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Pilot Implementation of Pavement Management Systems (PMS) for New Jersey Counties and Municipalities

FINAL REPORT
April 2006

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16. Abstract

A pilot study was performed to demonstrate to local government agencies in New Jersey the potential benefits of implementing PMS. In this study, a base PMS that can be used by any local government agency in New Jersey was developed. This base PMS was implemented for six local government agencies in New Jersey, representing different conditions of New Jersey local government agencies (county versus municipality, urban versus rural and large versus small).

As a part of this pilot implementation, limited performance prediction models and decision trees were developed. In addition, budget scenario analyses were performed using the base PMS to demonstrate some of the potential benefits of adopting a PMS. The pilot implementation demonstrated that a single PMS software can accommodate the basic needs of multiple NJ local government agencies and can be adopted with very limited effort. It also illustrated and documented the benefits of adopting a PMS.

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INTRODUCTION

The main goal of this research project was to implement, on a pilot basis, a base Pavement Management System (PMS) that could be used by local government agencies (counties and municipalities) in New Jersey, and to evaluate the success of this implementation. Six local government agencies in New Jersey were selected for the pilot implementation. These six agencies represents different conditions of New Jersey local government agencies (county versus municipality, urban versus rural and large versus small). The following are the local government agencies that were included in the pilot implementation:

1. Hamilton Township
2. Jersey City
3. Ocean County
4. Salem County
5. Union County
6. City of Vineland

Several tasks were performed in this project. These tasks can be grouped in two groups, technology transfer tasks and implementation tasks. The technology transfer tasks were performed to educate the local government engineers about the PMS concepts and anticipated benefits and achieved by conducting workshops on PMS concepts, requirements and benefits, as well as a state-wide workshop in which the results of the six implementations were presented. In addition, future steps and options for the six agencies that participated in the pilot implementation, as well as for others were discussed in the state-wide workshop. The implementation tasks were repeated for each of the six organizations considered in the implementation and included identifying the needs of the selected agencies; developing a base PMS; data collection; pilot implementation and presenting results to the agencies and collecting their feedback.

This report presents the process for implementing the base PMS for each agency, including the data collection process and the development of the Stantec's Highway Pavement Management Application (HPMA) database. The report also details the analysis models and parameters that were developed and presents the results of the PMS-generated budget analyses. In addition, future steps and options for the six agencies that participated in the pilot implementation, as well as for others are discussed in the conclusions and recommendations section of this report.

HAMILTON TOWNSHIP

Database Development

This section provides a description of the database developed for Hamilton Township for PMS implementation. This section also summarizes the condition of the network.

Data Sources

Hamilton Township HPMA database was developed from various sources. The street names and lengths were extracted from an official road map of the Township of Hamilton dated August 2003. The attribute and condition data used in the HPMA optimization analysis were gathered from two main sources, which are the field data collected by Stantec and the historic PMS data obtained from the Township.

Field Data Collection

Stantec collected pavement condition data from approximately 340 miles of streets from approximately 1,100-section within Hamilton Township. This data was collected using Stantec's Road Tester (RT) survey vehicle, which can simultaneously collect pavement condition, GPS, and Video logging (digital imagery) data.

The data collected included the following:

- Surface roughness
- Surface condition in terms of distress severities and extents
- Rut depths
- Longitudinal profiles
- Digital video images of right-of-way attributes
- GPS data and coordinates for location referencing

The roughness data was analyzed in terms of the International Roughness Index (IRI). IRI is the roughness index obtained from the longitudinal profile of the road, and is used to interpret the roughness/smoothness of each road segment. IRI is then used to calculate NJDOT Ride Quality Index (RQI). The RQI is on a decreasing scale with a maximum value of 5.0, which represent the smoothest possible pavement condition.

Distress data was collected using an automated technique through the use of line scan camera system mounted on the RT. Continuous pavement images of the entire 12-foot lane are collected at 25-foot intervals. These images were then processed in the office, where the imaging program developed by International Cybernetics Corporation (ICC) is used to enter distress type, severity, and extent for all identified distresses and to process the data. Figure 1 shows a sample of the images collected from the Hamilton Township and used for distress data identification. The distress data was then used to calculate NJDOT Surface Distress Index

(SDI). Similar to RQI, the SDI is on a decreasing scale with a maximum value of 5.0, which represent distress-free surface condition.

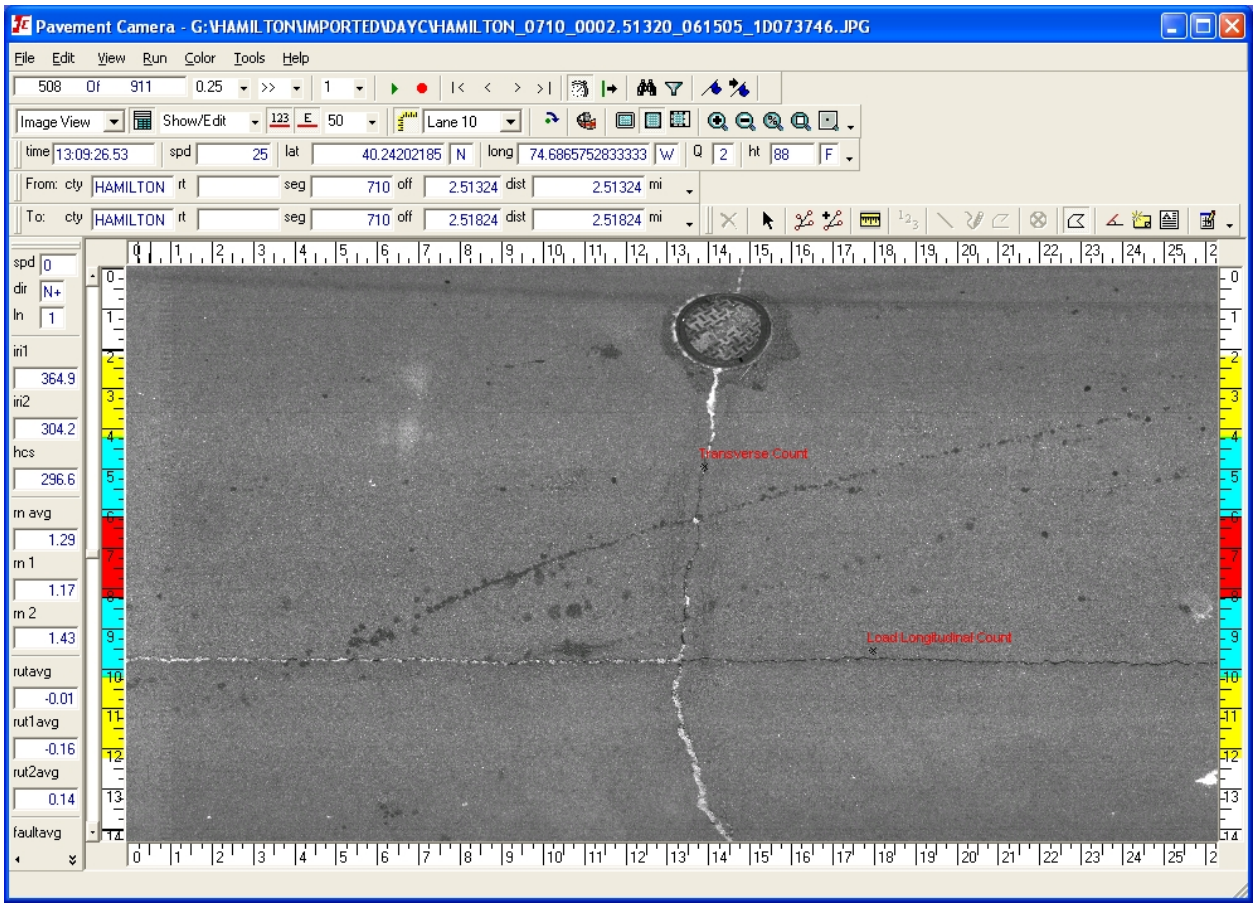

Figure 1: Line Scan Camera Image Processing

Historic PMS Data

Historic data, for approximately 67-miles of streets in Hamilton Township, was provided by the Township. This data included:

- Street names and descriptions
- Pavement condition data from the year 2004
- Geometric data such as pavement width
- Construction dates and pavement layers
- Curb data

The street names were cross-referenced with the names extracted from the map and the attribute data for the matching streets were loaded to the HPMA database.

The pavement condition data, provided by the Township in the database, did not match NJDOT standard distress data collection protocol. Therefore, it was not possible to convert the detail distress data to be loaded in to HPMA database. However, the overall pavement condition rating was converted on a scale similar to the SDI scale (between 0.0 and 5.0) and loaded into the HPMA database distress table for the Year 2004.

Network Condition

Hamilton Township road network condition was evaluated in terms of RQI, SDI, and the NJDOT overall Final Pavement Rating (FPR), which is a function of the RQI and SDI on a scale from 0.0 to 5.0, where 5.0 is the best possible pavement condition. Figures 2 through 4 show the condition of the network in terms of RQI, SDI, and FPR, respectively. In the figure, the condition is shown in categories: Poor (0.0 – 2.0), Fair (2.0 – 3.0), Good (3.0 – 4.0), and Excellent (4.0 – 5.0).

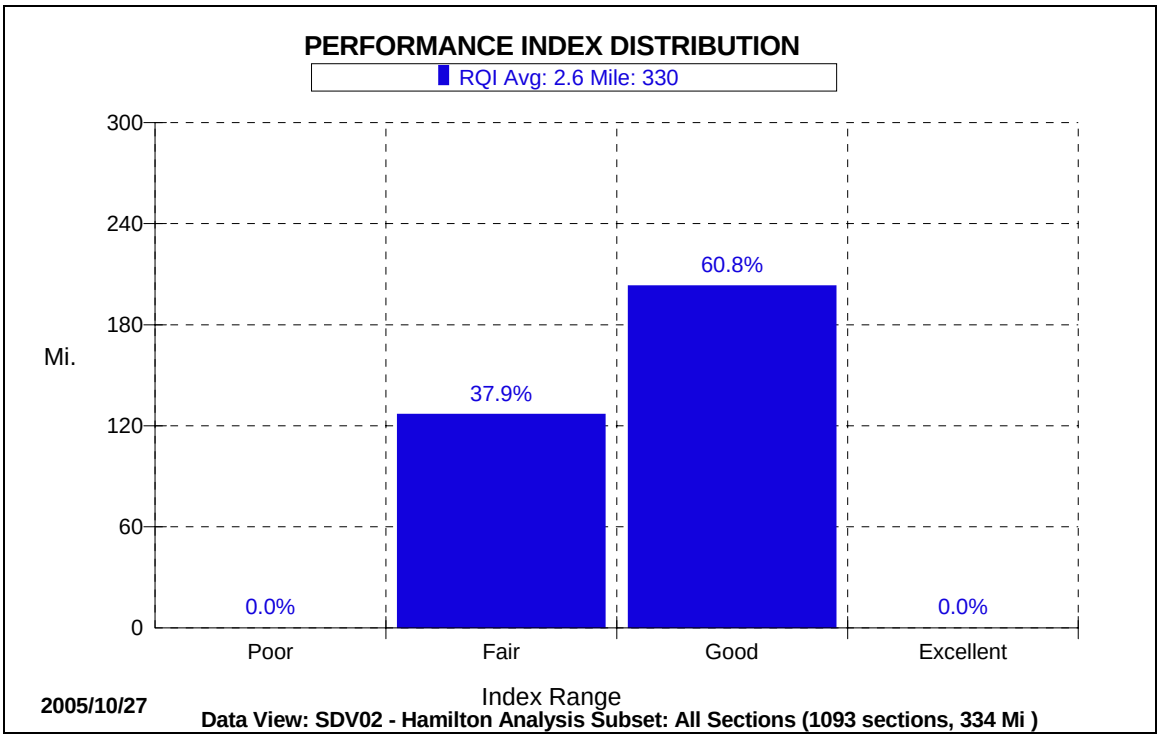

Figure 2: Hamilton Township Network Condition in Terms of RQI

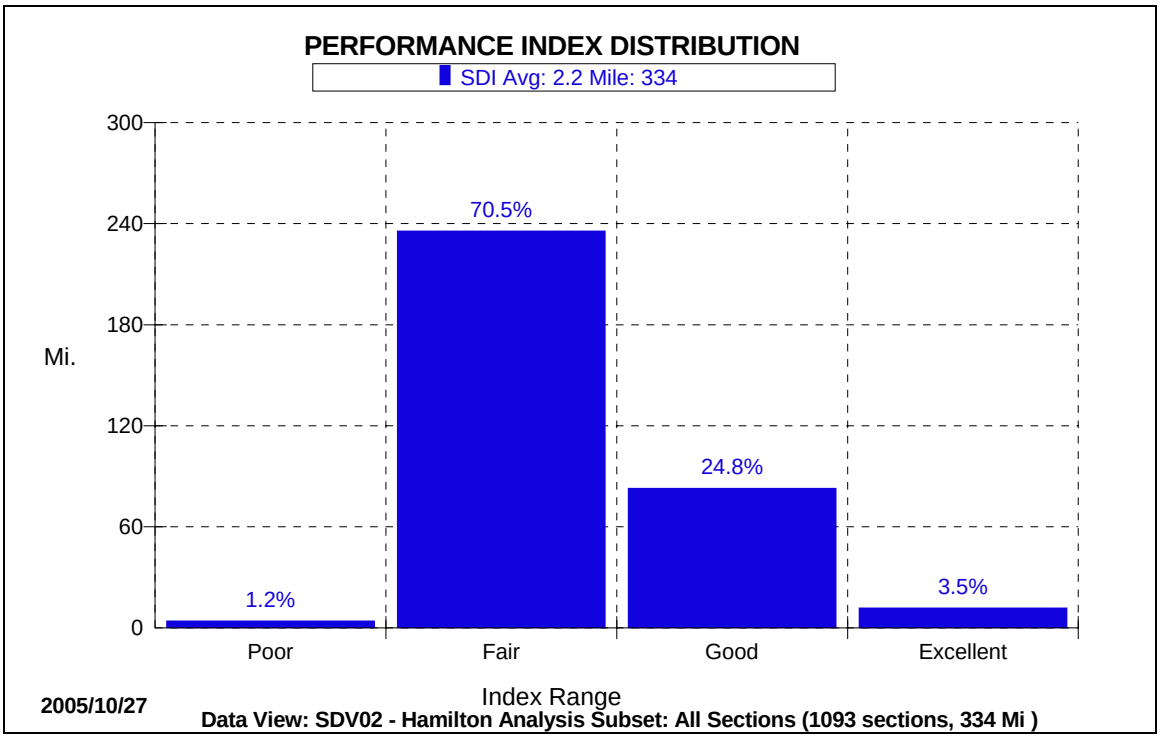

Figure 3: Hamilton Township Network Condition in Terms of SDI

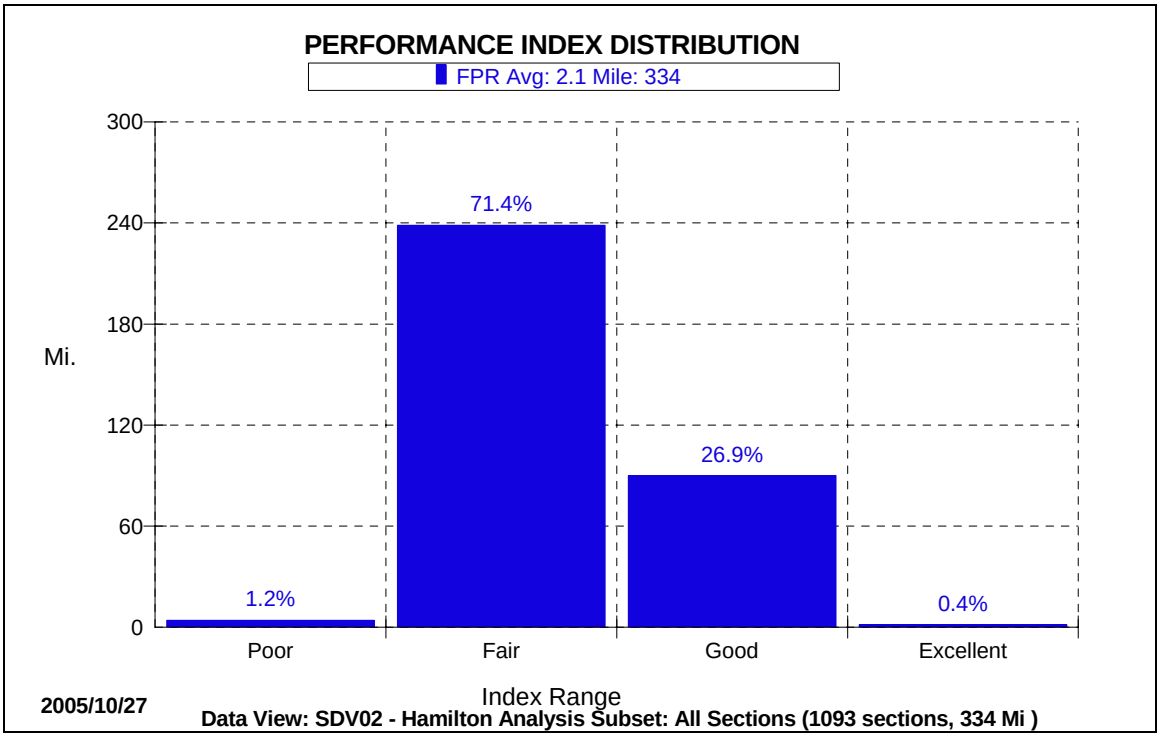

Figure 4: Hamilton Township Network Condition in Terms of FPR

Analysis Models

In this section, the analysis models used for the optimization analysis are presented. These models include the decision trees and the performance prediction models.

Decision Trees

A decision tree was developed for flexible pavements and used for the analysis. This decision tree is a similar to the decision tree used by NJDOT for pavement analysis at the county level.

Flexible Pavements: FPR < 1.5
- Y: Reconstruction
- N: 1.5 ≤ FPR ≤ 3.5
  - Y: SDI or RQI ≤2.0
    - Y: M4O4
    - N: M2O2
  - N: Crack seal/fill

Where,

FPR	=	Final Pavement Rating
SDI	=	Surface Distress Index
RQI	=	Ride Quality Index
M2O2	=	Mill 2”, Overlay 2”
M4O4	=	Mill 4”, Overlay 4”

Performance Prediction Models

The NJDOT prediction models were customized to reflect the expected service life of pavements based on discussions with the local agencies engineers and our own experiences. Figures 5 through 7 present the prediction models for pavement performance for the RQI, SDI, and FPR for all rehabilitation activity listed within the decision trees, respectively.

It should be noted that the performance models shown in the figures are based on the performance models used by NJDOT HPMA used for the Interstate and state routes. However, these models were revised to extend the service life the pavements by 2 to 3 years, such that it would better reflect the conditions of local roads, within the local agencies.

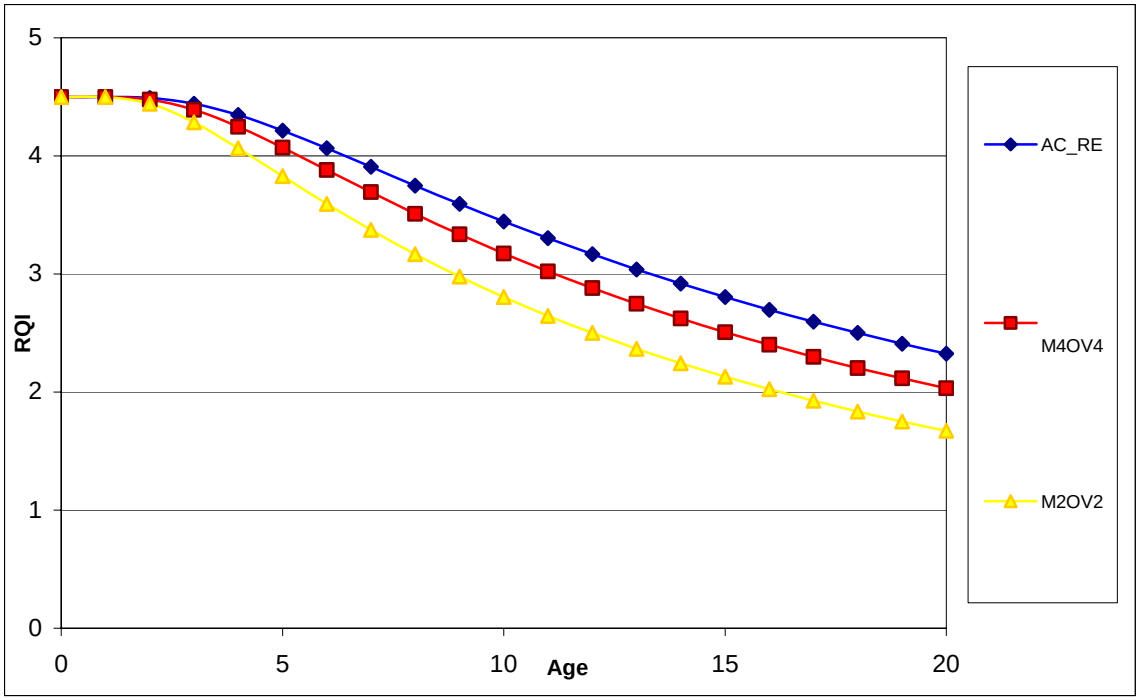

Figure 5: Performance RQI Model for AC Rehabilitation Activities

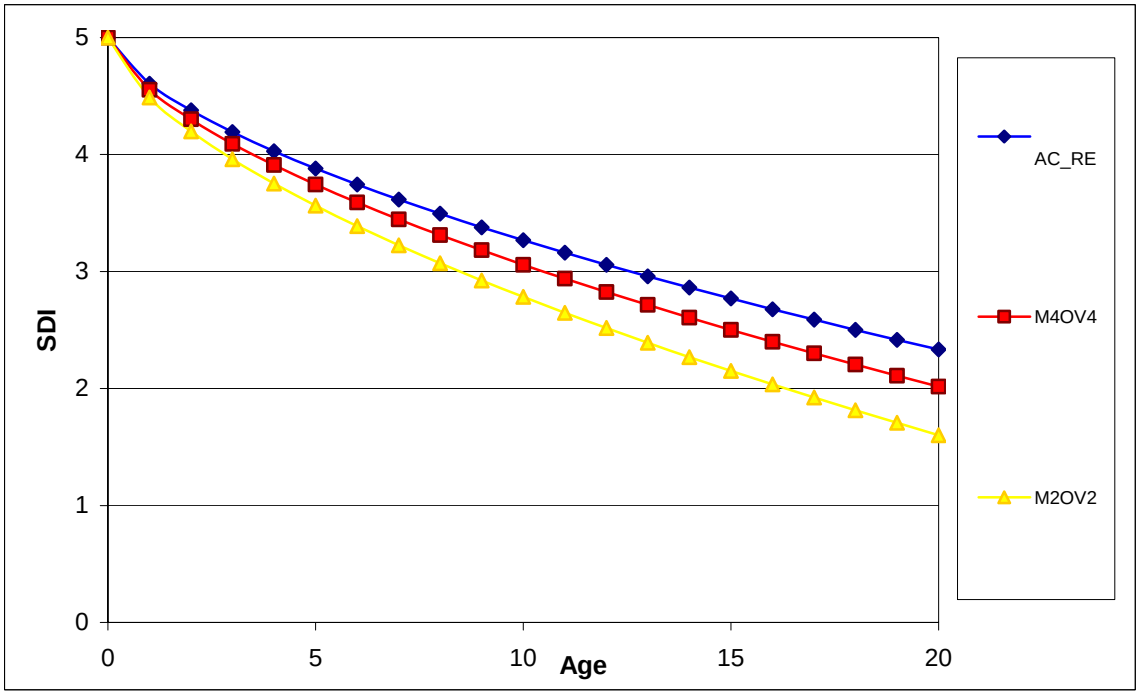

Figure 6: Performance SDI Model for AC Rehabilitation Activities

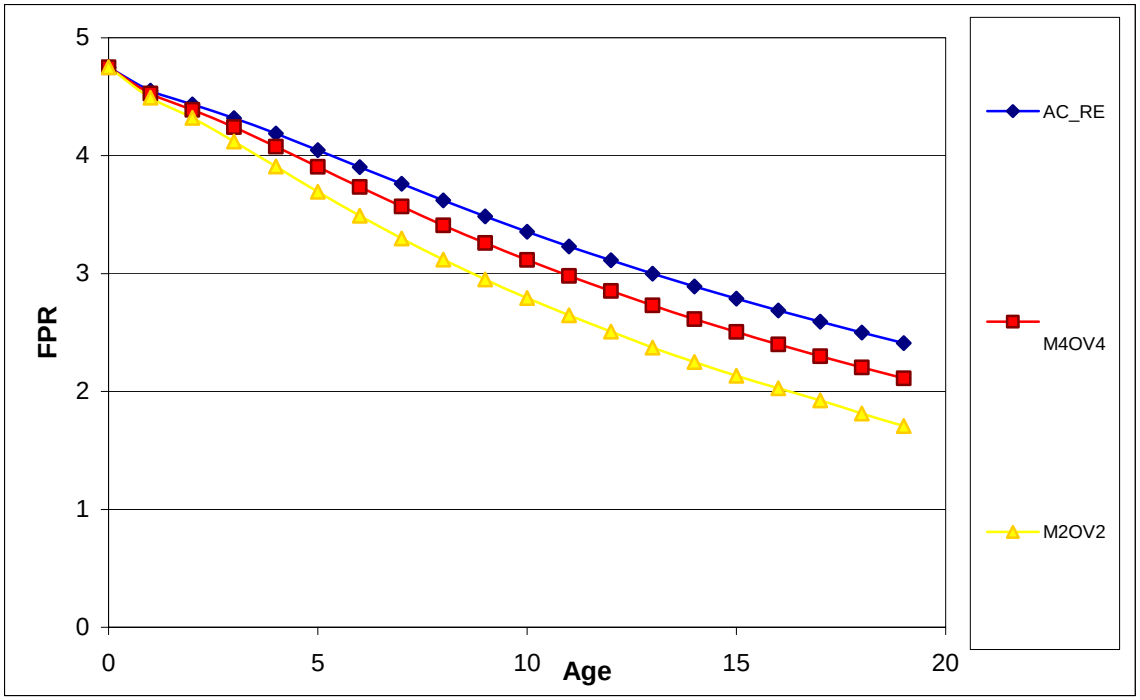

Figure 7: Performance FPR Model for AC Rehabilitation Activities

Budget Scenario Analysis

For the Hamilton Township analysis, four budget scenarios were considered. The four budget scenarios are:

1. UN03 – 3 million dollars per year starting from 2005 through 2014.
2. UN05 – 5 million dollars per year starting from 2005 through 2014.
3. UN07 – 7 million dollars per year starting from 2005 through 2014.
4. ND01 –Needs-based analysis, where the budget needed to maintain the average FPR at level of 3.0 starting from 2008 through 2014 is estimated.

Analysis Parameters

The analysis parameters were based on Stantec's past project experiences in New Jersey and the feedback from the Hamilton Township engineers. The parameters used in the analysis are as follows:

- The trigger levels for analysis for FPR are 2.0 for all streets. This trigger level is also used to define the deficiency level for any street, such that if the FPR is less that 2.0, the street will be considered deficient.
- The analysis was based on the latest performance data available for each section, which is the data collected in 2005.

- Since the analysis period extends to 2014, some projects might need to be rehabilitated more than once within the analysis period, depending on the first rehabilitation treatment performance prediction model.

- The rehabilitation treatments unit cost used in the analysis were based on the standard unit costs used by NJDOT, which were defined in 2003. However, to reflect the reduction of overhead costs including engineering cost, traffic control, etc., NJDOT standard unit costs were reduced by a factor of 25%, as shown in Table 1.

Table 1: Rehabiliation Treatments Unit Costs

Pavement Type	ID	Description	NJDOT Cost ($/s.y.)	Hamilton Cost ($/s.y.)
Flexible Pavements	M2+OV2	Mill 2"+ Overlay2"	18.60	13.95
	M4+OV4	Mill 4"+ Overlay4"	36.00	27.00
	AC Re	AC Reconstruction	86.8	65.10

Analysis Results

The results of the Hamilton Township Budget Scenario are presented in the following graphs. Figure 8 shows the total cost per year for Hamilton Township for an analysis period of 10 years in terms of the budget scenarios ND01 (average FPR=3.0 by 2008). Figures 9 through 14 show the network average and network percentage deficiency under each budget scenario in terms of the three performance indices.

