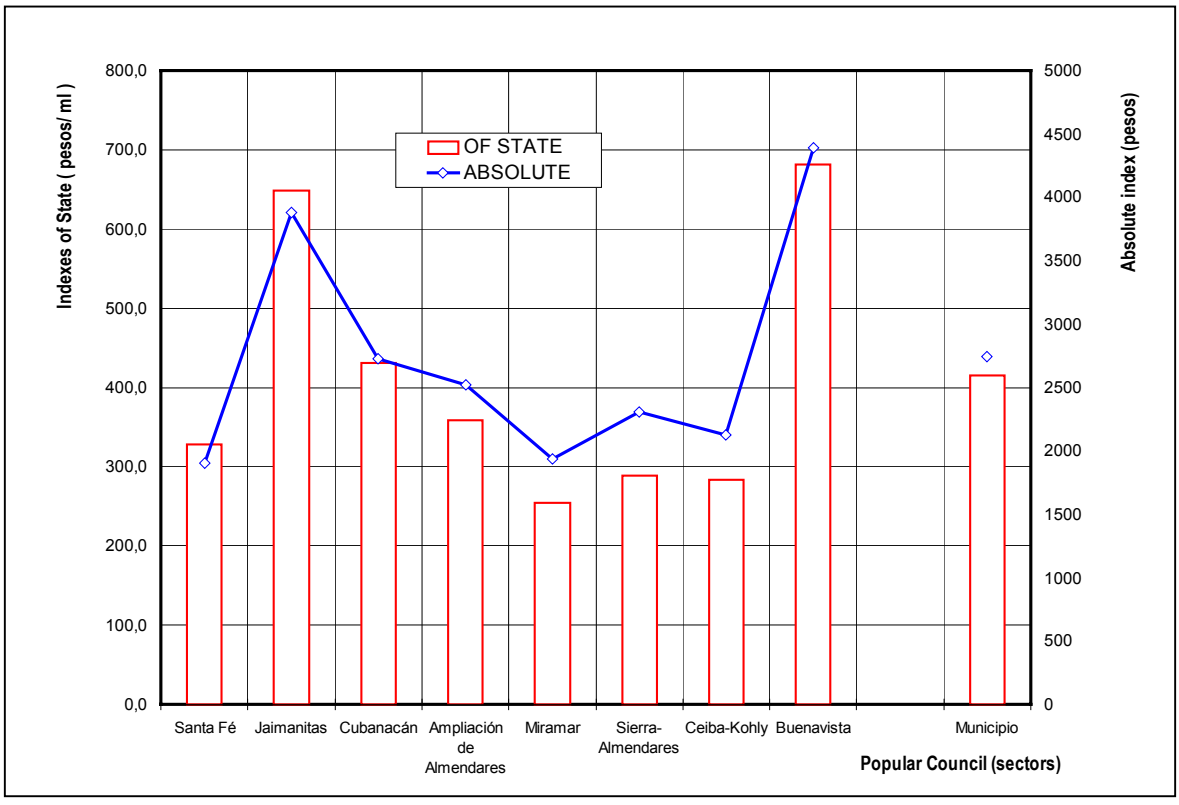


Figure 2: Graphic representation of the Indexes of State and Absolute in each sector of the network

3.4.3 Evaluation for rehabilitation projects

When a street or some of their road sections has been granted a preliminary qualification of 8 points or more, and resources exist for an important investment, it is necessary to elaborate a rehabilitation project. This is the reason why all their road sections will be evaluated.

The project will be carried out based on a detailed study of the faults, the causes that produce them and the solutions in each one of the road sections, and it includes:

1. Preliminary study:
   - Surveying, as the basis for the drainage project.
   - Detailed evaluation of the pavement and the sidewalks for visual inspection. Calculation of state indexes and necessary investments.
2. Analysis of the present characteristics of the traffic and perspectives.
3. Analysis and causes of faults.
4. Project of the pavement.
   - Analysis of variants of structures.
   - Characteristic of the materials and mixtures.
   - Constructive recommendations and quality control parameters.
5. Economic calculation of the possible variants of the pavement.
6. Drainage project.

