Pavement Management In Atlantic Canada's National Parks

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Abstract

Roads in Atlantic Canada's National Parks cover an extremely wide scope of usage, climate, geography and range from local access roads to the Trans-Canada Highway. As such they service a wide range of traffic volumes and users. They have in common, however, postcard scenery, abundant wildlife and a desire by senior park managers to emphasize the "park experience" to the traveler.

Eighteen years ago, Parks Canada invested in a pavement management system to effectively manage this widespread system. This paper details the management system used to measure the performance of these roads, establishment of criteria for rehabilitation based on these inspections, and the performance of the different pavement classes over the last eighteen years. Based on the data, performance models have been used to develop a multi-year plans for the rehabilitation of these roads.

Eighteen years ago, the pavements were mainly in good condition, however, budget limitations since that time have often prevented timely interventions or required the use of less than optimum rehabilitation techniques.

The pavement management system has been used to identify potential resurfacing projects for 2005 and 2006, creation of 5-year operational plans and the evaluation of suitable strategies for the roadway maintenance and capital improvements

INTRODUCTION

Roads in Atlantic Canada's National Parks cover an extremely wide scope of usage, climate, and geography. These highways range from local access roads to the Trans-Canada Highway. As such they service a wide range of traffic volumes and users.

Parks Canada has the mandate to protect and present nationally significant examples of Canada's natural and cultural heritage, and to foster public understanding, appreciation and enjoyment in a manner that ensures the ecological and commemorative integrity of these parks for present and future generations. The agency receives 25 million person visits annually at some 180 parks, sites and canals throughout Canada. Included in their mandate are the operation and maintenance and repair of provincially numbered through highways that belong to Parks Canada (1).

This paper deals with approximately 400 kilometres of pavement located in Atlantic Canada. In order to maintain reliable, safe through-transit highways, a pavement management system was required to identify potential resurfacing projects. This paper details the pavement management system used to measure the performance of these roads and the establishment of criteria for rehabilitation based on the inspections and the performance of different pavement classes over the last fifteen years. Based on the data collected since 1987, performance models have been developed to create a recommended multi-year plan for road rehabilitation.

PARK CANADA'S PAVEMENT MANAGEMENT SYSTEM

In 1987, Parks Canada implemented a Pavement Management System for roads in Canadian National Parks. The system has been developed to meet Park Canada's special requirements such as:

- Park roads for the most part, do not have high traffic volumes (except for the Trans-Canada Highway).
- Park roads do not emphasize through traffic but instead tend to emphasize the "park experience" to the traveller.
- Park roads cover an extremely wide scope of usage, climate and geography.

The pavement management system is used to evaluate pavements at 3 distinct levels:

Network: At this level, a generalized model of pavement performance is developed which enables the assessment of various funding alternatives to meet present and future needs based on the entire road network.

Section: At this level, sections that are showing moderate to severe distress are identified for further study at the project level.

Project: A detailed engineering study is carried out on those sections listed in the section analysis above.

The first two levels are the subject of this paper.

The Pavement Management System (PMS) has been updated on a regular basis since 1987. The frequency of inspections is normally a three-year interval, but the frequency is also dependent upon the amount of rehabilitation performed between inspection years and available resources for performing the inspections.

Major roadways included in this paper (Figure 1) are:

- Cabot Trail (80.6 kms) in Cape Breton Highlands National Park
- Highway 114 (20.1 kms) in Fundy National Park
- Highways 430 and 431 (105.3 kms) in Gros Morne National Park
- Main Park Road (11.3 kms) in Kejimkujik National Park
- Highway 117 and Main Park Road ((38 kms) in Kouchibouguac National Park
- Gulf Shore Highway (24.5 kms) in Prince Edward Island National Park
- Trans-Canada Highway and Highway 301 (50.3 Kms) in Terra Nova National Park.

The remainder of the 400 kilometres of pavement included in this study were various secondary roads in the National Parks and access roads to National Historic Sites. As such the roads covered in this study highlight the variableness of the geography and environmental conditions in a climate characterized by ocean coastal influences.