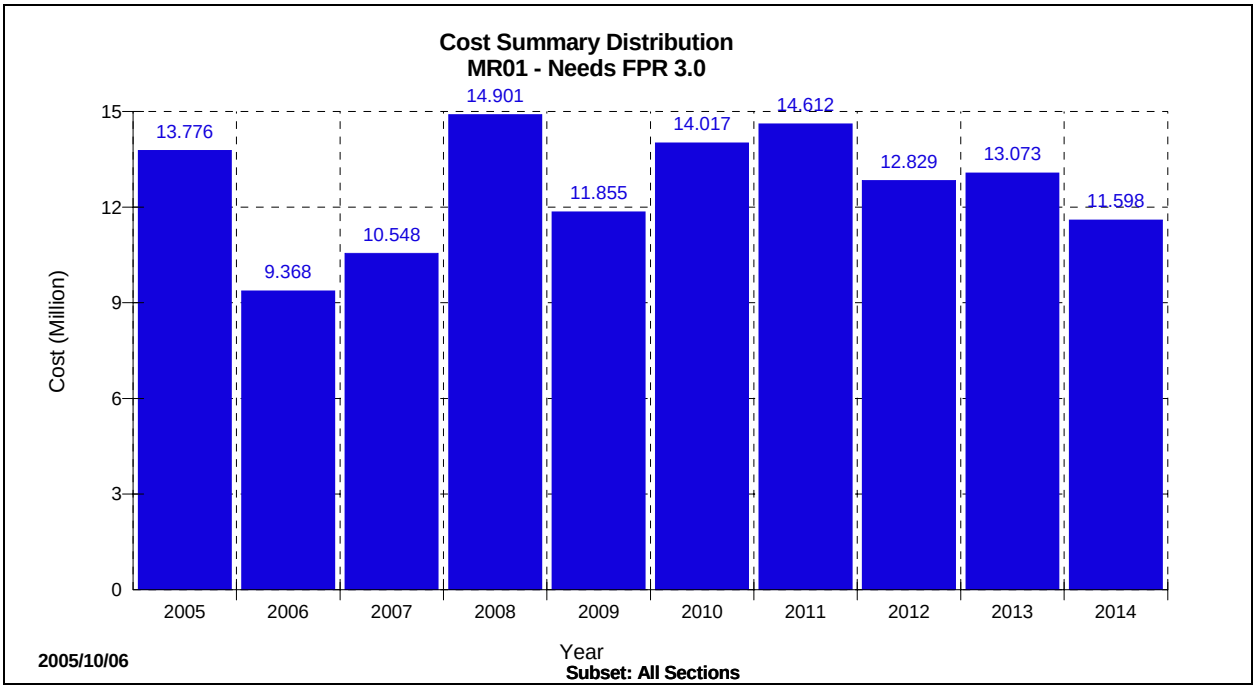

Figure 8: Need Analyses Costs - Total Cost Per Year for Hamilton Township

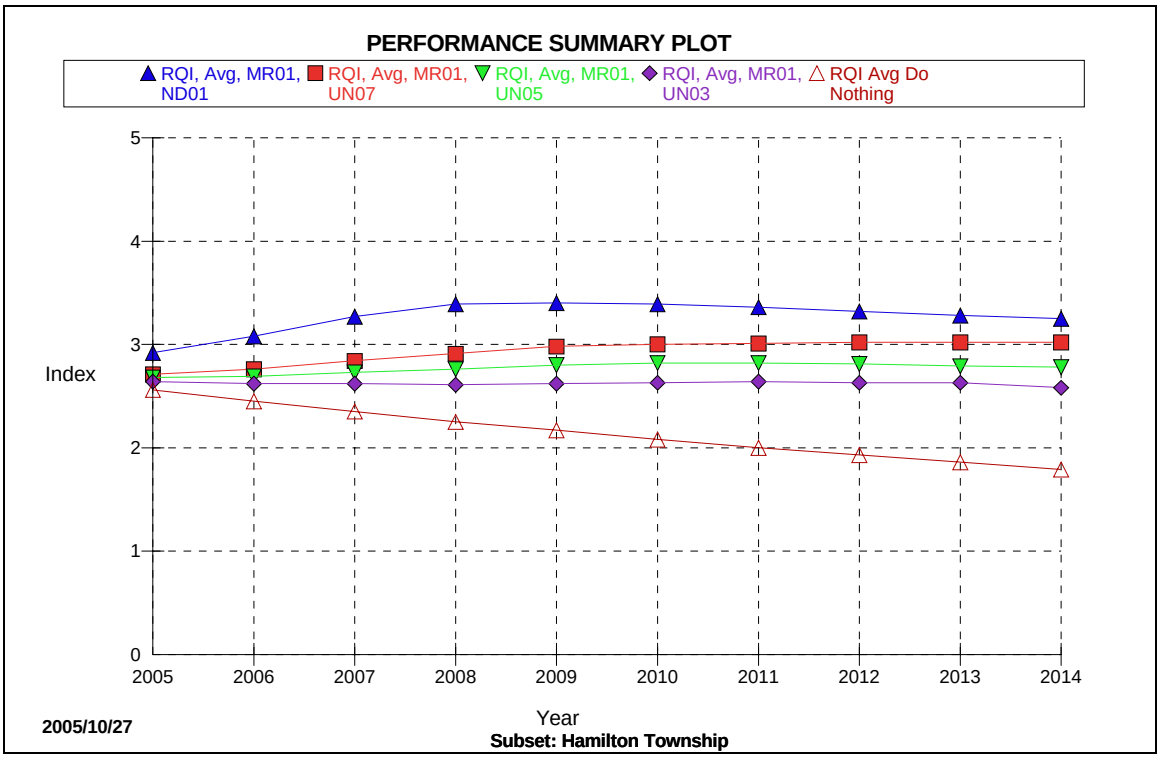

Figure 9: Hamilton Township Network Average RQI

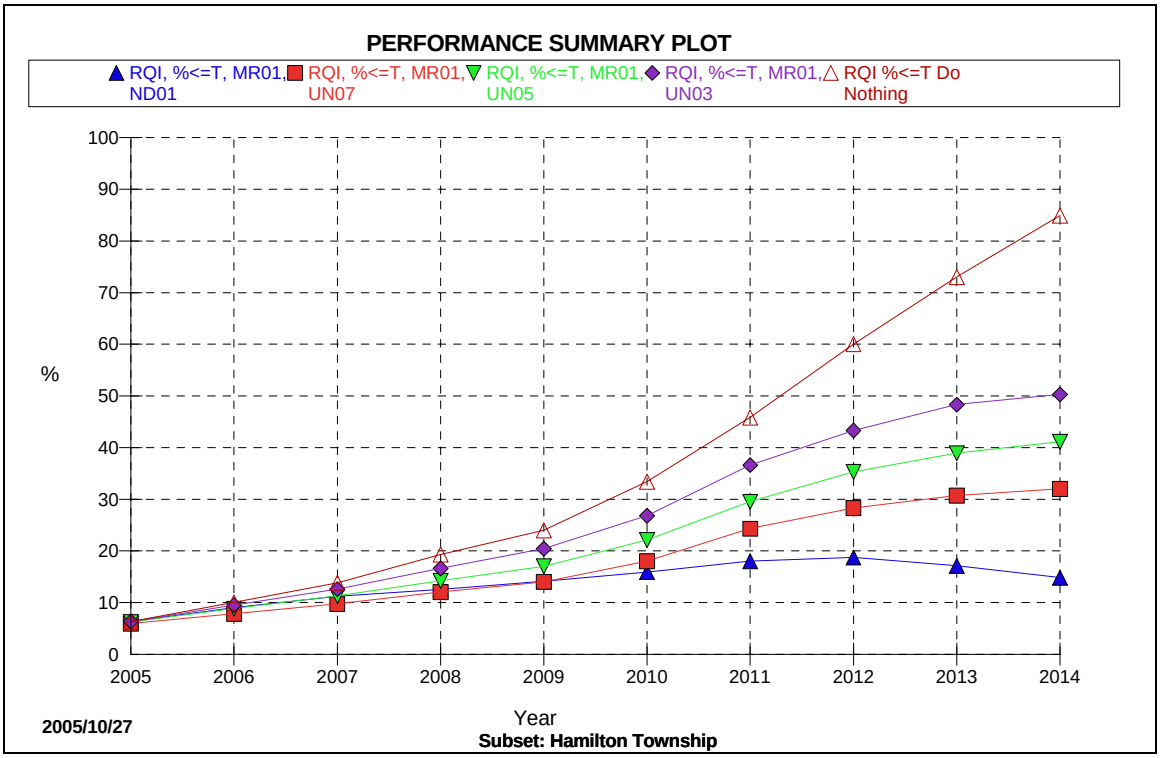

Figure 10: Hamilton Township Network Percentage Deficiency in Terms of RQI

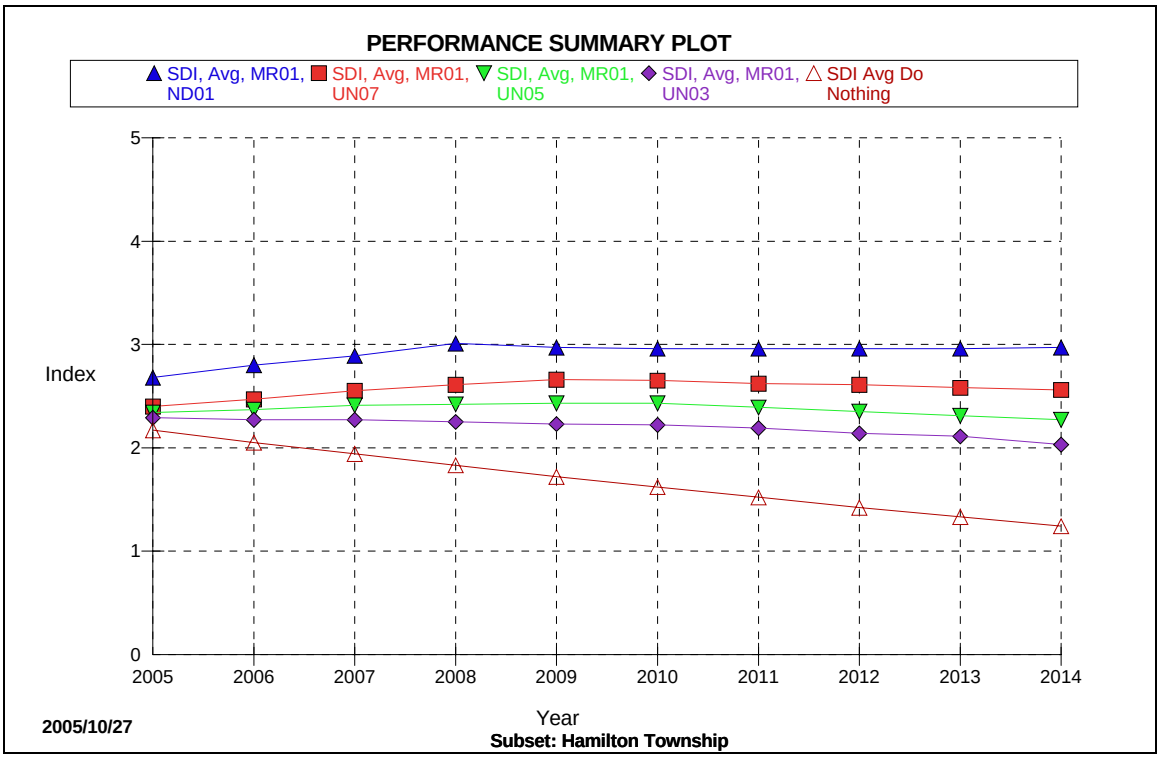

Figure 11: Hamilton Township Network Average SDI

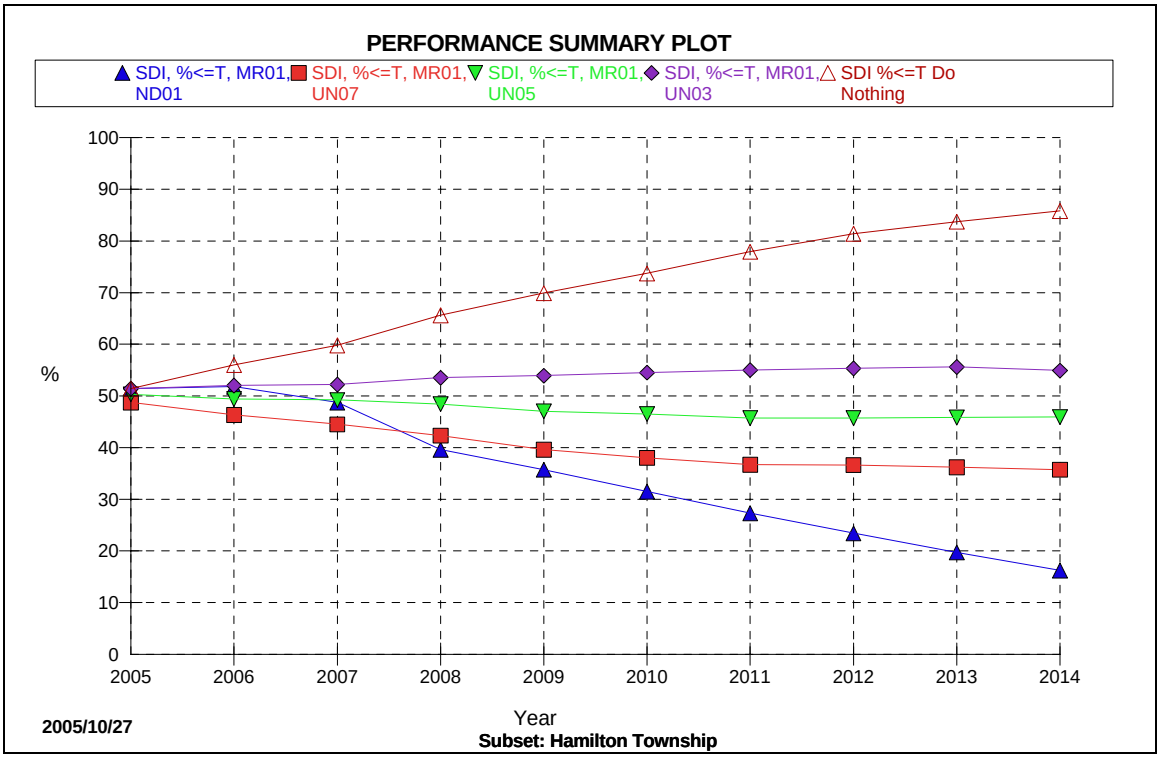

Figure 12: Hamilton Township Network Percentage Deficiency in Terms of SDI

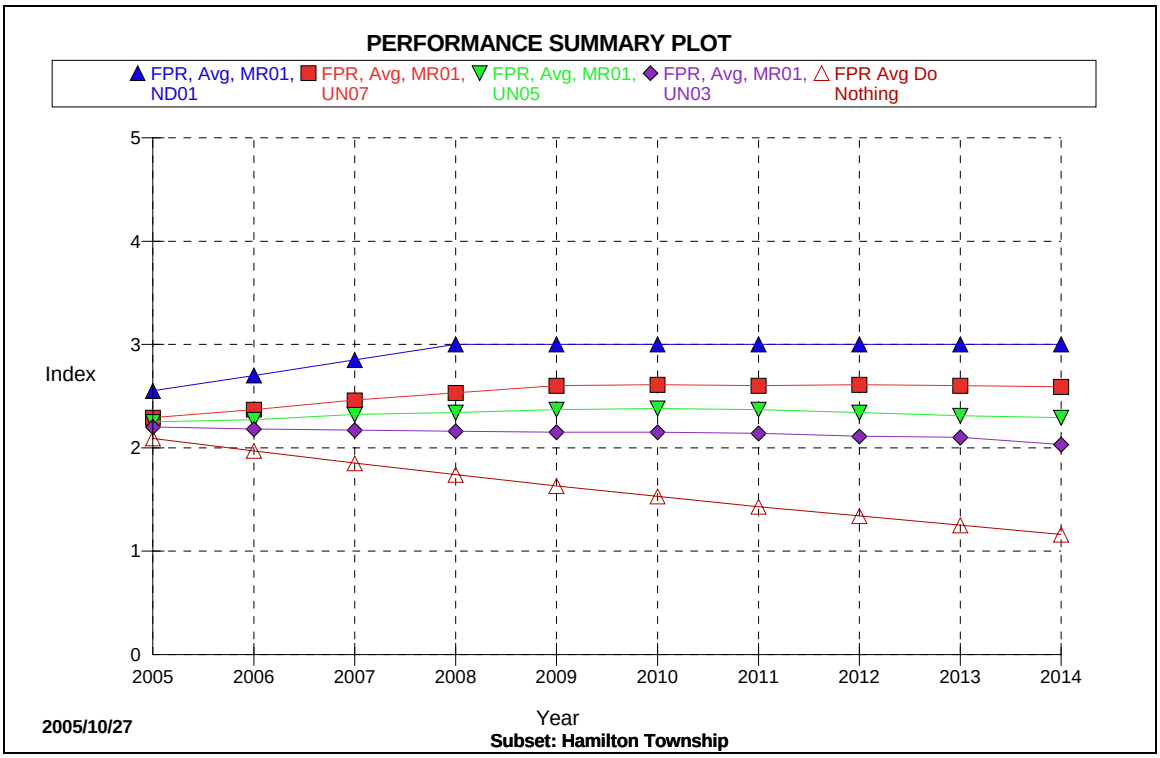

Figure 13: Hamilton Township Network Average FPR

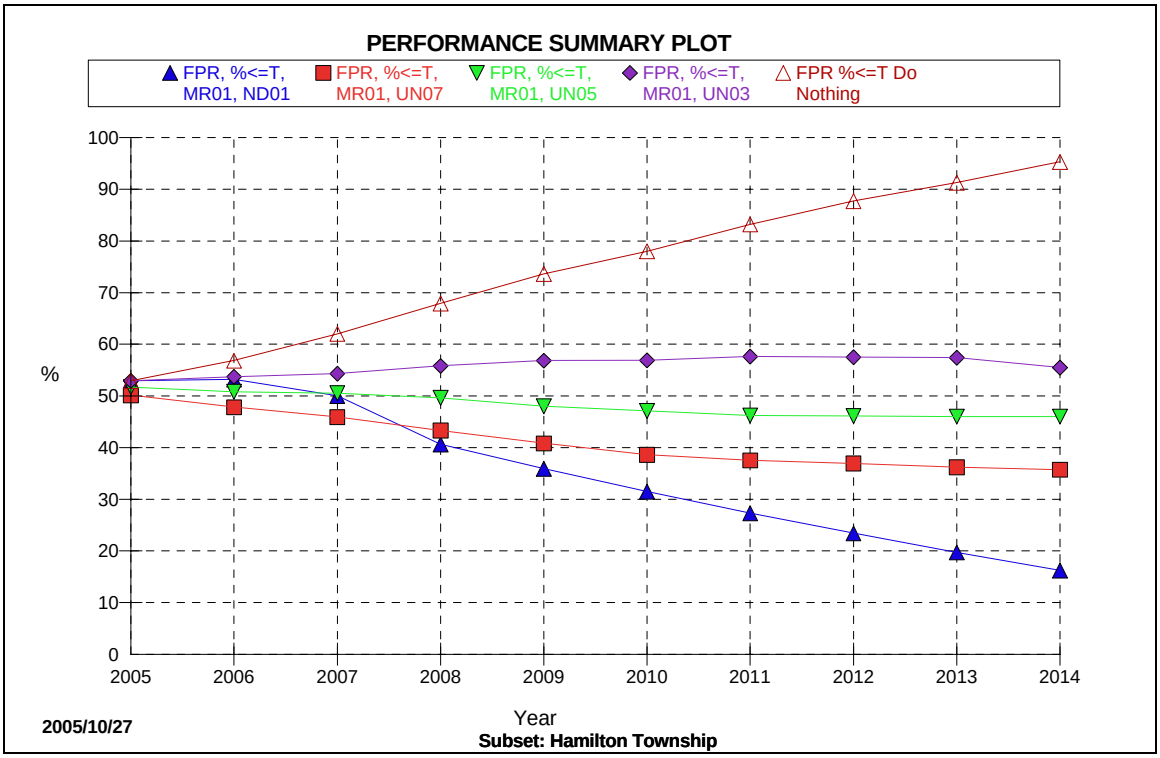

Figure 14: Hamilton Township Network Percentage Deficiency in Terms of FPR

Budget Summary

As mentioned earlier, four budget scenarios were run for the Hamilton Township road network. These budget scenarios are UN03 ($3.0 million per year), UN05 ($5.0 million per year), UN07 ($7.0 million per year), and ND01 (needs-based analysis to maintain the average RQI, SDI and FPR at level of 3.0 starting from **2008** through 2014.

The analysis results of these scenarios were described in the previous section. The budgets spent within each of these scenarios over the analysis period are summarized in Table 2.

Table 2: Budget Summaries

Year	UN03	UN05	UN07	ND01
2005	2,996,869	4,961,940	6,839,612	13,775,775
2006	2,998,811	4,978,109	6,989,550	9,368,158
2007	2,994,854	4,974,242	6,995,573	10,548,357
2008	2,999,275	4,992,608	6,995,733	14,901,165
2009	2,998,587	4,999,381	6,994,071	11,854,904
2010	2,992,569	4,992,856	6,997,916	14,017,390
2011	2,994,212	4,984,928	6,994,566	14,611,885
2012	2,999,167	4,982,377	6,994,169	12,829,463
2013	2,997,843	4,996,777	6,992,258	13,073,129
2014	2,996,612	4,992,928	6,985,796	11,598,154
Total	**29,968,799**	**49,856,146**	**69,779,244**	**126,578,380**

JERSEY CITY

Database Development

This section provides a description of the database developed for Jersey City for PMS implementation. This section also summarizes the condition of the network.

Data Sources

The development of the HPMA database for Jersey City involved two major activities, which are:

- Identification of Highway (Street) Definitions
- Collection of Pavement Condition Data

Identification of Highway (Street) Definitions

Highway definitions are needed to identify what roads exist in a network and their lengths. The highway definitions for Jersey City were developed using an official road map of the City. Street names and lengths of pavement sections were manually extracted and used to define the road definitions for data collection and loading the data into the HPMA.

Collection of Pavement Condition Data

Pavement condition data is essential for the implementation of a pavement management system. Stantec's experienced staff manually rated the pavement condition data for Jersey City. In total, more than 600 pavement sections, with a total length of approximately 200 miles were rated within Jersey City, which required more than 10 working days. The rating was performed according to the rating scheme used by NJDOT for evaluating pavement condition, which is shown in Table 3. This pavement condition data was loaded into the HPMA database as a SDI, which is NJDOT standard distress index.

The field rating also included collecting pavement attribute data to be loaded into the HPMA and used during the budget analysis. These attributes included the pavement type and the geometric attributes such as the number of lanes, divided vs. undivided roads, etc.

Table 3: Description of Pavement Ratings

FPR	Rating	Description
5.0	Very Good	Only new (or nearly new) pavements are likely to be smooth enough and sufficiently free of cracks and patches to qualify for this category. All pavements constructed or resurfaced during the data year would normally be rated very good.
4.0	Good	Pavements in this category, although not quite as smooth as those described above, give a first class ride and exhibit a few, if any, visible signs of surface deterioration. Flexible pavement may be beginning to show evidence of rutting and fine random cracks. Rigid pavements may be beginning to show evidence of slight surface deterioration such as minor cracks and spalling.

FPR	Rating	Description
3.0	Fair	The riding qualities of pavements in this category are noticeably inferior to those of new pavements, and may be barely tolerable for high-speed traffic. Surface defects of flexible pavements may include rutting, map cracking and extensive patching. Rigid pavement in this group may have a few joint failures, faulting and cracking, and some pumping.
2.0	Poor	Pavements that have deteriorated to such an extent that they affect the speed of free flow traffic. Flexible pavement may have large potholes and deep cracks. Distresses include raveling, cracking and rutting which occurs over 50 percent or more of the surface. Rigid pavement distresses include joint spalling, faulting, patching, cracking, scaling, and may include pumping and faulting.
1.0	Failed	Pavements that are in an extremely deteriorated condition. The facility is passable only at reduced speeds, and with considerable ride discomfort. Large potholes and deep cracks exist. Distress occurs over 75 percent or more of the surface.

Network Condition

Jersey City network condition was evaluated in terms of NJDOT overall FPR. The FPR is a function of NJDOT's SDI and RQI (the Ride Quality Index, which is a measure of the pavement roughness). In the case of Jersey City, the FPR is numerically identical to the SDI, due to the absence of roughness data.

Figure 15 shows the condition of the network, in terms of FPR, in categories; Poor (0.0 – 2.0), Fair (2.0 – 3.0), Good (3.0 – 4.0), and Excellent (4.0 – 5.0). It should be noted however, that the roughness data might significantly change the network condition shown in the figure.

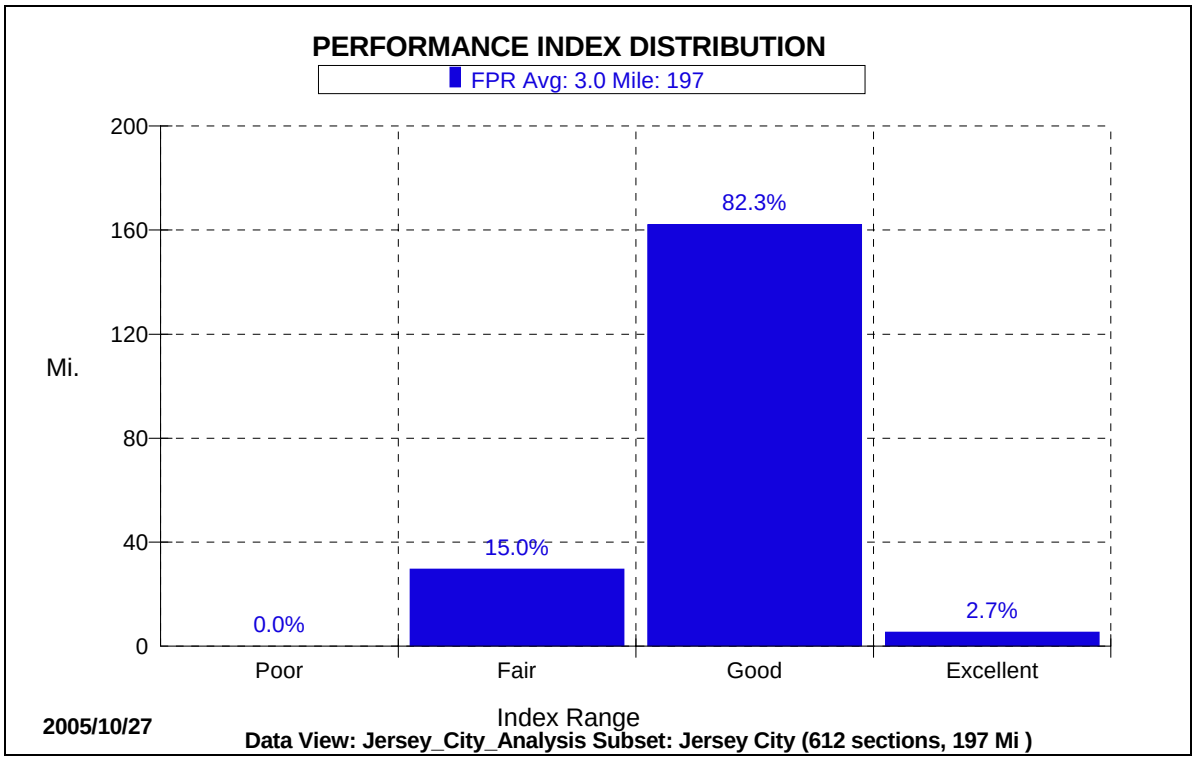

Figure 15: Jersey City Network Condition

Analysis Models

In this section, the analysis models used for the optimization analysis are presented. These models include the decision trees and the performance prediction models.

Decision Trees

Two decision trees were developed, with one for flexible pavements and the second for rigid pavements. These decision trees are similar to the decision tree used by NJDOT for pavement analysis at the county level. The two trees used for the analysis are:

Flexible Pavements:

FPR < 1.5
- Y: Reconstruction
- N: 1.5 ≤ FPR ≤ 3.5
  - Y: SDI or RQI ≤2.0
    - Y: M2O4
    - N: M2O2

Rigid Pavements:

FPR < 1.5
- Y: PPCC R, ACPC (AC Overlay)
- N: 1.5 ≤ FPR ≤ 3.5
  - Y: SDI or RQI ≤2.0
    - Y: 4PCII
    - N: 2PCII
  - N: Crack seal, or surface texturing.

Where,

FPR	=	Final Pavement Rating
SDI	=	Surface Distress Index
RQI	=	Ride Quality Index
M2O2	=	Mill 2", Overlay 2"
M2O4	=	Mill 2", Overlay 4"
PPCC R	=	Partial PCC Reconstruction
ACPC	=	Asphalt Concrete Overlay over Portland Cement Concrete
2PCII	=	Overlay 2" over PCC (II)
4PCII	=	Overlay 4" over PCC (II)

Performance Prediction Models

The NJDOT prediction models were customized to reflect the expected service life of pavements based on discussions with the local agencies engineers and our own experiences. Figure 16 through Figure 21 presents the prediction models for each of the three indices (SDI, RQI and FPR) for each rehabilitation activity listed within the decision trees based on pavement type studied.

It should be noted that the performance models shown in the figures are based on the performance models used by NJDOT HPMA used for the Interstate and state routes. However, these models were revised to extend the service life the pavements by 2 to 3 years, such that it would better reflect the conditions of local roads, within the local agencies.

