MANAGEMENT OF PRIMARY ROAD PAVEMENTS OF MEXICO CITY

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ABSTRACT

Nowadays, pavement management is an increasingly important issue due to the need to economically and technically manage pavements which represent an important part of the Administrations budgets.

In addition to this, there is a vital need to offer users roads in correct functional state thus, making a rideability as safe and comfortable as possible.

As a consequence, the government of the Federal District decided to implement a modern management system in a part of the road network. The management includes primary roads of the Mexico City, a total of 2150 km.

Firstly, a condition survey campaign was carried out through the selected roads, where the following parameters were measured:

- Superficial regularity
- Deterioration
- Bearing capacity
- Tyre-pavement friction

Moreover, before this process, an inventory of roads was conducted which included some information such as geometrical data, signage, safety barriers, etc, and a video of the route.

Then, this data was used to undertake a research with the help of a pavement management system. Finally and depending on the economic possibilities of the Government a plan of works for the following years was carried out on the network.

This process will not only improve the serviceability but also take into account economic factors according to technical issues.

1. HEADING

The definition of management is *to do what is necessary to make a business succeed.* This means that the management of a road implies doing the necessary works to maintain the Administration's and user's capital in an appropriate condition at the lowest possible cost.

Streets and roads are forms of capital that lose their value with use and time. Thus, it is important to re-invest money in the form of conservation works and with a certain frequency to avoid a capital depletion, or, in other words, to avoid the complete deterioration of the road.

Not so long ago, roads were not managed although they were maintained. That is to say winter serviceability, restitution of signing, replacement of guardrails, etc. When the pavement broke, it used to be fixed alter a bureaucratic year, starting with the Study request and finishing with the end of works.

In the case of infrastructure, management can go from doing nothing –option zero- to successfully managing it.

Option zero leads to a sure deterioration and the only solution is to rebuild the road within the following years –the quantity of years will depend on the traffic burden. This is the option when there is no money allocated to the road management. The World Bank has one said: "No country is reach enough to do away with road management".

On the other hand, option one, view tab, consists in replacing the street or road elements when necessary.

When the manager sees that the pavement or any other infrastructure element has broken, he or she gives the green light to the element reposition or fixing.

Taking action once the pavement is already broken, for example, makes the condition of the pavement –whose deterioration is increasing- become more serious and the works more expensive than taking action no sooner the crack is noticed. Besides, in the first case the user will drive on poor-condition pavement longer resulting in complaints and the loss of manager's image.

A second option is to take action before the pavement deteriorates. This means acting "in time", ensuring the good maintenance of the pavement, with a low cost and an always-satisfied user.

This option calls for PREVIEW on the part of the road manager. The manager must be able to anticipate the evolution of the parameters defining the pavement condition; hence he/she must be familiarized with evolution models to be able to determine when the appropriate moment to intervene is.

These actions can only take place if the pavement is in moderate condition. The manager must keep a record of his/her decisions by using a management programme or by carrying out a comprehensive study that backs the decision objectively as the most economic solution for the road.

A third and intermediate option is to intervene when the pavement reaches certain degree of deterioration, which also requires VIEW of its evolution. However, in this there would be deterioration on the road.

As we already said, this last option would be intermediate, between options one and two.

It is not easy to choose between the Preview and View options: both can be valid; however the cost the best option implies, the first one, may lead to resorting to the second one.

For any option, the steps are similar:

- Inventory
- Definition of the condition parameters
- Systematic condition survey of the condition parameters
- Obtaining evolution models
- Decision-taking, according to pre-established ranges and economic possibilities

The first step is to deeply know the element to manage that is why an inventory is needed.

If it is a pavement the network will have to be divided into stretches, we will need the length and width of each stretch, the length of the shoulders, the type of pavement, etc. The inventory can go from very simple to very complex.

A street or road general inventory serves as a global comprehension of the network. It includes the general elements to manage and allows for obtaining the inventory general data of the different elements considered for the management. It is essential to count with a general view of the problem.

Obviously, the more complex the management is the more data the inventory will need. In any case, the inventory will have to include the division into stretches and a common geo-reference.

For example, a pavement inventory will need to include at least the structure of the pavements composing the network, together with the quantity of layers and kind of material, the year of each layer, etc.