The evaluation consists of a visual inspection of the roadway surface by a panel of experienced highway engineers. The panel rates cracking, bleeding, ravelling, rutting, distortions and rippling of the asphalt surface in terms of the severity and the extent of the distress (Table 1) within the rating section.

The severity of the distress is rated from 0 (no distress) to 4 (very severe distress) and the extent is rated from 0 (no distress) to 4 (distress throughout).

The ride-score or Ride Comfort Index (RCI) (2) is evaluated on the scale of 0 to 10 by the rating panel. A ride of 8 is typical of a new pavement in Canada and few sections have ride-scores of less than 3. They are usually reverted to gravel if the ride becomes too severe.

The Pavement Condition Index (PCI) is a single index which combines all the distress extent, and severity factors with ride score (3). This index is particularly useful in the network phase of the project management system as it provides engineers and managers with a numerical value for pavement condition that reflects the structural integrity and operational surface condition of pavements. The first factor in determining the PCI is the calculation of the Distress Manifestation Index (DMI).

$$DMI = \sum_{i=1}^{n} w_i (s_i + d_i)$$

Where: DMI = Distress Manifestation Index. DMI is an overall characteristic describing pavement surface condition in terms of distress manifestations.

w_i = Weighting value representing the relative weight of each distress manifestation. More serious distresses are given larger weighting values (w_i). (Table 2)

s_i = Severity of distress manifestations expressed on a scale from 0 - 4.

d_i = extent of distress manifestations expressed on a scale from 0 - 4.

n = the total number of distress types

The PCI is an overall rating of the pavement section on the scale of 0 to 100. The higher the PCI, the better the condition of the pavement. The PCI is calculated using the following formula:

$$PCI = (100 * \sqrt{0.1 * RCI} * (205 - \frac{DMI}{205}) * 0.924) + 8.856$$

PRESENT SYSTEM ANALYSIS

The objective of the Present System Analysis is to identify potential rehabilitation sections that will require further study in the Project phase of the Pavement Management System. In general, these sections will need work in the short term (1 to 2 years).

Not all distresses in themselves are justification for reconstruction or rehabilitation. Projects are normally undertaken when the pavement condition meets one of the following criteria:

- The ride-score falls below the level of public acceptance. This is normally at or below a ride-score of 4.5.
- The condition of the road is such that it poses a safety hazard to the motoring public. This normally occurs with bleeding or rutting distresses.

- The condition of the road is such that major work is required to prevent its rapid deterioration. Single and/or alligator cracking in the wheel paths or pavement ravelling are typical distresses of this failure mode.

In some cases rehabilitation (thin overlays or chipseals) may be more cost effective than extensive routine maintenance.

In other cases, the severity of the distress by itself may dictate that rehabilitation is required. However, in most instances, it is the combination of the severity of the distress and the extent of the distress that is the controlling factor. A parameter that captures the seriousness of the distress, the extent of the distress and the severity of the distress is the distress factor that is defined as:

$$Distress\_Factor = w_i * (s_i + d_i)$$

Table 3 contains the criteria used in the following analysis, which evaluated the major distresses in terms of both severity and the distress factor. The distresses are grouped into three areas; Safety (bleeding and rutting), Asset Preservation (ravelling and wheel track cracking) and Rehabilitation Efficiency (panel recommendation for rehabilitation).

It should be noted that although all identified sections are potential candidate projects, a priority for their rehabilitation must be established, as priorities for each individual section are a function of traffic volumes, use, maintenance and construction costs as well as available budgets.

Table 4 reflects the condition of through highways in the Atlantic National Parks in 2004.

In general terms, a highway with a PCI of 73 or greater is in very good condition, a highway with a PCI of 68 to 73 is in good condition, a highway with a PCI of 60 to 68 is in fair condition, a highway with a PCI between 55 and 60 is in poor condition requiring an overlay/milling-overlay and a highway with PCI less than 55 is in very poor condition and requires extensive repairs before rehabilitation.