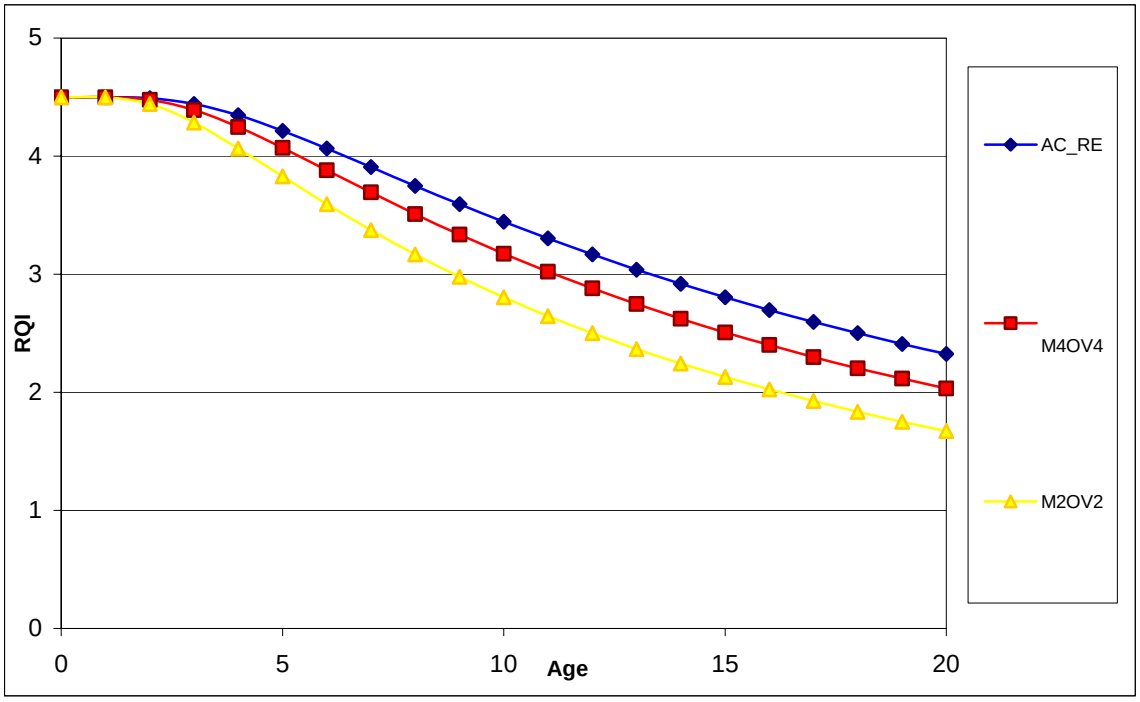

Figure 16: Performance RQI Model for AC Rehabilitation Activities

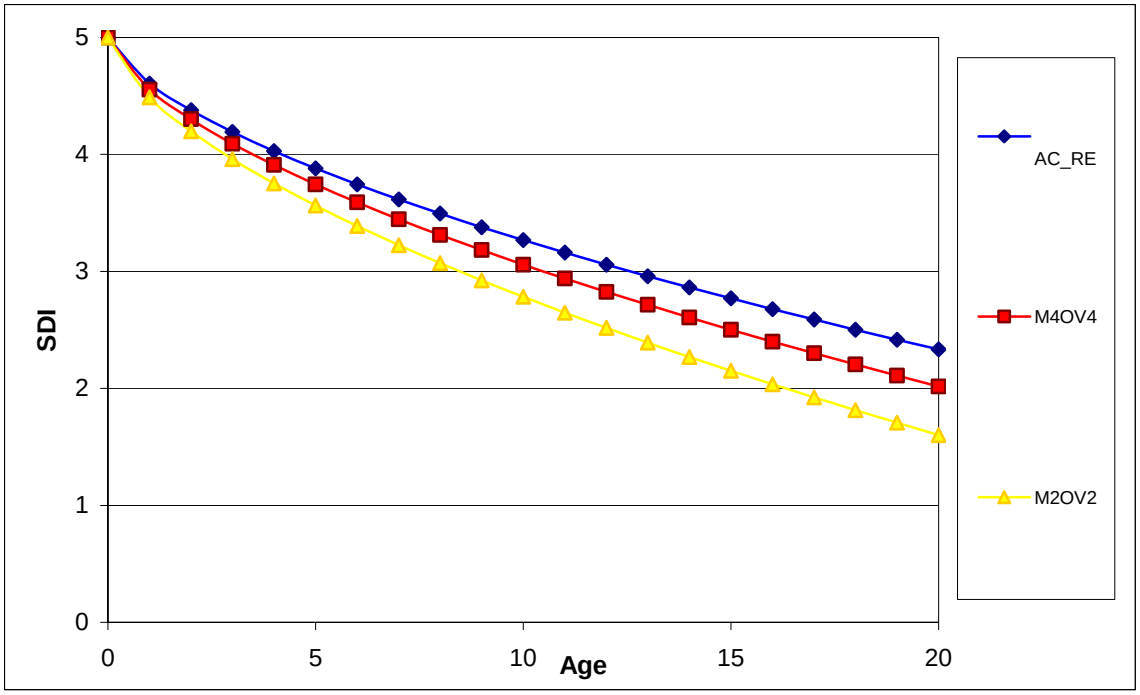

Figure 17: Performance SDI Model for AC Rehabilitation Activities

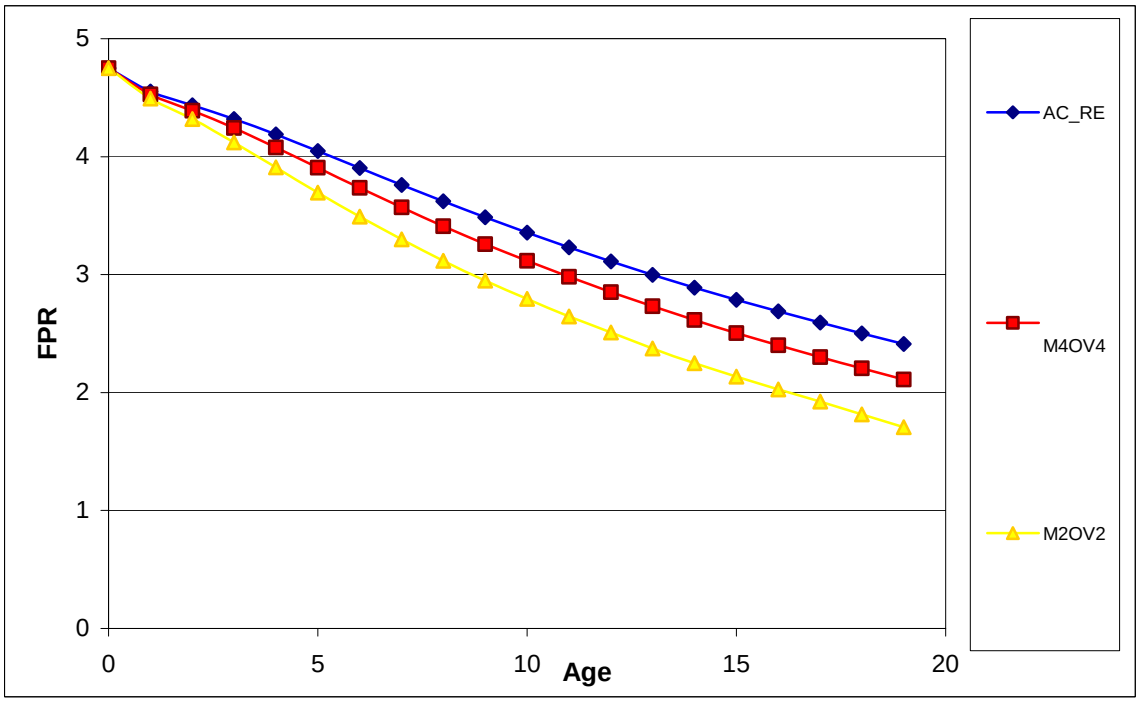

Figure 18: Performance FPR Model for AC Rehabilitation Activities

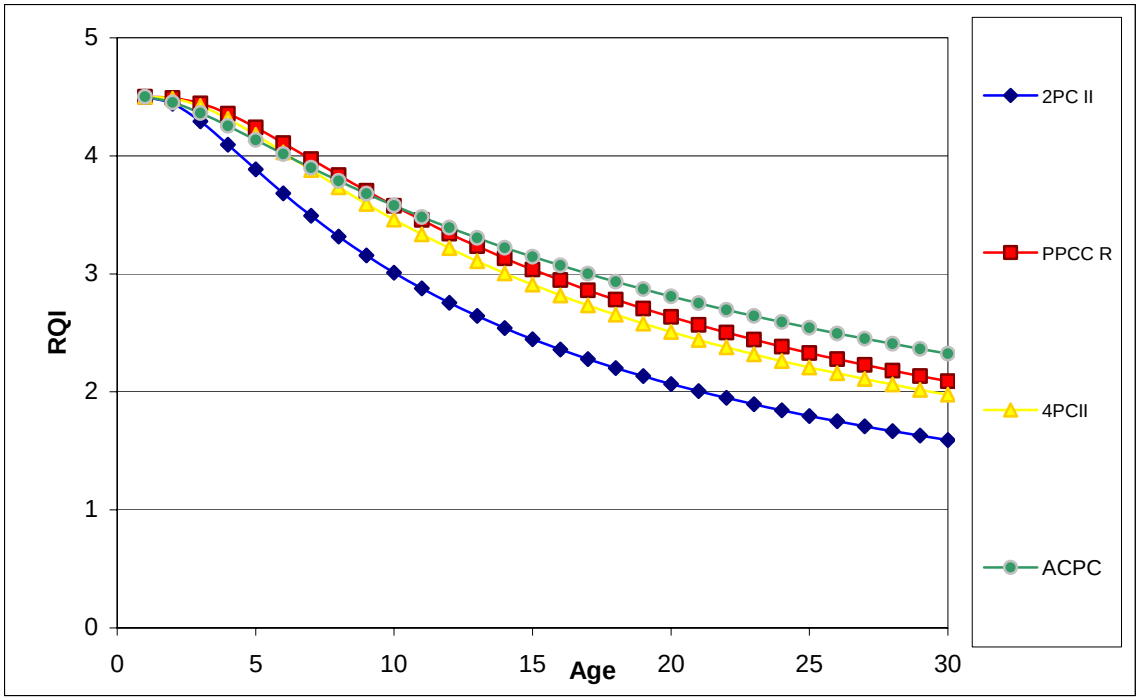

Figure 19: Performance RQI Model for PCC Rehabilitation Activities

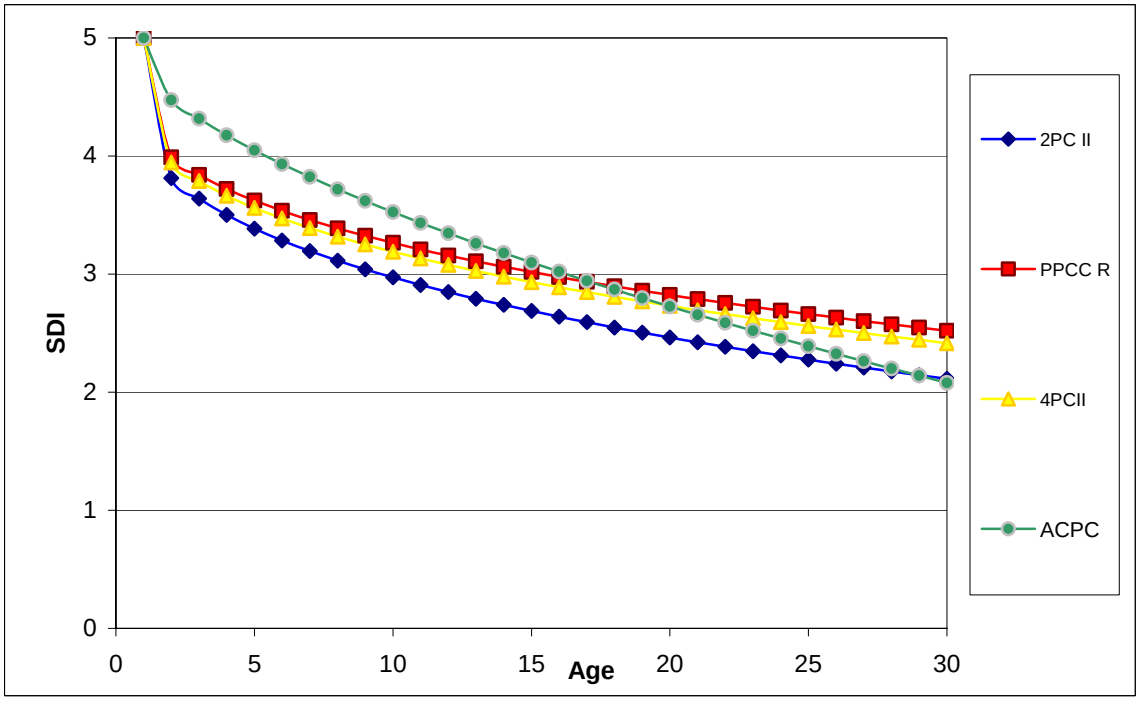

Figure 20: Performance SDI Model for PCC Rehabilitation Activities

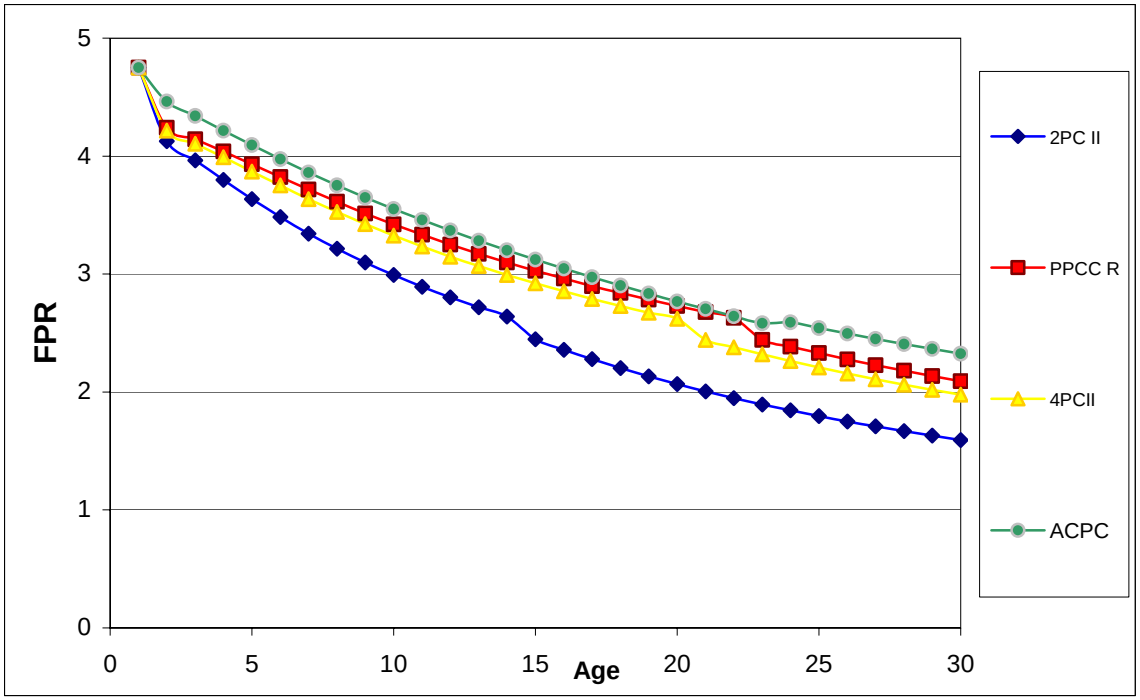

Figure 21: Performance FPR Model for PCC Rehabilitation Activities

Budget Scenario Analysis

For Jersey City analysis, three budget scenarios were considered. The three budget scenarios are:

1. UN02 – 2 million dollars per year starting from 2005 through 2014.
2. UN03 – 3 million dollars per year starting from 2005 through 2014.
3. ND01 – A Needs-Based Budget Analysis, where the budget needed to maintain the average FPR at a level of 3.5 starting from 2005 through 2014 is estimated.

Analysis Parameters

The analysis parameters were based on Stantec's past project experiences in New Jersey. The parameters used in the analysis are as follows:

- The trigger levels for analysis for FPR are 3.0 for all streets. This trigger level is also used to define the deficiency level for any street, such that if the FPR is less that 3.0, the street will be considered deficient.

- The rehabilitation treatments unit cost used in the analysis were based on the standard unit costs used by NJDOT, which were defined in 2003. However, to reflect the reduction of overhead costs including engineering cost, traffic control, etc., the NJDOT standard unit costs were reduced by a factor of 25%, as shown in Table 4.

Table 4: Rehabiliation Treatments Unit Costs

Pavement Type	ID	Description	NJDOT Cost ($/s.y.)	Jersey City Cost ($/s.y.)
Flexible Pavements	M2+OV2	Mill 2"+ Overlay2"	18.60	13.95
	M4+OV4	Mill 4"+ Overlay4"	36.00	27.00
	AC Re	AC Reconstruction	86.8	65.10
Rigid Pavements	2PC II	Overlay2" over PC II	59.50	44.63
	PPCC R	Partial PCC Reconstruction	61.10	45.83
	4PCII	Overlay4" over PC II	63.30	47.48
	ACPC	Pubb PCC+OV6"	65.10	48.83

- The analysis was based on the latest performance data available for each section, which is the data collected in 2005.
- Since the analysis period extends to 2014, some projects might need to be rehabilitated more than once within the analysis period, depending on the first rehabilitation treatment performance prediction model.

Analysis Results

The results of Jersey City Budget Scenario are presented in the following graphs. Figure 22 shows the total cost per year for Jersey City for an analysis period of 10 years in terms of the budget scenarios ND01. Figures 23 and 24 show the network average and network percentage deficiency in terms of FPR.

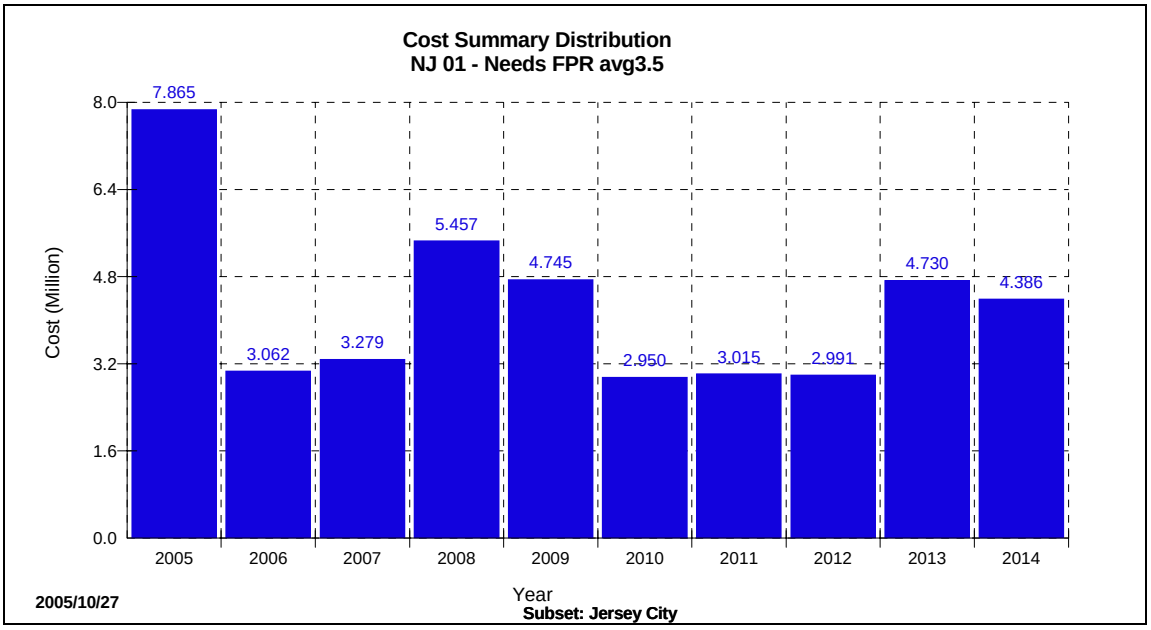

Figure 22: Need Analyses Costs - Total Cost Per Year for Jersey City

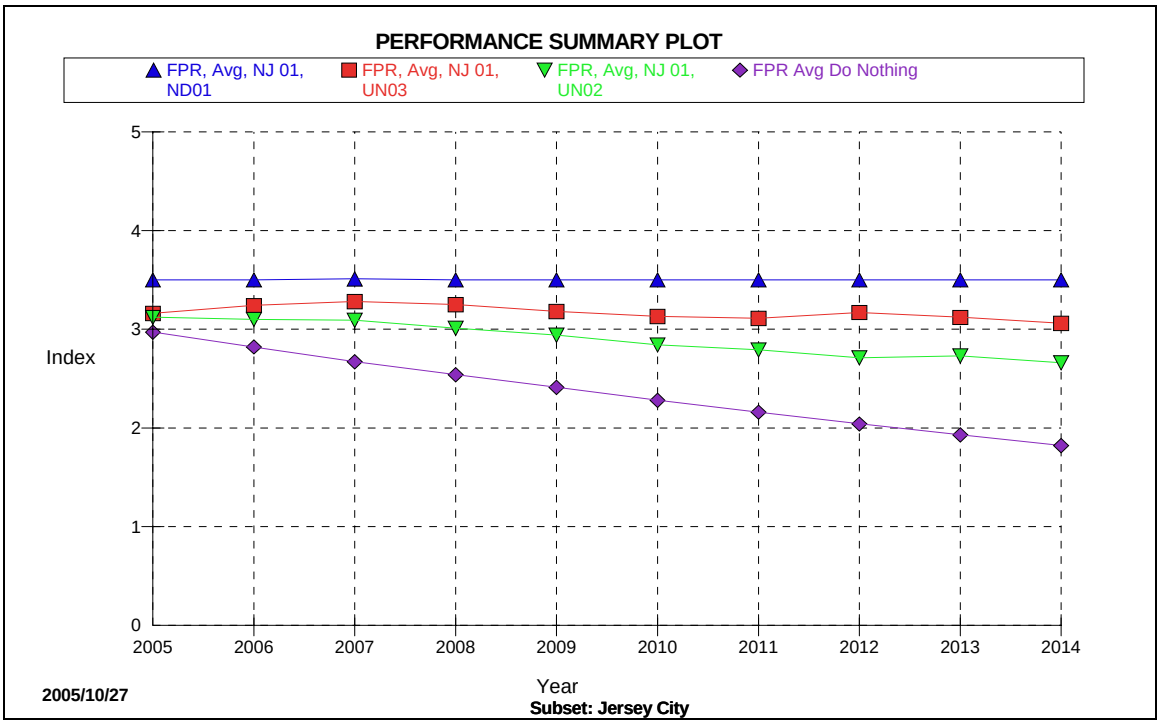

Figure 23: Jersey City Network Average FPR

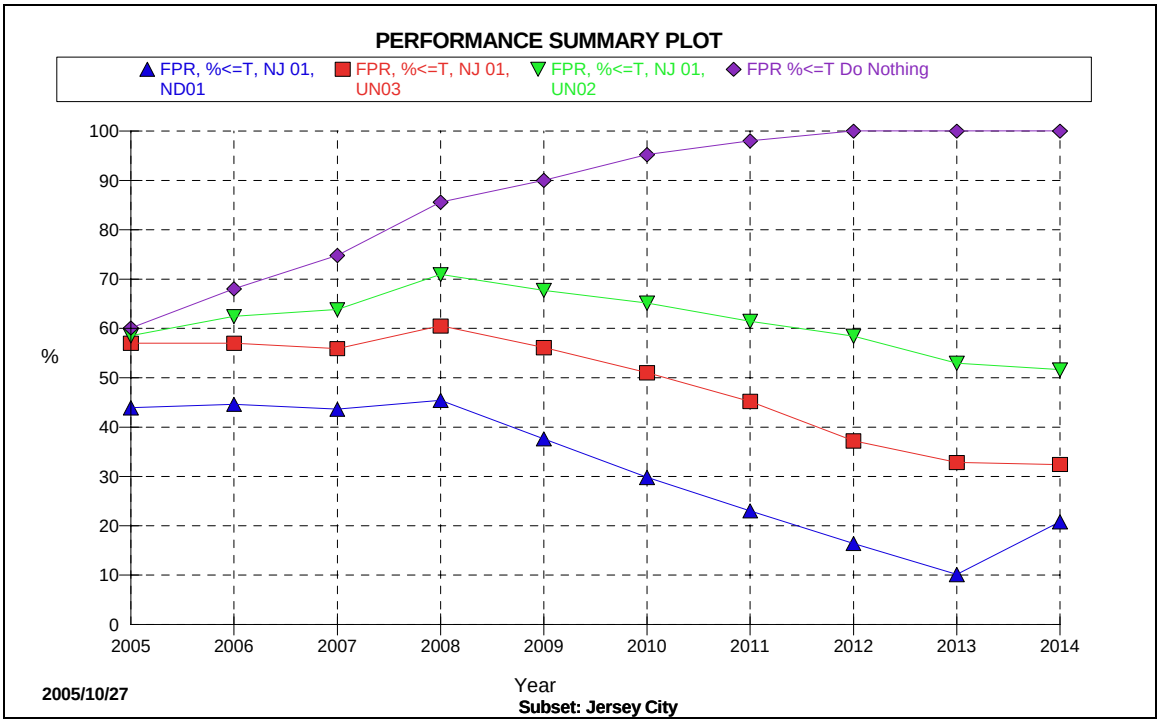

Figure 24: Jersey City Network Percentage Deficiency in Terms of FPR

Budget Summary

As mentioned earlier, three budget scenarios were run for the entire Jersey City network. These budget scenarios are UN02 ($2.0 million per year), UN03 ($3.0 million per year), and ND01 (needs-based analysis to maintain the average RQI, SDI and FPR at 3.5).

The analysis results of these scenarios were described in the previous section. The budgets spent within each of these scenarios over the analysis period are summarized in Table 5.

Table 5: Budget Summaries

Year	UN02	UN03	ND01
2005	1,998,603	2,998,492	7,865,151
2006	1,997,941	2,997,829	3,062,385
2007	1,999,777	2,997,433	3,278,575
2008	1,999,254	2,999,797	5,457,091
2009	1,998,463	2,998,614	4,744,628
2010	1,998,732	2,998,358	2,949,646
2011	1,999,646	2,999,798	3,014,721
2012	1,997,946	2,996,784	2,991,158
2013	1,998,596	2,998,449	4,729,702
2014	1,998,122	2,996,677	4,385,523
Total	**19,987,080**	**29,982,231**	**42,478,580**

OCEAN COUNTY

Database Development and Network Condition

This section provides a description of the database developed for Ocean County for PMS implementation. This section also summarizes the condition of the network.

Database Development

The Ocean County HPMA database was developed from various sources. The attribute data were extracted from the Straight Line Diagram (SLD) database (2002), while the County provided the construction history data. The performance data were collected as part of the Road Tester (RT) survey for local county roads task conducted in 2003 as part of the Development of the Second Generation of New Jersey Pavement Management System project. In this task, Stantec collected functional pavement data on approximately 17,000 miles (8,500 centerline miles) of Non-NHS FA and SHS routes using its proprietary RT vehicle. This testing included roads within Ocean County.

Section Attribute Data

The SLD database available from NJDOT was used to extract information about all available roads, firstly for the RT survey and then for pilot implementation into the HPMA. The following information, based on availability within the SLD database source, was extracted for roads under the jurisdictions of counties and municipalities:

- Administrative System (Functional Class, Funding)
- Jurisdiction (MPO, County, Municipality, Owner)
- Total miles of road – including 500 series roads
- Geometric data (number of lanes, pavement width, shoulder width, median type and width (if applicable))
- Limited traffic counts

Pavement Condition Data

As stated above, the performance data for Ocean County was collected in 2003 as part of a task within the Development of the Second Generation of New Jersey Pavement Management System project. The survey was conducted using Stantec's RT3000 survey vehicles that simultaneously collect pavement condition (distress, roughness, rutting), GPS, and video-logging (digital imagery) data.

The roads within Ocean County, including the 500 series roads, were surveyed with the RT and the data collected included the following:

- Surface condition in terms of distress severities and extents
- Surface roughness

- Rut depths
- Longitudinal profiles
- Digital video images of right-of-way attributes
- GPS data and coordinates for location referencing

The roughness data was collected and analyzed in terms of the International Roughness Index (IRI). IRI is the roughness index obtained from the longitudinal profile of the road, and is used to interpret the roughness/smoothness of each road segment. IRI was then used to calculate NJDOT RQI.

Distress data was collected using a semi-automatic process whereby pavement distresses are recorded on an event keyboard. The distress data collection followed NJDOT distress data collection protocol, where each distress type was rated for severity as well as extent. The distress data was then used to calculate NJDOT SDI.

Network Condition

Ocean County road network condition was evaluated in terms of RQI, SDI, and the NJDOT overall FPR, which is a function of the RQI and SDI on a scale from 0.0 to 5.0, where 5.0 is the best possible pavement condition. Figures 25 through 27 show the condition of the network in terms of RQI, SDI, and FPR, respectively. In the figure, the condition is shown in categories: Poor (0.0 – 2.0), Fair (2.0 – 3.0), Good (3.0 – 4.0), and Excellent (4.0 – 5.0).