Any element will deteriorate due to the passing of time and, sometimes, to traffic, rains or other parameters.

Deterioration affects the element functionality and with time the element becomes useless and cannot serve the purpose it was created for.

For example, the parameters that define the condition of a pavement are:

- Functional parameters
    - Superficial regularity
    - Sideway force coefficient
- Structural paremetres
    - Deflections
    - Superficial deterioration

In the case of streets, within the group of superficial deterioration, cracks and potholes are considered parameters, but ruts are not, since because of the traffic expected in a street there should not be any.

Once the inventory has been drawn, the next step is to know the current condition of the parameters defining the functionality of each element.

The manager will have a picture of the element, which in turn will help him to know the functionality condition of the network. This is the first step to define an evolution model of the parameter or parameters.

In road management there are parameters that change faster than others. The coefficient of friction, for example, evolves quickly in a new asphalt mix, where it can even increase. After one or two winters, sand and aggregates will come off the bitumen film that covers them and this will lead to a fall in the coefficient of friction, mainly because of sand and cement polishing, which usually changes at a slow speed.

It is important to survey during the first two years after the application of a new asphalt mix. After these first years, condition surveys can take place less frequently.

The greater the importance of the road, the more frequent the surveys. Not only because the more cars the quicker the deterioration, but also because it is important to show efficiency in maintenance, and, as a consequence, it is convenient to do away with the risk of accelerating deterioration and making it unnoticeable between two successive surveys.

The following is an example of a table with average recommendations for surveys:

ROAD TYPE	HIGH	LOW
ROUGHNESS	A YEAR	THREE YEARS
BEARING CAPACITY	THREE YEARS	FIVE YEARS
SKID RESISTANCE	TWO YEARS	FOUR YEARS
SURFICIAL DETERIORATION	TWO YEARS	FOUR YEARS

After systematic condition survey works, evolution models may be adapted to stretches. Meanwhile, management programmes work with theoretical models, properly compared, though need adjustment.

2. WORKS DONE IN THE PRIMARY ROADS OF MEXICO DC

These works consisted of the Inventory of the Primary Roads of Mexico DC and of the collection and processing of data deterioration (cracks and potholes), IRI, deflections (bearing capacity) and skid resistance. All the data were collected with high-performance vehicles and in all primary roads in Mexico DC. Finally, all this information was entered in the Management System

The roads of this contract were 105 and more than 500 kilometres long.

2.1. ON SITE DATA COLLECTION

2.1.1. Inventory data collection

The collection of images, georeference and geometric information of the road network every 10 metres gave way to a visual database of the managed road network. The performance of this equipment in highways is high, but, because of the heavy traffic and considering it was not used when the weather conditions were not the appropriate, the performance in the city was of 30km/day.

2.1.2. IRI data collection

Through laser sensors and accelerometres, the high-performance vehicle got the levelled profile of roads that together with a maths model that simulates the suspension and mass of an ordinary vehicle, going at an average speed of 80 km/h allows for knowing I.R.I parmetre, which represents roughness and user´s comfort.

2.1.3. Deterioration data collection

The data of the road images were collected with an artificial vision equipment with a camera and artificial light. This collection of deterioration data was done at night, not to interfere with traffic.

2.1.4. Deflection data collection

The falling weight deflectometer –normally used for surveying the bearing capacity of pavements- measured deflections. It uses many sensors (geophones). One is put below the loading plate (which measures the maximum deflection) and the others are placed keeping a distance of up to 2.5 m from the point of impact, according to the thickness and type of pavement. The weight in each point depended on the type of pavement: 7 tons for flexible pavements, and 7, 10 and 13 tons in hydraulic cement concrete.

Again, the data was collected at night not to disturb traffic.