PAVEMENT MAINTENANCE AND REPAIR STRATEGIES

The basic concept of pavement management is that maintenance and rehabilitation resources should be spent in the most efficient way possible. Resources should not be spent on pavements that are beyond repair or on pavements that are in very good condition. However minor deficiencies, if not corrected at an early stage can develop quickly into major structural deficiencies. When this occurs, the costs of rehabilitation can escalate dramatically in a short period of time.

There are 5 broad classes of maintenance strategies:

1. Routine Maintenance: This strategy is applicable to pavements in very good condition (PCI > 73). Routine maintenance usually includes local patching of potholes or distortions and crack sealing.

2. Preventative Maintenance: This is a more extensive activity designed to arrest deterioration before it becomes a more serious problem. This normally applies to pavements that are in good condition (PCI between 68 and 73) with a satisfactory ride-score (greater or equal to 5.5). The majority of pavements in this class have severe ravelling distresses, severe bleeding or minor alligator cracking or in some instances, extensive fine transverse and longitudinal cracking. Chip seals, micro-surfacing, major crack sealing and thin overlays are typical of major preventative maintenance activities. Local maintenance forces would not normally perform these activities and as such rehabilitation budgets must be developed in consequence.

3. Deferred Action: These sections are beyond the point where preventative maintenance would be effective but have not yet deteriorated to the point where rehabilitation is required. Typically, pavements that are in fair condition (PCI between 60 and 68) are in this category. Routine maintenance consists of patching potholes, distortions, ruts, and wheel track cracking as required.

4. Rehabilitation: These pavements require thin to medium overlays, milling and overlay, or hot and cold in-place recycling. Pavements in this category are in poor condition (PCI between 55 and 60) with ride-scores of 5 or lower. The critical number for rehabilitation varies from 55 to 63 depending on the class of road and available funding.

5. Major Rehabilitation or Reconstruction: Pavements in this category (PCI < 55) are in very poor condition and have deteriorated to the point where more work than is envisaged in the rehabilitation class above is required. Complete removal of the existing pavement is necessary and base, subbase and subgrade repairs or thick overlays (>150 mm) are required.

For most highway systems, the most cost effective strategy is to allocate resources to the strategies in the order given below:

First Priority:	Routine Maintenance
Second Priority:	Preventative Maintenance
Third Priority:	Rehabilitation
Fourth Priority:	Major Rehabilitation

In determining the appropriate strategy within the above PCI ranges, consideration must be given to the type of distress that has caused the drop in the PCI. Surface distresses such as severe ravelling indicate a need for preventative maintenance while structural distresses such as rutting or wheel track cracking cannot be corrected with preventative maintenance strategies.

Recommendations for specific rehabilitation of a particular highway section are based on the recommendations of the field staff at the time of the survey and the PCI rating. Pavements identified by the rating panel as requiring rehabilitation should be subjected to a thorough engineering review to determine the most appropriate type of rehabilitation. However, the overall condition of the pavement (PCI) and field recommendations can be used as a guideline to determine an initial strategy.

NETWORK ANALYSIS

Network analysis is based on the use of the pavement data for short-term pavement management. A longer-term analysis is required for long term planning strategies and the preparation of Multi-Year Operational Plans. The network analysis uses the predicted overall condition rating (PCI) for determining the required funding level.

The key to predicting future requirements is a suitable performance model. Figure 2 contains the data from all Main Park Highways in Atlantic Canada. While the performance curve may be in error for an individual section, overall predictions should give reasonable results on a network level, as individual errors will cancel each other out.

From the figure, it is difficult to ascertain if the highways in the region all have the same performance or if an individual highway has a different life expectancy. As it is difficult to evaluate different performance visually, the sections were compared using the statistical t-test analyses where the performance for each year of each of the main pavements was compared to an overall performance curve. With the odd exception in a given year on a given highway, the analysis indicated that the performance of each individual highway was the same as the overall curve. The analysis indicated that there was not a statistical difference in the performance of all the main highways in Atlantic Canada Parks. The practical implication is that the same overall performance curve can be used for all main highways in Atlantic Canada.