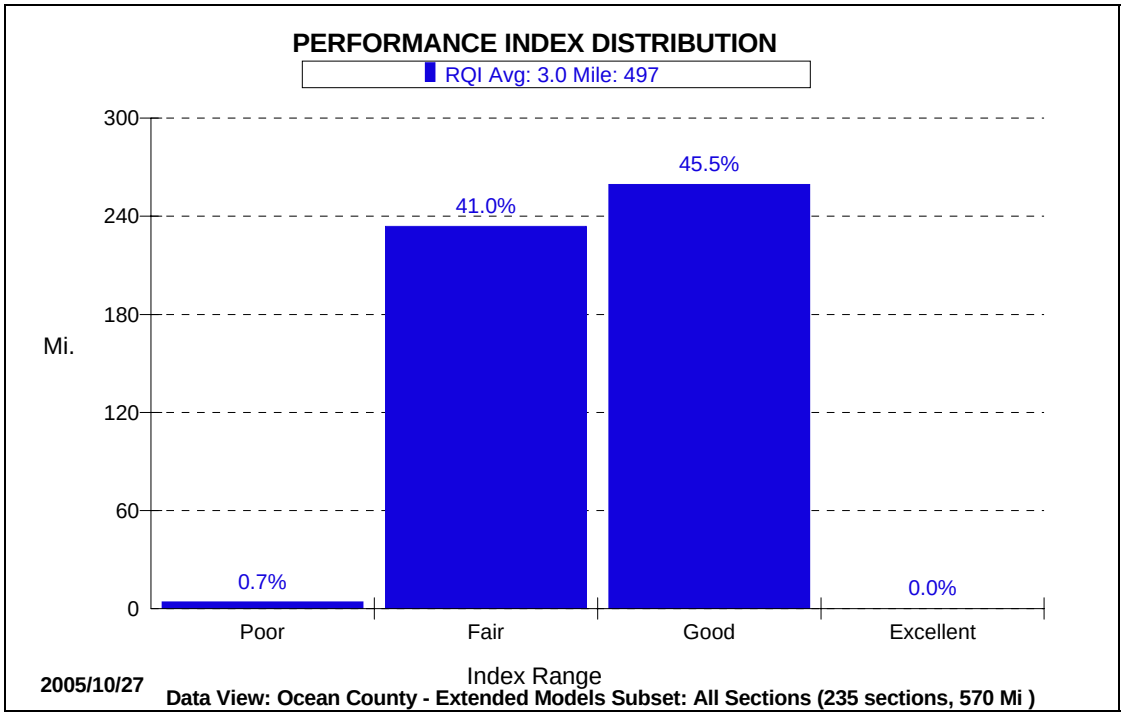

Figure 25: Ocean County Network Condition in Terms of RQI

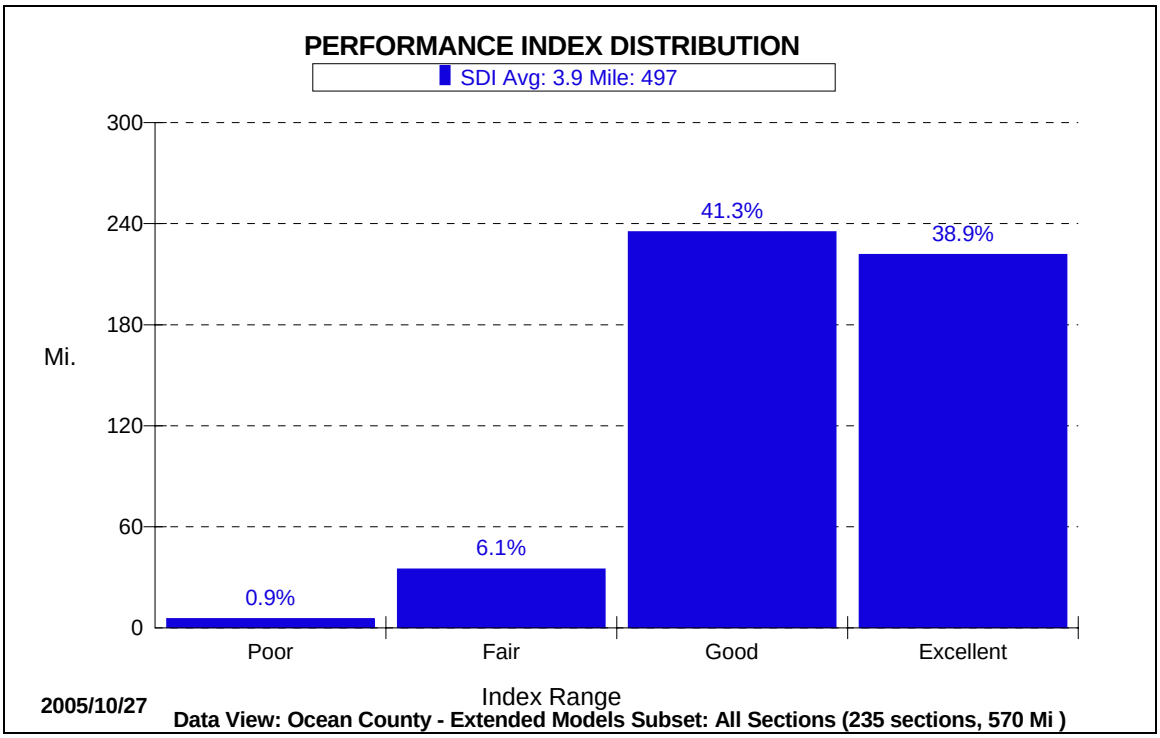

Figure 26: Ocean County Network Condition in Terms of SDI

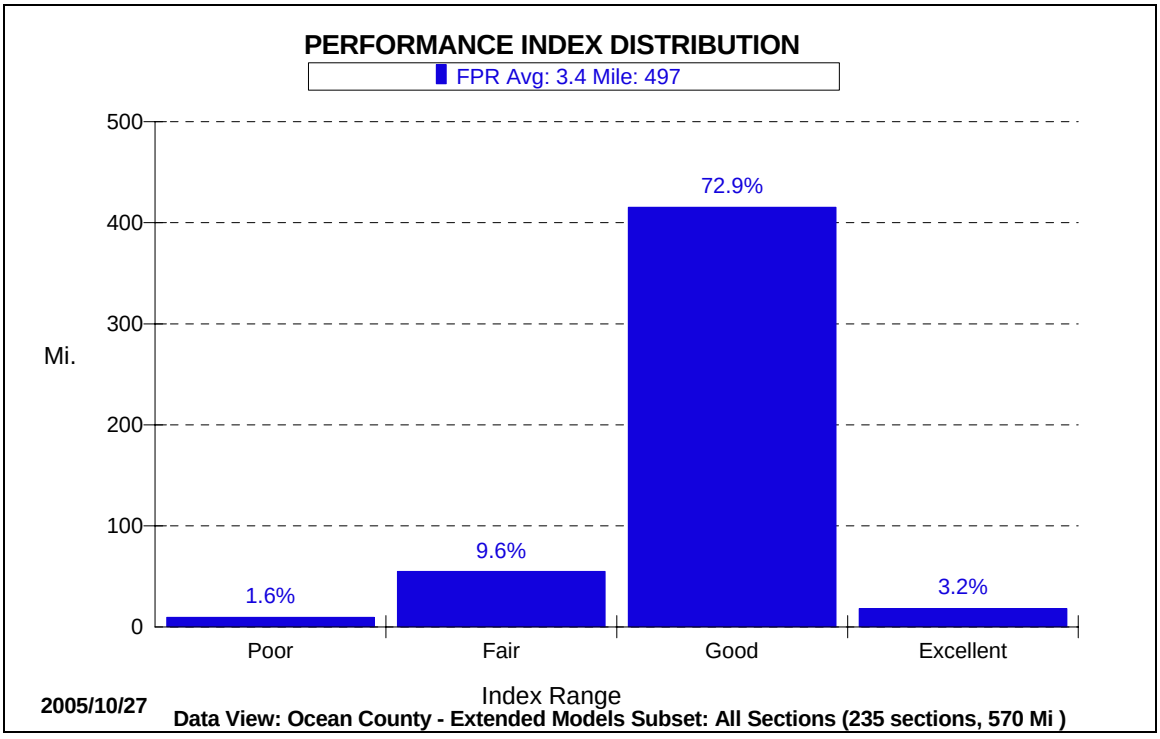

Figure 27: Ocean County Network Condition in Terms of FPR

Analysis Models

In this section, the analysis models used for the optimization analysis are presented. These models include the decision trees and the performance prediction models.

Decision Trees

Two decision trees were developed: the first for flexible pavements and the second for rigid pavements. These were based on the feedback received from the staff from each of the selected counties and from Stantec's own experiences. The two trees used for the analysis were:

Flexible Pavements: FPR < 1.5

- Y: Reconstruction
- N: 1.5 ≤ FPR ≤ 3.5
  - Y: SDI or RQI ≤2.0
    - Y: M2O4
    - N: M2O2
  - N: Crack seal/fill

Rigid Pavements: FPR < 1.5

- Y: PPCC R, ACPC (AC Overlay)
- N: 1.5 ≤ FPR ≤ 3.5
  - Y: SDI or RQI ≤2.0
    - Y: 4PCII
    - N: 2PCII
  - N: Crack seal, or surface texturing.

Where,

FPR	=	Final Pavement Rating
SDI	=	Surface Distress Index
RQI	=	Ride Quality Index
M2O2	=	Mill 2", Overlay 2"
M2O4	=	Mill 2", Overlay 4"
PPCC R	=	Partial PCC Reconstruction
ACPC	=	Asphalt Concrete Overlay over Portland Cement Concrete
2PCII	=	Overlay 2" over PCC (II)
4PCII	=	Overlay 4" over PCC (II)

Performance Prediction Models

The NJDOT prediction models were customized to reflect the expected service life of pavements based on discussions with the County engineers and Stantec's own experiences. Figures 28 through 33 present the prediction models for each of the three indices (SDI, RQI, and FPR) for each rehabilitation activity listed within the decision trees depending on the pavement type.

It should be noted that the performance models shown in the figures are based on those used by the NJDOT HPMA for the Interstate and state routes. However, these models were revised after feedback from Ocean County in order to extend the service life the pavements by 2 to 3 years.

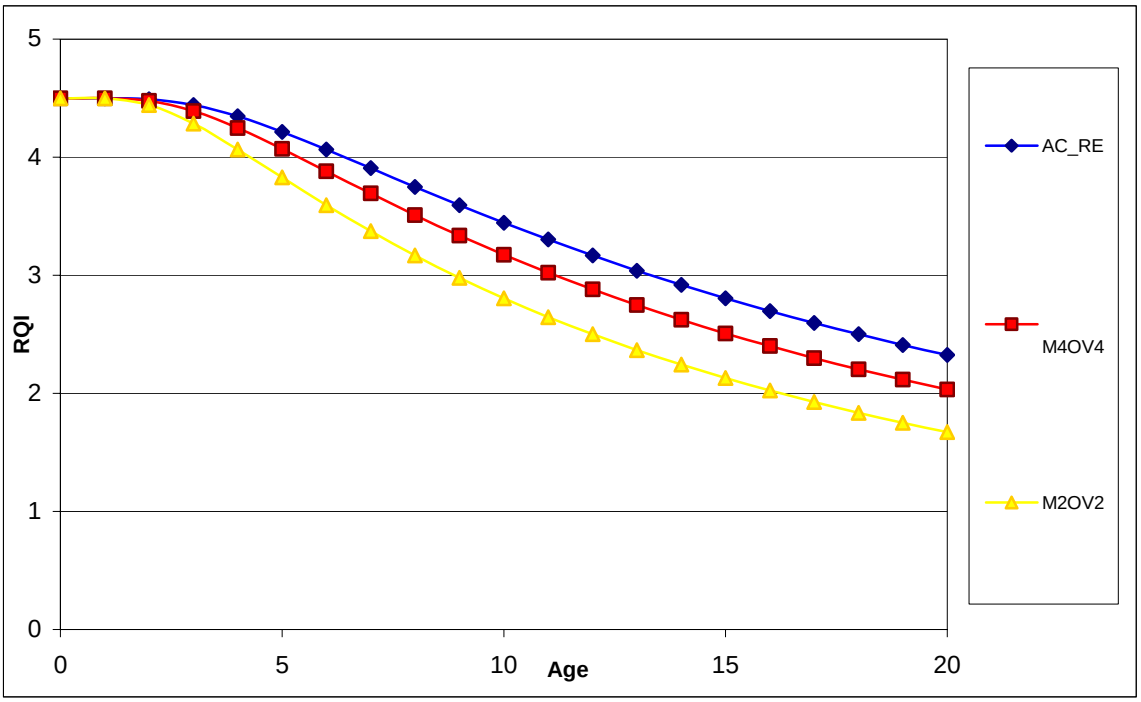

Figure 28: Performance RQI Model for AC Rehabilitation Activities

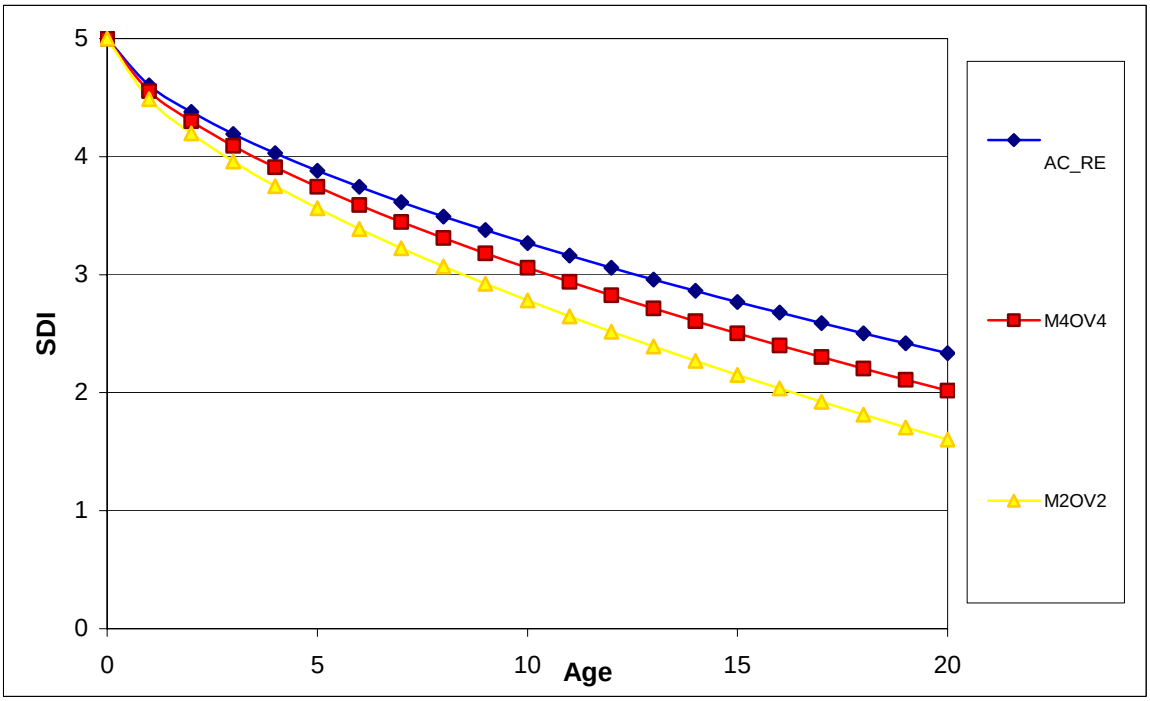

Figure 29: Performance SDI Model for AC Rehabilitation Activities

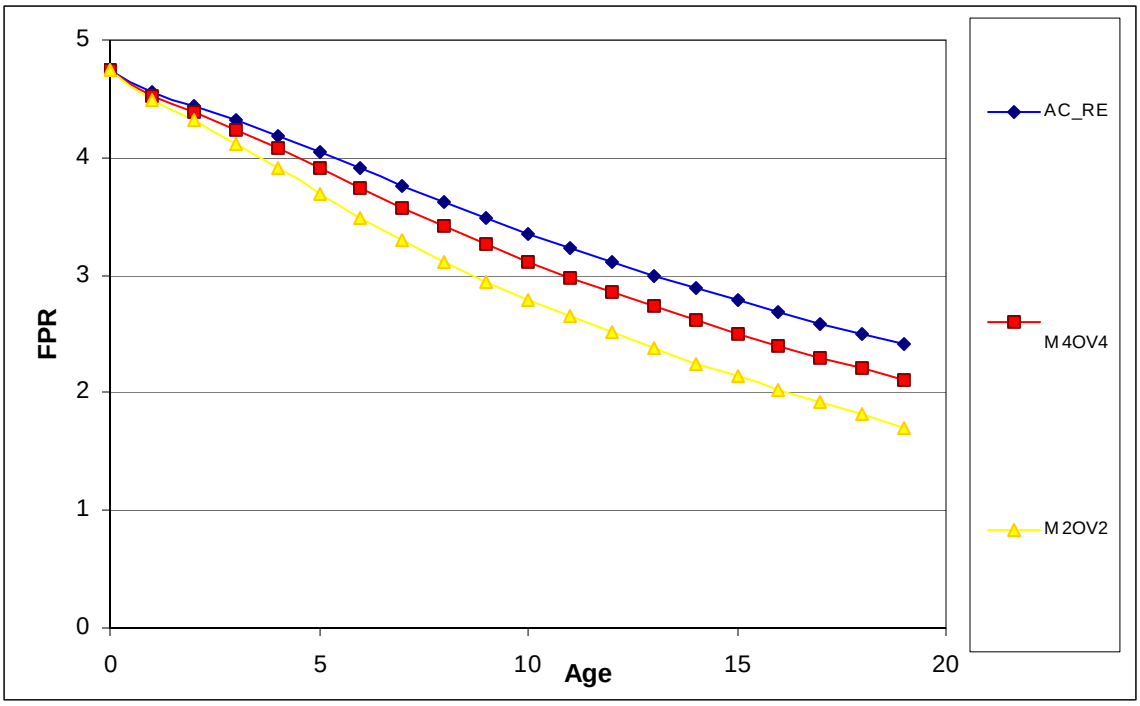

Figure 30: Performance FPR Model for AC Rehabilitation Activities

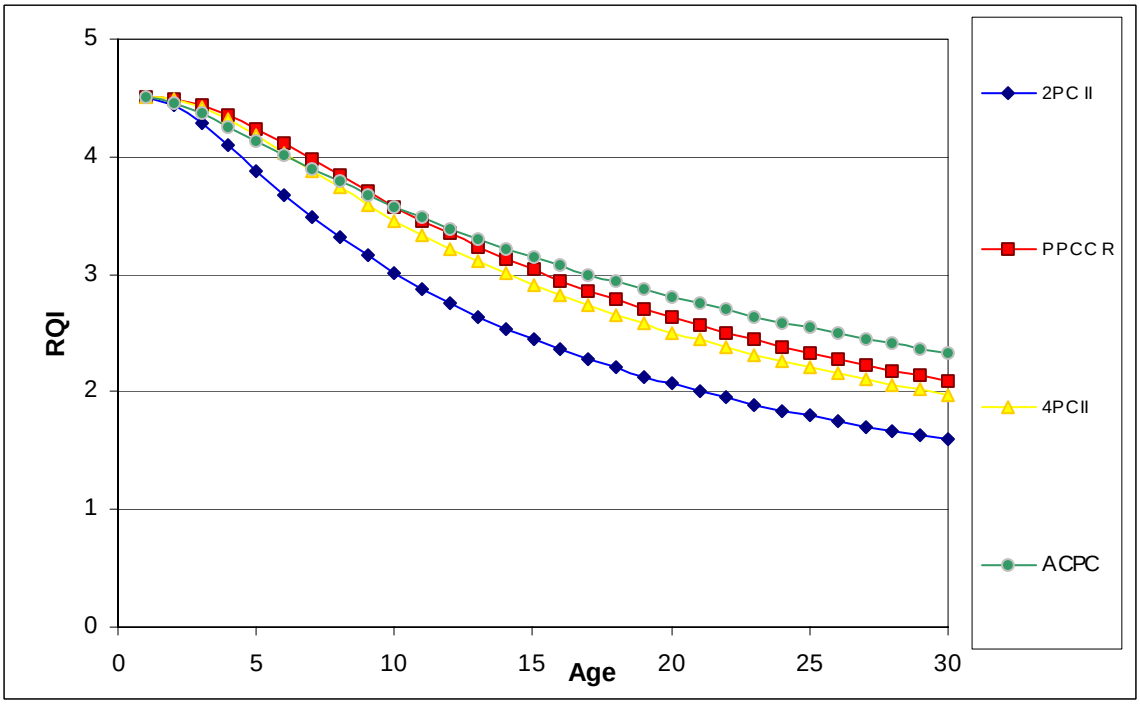

Figure 31: Performance RQI Model for PCC Rehabilitation Activities

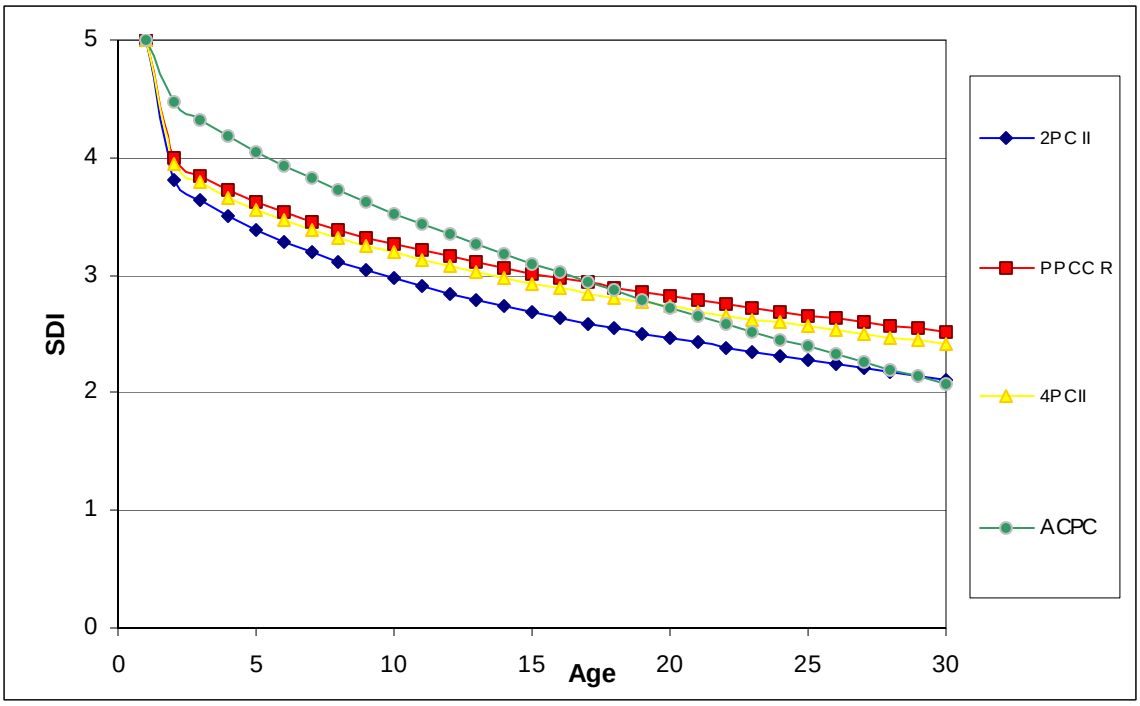

Figure 32: Performance SDI Model for PCC Rehabilitation Activities

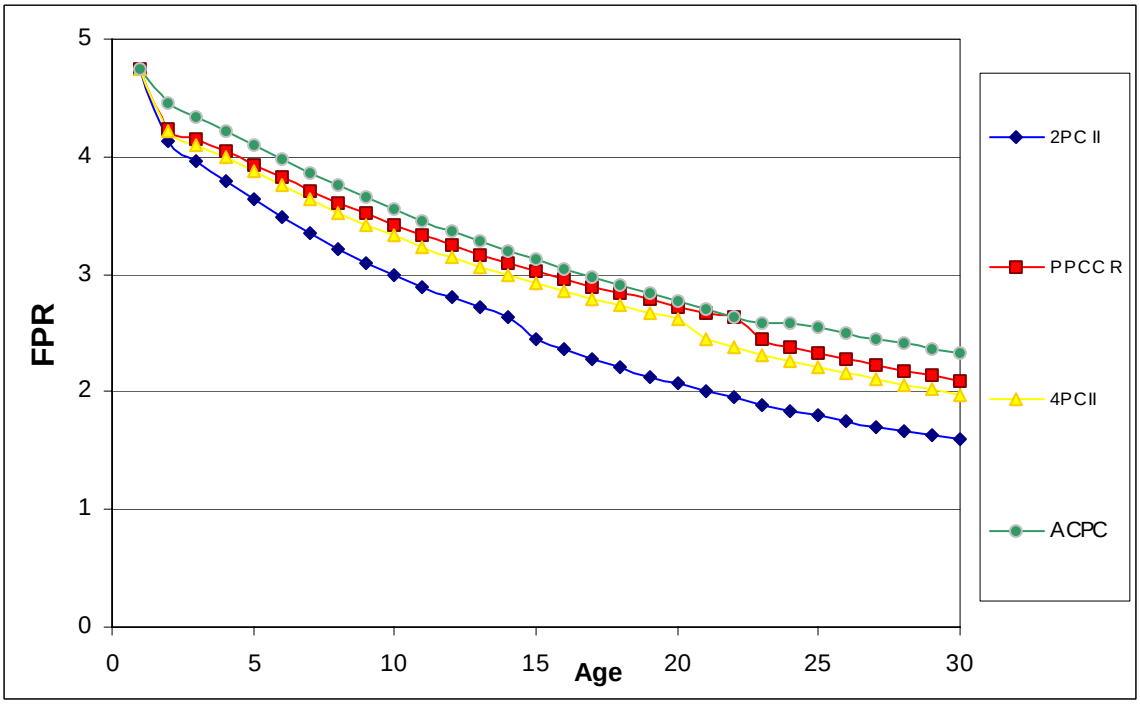

Figure 33: Performance FPR Model for PCC Rehabilitation Activities

Budget Scenario Analysis

For the Ocean County analysis, four budget scenarios were considered. The budget figures were obtained from discussions with Ocean County engineers, and updated during the meetings held in February 2005. The project lengths for the budget scenarios were set to a maximum of 6.0 miles. The four budget scenarios are:

1. U04 – 4 million dollars per year starting from 2006 through 2014 ($12 mil in 2005)

2. U06 – 6 million dollars per year starting from 2006 through 2014 ($14 mil in 2005)

3. ND01 – Needs-based analysis, where an unlimited budget is available to maintain the average RQI, SDI and FPR at level of 3.0 starting from 2005 through 2014.

4. ND02 – Needs-based analysis, where an unlimited budget is available to achieve an average FPR at level of 3.5 starting from **2008** through 2014.

It should be noted that the pavement condition data was last collected in 2003, but no information about the rehabilitation projects was available for the years 2003 and 2004. Therefore, in order to account for the missing as built data and the actual spending on pavement rehabilitation since the last data collection cycle, extra budget was added in 2005, where $8 million ($4 million for each of 2003 and 2004) was added to the 2005 budget for the budget-constrained analyses, which are U04 and U06.

Analysis Parameters

The analysis parameters were based on Stantec's past project experiences in New Jersey and the feedback from the Ocean County engineers. The parameters used in the analysis are as follows:

- The decision trees were set up based on SDI and RQI, which were shown previously.

- Since the analysis period extends to 2014, some projects may need to be rehabilitated more than once within the analysis period, depending on the first rehabilitation treatment prediction model.

- The trigger levels for analysis, and deficiency levels, for RQI and SDI are 2.0 and 2.5 for Local and Collector roads, respectively.

- The analysis was based on the latest performance data available for each section.

- The rehabilitation treatments and unit cost settings used in the analysis are the standard analysis settings used for all previous budget scenario analyses using the NJDOT HPMA, which were defined in 2003, and shown in Table 6.

Table 6: Rehabiliation Treatments Unit costs

Pavement Type	ID	Description	Cost ($/s.y.)
Flexible Pavements	M+OV2	Mill 2"+ Overlay2"	18.60
	M2+OV4	Mill 2"+ Overlay4"	36.00
	ACRe	AC Reconstruction	86.8
Rigid Pavements	2PC II	Overlay2" over PC II	59.50
	PPCC R	Partial PCC Reconstruction	61.10
	4PCII	Overlay4" over PC II	63.30
	ACPC	Pubb PCC+OV6"	65.10

Analysis Results

The results of the Ocean County Budget Scenario are presented in the following graphs. Figure 34 shows the total cost per year for Ocean County for an analysis period of 10 years in terms of the budget scenarios ND01 (average FPR=3.0) and ND02 (average FPR=3.5). It should be noted the budget in the first year (2005) should be reduced by $8 million to reflect the actual spending in the years 2003 and 2004.

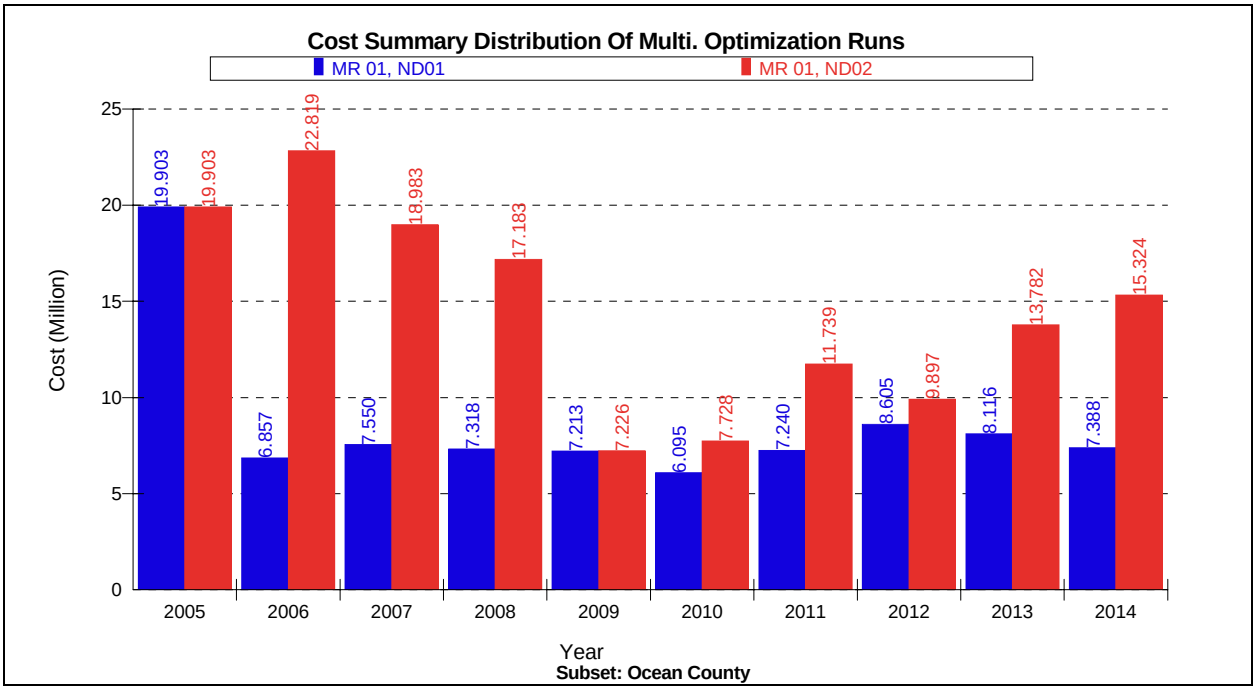

Figure 34: Need Analyses Costs - Total Cost Per Year for Ocean County

Figure 35 through Figure 40 show the network average and network percentage deficiency under each budget scenario in terms of the three performance indices.