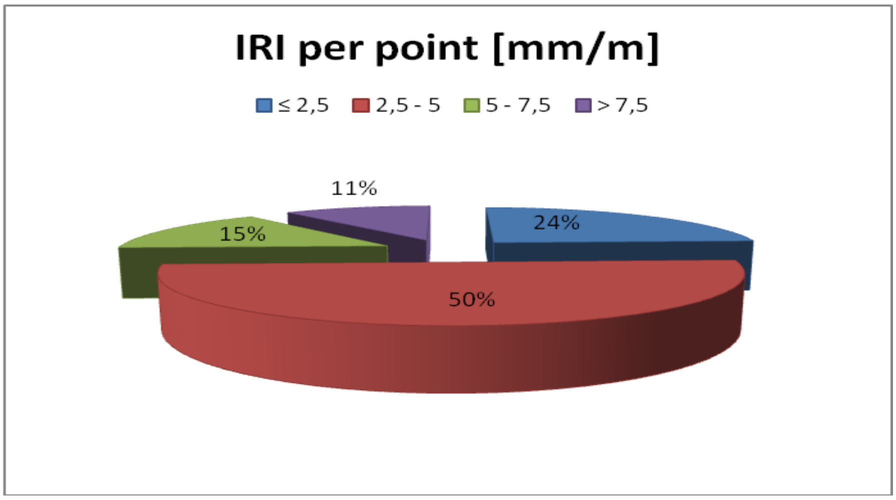
2.1.5. Skid resistance data collection

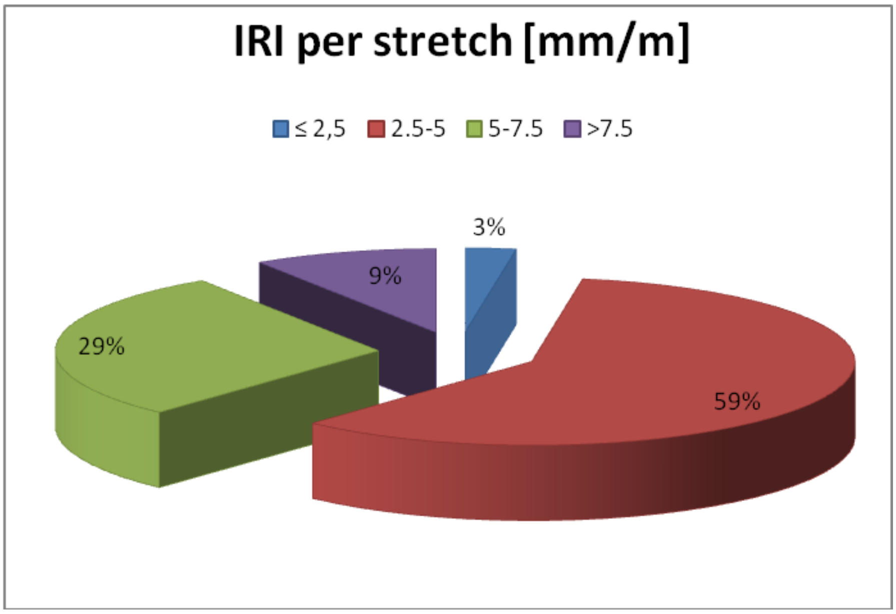
The skid resistance parameter stands for the level of grip of the tire to the pavement and it is related to road safety. This value is calculated through the conversion of the data obtained with GRIPTESTER equipment -which operates at an average speed of 50km/h- every time a longitudinal coefficient is first obtained. The data was collected with the use of a constant flow of water that kept the pavement humid. This allowed for the calculation of friction under the worst climatic conditions.

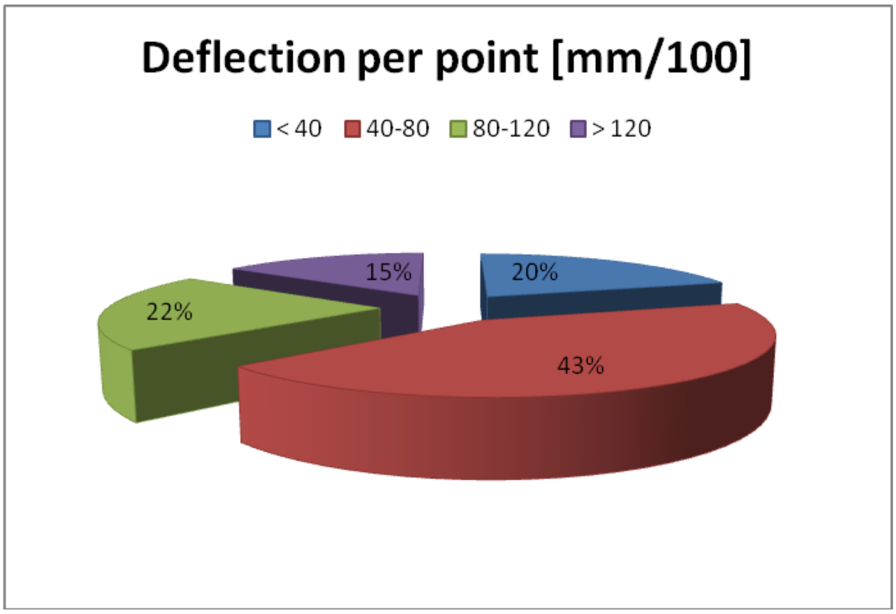
These data was also collected at night, not to interfere with traffic.