The pavement performance equation based on the main park highways in Atlantic Canada Parks is:

$$\mathbf{PCI = -0.0005\ Age^3 + 0.0522\ Age^2 - 2.2986\ Age + 81.488 \qquad r^2 = 0.93}$$

Of interest is the performance of main roads in Western Canadian National Parks (4), which is also plotted on Figure 2. There is very little difference in the performance of Atlantic and Western Canada Park pavements for the first 15 years, co-incidentally the age at which they end their service lives (PCI (60 to

63)). Beyond this point however, Western Canadian pavements show better performance than Atlantic pavements. This could be due to different maintenance procedures, different subgrades and different climates due to the difference between a prairie climate and the ocean coastal influence with its many more freeze-thaw cycles in Atlantic Canada. Typically subgrades in western Canadian Parks are granular materials whereas many Atlantic subgrades are frost-susceptible.

Table 5 contains the costs based for various intervention levels. In terms of overall costs, an intervention level of 63 is the most cost efficient in terms of both Capital Costs and total costs (capital, maintenance and user costs) (5). However, many pavements are already below this threshold and will incur increased costs. Table 5 is based on recent rehabilitation work done on Atlantic Park Pavements. Costs are significantly higher for pavements that have PCIs below 55 as rehabilitation of these pavements generally requires extensive subgrade excavation and backfill. The costs are based on a per kilometre basis and although they should be representative for the entire regional network, they may be significantly in error on individual sections. They are Class D estimates overall but are less accurate for an individual section.

Table 6 allows for three funding scenarios, as there is a significant backlog of projects. The scenarios indicate funding requirements to clear the backlog in 1,3, and 5 years. The shorter the period used, the more advantageous as early rehabilitation reduces both maintenance and user costs.

Clearing the backlog in one year is unrealistic, and the three-year scenario is doubtful in terms of funding, so the five-year scenario is the most probable.

WHAT-IF SCENARIOS

Ideally, Parks Canada should obtain the full funding required for its rehabilitation program. This section considers the effects of no funding and/or partial funding of the rehabilitation program. It should be noted that the analysis of this section of the report applies only to the main roads in Atlantic Canada's National Parks. (i.e. Category 1 to 3 (see Table 4 for definition of Categories) highways only).

Figures 3 and 4 indicate the PCI for various levels of annual rehabilitation investments.

Figure 3 also shows the overall condition of the Atlantic Parks Canada main road pavement network since 1987. The average network condition has decreased from 68 in 1987 to 57 in 2004. The magnitude of the decrease is significant. The overall average of the system is below the recommended level of service (PCI =63) for individual sections. If there is no rehabilitation work in the next five years the overall PCI will decrease to 50.

Figure 3 also indicates the PCI for various levels of annual rehabilitation investments. Using interpolation of the data in Figure 3, an investment of $5 million per year over the next five years is needed just to hold the system at its present substandard condition. An annual investment of $10 million is required just to bring the system up to an average PCI of 63 (mid-range of fair) over the next five years. This, however, will still leave a backlog of deficient pavements of 30%.

Figure 4 provides another view of funding requirements for Atlantic National Park pavements. It indicates the number of kilometers of pavements that are below the PCI level of 63. Currently over 58% of the pavements have a PCI less than 63. Without further funding the number of deficient kilometers will rise steadily over the next five years and the percentage of deficient sections would rise to 80%. The figures indicate that an annual funding level of $5 million is required just to keep the system at its current level. With an annual investment of $10 million the backlog will be about 30% of roads in poor or very poor condition.

SUMMARY AND CONCLUSIONS

This paper has dealt with the pavement management of some 405 kilometres of pavement in the Atlantic Region that were evaluated in 2004.