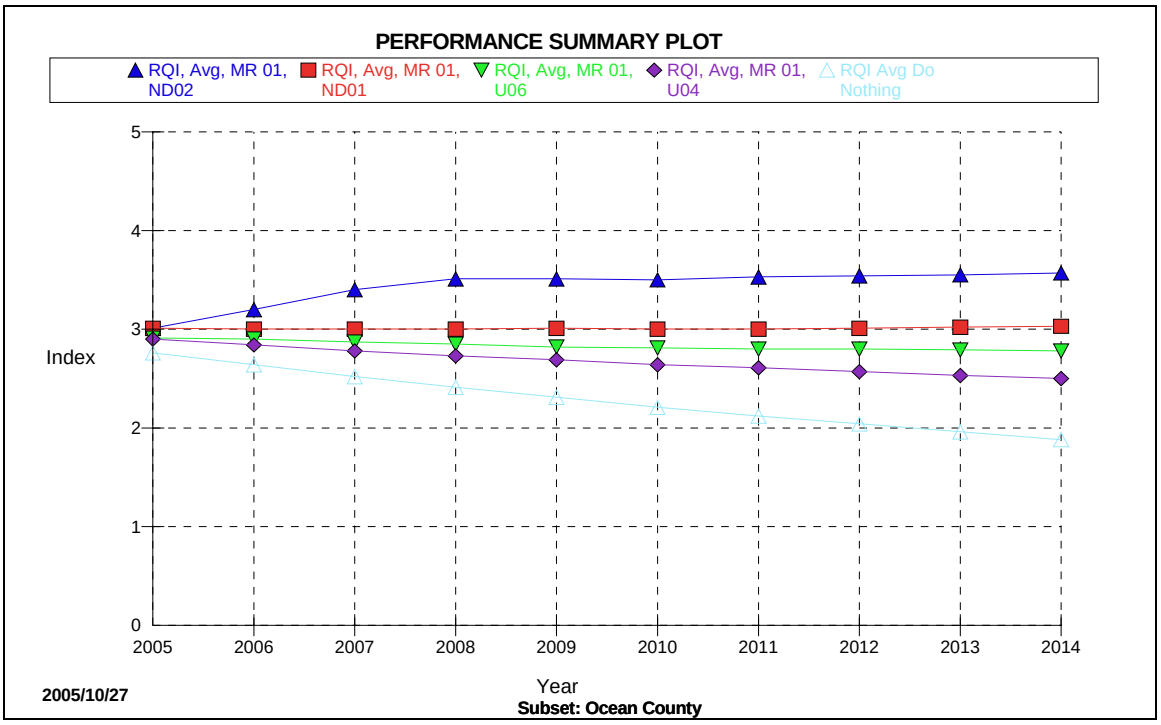

Figure 35: Ocean County Network Average RQI

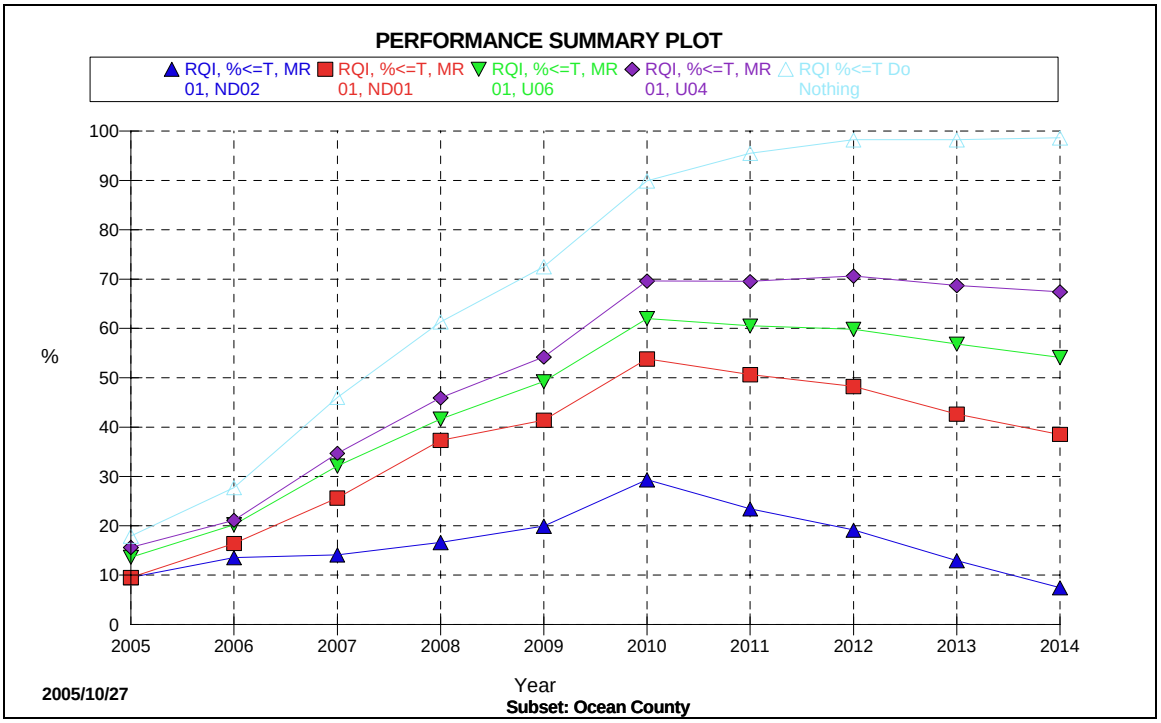

Figure 36: Ocean County Network Percentage Deficiency in Terms of RQI

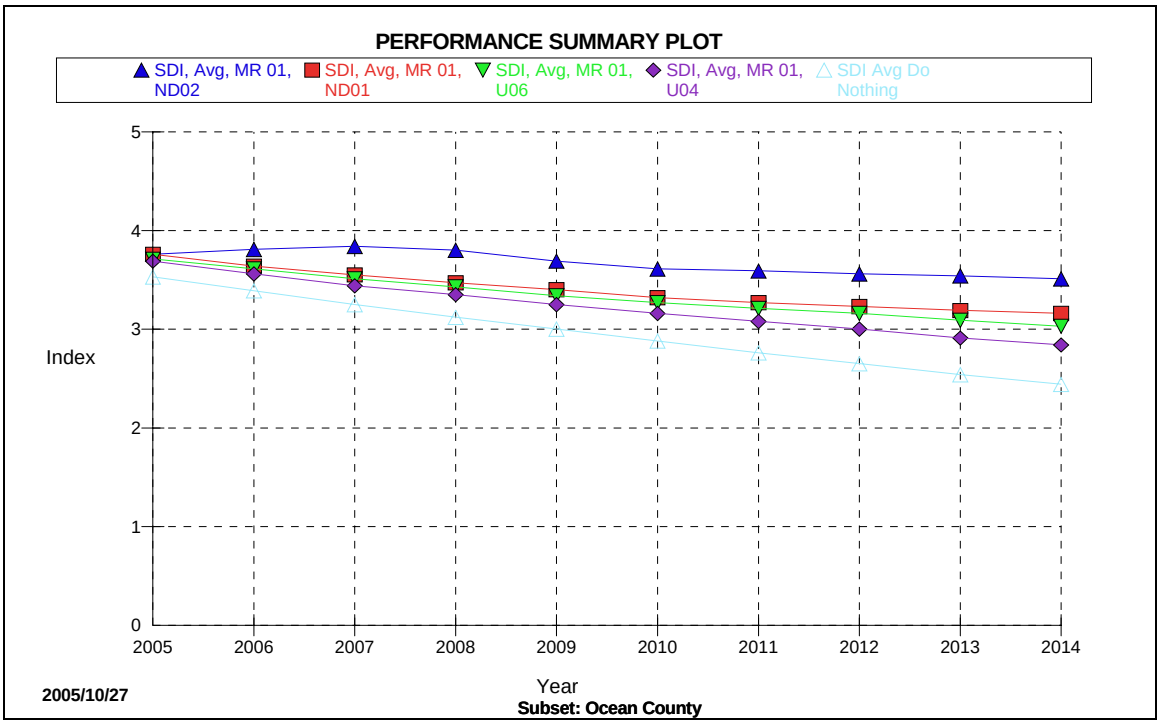

Figure 37: Ocean County Network Average SDI

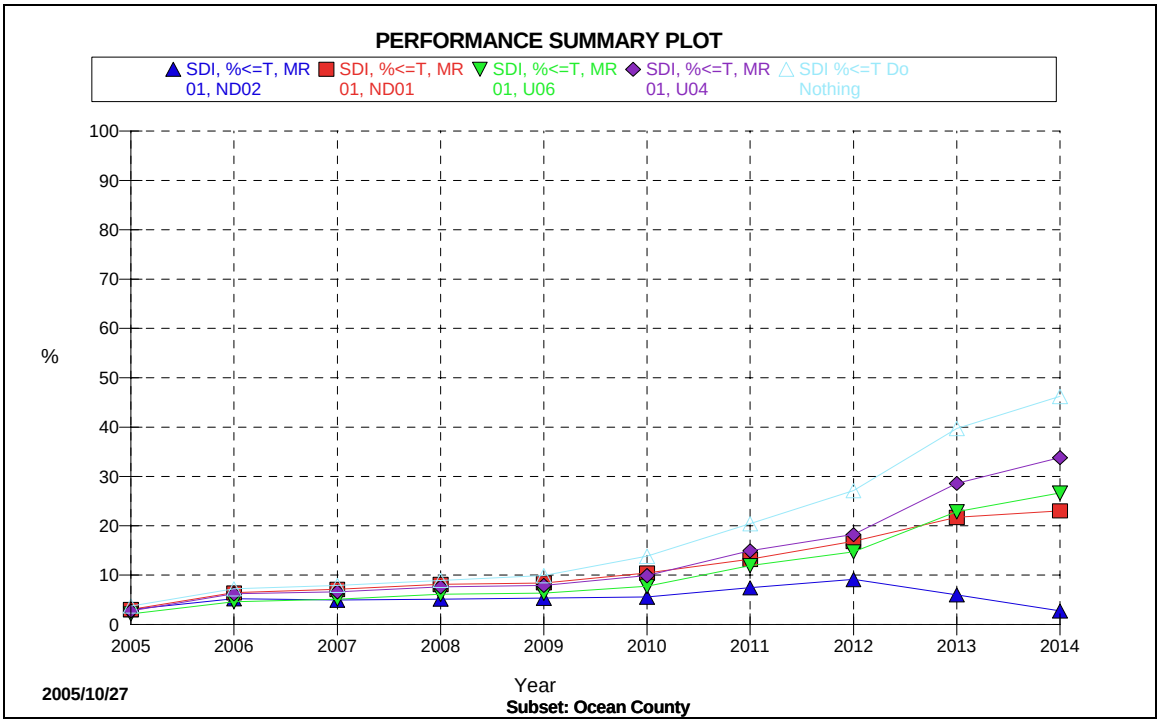

Figure 38: Ocean County Network Percentage Deficiency in Terms of SDI

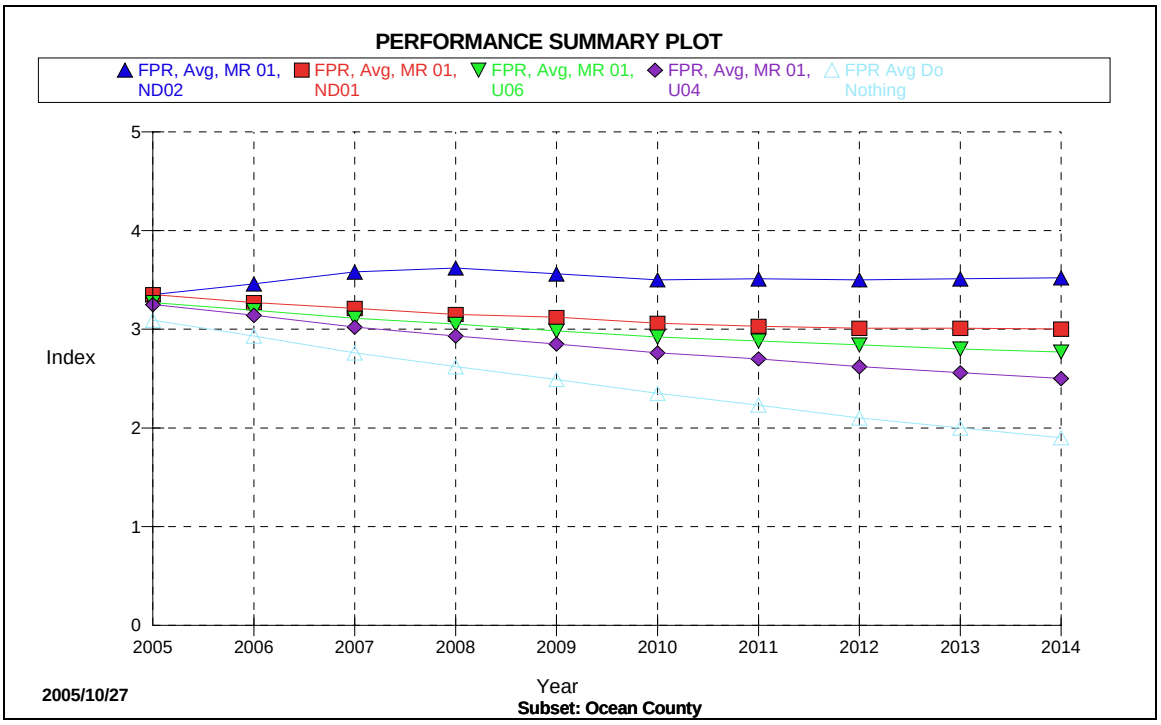

Figure 39: Ocean County Network Average FPR

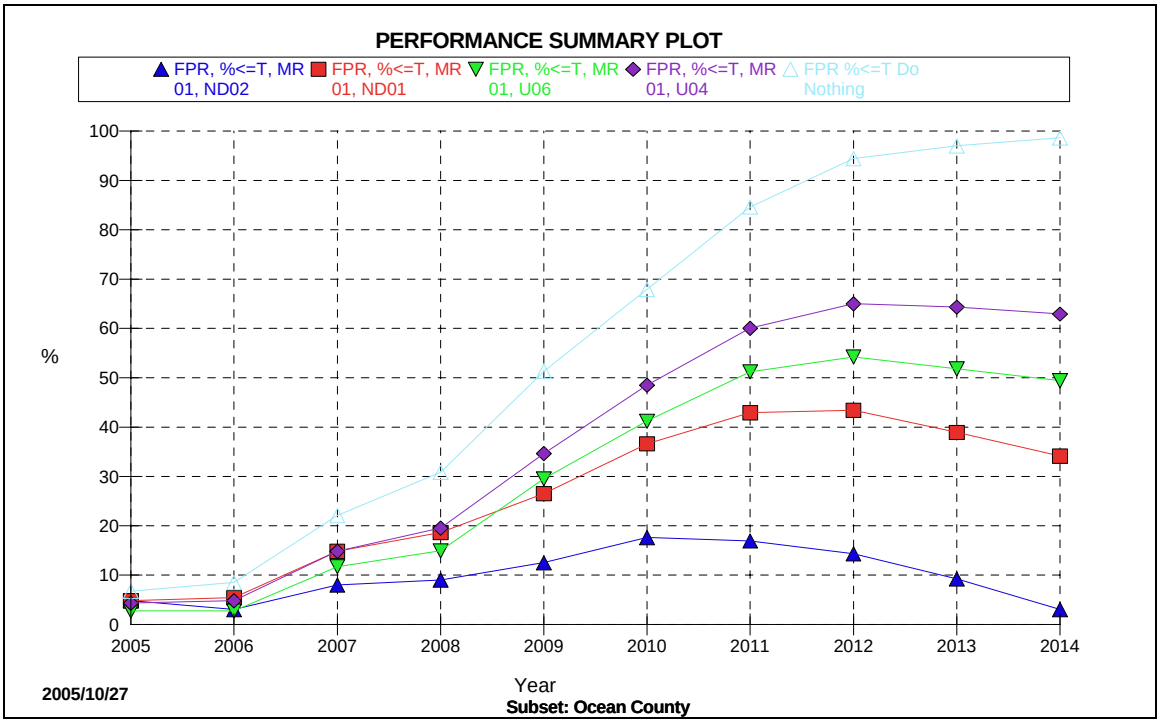

Figure 40: Ocean County Network Percentage Deficiency in Terms of FPR

Budget Summary

For Ocean County, four budget scenarios were run for the entire network. These budget scenarios are U04 ($4.0 million per year), U06 ($6.0 million per year), ND01 (Needs-based analysis to maintain the average RQI, SDI and FPR at 3.0), ND02 (needs-based analysis to achieve an average FPR of 3.5 starting from **2008)**.

The analysis results of these scenarios were described in the previous section. The budgets spent within each of these scenarios over the analysis period are summarized in Table 7.

Table 7: Budget Summaries

Year	U04	U06	ND01	ND02
2005	11,924,975*	13,951,504*	19,903,496**	19,903,496**
2006	3,925,037	5,992,360	6,857,235	22,819,285
2007	3,972,570	5,977,345	7,550,278	18,983,135
2008	3,950,470	5,951,056	7,318,202	17,182,647
2009	3,942,355	5,945,166	7,213,174	7,225,875
2010	3,942,224	5,947,065	6,095,120	7,727,577
2011	3,970,388	5,990,494	7,239,809	11,739,004
2012	3,964,626	5,997,436	8,604,663	9,897,190
2013	3,967,135	5,949,920	8,115,914	13,781,766
2014	3,928,012	5,920,781	7,387,733	15,324,196
Total	**47,487,792**	**67,623,127**	**86,285,624**	**144,584,171**

* Include $8.0 Million to account for spending in 2003 and 2004

** Should be reduced by $8.0 Million to account for spending in 2003 and 2004

SALEM COUNTY

Database Development and Network Condition

This section provides a description of the database developed for Salem County for PMS implementation. This section also summarizes the condition of the network.

Source of Data

The Salem County HPMA database was developed from various sources. The attribute data were extracted from the SLD database (2002), while the County provided the construction history data. The performance data were collected as part of the RT survey for local county roads task conducted in 2003 as part of the Development of the Second Generation of New Jersey Pavement Management System project. In this task, Stantec collected functional pavement data on approximately 17,000 miles (8,500 centerline miles) of Non-NHS FA and SHS routes using its proprietary RT vehicle. This testing included roads within Salem County.

Section Attribute Data

The SLD database available from NJDOT was used to extract information about all available roads, firstly for the RT survey and then for pilot implementation into the HPMA. The following information, based on availability within the SLD database source, was extracted for roads under the jurisdictions of counties and municipalities:

- Administrative System (Functional Class, Funding)
- Jurisdiction (MPO, County, Municipality, Owner)
- Total miles of road – including 500 series roads
- Geometric data (number of lanes, pavement width, shoulder width, median type and width (if applicable))
- Limited traffic counts

Pavement Condition Data

As stated above, the performance data for Salem County was collected in 2003 as part of a task within the Development of the Second Generation of New Jersey Pavement Management System project. The survey was conducted using Stantec's RT3000 survey vehicles that simultaneously collect pavement condition (distress, roughness, rutting), GPS, and video-logging (digital imagery) data.

The roads within Salem County, including the 500 series roads, were surveyed with the RT and the data collected included the following:

- Surface condition in terms of distress severities and extents
- Surface roughness

- Rut depths
- Longitudinal profiles
- Digital video images of right-of-way attributes
- GPS data and coordinates for location referencing

The roughness data was collected and analyzed in terms of the IRI. IRI is the roughness index obtained from the longitudinal profile of the road, and is used to interpret the roughness/smoothness of each road segment. IRI was then used to calculate NJDOT RQI.

Distress data was collected using a semi-automatic process whereby pavement distresses are recorded on an event keyboard. The distress data collection followed NJDOT distress data collection protocol, where each distress type was rated for severity as well as extent. The distress data was then used to calculate NJDOT SDI.

Network Condition

Salem County road network condition was evaluated in terms of RQI, SDI, and the NJDOT overall FPR, which is a function of the RQI and SDI on a scale from 0.0 to 5.0, where 5.0 is the best possible pavement condition. Figure 41 through Figure 43 show the condition of the network in terms of RQI, SDI, and FPR, respectively. In the figure, the condition is shown in categories: Poor (0.0 – 2.0), Fair (2.0 – 3.0), Good (3.0 – 4.0), and Excellent (4.0 – 5.0).

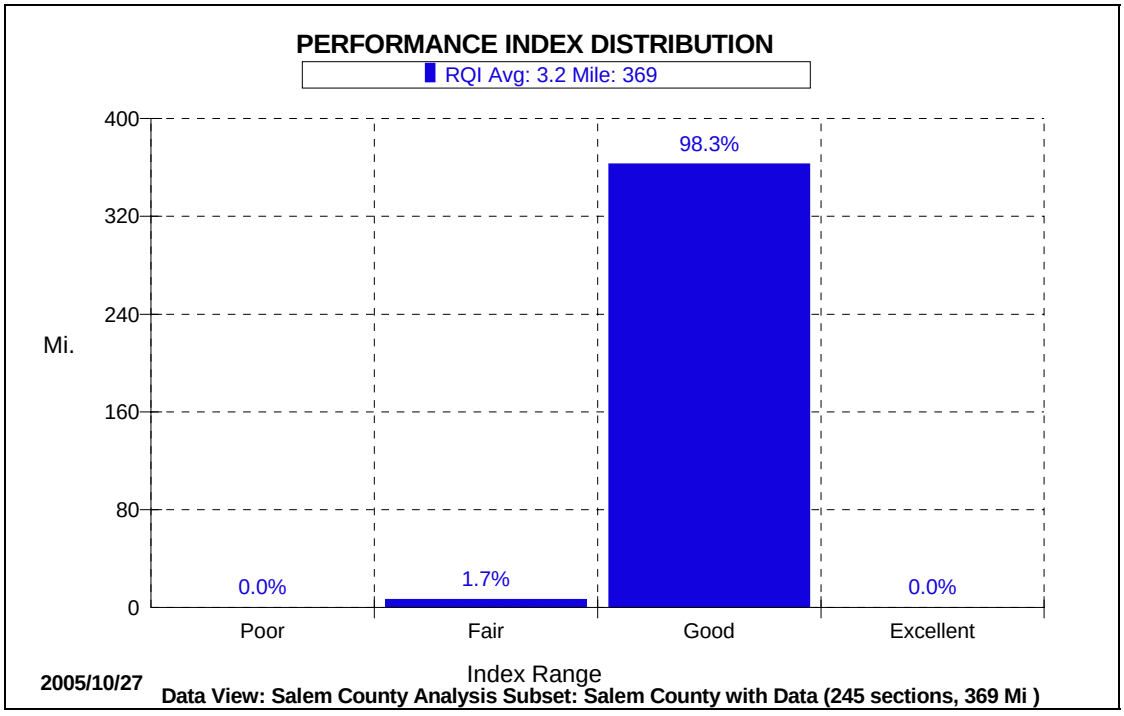

Figure 41: Salem County Network Condition in Terms of RQI

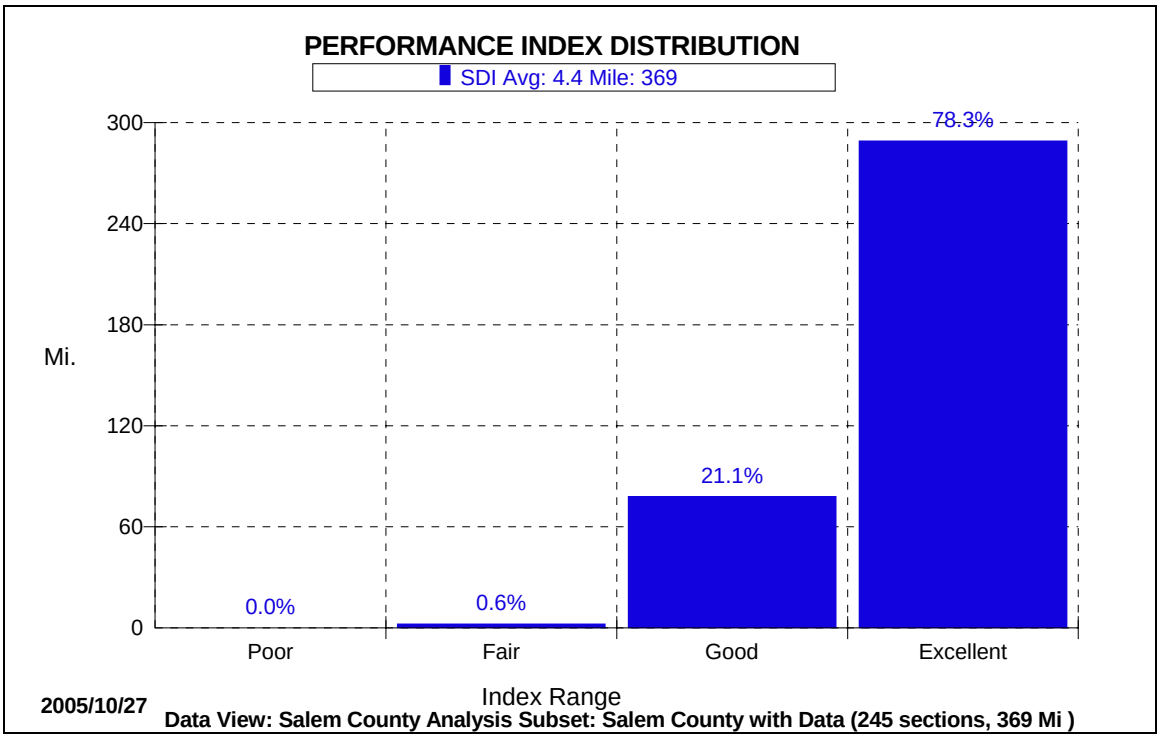

Figure 42: Salem County Network Condition in Terms of SDI

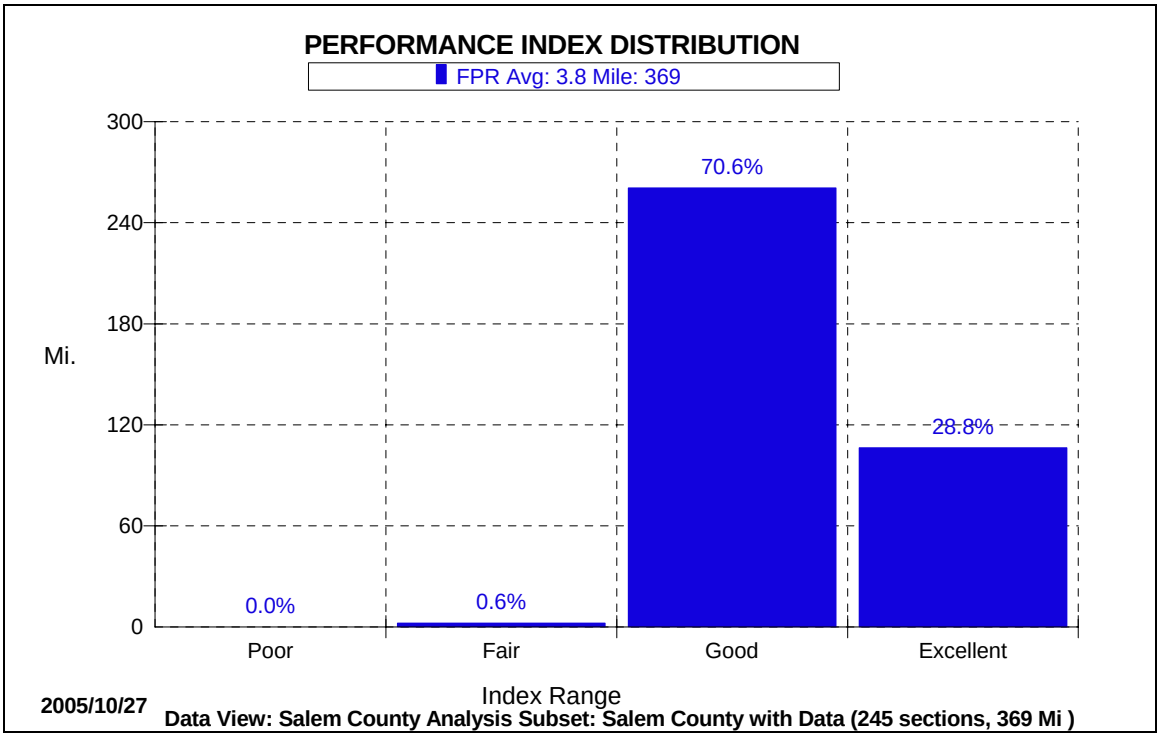

Figure 43: Salem County Network Condition in Terms of FPR

Analysis Models

In this section, the analysis models used for the optimization analysis are presented. These models include the decision trees and the performance prediction models.

Decision Trees

Two decision trees were developed: the first for flexible pavements and the second for rigid pavements. These were based on the feedback received from the staff from each of the selected counties and from Stantec's own experiences. The two trees used for the analysis were:

Flexible Pavements: FPR < 1.5

- Y: Reconstruction
- N: 1.5 ≤ FPR ≤ 3.5
  - Y: SDI or RQI ≤2.0
    - Y: M2O4
    - N: M2O2
  - N: Crack seal/fill

Rigid Pavements: FPR < 1.5

- Y: PPCC R, ACPC (AC Overlay)
- N: 1.5 ≤ FPR ≤ 3.5
  - Y: SDI or RQI ≤2.0
    - Y: 4PCII
    - N: 2PCII
  - N: Crack seal, or surface texturing.

Where,

FPR	=	Final Pavement Rating
SDI	=	Surface Distress Index
RQI	=	Ride Quality Index
M2O2	=	Mill 2", Overlay 2"
M2O4	=	Mill 2", Overlay 4"
PPCC R	=	Partial PCC Reconstruction
ACPC	=	Asphalt Concrete Overlay over Portland Cement Concrete
2PCII	=	Overlay 2" over PCC (II)
4PCII	=	Overlay 4" over PCC (II)

Performance Prediction Models

The NJDOT prediction models were customized to reflect the expected service life of pavements based on discussions with the County engineers and Stantec's own experiences. Figure 44 through Figure 49 present the prediction models for each of the three indices (SDI, RQI, and FPR) for each rehabilitation activity listed within the decision trees depending on the pavement type.

It should be noted that the performance models shown in the figures are based on those used by the NJDOT HPMA for the Interstate and state routes. However, these models were revised after feedback from Salem County in order to extend the service life the pavements by 2 to 3 years.