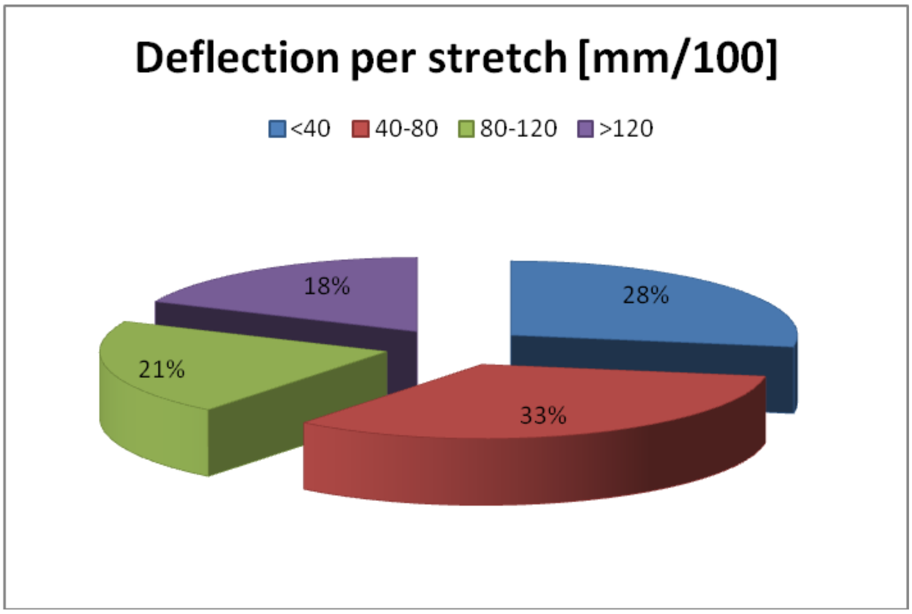
3. ANALYSIS OF THE REAL CONDITION OF THE ROADS

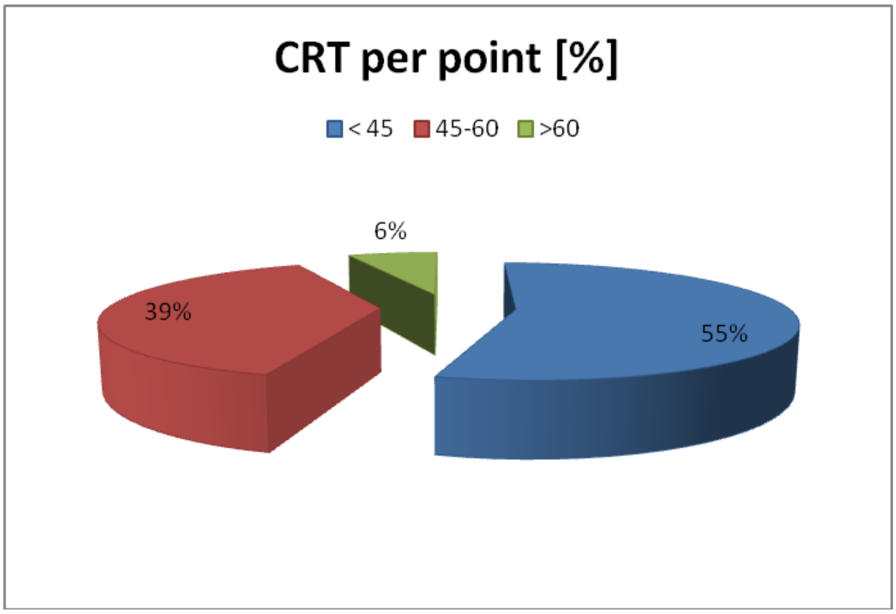
The first result of the works described above is the information related to real condition of the road. It is represented in percentage data of each point and representative data of each stretch once the road has been divided into homogeneous stretches.