In Figure 3 an example of the results is shown that can be obtained, in the evaluation of all the road sections of a street, for a rehabilitation project. In this street the pavement has been deteriorating per years, due to different cuts for technical networks not well performed, conservation tasks carried out with technical problems and for spilling towards the streets.

In these cases, in order to analyze the faults and their causes, it is convenient to make a recount of the deteriorated areas, separated by type of faults, superficial and deep. Through the information that offers the evaluation method these differences can be established, in road sections and which types prevail and so to decide a solution.

Figure 4 shows the same case, separating the deteriorated areas in superficial and deep faults. This way to represent the results allows the manager to appreciate the differences by road sections, trying to relate them with the possible causes that produce them. In this case it was proven that two road sections (21-23 and 23-25), presented deep faults even bigger than the rest and related to the drainage problems in the street.

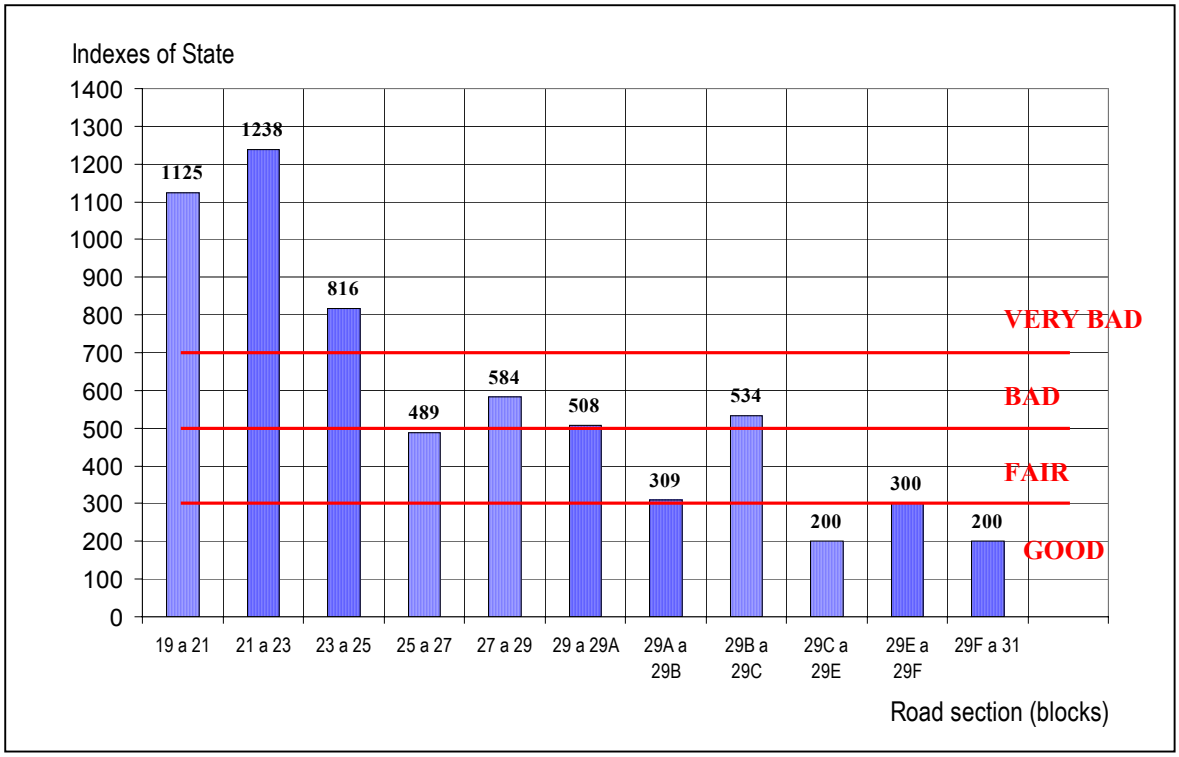
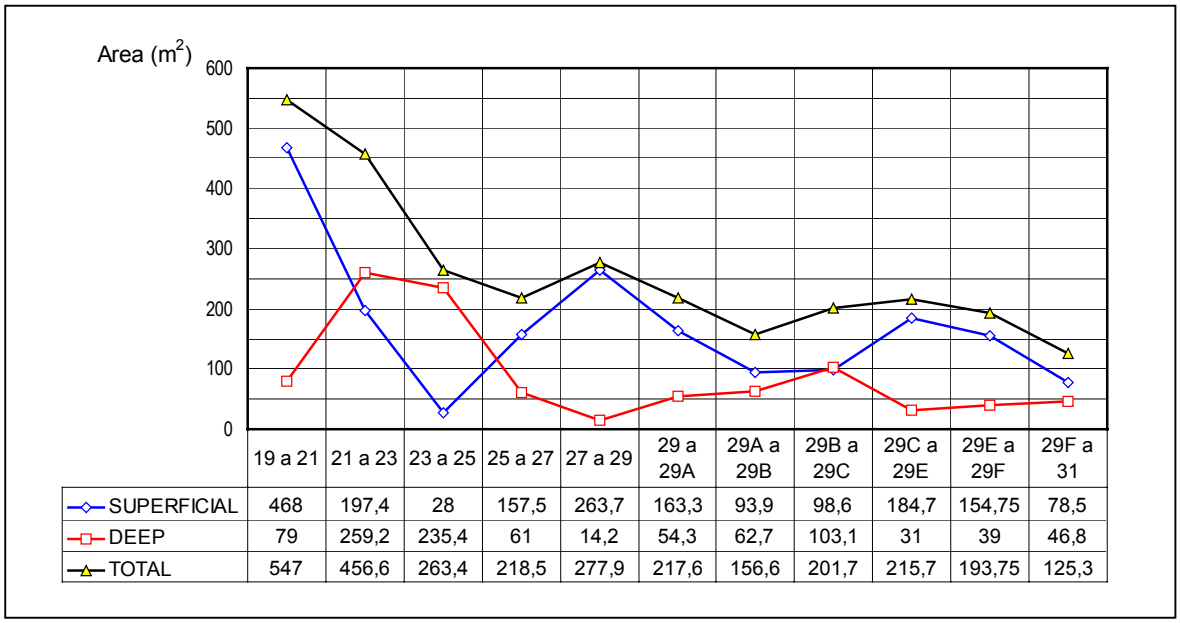