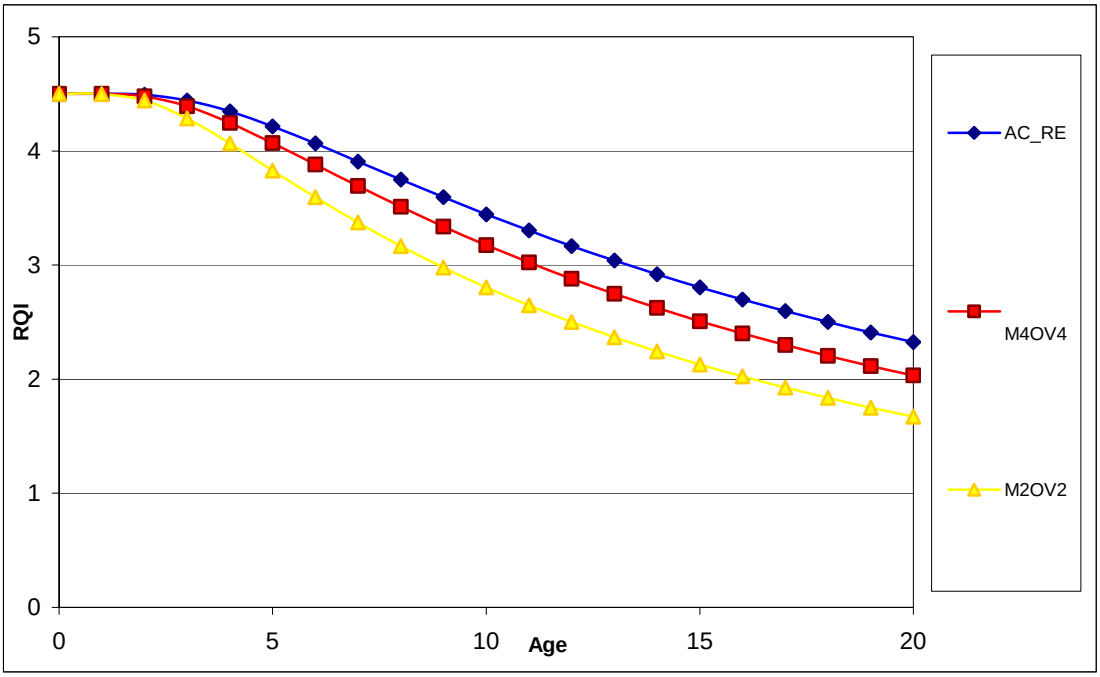

Figure 44: Performance RQI Model for AC Rehabilitation Activities

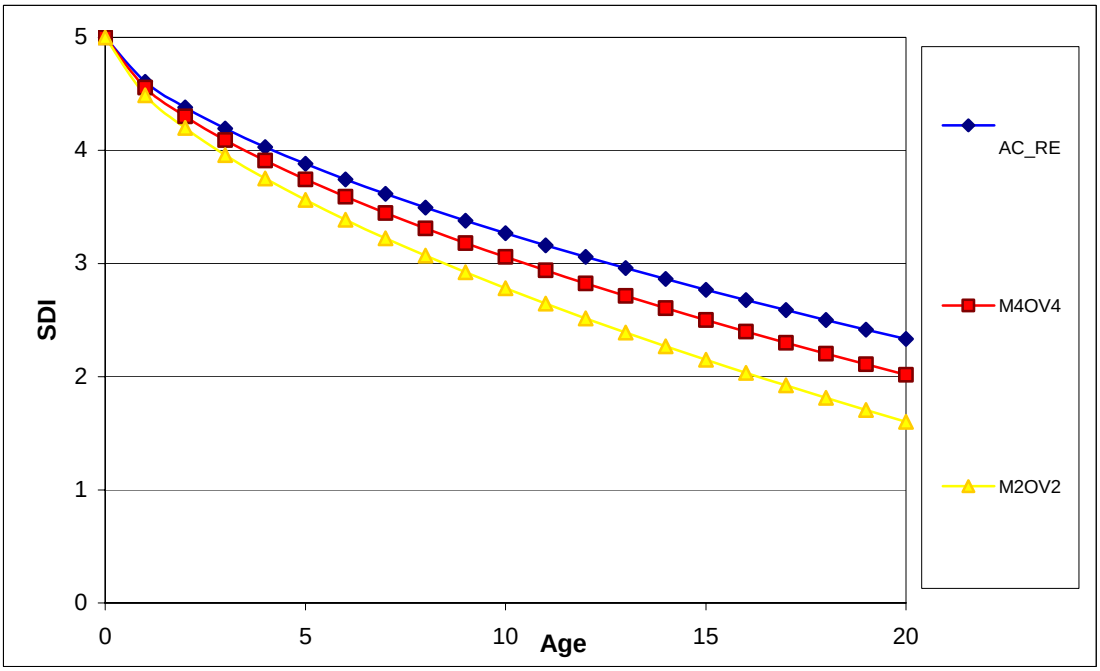

Figure 45: Performance SDI Model for AC Rehabilitation Activities

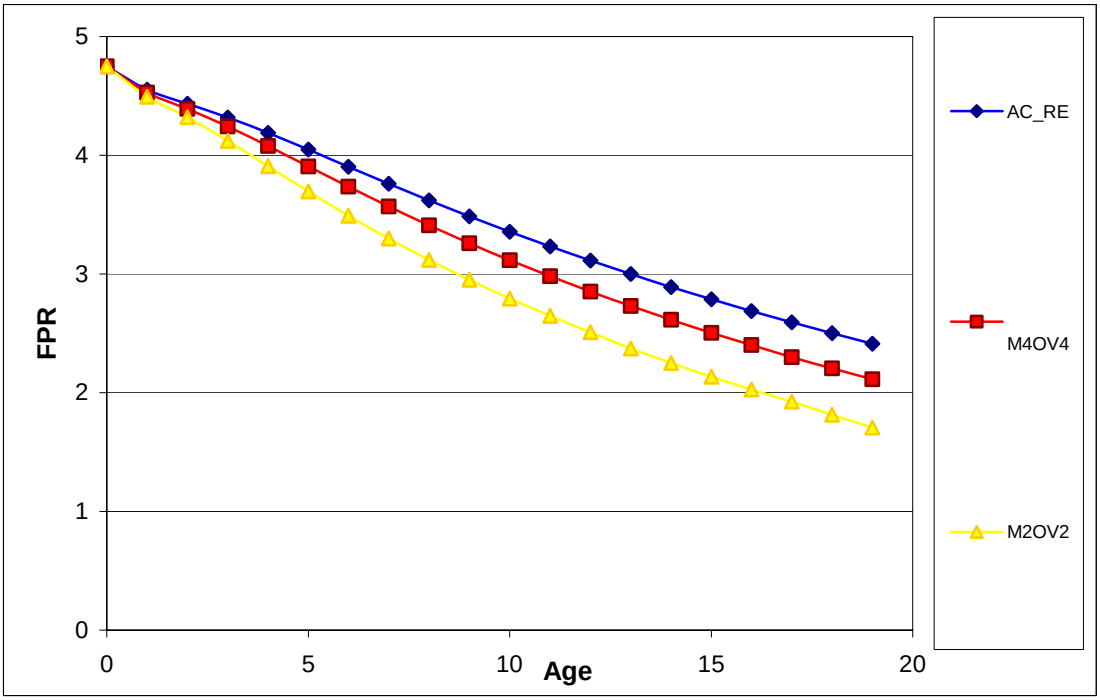

Figure 46: Performance FPR Model for AC Rehabilitation Activities

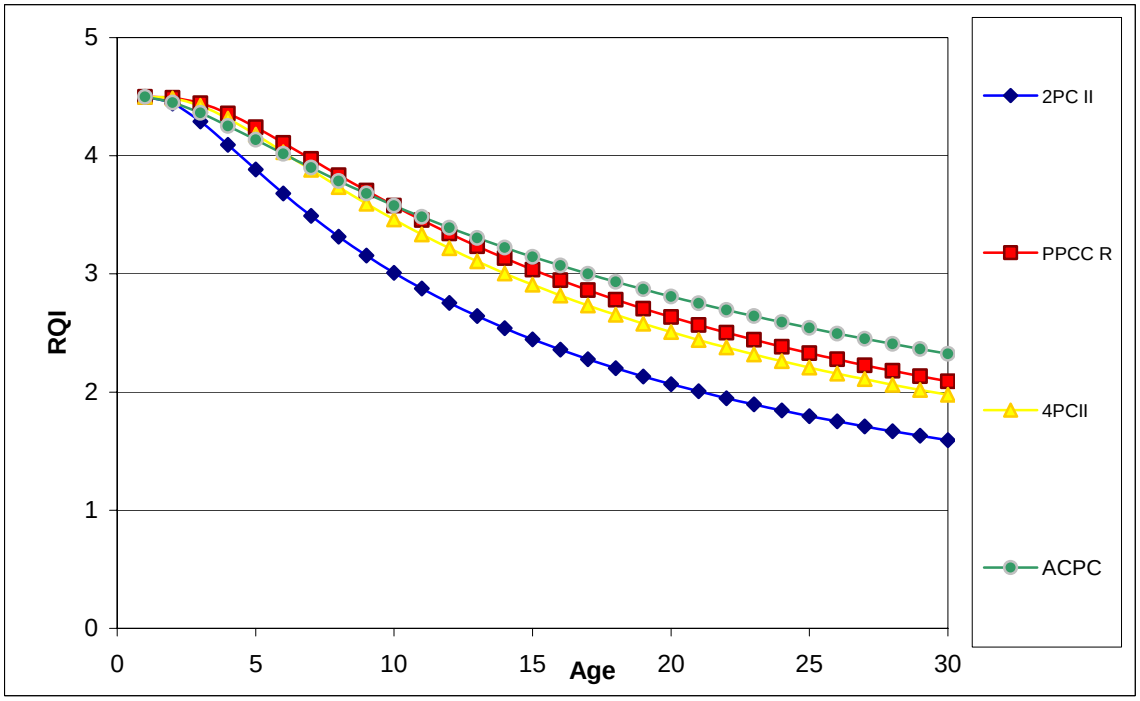

Figure 47: Performance RQI Model for PCC Rehabilitation Activities

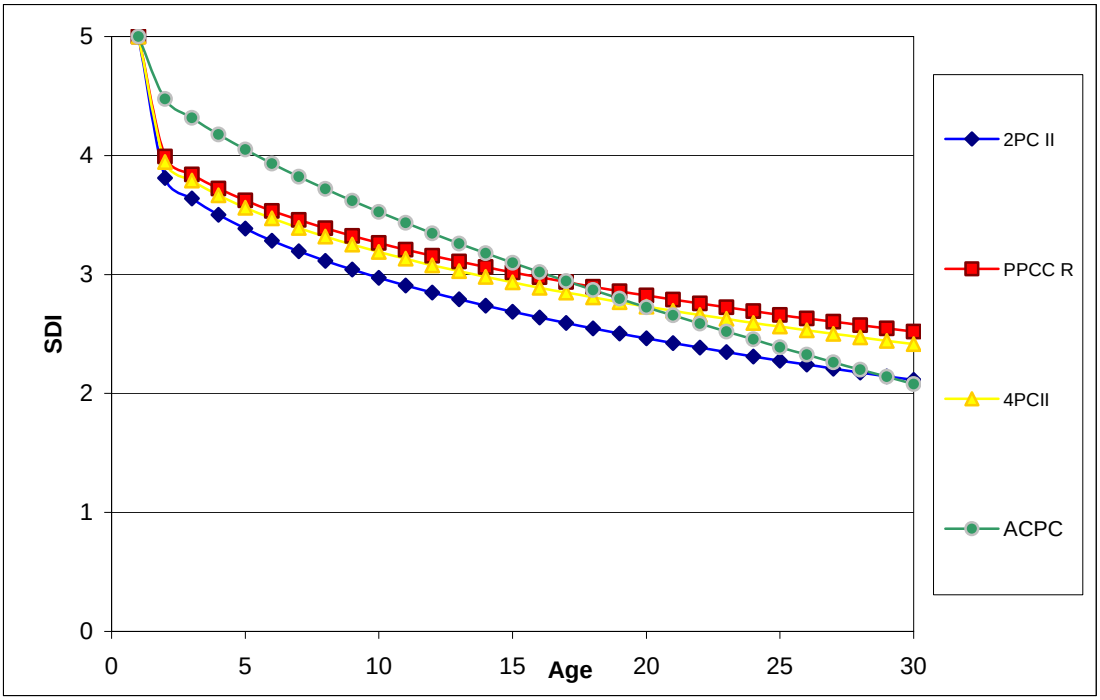

Figure 48: Performance SDI Model for PCC Rehabilitation Activities

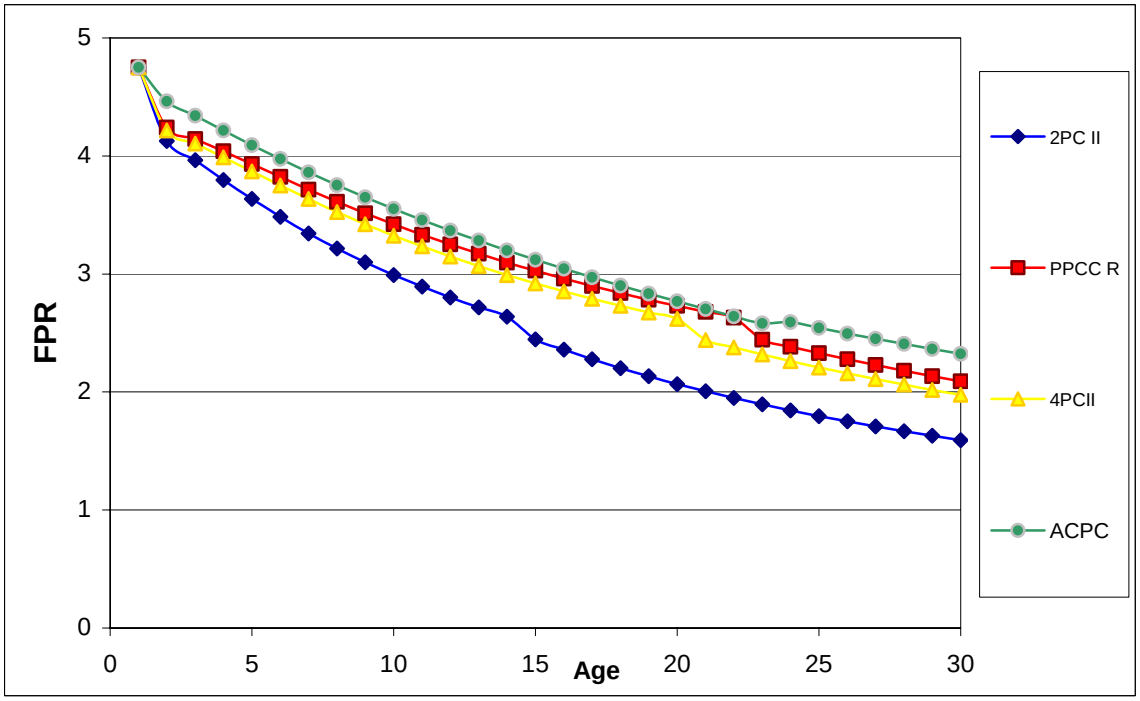

Figure 49: Performance FPR Model for PCC Rehabilitation Activities

Budget Scenario Analysis

For the Salem County analysis, four budget scenarios were considered. The budget figures were obtained from discussions with Salem County engineers, and updated during the meetings held in February 2005. The project lengths for the budget scenarios were set to a maximum of 2.0 miles. The four budget scenarios are:

1. U02 – 2 million dollars per year starting from 2006 through 2014 ($8 mil in 2005)

2. U03 – 3 million dollars per year starting from 2006 through 2014 ($9 mil in 2005)

3. ND01 – A Needs Budget Analysis, where an unlimited budget is available to maintain the average RQI, SDI and FPR at level of 3.0 starting from 2005 through 2014.

4. ND02 – A Needs Budget Analysis, where an unlimited budget is available to achieve an average FPR at level of 3.5 starting from **2007** through 2014.

It should be noted that the pavement condition data was last collected in 2003, but no information about the rehabilitation projects was available for the years 2003 and 2004. Therefore, in order to account for the missing as built data and the actual spending on pavement rehabilitation since the last data collection cycle, extra budget was added in 2005, where $6 million ($3 million for each of 2003 and 2004) was added to the 2005 budget for the budget-constrained analyses, which are U02, U03, and U05.

Analysis Parameters

The analysis parameters were based on Stantec's past project experiences in New Jersey and the feedback from the Salem County engineers. The parameters used in the analysis were as follows:

- The decision trees are set up based on SDI and RQI, which were shown previously.

- Since the analysis period extends to 2014, some projects may need to be rehabilitated more than once within the analysis period, depending on the first rehabilitation treatment prediction model.

- The trigger levels for analysis, and deficiency levels, for RQI and SDI are 2.0 and 2.5 for Local and Collector roads, respectively.

- The analysis is based on the latest performance data available for each section.

- The rehabilitation treatments and unit cost settings used in the analysis are the standard analysis settings used for all previous budget scenario analyses in the NJDOT HPMA that were defined in 2003. These settings are shown in Table 8.

Table 8: Rehabiliation Treatments Unit Costs

Pavement Type	ID	Description	Cost ($/s.y.)
Flexible Pavements	M+OV2	Mill 2"+ Overlay2"	18.60
	M2+OV4	Mill 2"+ Overlay4"	36.00
	ACRe	AC Reconstruction	86.8
Rigid Pavements	2PC II	Overlay2" over PC II	59.50
	PPCC R	Partial PCC Reconstruction	61.10
	4PCII	Overlay4" over PC II	63.30
	ACPC	Pubb PCC+OV6"	65.10

Analysis Results

The results of the Salem County Budget Scenario are presented in the following graphs. Figure 50 shows the total cost per year for Salem County for an analysis period of 10 years in terms of the budget scenarios ND01 (average FPR=3.0) and ND02 (average FPR=3.5). It should be noted the budget in the first year (2005) should be reduced by $6 million to reflect the actual spending in the years 2003 and 2004.

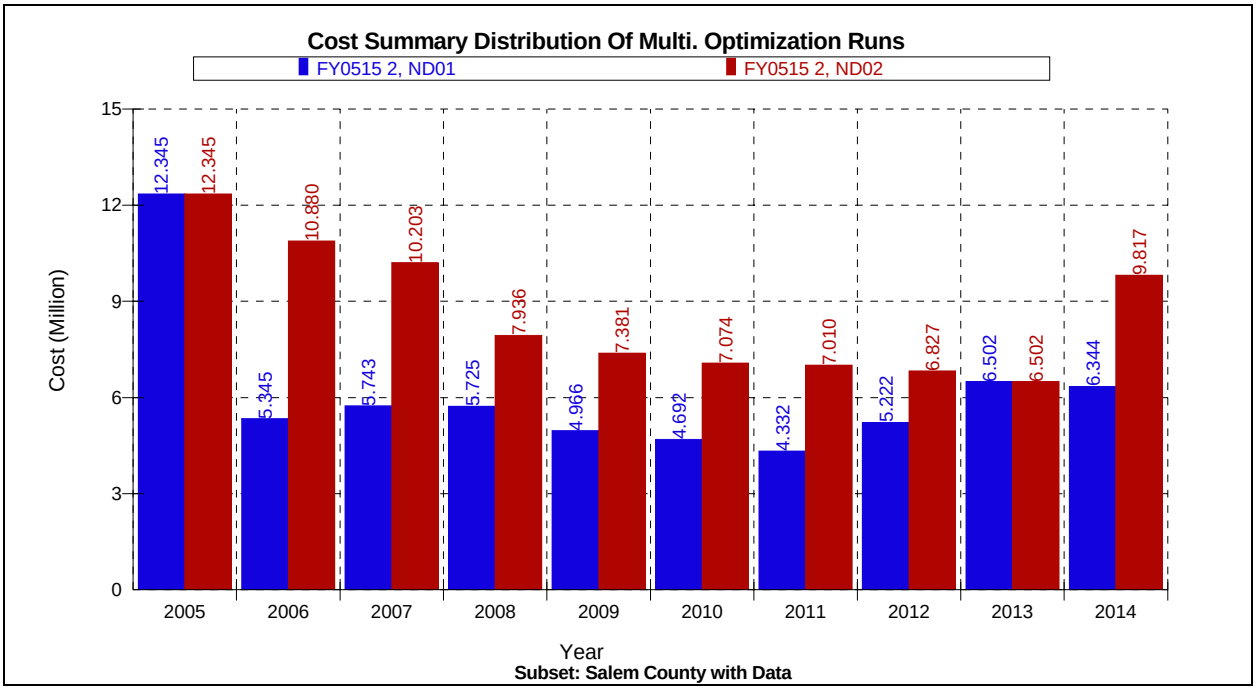

Figure 50: Need Analyses Costs - Total Cost Per Year for Salem County

Figure 51 through Figure 56 show the network average and network percentage deficiency under each budget scenario in terms of the three performance indices.