In general terms, at present, only 30% of Atlantic Park Highways are in good or very good condition. Forty-five percent are in poor or very poor condition and need extensive repairs before rehabilitation.

The pavement rehabilitation program for Atlantic Parks has been under-funded for the past decade with the result that a road network that was in good shape in 1987 has fallen to road network that on average is in poor condition, and without increased funding will be a network that is in very poor condition within the next 5 years.

Parks Canada requires annual funding to restore the pavements on major highways to acceptable standards. The intent of a pavement management system is to allow the agency, the flexibility to prioritise their current yearly expenditures to obtain the maximum benefit with limited available funds.

An annual investment of over $5 million over the next 5 years are required just to maintain the main highways at the present network condition level. Investments in the magnitude of $170 million over the next five years are required for the main highway network to bring the pavements to the point where no section is in poor or very poor condition. This figure increases to $190 million when the local roads are taken into consideration.

An annual funding level of $10 million is required to bring the network back to mid-range of the fair condition category (PCI = 63 which was the condition of the network in 1997/98). This more realistic scenario recognizes that there will be a backlog of poor and very poor pavements of about 30 %.

The prediction models for highways were employed to develop scenarios to estimate the amount of deterioration of various segments of the pavement system. These 'what-if' scenarios allow for an efficient way to maintain the pavement network at an optimum service level condition, and can be used as an objective tool to justify additional funding.

The Pavement Management System has been used to prioritise pavement rehabilitations. The process of obtaining funds for road rehabilitation projects is a complex one based on a variety of factors such as timing, context and competing issues. The pavement management has been a useful tool in attempts to obtain funding, and although not always successful in obtaining sufficient funding it has been used to obtain ad-hoc funding for significant sections of Park Canada pavement inventory. It also has been used as an asset inventory database and as an effective mechanism for determining pavement life cycles and rehabilitation strategies.

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Table 1 Distress severity and extent rating values

Severity	Extent	Value
	None	0
Very Slight	Few (<10%)	0.5
Slight	Intermittent (<20%)	1
Moderate	Frequent (<50%)	2
Severe	Extensive (<80%)	3
Very Severe	Throughout (>80%)	4

Table 2 - Distress weighting values

Distress	Weighting Value
Ravelling	3
Bleeding	0.5
Rippling	1
Rutting	3
Distortions	3
Longitudinal Wheel Track - Single	1
Longitudinal Wheel Track Alligator	3
Centreline Single	0.5
Centreline Alligator	2
Edge Single	0.5
Edge Alligator	1.5
Transverse Single	1
Transverse Alligator	3
Long Meander	1
Block	0.5

Table 3 Distress Criteria Used to Identify Potential Sections Requiring Rehabilitation

	Section Requires Immediate Attention		Section Shows Marginal Distress
Ridescore	<=4.5		<5.0
	Severity	**Distress Factor**	**Distress Factor**
	Safety Concerns		
Flushing	>=3.0	>2.5	>2.0
Rutting	>=3.0	>15.0	=15
	Asset Preservation		
Ravelling	>=3.0	>15.0	=15
Wheel Track Crack Single	>=3.0		>=15
Wheel Track Crack Alligator	>=3.0	>=15.0	
Rehabilitation Efficiency			
Field recommendation for chip seal, micro-surfacing or overlay			

Table 4 Summary of the Condition of Highway Sections Atlantic Canada Parks in 2004.

	Category	Total	1	2	3	4-6
PCI > 73	Very Good	17.6%	13.5%	20.6%	0.0%	20.1%
68 < PCI < 73	Good	11.9%	22.3%	9.2%	15.8%	12.1%
60 < PCI < 68	Fair	26.1%	64.1%	16.4%	13.9%	38.7%
55 < PCI < 60	Poor	9.1%	0.0%	11.8%	6.9%	7.4%
PCI < 55	Very Poor	35.3%	0.0%	42.0%	63.4%	21.7%
Km Surveyed		405.4	42.1	230.6	41.8	90.9

Category 1 road is the Trans-Canada Highway
Category 2 roads are through highways that are connected to provincial roads.
Category 3 roads are special attraction roads (e.g. PEI Gulf Shore Highway)
Category 4 roads are campground and information center roads.
Category 5 roads are roads to private operations (e.g. ski hills, cottages).
Category 6 roads are service roads. Category 4 to 6 roads are analyzed as a single group in this report.