Figure 3: Indexes of State, obtained in the evaluation of the pavement of each block



	19 a 21	21 a 23	23 a 25	25 a 27	27 a 29	29 a 29A	29A a 29B	29B a 29C	29C a 29E	29E a 29F	29F a 31
SUPERFICIAL	468	197,4	28	157,5	263,7	163,3	93,9	98,6	184,7	154,75	78,5
DEEP	79	259,2	235,4	61	14,2	54,3	62,7	103,1	31	39	46,8
TOTAL	547	456,6	263,4	218,5	277,9	217,6	156,6	201,7	215,7	193,75	125,3

Figure 4: Total areas for type of faults in each block (road section)

These elements and others are obtained from the information that gives us the detailed visual evaluation. A generalized solution is given for the whole street or a particular solution for each road section from the analysis of these results. This decision should be in correspondence with the resources available in that moment.

In cases where it is decided to reconstruct the structure, it is necessary to incorporate a traffic study that offers information on the loads, estimating the quantity of axes that will circulate during a certain period, stating in this way to maintain the existent structure, or to apply a reinforcement.

3.5 Evaluation of the signing

All the signs in each road section will be evaluated writing down the number that identifies the type of the sign and two other numbers between 0 and 10, written as a quotient, where the upper indicates the qualification that the specialist grants to the location of the sign and the lower to her state.

For the qualification of their state (between 0 and 10) the specialist will keep in mind the affectations of the sign as for her degree of: fading, waste, oxidation, disintegration or other faults caused by people.

3.6 Conservation strategies

The methods of visual inspection try to infer the structural state of the pavement by means of observations in the surface. For this reason it is not possible to evaluate the capacity of the structure accurately, since it should be aided by measuring equipment as the Benkelman beam.

It is not possible to define conservation strategies, for the structures if studies do not exist on the evolution of the faults. These observations are possible by means of the pursuit of the faults of different types, in time, relating them with the changes of temperature, precipitation and traffic. It is more convenient to refer to investment strategies.