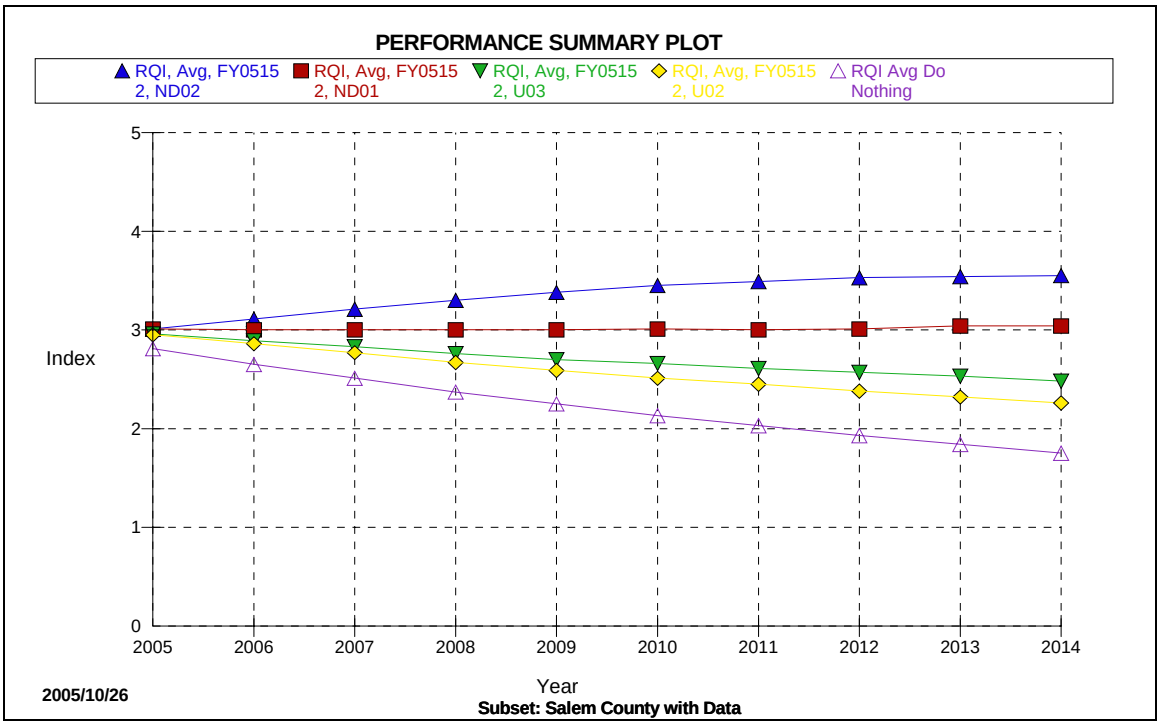

Figure 51: Salem County Network Average RQI

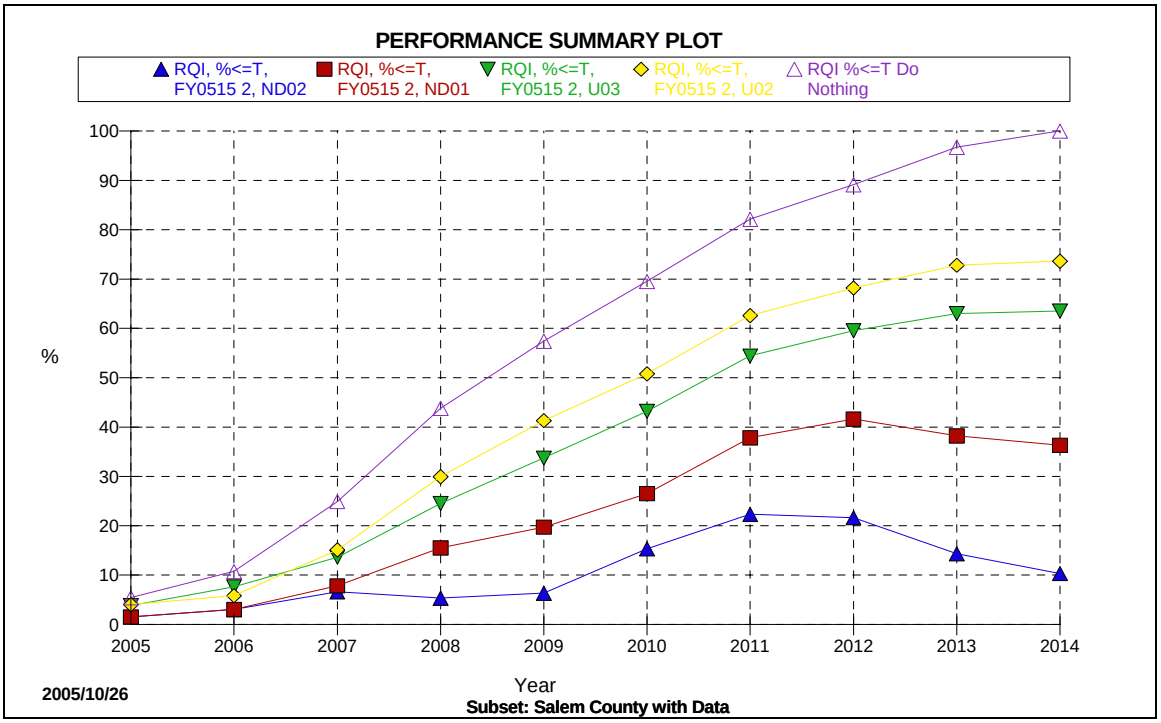

Figure 52: Salem County Network Percentage Deficiency in Terms of RQI

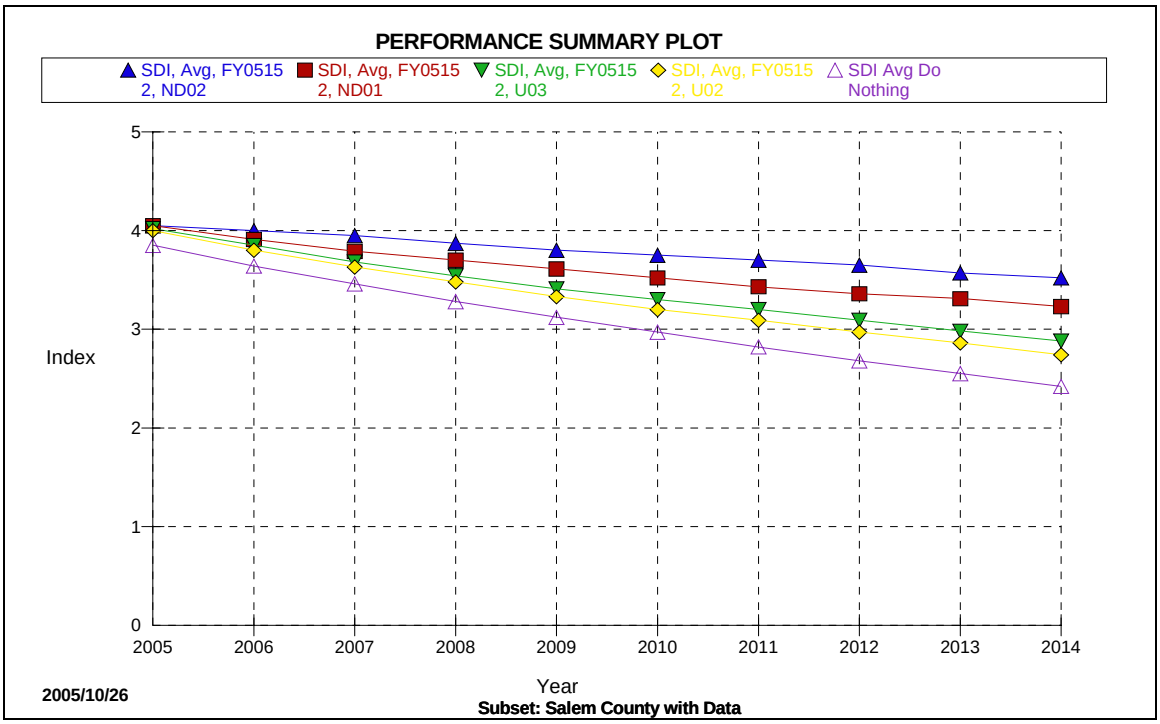

Figure 53: Salem County Network Average SDI

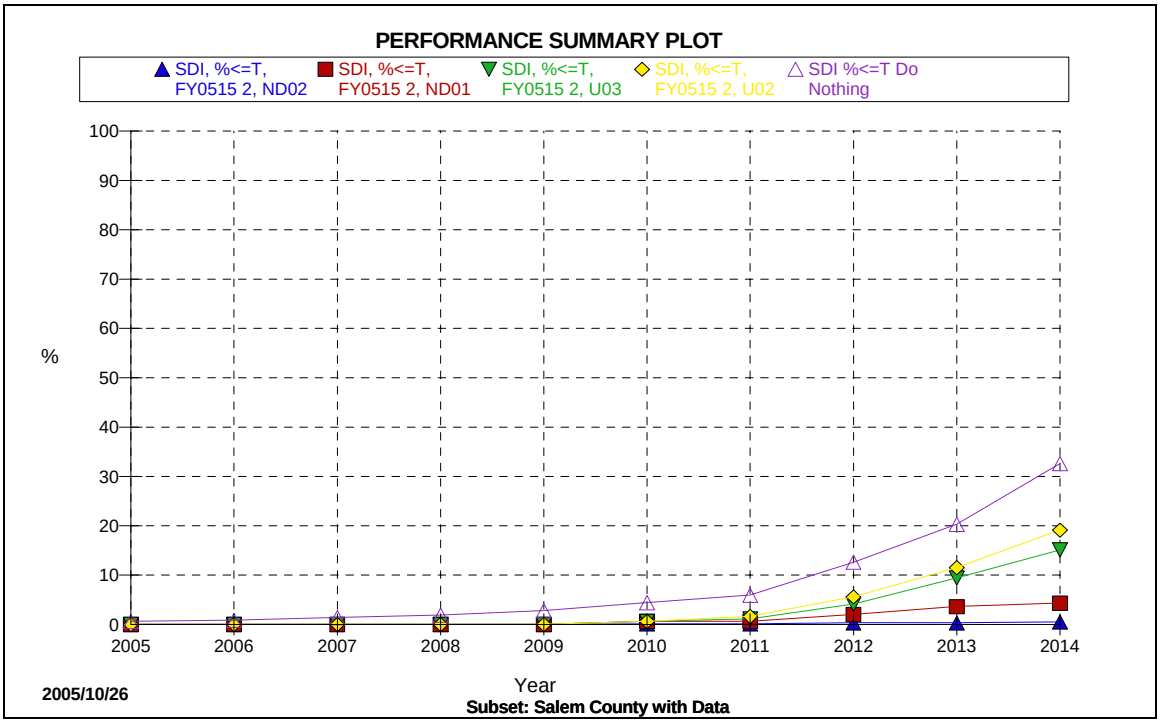

Figure 54: Salem County Network Percentage Deficiency in Terms of SDI

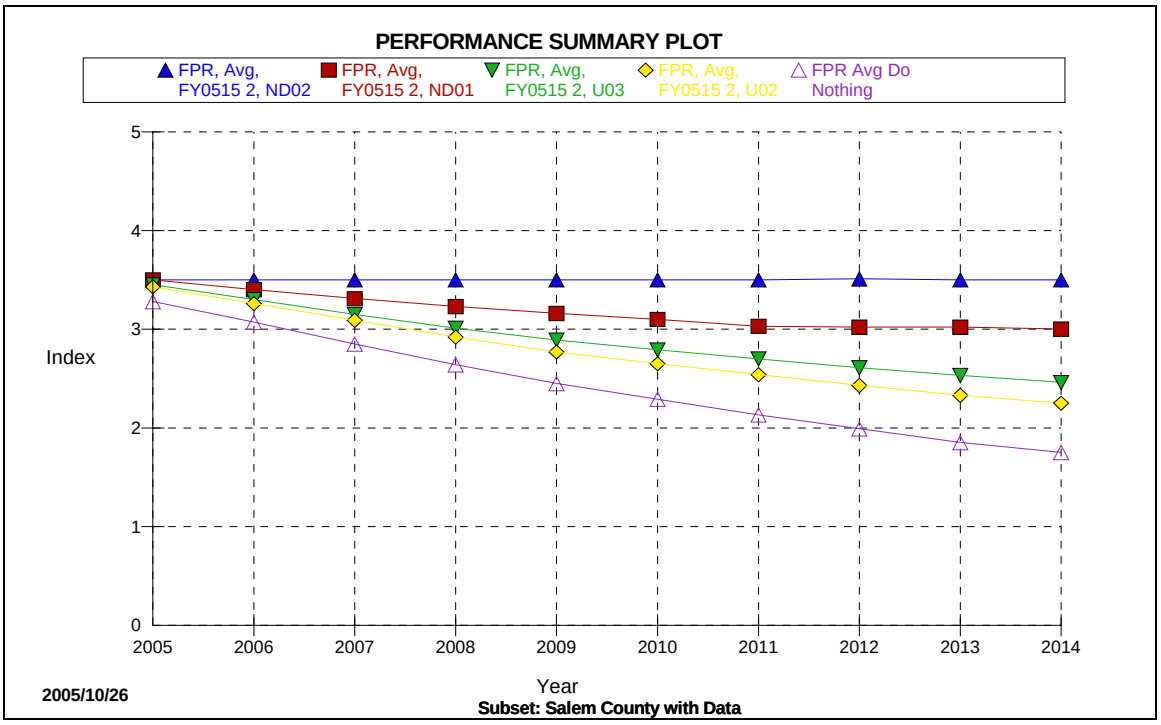

Figure 55: Salem County Network Average FPR

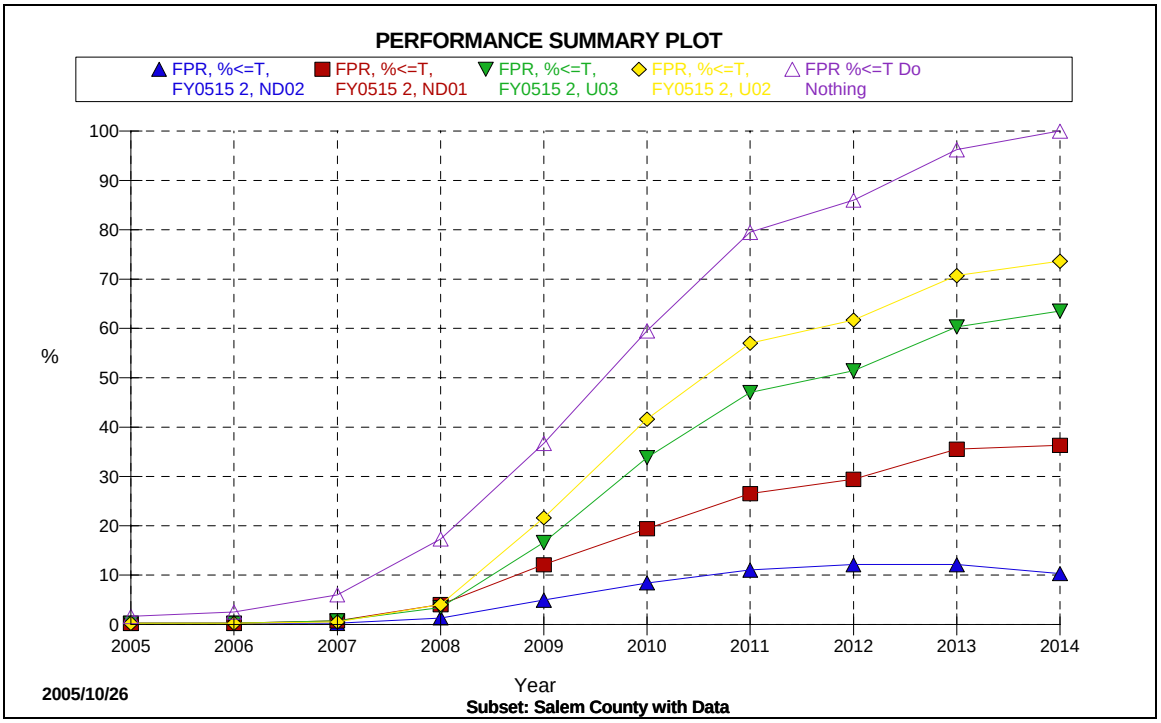

Figure 56: Salem County Network Percentage Deficiency in Terms of FPR

Budget Summary

For Salem County, four budget scenarios were run for the entire network. These budget scenarios are U02 ($2.0 million per year), U03 ($3.0 million per year), ND01 (Needs-based analysis to maintain the average RQI, SDI and FPR at 3.0), ND02 (needs-based analysis to achieve an average FPR of 3.5 starting from **2007)**.

The analysis results of these scenarios were described in the previous section. The budgets spent within each of these scenarios over the analysis period are summarized in Table 9.

Table 9: Budget Summaries

Year	U02	U03	ND01	ND02
2005	7,992,690*	8,988,480*	12,344,891**	12,344,891**
2006	1,984,707	2,997,050	5,344,591	10,880,142
2007	1,989,629	2,999,754	5,743,316	10,203,484
2008	1,992,569	2,963,156	5,725,199	7,936,386
2009	1,989,302	2,994,683	4,965,724	7,381,382
2010	1,993,355	2,997,430	4,691,735	7,074,087
2011	1,997,224	2,982,214	4,331,871	7,010,210
2012	1,960,065	2,951,784	5,221,656	6,827,181
2013	1,964,160	2,987,706	6,501,697	6,501,697
2014	1,928,879	2,949,151	6,344,275	9,817,453
Total	**25,792,580**	**35,811,408**	**61,214,955**	**85,976,913**

* Include $6.0 Million to account for spending in 2003 and 2004

** Should be reduced by $6.0 Million to account for spending in 2003 and 2004

UNION COUNTY

Database Development

This section provides a description of the database developed for Union County for PMS implementation. This section also summarizes the condition of the network.

Data Sources

The Union County HPMA database was developed from various sources. The attribute data were extracted from the SLD database (2002), while the County provided the construction history data. The performance data were collected as part of the RT survey for local county roads task conducted in 2003 as part of the Development of the Second Generation of New Jersey Pavement Management System project. In this task, Stantec collected functional pavement data on approximately 17,000 miles (8,500 centerline miles) of Non-NHS FA and SHS routes using its proprietary RT vehicle. This testing included roads within Union County.

Section Attribute Data

The SLD database available from NJDOT was used to extract information about all available roads, firstly for the RT survey and then for pilot implementation into the HPMA. The following information, based on availability within the SLD database source, was extracted for roads under the jurisdictions of counties and municipalities:

- Administrative System (Functional Class, Funding)
- Jurisdiction (MPO, County, Municipality, Owner)
- Total miles of road – including 500 series roads
- Geometric data (number of lanes, pavement width, shoulder width, median type and width (if applicable))
- Limited traffic counts

As Built Data

Construction history information for the pavement sections rehabilitated between 2003 and 2005 were provided by Union County. This information was compiled based on the street names and SLD attribute information, and loaded to the Union County HPMA. The list of projects compiled from the data provided by Union County and loaded to the HPMA is shown in Table 10.

Table 10: Pavement Sections Rehabilitated between 2003 and 2005

Route Type	Route No	Dir	Length (Miles)	MP From	MP To	Year
CO	655	B	1.05	5.79	6.84	2003
CO	607	B	0.51	1.3	1.82	2003
CO	614	B	0.43	0.3	0.72	2003
CO	656	B	0.82	0	0.71	2003
CO	623	B	0.31	1.98	3.59	2003
CO	509	S	0.33	8.48	8.81	2003
CO	514	B	1.23	41.15	42.4	2003
CO	645	B	0.66	0.49	1.15	2003
CO	641	B	0.39	0	0.39	2003
CO	647	B	0.44	2.05	2.49	2003
CO	601	B	1.84	1.89	3.73	2003
CO	531	B	1.13	8.06	9.19	2003
CO	630	B	3.64	0.19	3.83	2004
CO	640	B	0.69	0.53	1.22	2004
CO	611	B	1.02	1.53	2.55	2004
CO	619/625	B	1.24	0.81	2.18	2004
CO	607	B	0.41	1.82	2.24	2004
CO	607	B	0.75	0.4	1.15	2004
CO	655	B	0.37	0	0.36	2004
CO	619	B	0.16	1.32	1.48	2004
CO	621	B	0.18	1.62	1.75	2004
CO	514	B	0.57	39.55	42.06	2004
CO	621	B	0.36	1.18	1.63	2004
CO	625	B	0.78	1.48	2.29	2004
CO	612	B	0.71	2.35	3.06	2004
CO	612	B	0.87	1.48	2.35	2004
CO	512	B	1.69	30.81	32.5	2005
CO	622	B	2.14	2.69	4.83	2005
CO	658	B	0.9	0	0.84	2005
CO	619	B	1.1	4.55	5.65	2005
CO	628	B	0.7	0	0.73	2005
CO	617	B	0.75	2.77	3.48	2005
CO	655	B	0.97	0.36	1.33	2005
CO	632	B	1.1	0.14	1.25	2005
LO	1293	B	1.01	0.59	1.6	2005

Pavement Condition Data

As stated above, the performance data for Union County was collected in 2003 as part of a task within the Development of the Second Generation of New Jersey Pavement Management System project. The survey was conducted using Stantec's RT3000 survey vehicles that simultaneously collect pavement condition (distress, roughness, rutting), GPS, and video-logging (digital imagery) data.

The roads within Union County, including the 500 series roads, were surveyed with the RT and the data collected included the following:

- Surface condition in terms of distress severities and extents
- Surface roughness
- Rut depths
- Longitudinal profiles
- Digital video images of right-of-way attributes
- GPS data and coordinates for location referencing

The roughness data was collected and analyzed in terms of the IRI. IRI is the roughness index obtained from the longitudinal profile of the road, and is used to interpret the roughness/smoothness of each road segment. IRI was then used to calculate NJDOT RQI.

Distress data was collected using a semi-automatic process whereby pavement distresses are recorded on an event keyboard. The distress data collection followed NJDOT distress data collection protocol, where each distress type was rated for severity as well as extent. The distress data was then used to calculate NJDOT SDI.

Network Condition

Union County road network condition was evaluated in terms of RQI, SDI, and the NJDOT overall FPR, which is a function of the RQI and SDI on a scale from 0.0 to 5.0, where 5.0 is the best possible pavement condition. Figure 57 through Figure 59 show the condition of the network in terms of RQI, SDI, and FPR, respectively. In the figure, the condition is shown in categories: Poor (0.0 – 2.0), Fair (2.0 – 3.0), Good (3.0 – 4.0), and Excellent (4.0 – 5.0).

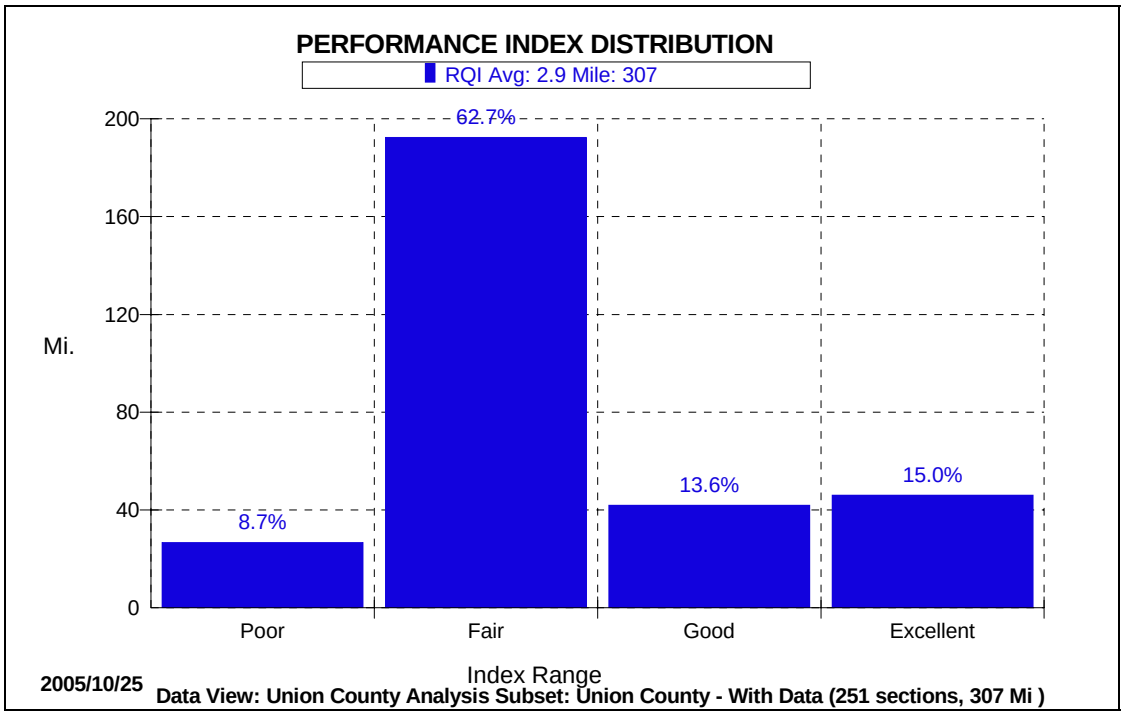

Figure 57: Union County Network Condition in Terms of RQI

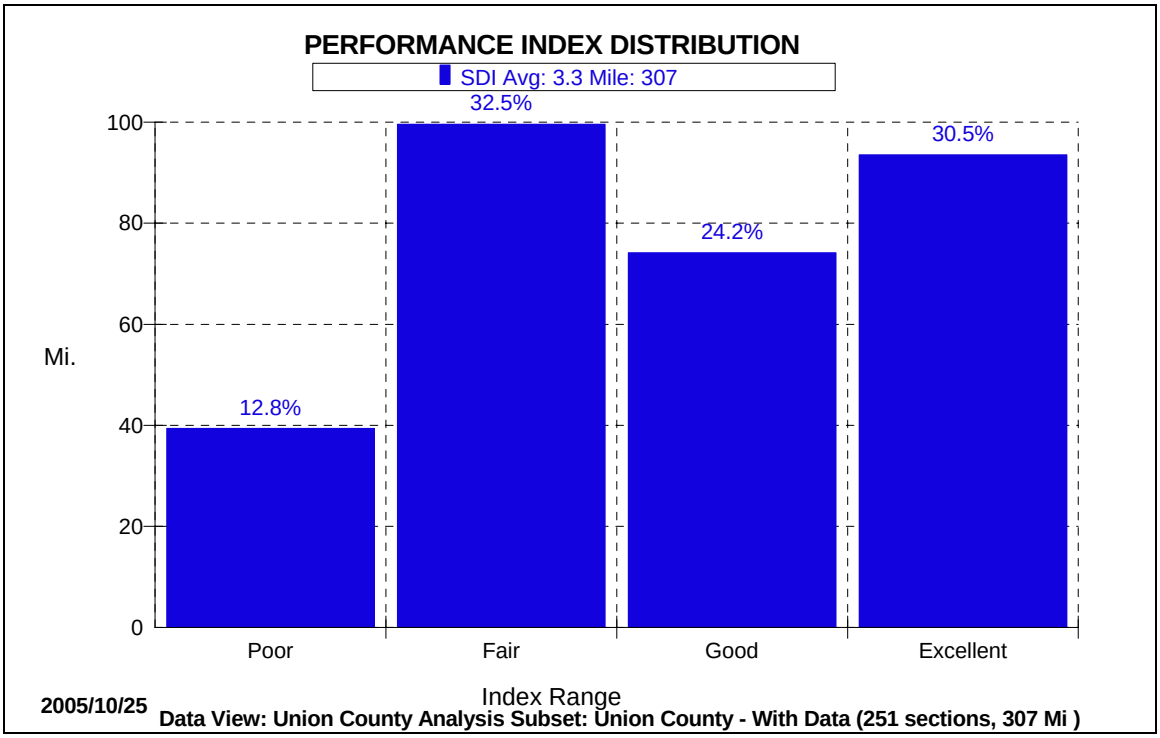

Figure 58: Union County Network Condition in Terms of SDI

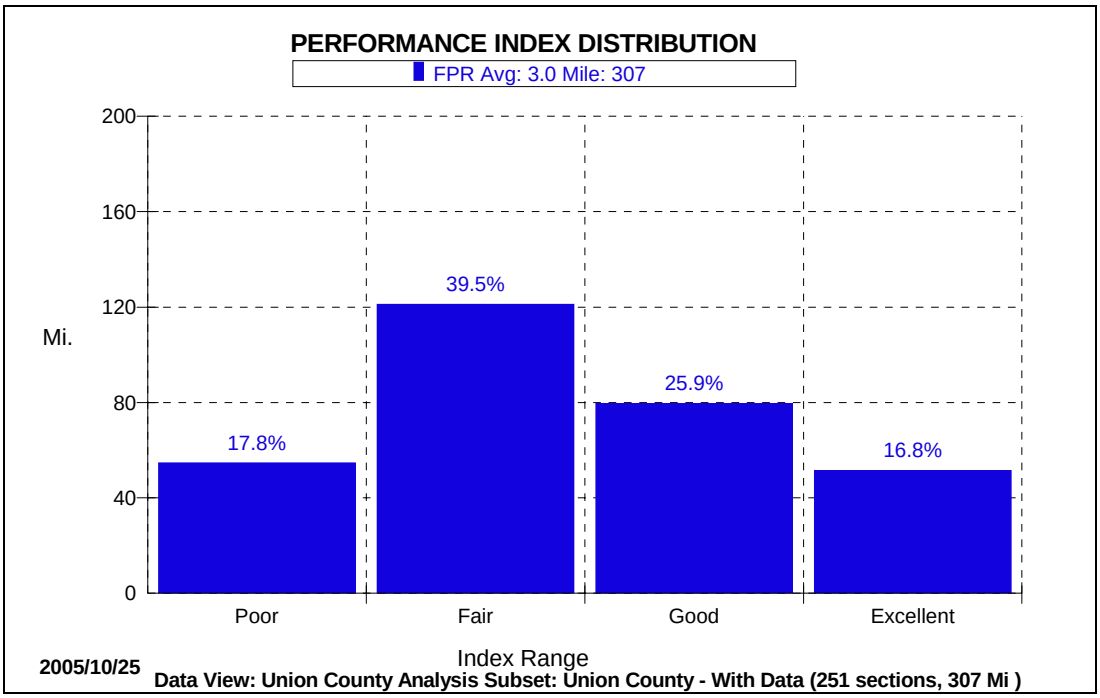

Figure 59: Union County Network Condition in Terms of FPR

Analysis Models

In this section, the analysis models used for the optimization analysis are presented. These models include the decision trees and the performance prediction models.

Decision Trees

Two decision trees were developed: the first for flexible pavements and the second for rigid pavements. These were based on the feedback received from the staff from each of the selected counties and from Stantec's own experiences. The two trees used for the analysis were:

Flexible Pavements:

FPR < 1.5
- Y: Reconstruction
- N: 1.5 ≤ FPR ≤ 3.5
  - Y: SDI or RQI ≤2.0
    - Y: M2O4
    - N: M2O2
  - N: Crack seal/fill

Rigid Pavements:

FPR < 1.5
- Y: PPCC R, ACPC (AC Overlay)
- N: 1.5 ≤ FPR ≤ 3.5
  - Y: SDI or RQI ≤2.0
    - Y: 4PCII
    - N: 2PCII
  - N: Crack seal, or surface texturing.

Where,

FPR	=	Final Pavement Rating
SDI	=	Surface Distress Index
RQI	=	Ride Quality Index
M2O2	=	Mill 2", Overlay 2"
M2O4	=	Mill 2", Overlay 4"
PPCC R	=	Partial PCC Reconstruction
ACPC	=	Asphalt Concrete Overlay over Portland Cement Concrete
2PCII	=	Overlay 2" over PCC (II)
4PCII	=	Overlay 4" over PCC (II)

Performance Prediction Models

The NJDOT prediction models were customized to reflect the expected service life of pavements based on discussions with the County engineers and Stantec's own experiences. Figure 60 through Figure 65 present the prediction models for each of the three indices (SDI, RQI, and FPR) for each rehabilitation activity listed within the decision trees depending on the pavement type.

It should be noted that the performance models shown in the figures are based on those used by the NJDOT HPMA for the Interstate and state routes. However, these models were revised after feedback from Union County in order to extend the service life the pavements by 2 to 3 years.