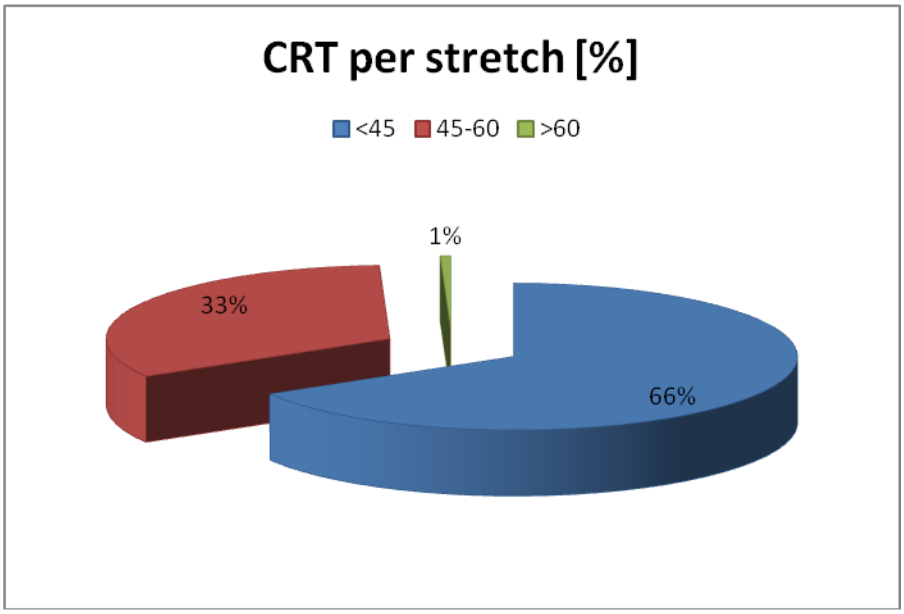


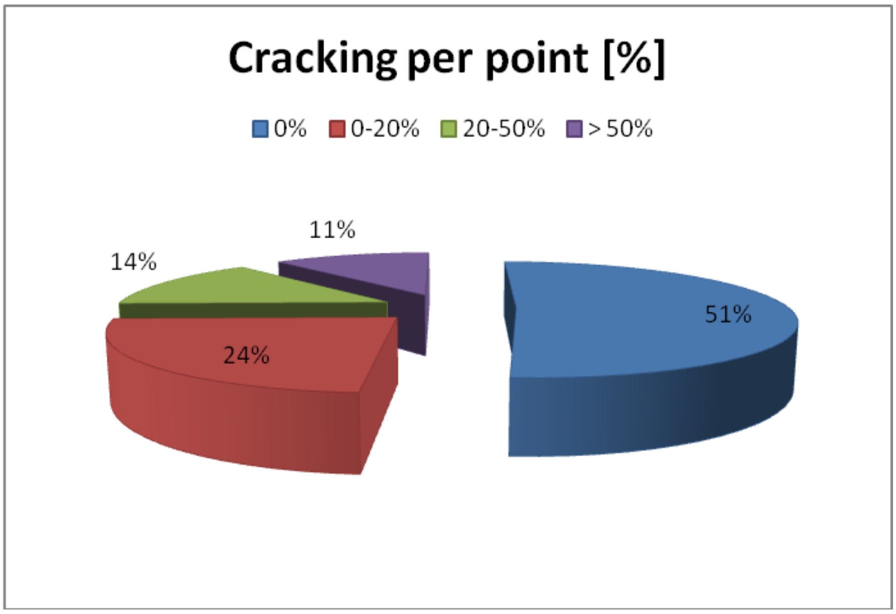

IRI per stretch [mm/m]
≤ 2,5
2.5-5
5-7.5
>7.5
3%
9%
29%
59%

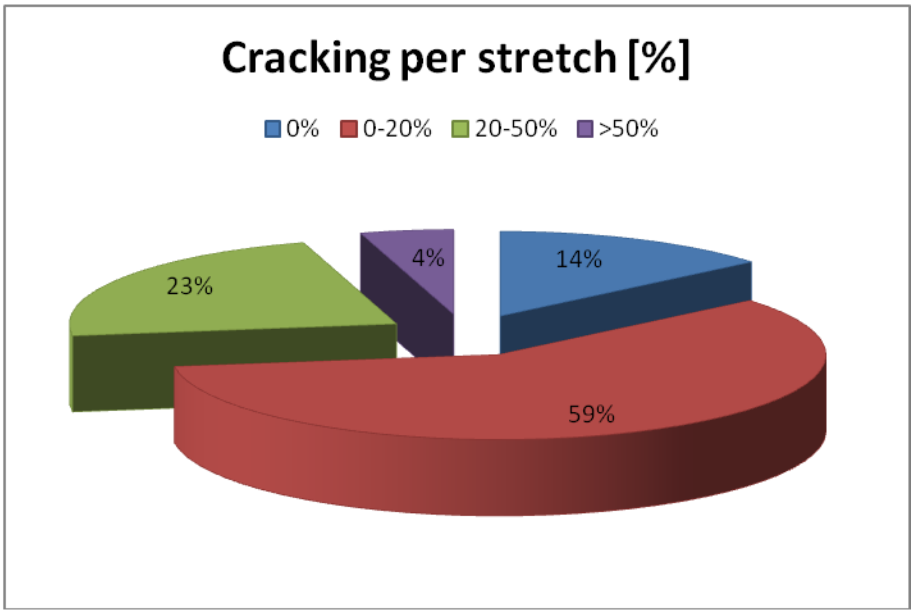

Deflection per point [mm/100]
< 40
40-80
80-120
> 120
15%
20%
22%
43%

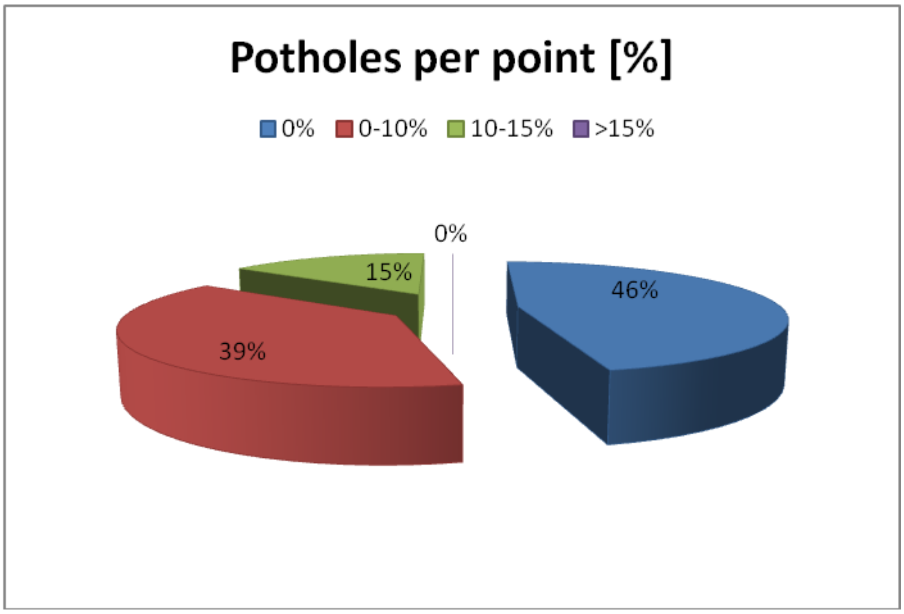

Deflection per stretch [mm/100]
<40
40-80
80-120
>120
18%
28%
21%
33%

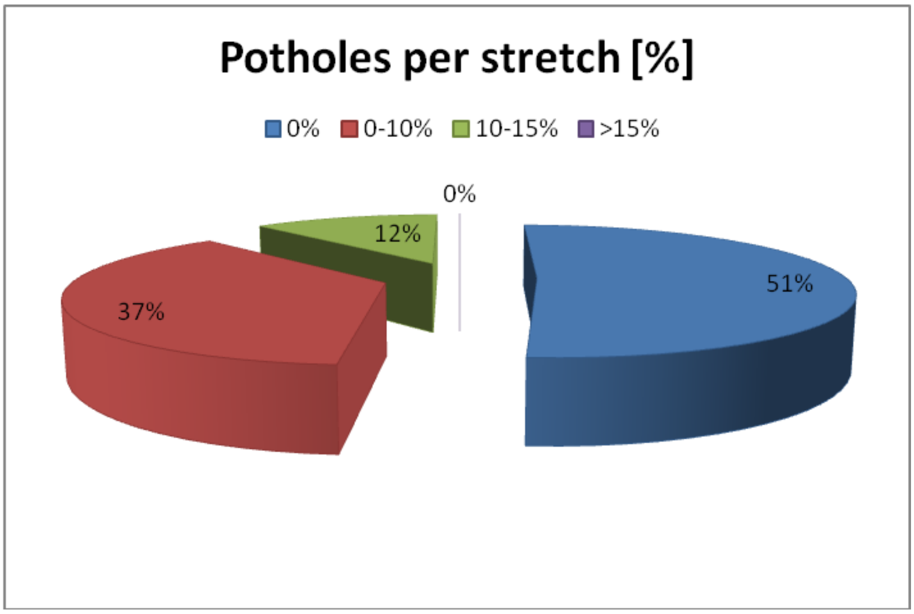

CRT per point [%]
< 45
45-60
>60
6%
39%
55%


CRT per stretch [%]
<45
45-60
>60
1%
33%
66%


Cracking per point [%]
0%
0-20%
20-50%
> 50%
11%
14%
24%
51%


Cracking per stretch [%]
0%
0-20%
20-50%
>50%
4%
14%
23%
59%


Potholes per point [%]
0%
0-10%
10-15%
>15%
0%
15%
46%
39%


Potholes per stretch [%]
0%
0-10%
10-15%
>15%
0%
12%
51%
37%

4. STUDY OF FUTURE WORKS WITH THE MANAGEMENT ROAD SYSTEM

Once the network had been divided into stretches, we did three studies to adapt technical results to economic possibilities.