Table 5 Costs for Rehabilitation Strategies

PCI Value	Cost/km	PCI Value	Cost/km
Category 1		**Category 3**	
60 < PCI < 63	$ 150,000	60 < PCI < 63	$ 125,000
55 < PCI < 60	$ 250,000	55 < PCI < 60	$ 200,000
PCI < 55	$ 1,200,000	PCI < 55	$ 1,200,000
Category 2		**Category 4-6**	
60 < PCI < 63	$ 125,000	60 < PCI < 63	$ 100,000
55 < PCI < 60	$ 200,000	55 < PCI < 60	$ 175,000
PCI < 55	$ 1,200,000	PCI < 55	$ 500,000

Table 6 Summary of 5-Year Funding Levels

	Categories 1 to 3 – Through Roads				
	2005/06	2006/07	2007/08	2008/09	2009/10
1 Year Catch-up	$158,706,000	$4,900,000	$2,427,500	$942,500	$1,415,000
3 Year Catch-up	$55,344,500	$55,344,500	$55,344,500	$942,500	$1,415,000
5 Year Catch-up	$33,678,200	$33,678,200	$33,678,200	$33,678,200	$33,678,200
Five Year Total					$168,391,000

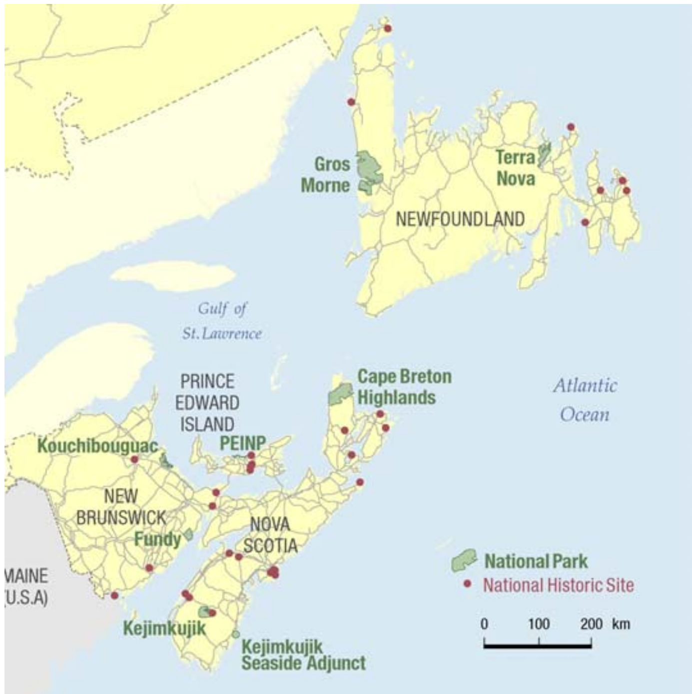

Figure 1 National Parks in Atlantic Canada

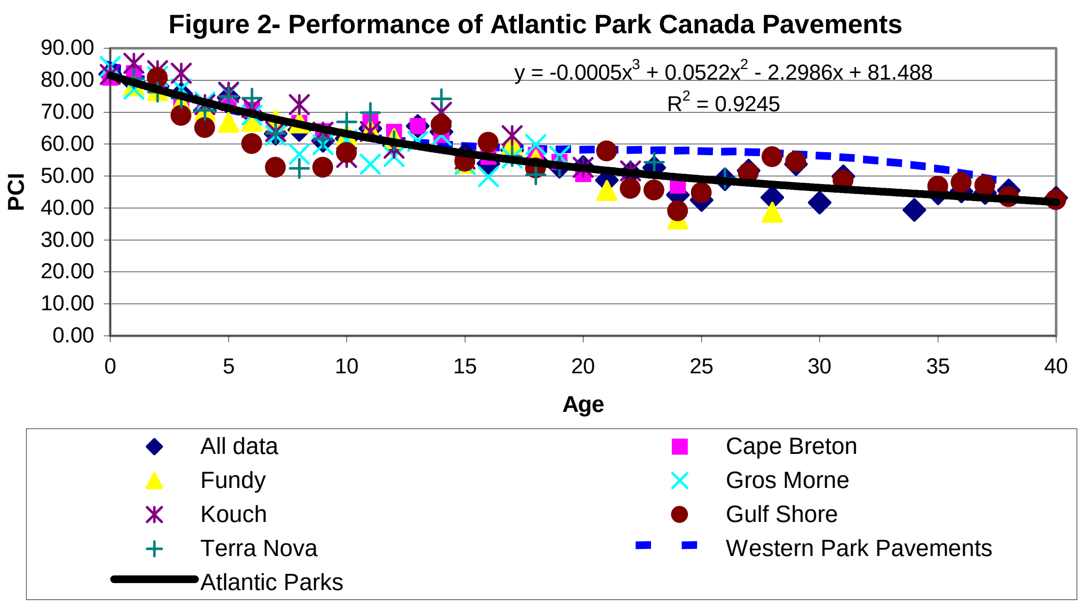

Figure 3 Effect of Funding Level on PCI

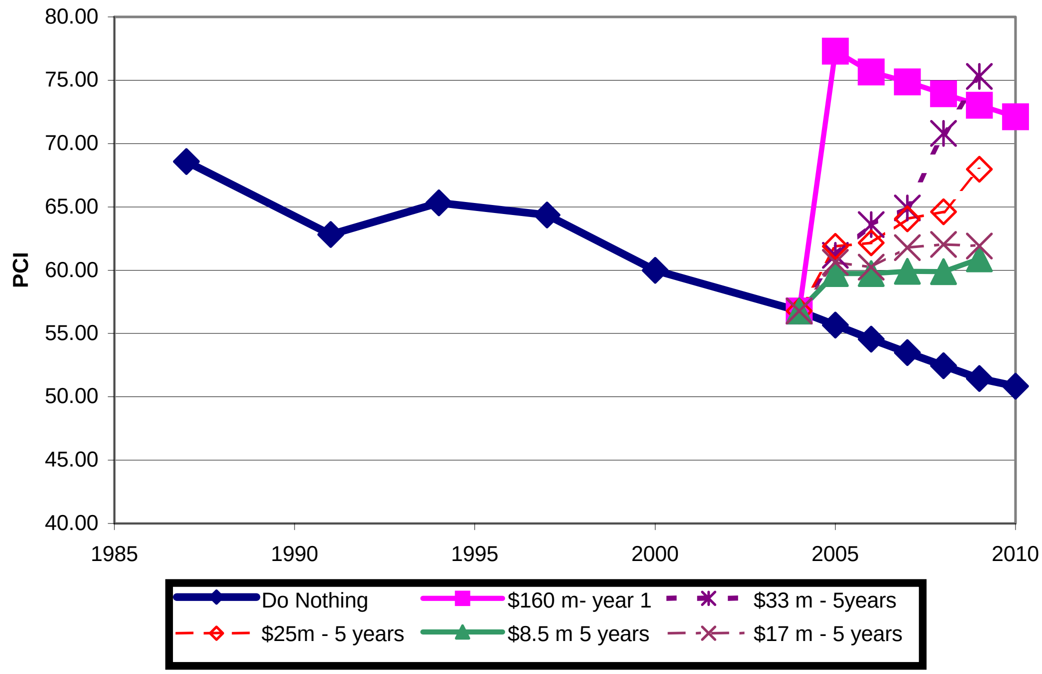

Figure 4 Percentage of Pavements with PCI <63