3.7 Investment strategies

These define what it should be made in every period with the available budget. That is to say in which road sections or streets of the network the work will be carried out during the next ones 3 to 5 years. All the information of the detailed evaluation that is obtained is a tool, because it may be used as a tool to establish the strategies, and then, to define the priorities, as well as to elaborate the conservation plans for every three months, always adjusting it to the available budget.

The strategy will therefore define:

1. In which way priorities in the investments are carried out depending on the qualifications and amount of work.
2. Necessary budget needed for each amount of work
3. How long the state of the network will take until an appropriate level, keeping in mind the resources that traditionally are available.

An example is shown in Figure 5 to represent the distribution of qualifications. Taking into consideration these results, the manager would define which general strategies will be the ones defined for the conservation of the network and which sector independently.

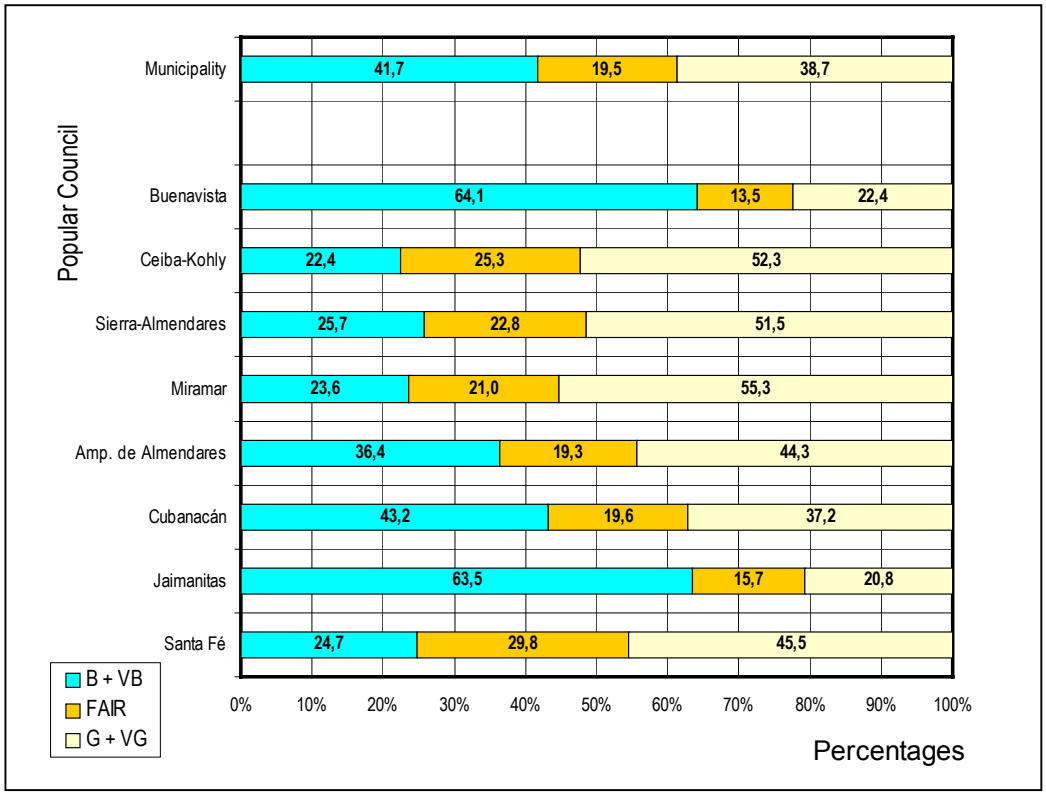


Figure 5: Distribution of qualifications in the network of the Municipality Playa, starting from the evaluation carried out in the 2001

3.8 Priorities

Priorities constitute an orderly relationship of road sections or streets, in function of the order in which the performance plans are included, and they are the basis of the execution of the plans every three months. The Department will propose these priorities, considering fundamentally, the technical criteria, given by the obtained indexes, as well as the opinions of the population that are received and other factors of social character.

It is important to consider that the priorities, in principle, should be analyzed by streets, or segments of these streets, considering that the index of the street will be the average of all the road sections that were evaluated in that itinerary. This has several advantages. It allows rationalizing the movements during the maintenance works. Also from the user's point of view, to guarantee the displacement through a certain itinerary and appreciating better the results of the carried out investment.