To this end, we considered two different configurations in the thresholds of quality for the network, taking into account that quality can be improved with stricter thresholds when more works are carried out.

Flexible pavements		
Parameter	**Threshold**	
	A	**B**
IRI [mm/m]	4.0	3
Skid resistance [%]	50	60
Deflection [mm/100]	100	100
Cracking [%]	10	10
Potholes [%]	5	5

Pavements of hydraulic concrete cement		
Parameter	**Threshold**	
	A	**B**
IRI [mm/m]	4	3
Skid resistance [%]	40	60
Cracking [%]	5	5
Load transfer [%]	20	20
Residual Deflection [mm/100]	100	100
Load transfer [%]	20	20
Joints spalling [%]	5	5

The following table shows works considered for this study and the code used to represent each of them:

Work	Type of pavement	Code	Thickness
Routine Maintenance	Both	0	-
Pothole fixing	Flexible	1	10mm
Slurry	Flexible	3	4mm
Overlay	Flexible	6	10 mm
Reconstruction	Flexible	10	600 mm
Irrigation seal	Flexible	12	9 mm
Caulking	Flexible	2	-
Cement grouting	Hydraulic cement concrete	21	-
Crack sealing	Hydraulic cement concrete		-
Grinding	Hydraulic cement concrete	23	-
Partial fixing	Hydraulic cement concrete	24	10 mm
Reconstruction	Hydraulic cement concrete	20	600mm

The following is a description of the three studies:

4.1. STUDY 1

- Inner area –area of roads limited by Circuito Interior Road- with works during the first four years.
- Works done in 2010 in primary roads and arterial roads (slurry and pothole fixing) amounted to $59,941,000 mexican pesos
- Delay in these works:
    - Pothole fixing: 1 year
    - Slurry: 2 years
- Consideration of works in the Inner Area from 2014
- Works in the rest of stretches from 2014
- Quality Levels type A, from 2010 to 2013, more restrictive levels type “B”, from 2014

4.2. STUDY 2

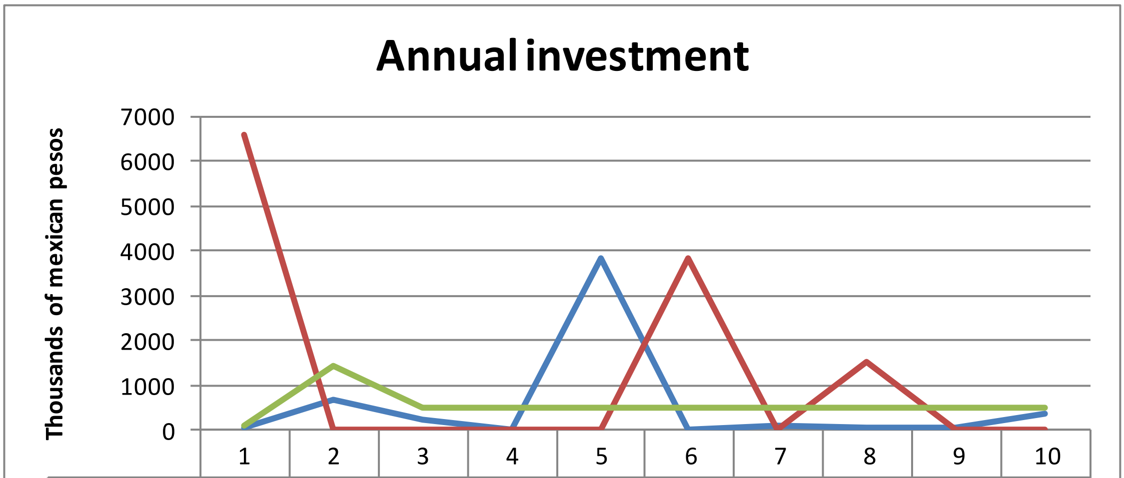
- All primary roads considered from the very first year.
- Period of study: ten years
- Short period of time for works
- No budget restriction
- Null investment in 2010
- Budget of 1,400 million Mexican pesos with no annual expenditure every time ideal values of the parameters have been reached
- Technical Solution from 2014 onward, including all works needed to maintain all roads considered in an ideal condition
- Restrictive quality levels type “B” from 2011 onward

4.3. STUDY 3

- Works done in 2010 with a cost of 60 million Mexican pesos
- With no delay in works in the Inner Area
- Works done up to that day and over the previous year
- With an annual budget of 1,400 million of Mexican pesos for 2011
- Restrictive quality levels from 2010
- With no budget limits
- Prorating technical solution from 2011

The studies show what maintenance works should be done. To maintain the network within the quality levels previously established certain conditions were set to DGPE needs: priority of intervention in certain areas, works done up to date, approximate budget and prorating of spendings. All this will guarantee the best solutions for the possibilities and the situation of the corresponding government.

The following graph shows the results obtained:



	1	2	3	4	5	6	7	8	9	10
Study 1	60	686	234	16	3808	0	91	45	40	362
Study 2	6586	0	0	0	0	3819	0	1491	1	0
Study 3	60	1400	474	474	474	474	474	474	474	474

These results will be analysed to come to the most appropriate solution for the management of the studied roads.

5. CONCLUSIONS

The conclusions we came to correspond to models of theoretical evolution. Necessarily, theoretical models must be contrasted with measures from period condition surveys with high-performance equipment. This is why this work must be the beginning of a periodic and systematic study.

Once the network has undergone through measurement, it is possible to observe the evolution of the parameters of all stretches in the main roads network and it is also possible to analyse this evolution. This evolution will show that there are parameters that evolve more quicky in some roads and more slowly in others.

Consequently, it is possible to decide what parameters and what roads need survey review more frequently -based on their quick evolution- and which surveys can be postponed, in the case of parameters with a slower evolution in some roads.

To conclude, all this will narrow down solutions and the economic result of the Management will improve. We will be able to achieve the ultimate goal of all the works here described.