Nevertheless, critical road sections will also exist, which are also given priority in an independent way. Those that are justified for the magnitude of the faults, or located in the proximity of some institution of social, economic or political importance, or because accidents have been reported and represent a real danger to the security of the vehicles and pedestrians.

3.9 Research

Research is an important aspect in management, directed to the improvement of the system and the introduction or evaluation of new construction techniques.

The rehabilitation of a pavement is generally made placing the reinforcement directly on the existent layer to elevate the vertical alignment. This also consumes a great quantity of Aries and binders with the unavoidable fault of the environment. These inconveniences can be previously reduced milling the surface and reusing the extracted material of the road in the extension of the new layer by means of recycling techniques.

The introduction of these techniques, the employment of soils stabilization, the improvement of the evaluation techniques should be incentivated as well as the introduction of means and methods to save resources, giving possibilities to the technical personnel that develop them and put them into practice. To motivate the constant search of new technologies that facilitate the use of new materials, energy saving, reduction of costs, and protection of the medium. All this should be seen as a work method in the system.

3.10 The role of the users

The plans that are elaborated for the conservation of the network are based, not only in the survey that technicians carry out to know the state of the roads and to locate the problems but also in the opinion of the population.

Although it is certain that the population participates in the detection of the problems, it is not only the role that should carry out. This, of course, can not be the fundamental approach when deciding the priorities in the conservation. It is the Department, specialized in the conservation who should decide where, when and in what magnitude the resources are designated, with technical approaches, conjugating them with those opinions. The population in their user role should also look after the conservation, maintaining the cleaning, not causing spilling towards the streets, or claiming for the good quality of the works.

4. CONCLUSIONS

The biggest percentage in the affectations present in the secondary networks, when one does not neglect the conservation is feasible of solving with isolated corrections, by means of works of ordinary repairs where important repairs or reconstructions are not important. Nevertheless, the affectations accumulated per years justify the intensity of the current rhythms of conservation to stop the fault of the network and to begin their recovery.

Different causes are present in the bad conditions of the network:

- Deficiencies of the pluvial drainage
- Occurrence of spilling towards the streets.

- Bad quality of the materials used, especially the asphalt concrete that arrive with low temperatures at the work site, or with inadequate asphalt contents.
- Deficiencies in the performance of the repairs given by low compact densities, mixtures not well extended, resurfacing performance without demolitions, etc.
- Bad performance when covering the cuts in the roads for the buried networks (aqueduct, electric, gas or telephone).

This paper has intended to focus the conservation activity like a system, where each one of the parts is as important as the other ones, and in which the evaluation plays a fundamental role. It is necessary to know the state of the pavements to make the right decisions in each case, to define the strategy of more appropriate investment and in consequence, to establish priorities from the repairs and the performance of the work plans-

The contribution of these recommendations does not consist on established rules to apply them rigidly. It is the summary of some experiences that were put into practice and others that are derived of those applied. It is also a material that should be analyzed among the specialists to contribute to the reflection of these topics, to the necessary debate, in order to improve in the smallest possible time the conservation activity.

An integral analysis in management is proposed, and not merely an evaluation procedure. The proposal includes also a methodology for the collection of information, a method of economic calculation, solution criteria for the faults, and mainly it incorporates technical criteria to management. Necessary decisions to take in the conservation are also stated, defining the work strategy and leaving criteria technical, economical, social and territorial ones.

The system should worked for the improvement of the organization of the maintenance brigades and their equipment, and to increase the means of protection to the workers, as well as to use new and modern techniques. It should be indispensable to work according to itineraries. This rationalizes the movement of the brigade and makes a good use of the available resources.

Many times the conservation budget is conceived erroneously because it is related exclusively to the quantity of mixture to be used, without taking into consideration the evaluation of the network as part of this budget. This allows the manager to make a good use of this budget within the network and in which places according to the priorities.

In the developing countries much resources could not be assigned to repair the secondary networks in a short period of time, because other more urgent necessities will always exist.. However, to preserve what has been made by our precedent generations, the patrimony of highways that has been able to be in use in all these years, is a responsibility of our engineers. The only way will be to introduce methods that can perfect our work, making it more effective and efficient.

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