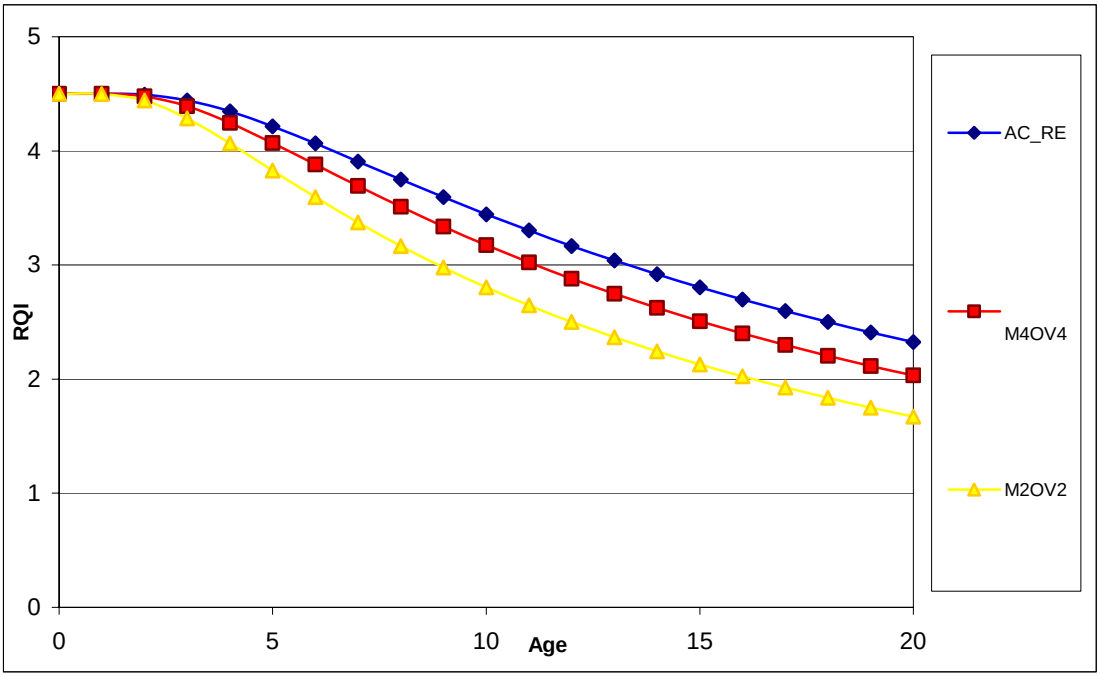

Figure 60: Performance RQI Model for AC Rehabilitation Activities

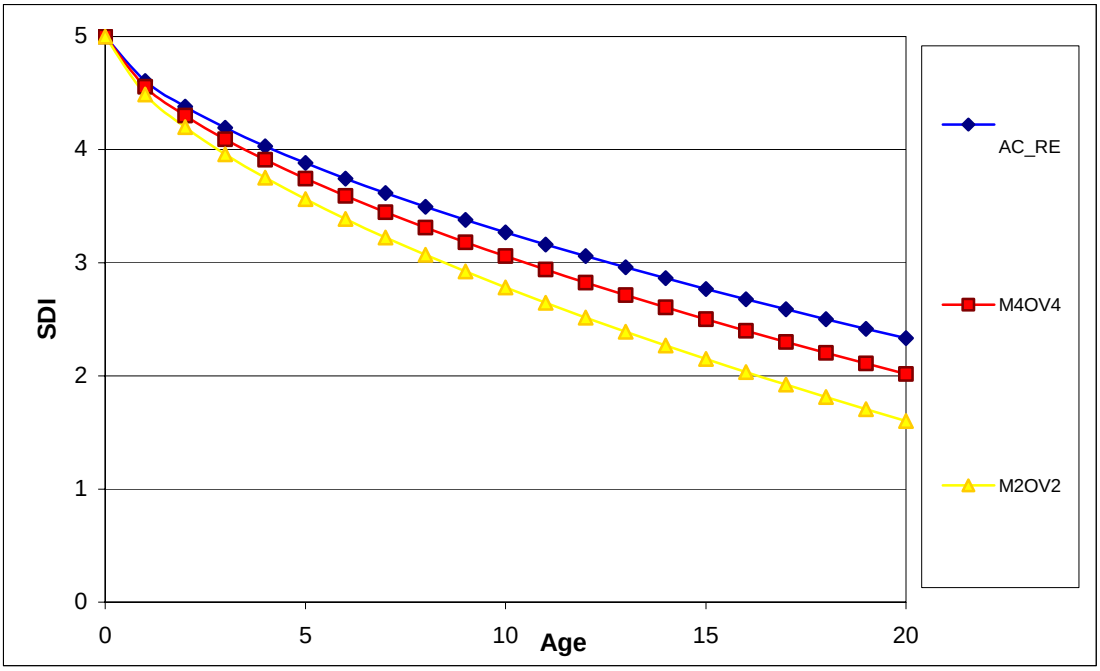

Figure 61: Performance SDI Model for AC Rehabilitation Activities

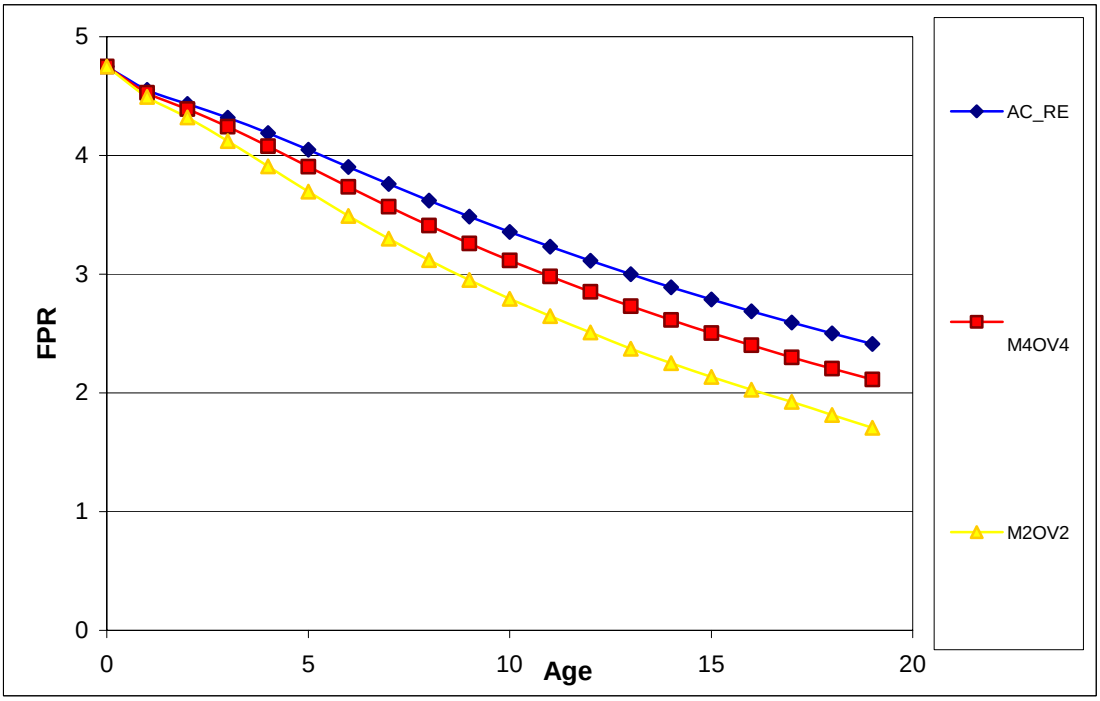

Figure 62: Performance FPR Model for AC Rehabilitation Activities

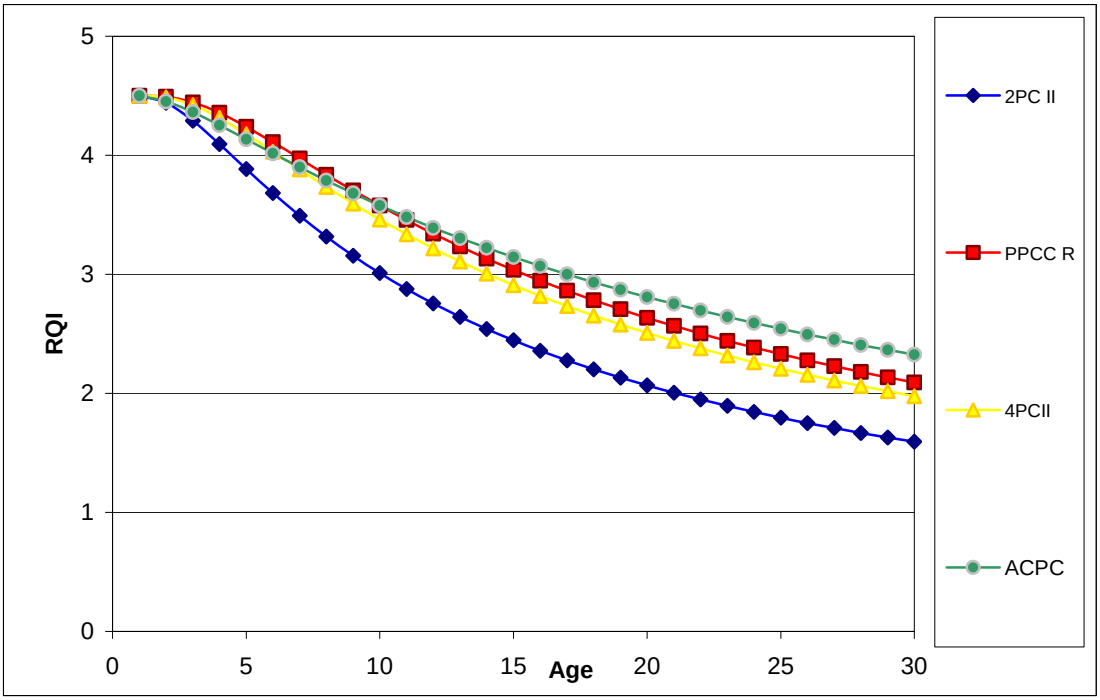

Figure 63: Performance RQI Model for PCC Rehabilitation Activities

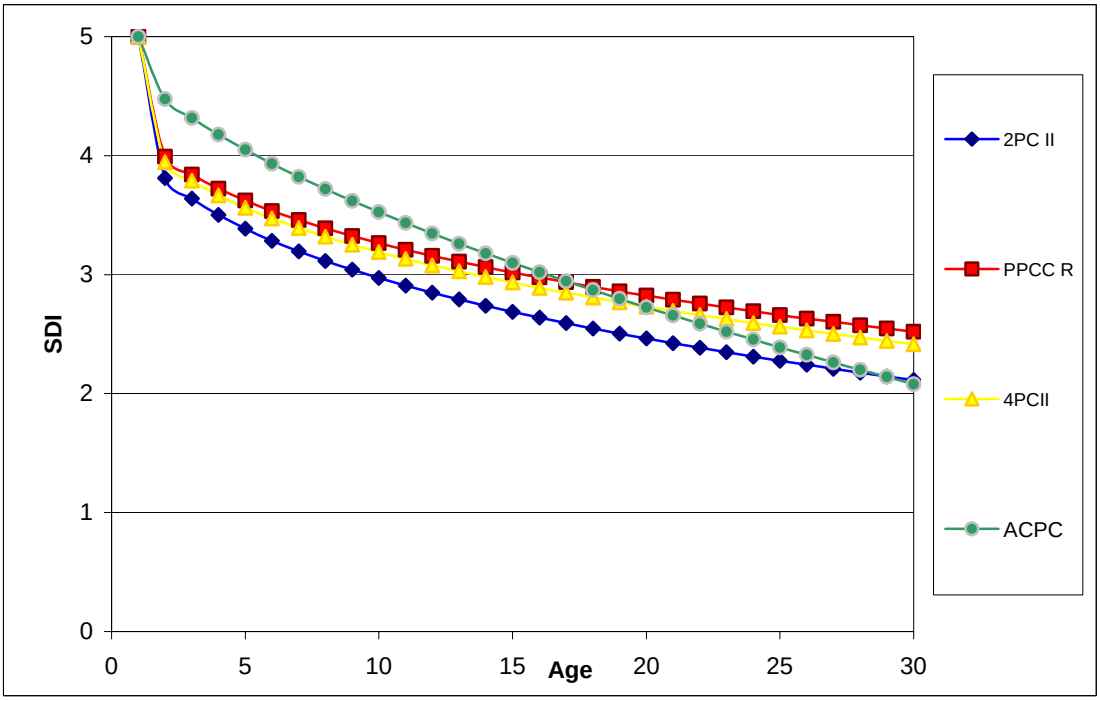

Figure 64: Performance SDI Model for PCC Rehabilitation Activities

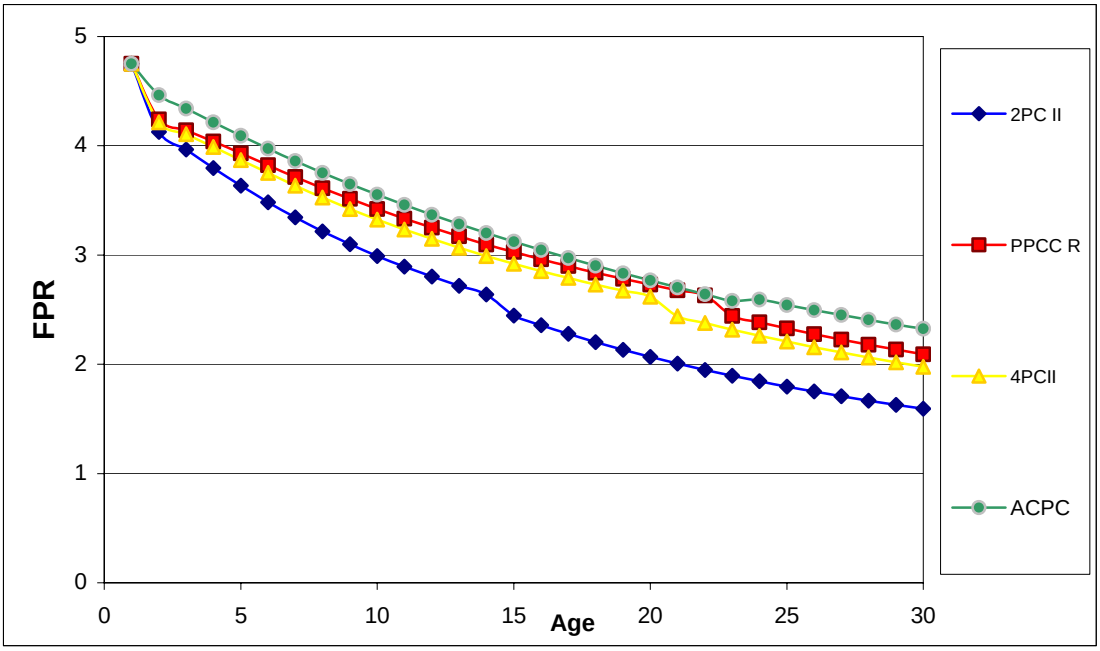

Figure 65: Performance FPR Model for PCC Rehabilitation Activities

Budget Scenario Analysis

For the Union County analysis, three budget scenarios were considered. The budget figures were obtained from discussions with Nicholas J. Pantina from Union County. The project lengths for the budget scenarios were set to a maximum of 3.0 miles. The three budget scenarios were:

1. U03 - 3 million dollars per year from 2005 through 2014.
2. U05 - 5 million dollars per year from 2005 through 2014.
3. ND01 - a Needs Budget Analysis, where an unlimited budget is available to maintain the average RQI, SDI, and FPR at level of 3.0, from 2005 through 2014.

Analysis Parameters

The analysis parameters were based on Stantec's past project experiences in New Jersey and the feedback from the Union County engineers. The parameters used in the analysis were as follows:

- The decision trees are set up based on SDI and RQI, which were shown previously.
- Since the analysis period extends to 2014, some projects may need to be rehabilitated more than once within the analysis period, depending on the first rehabilitation treatment prediction model.

- The trigger levels for analysis, and deficiency levels, for RQI and SDI are 2.0 and 2.5 for Local and Collector roads, respectively.
- The analysis is based on the latest performance data available for each section.
- Recent as built data loaded to the system is considered in the analysis.
- The rehabilitation treatments and unit cost settings used in the analysis are the standard analysis settings used for all previous budget scenario analyses in the NJDOT HPMA that were defined in 2003. These settings are shown in Table 11.

Table 11: Rehabiliation Treatments Unit Costs

Pavement Type	ID	Description	Cost ($/s.y.)
Flexible Pavements	M+OV2	Mill 2"+ Overlay2"	18.60
	M2+OV4	Mill 2"+ Overlay4"	36.00
	ACRe	AC Reconstruction	86.8
Rigid Pavements	2PC II	Overlay2" over PC II	59.50
	PPCC R	Partial PCC Reconstruction	61.10
	4PCII	Overlay4" over PC II	63.30
	ACPC	Pubb PCC+OV6"	65.10

Analysis Results

The results of the Union County budget scenario are presented in the following graphs. Figure 66 shows the total cost per year for Union County for an analysis period of 10 years for the ND01 needs analysis. Figure 67 through Figure 72 show the network average and network percentage deficiency under each budget scenario in terms of the three performance indices.

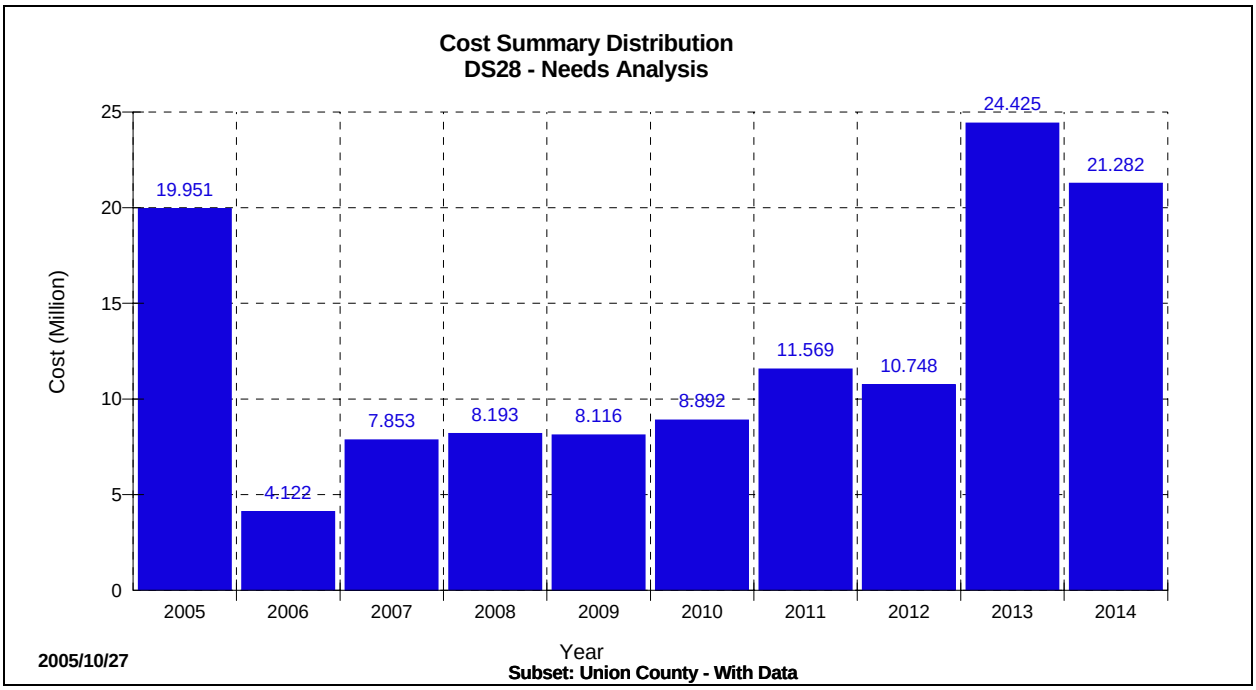

Figure 66: Need Analyses Costs - Total Cost Per Year for Union County

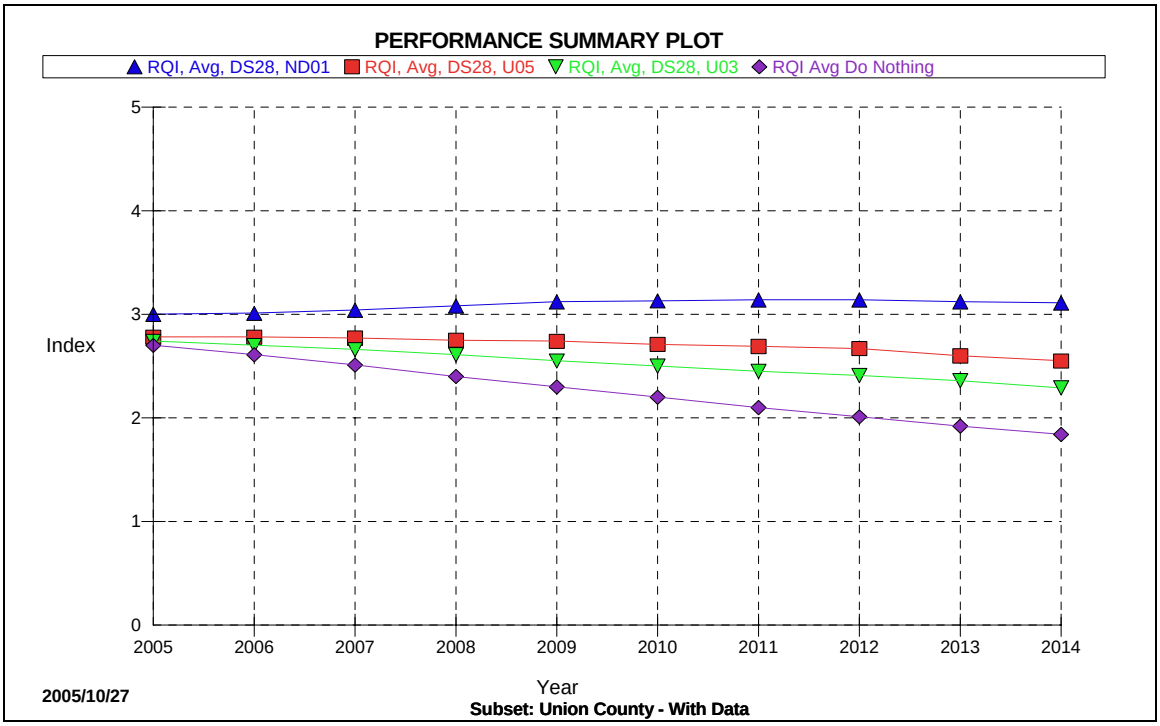

Figure 67: Union County Network Average RQI

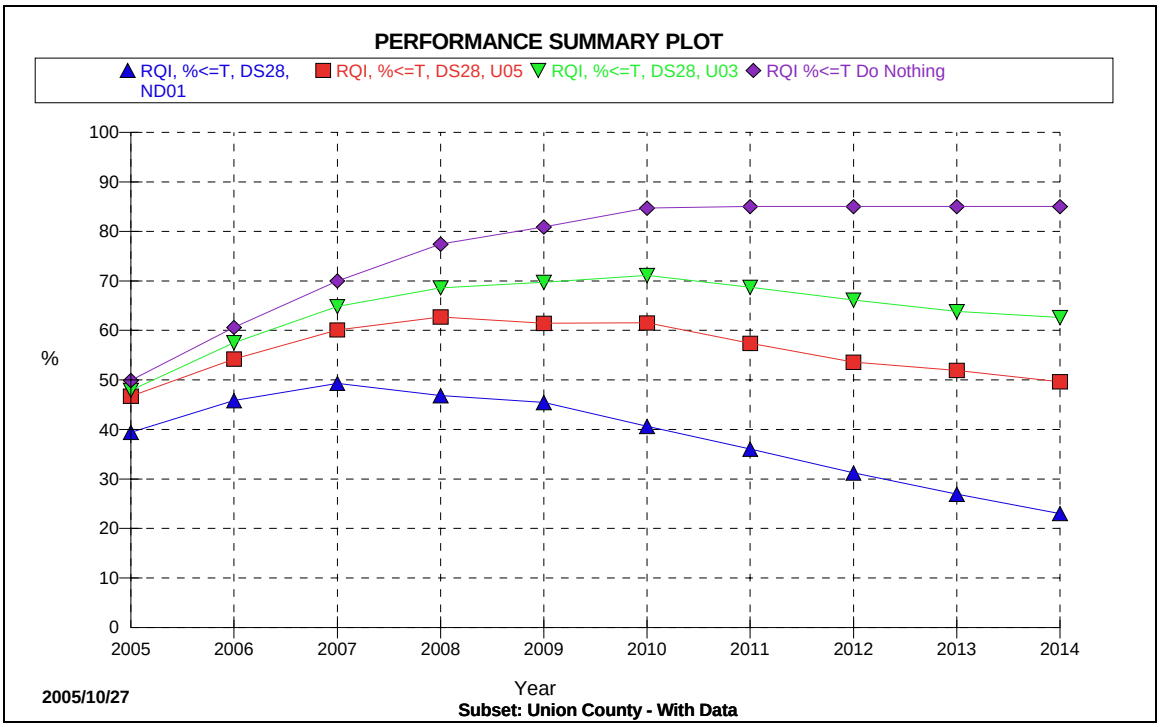

Figure 68: Union County Network Percentage Deficiency in Terms of RQI

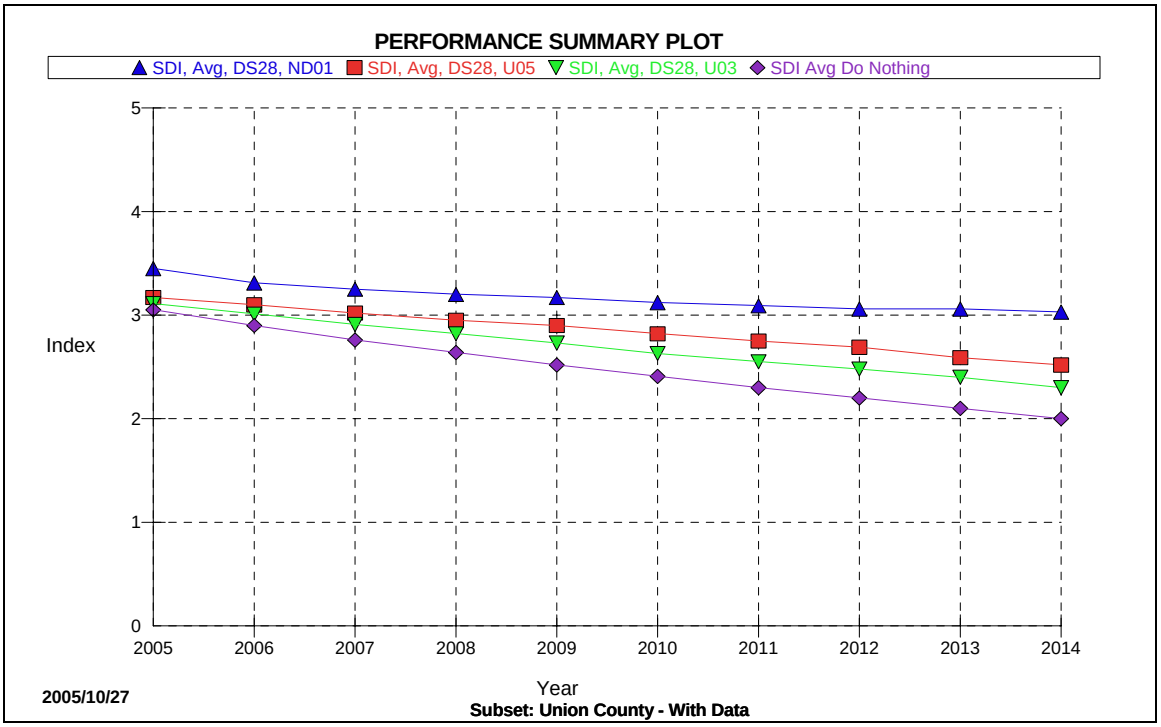

Figure 69: Union County Network Average SDI

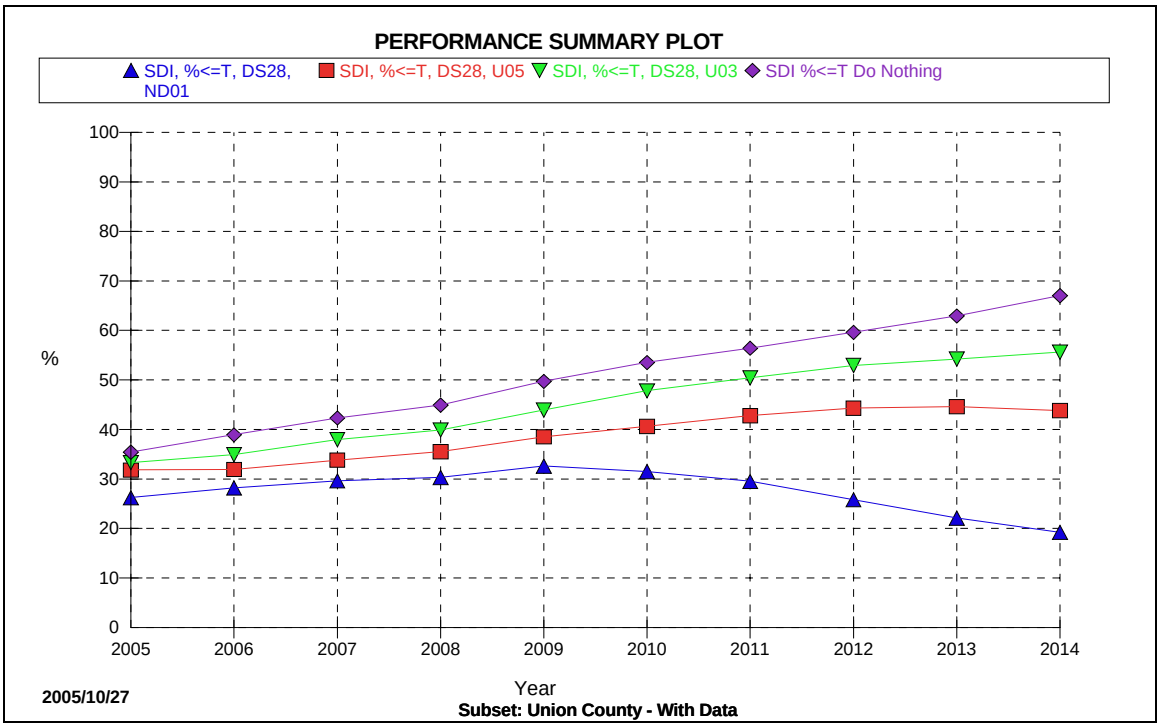

Figure 70: Union County Network Percentage Deficiency in Terms of SDI

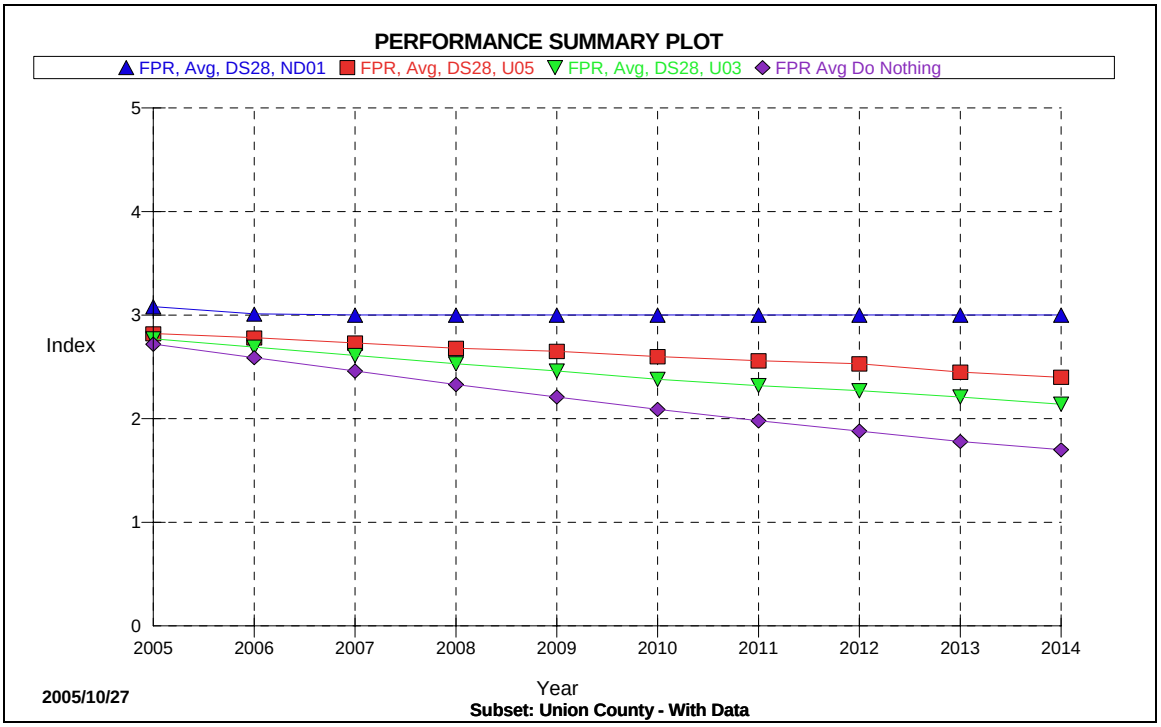

Figure 71: Union County Network Average FPR

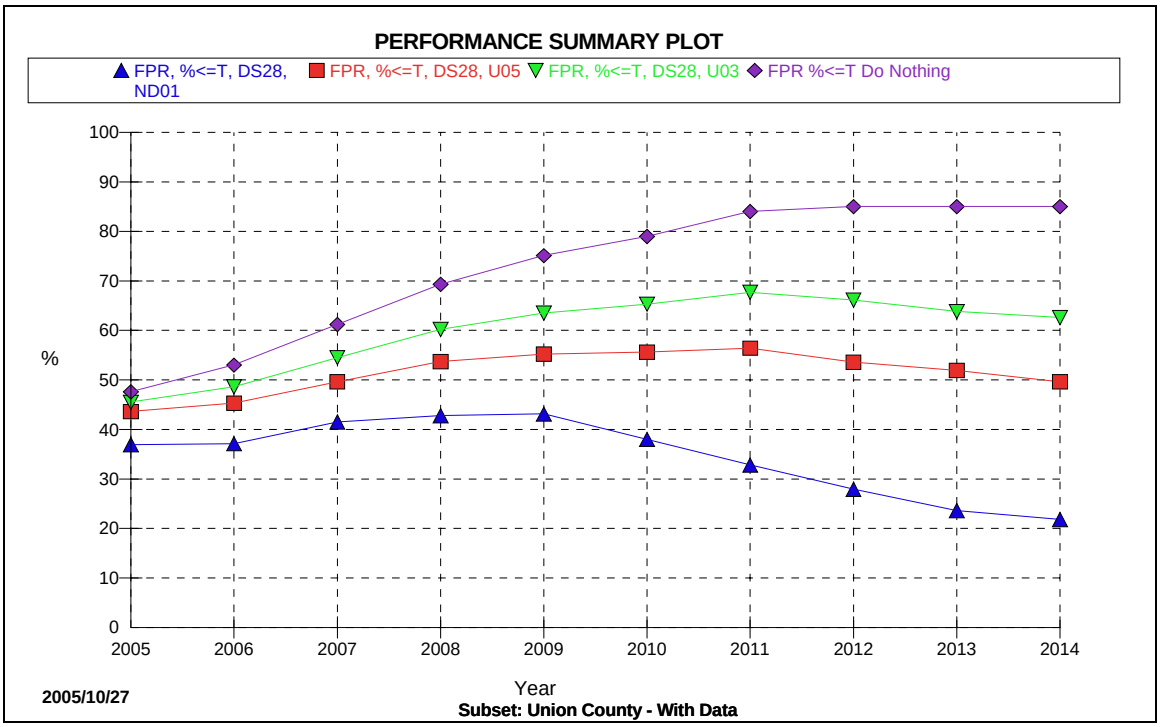

Figure 72: Union County Network Percentage Deficiency in Terms of FPR

Budget Summary

For Union County, three budget scenarios were run for the entire network. These budget scenarios were U03 ($3.0 million per year), U05 ($5.0 million per year), and ND01 (needs-based analysis).

The analysis results of these scenarios were described in the previous section. The budgets spent within each of these scenarios over the analysis period are summarized in Table 12.

Table 12: Budget Summaries

Year	U03	U05	ND01
2005	2,901,772	4,992,782	19,950,980
2006	2,958,266	4,947,798	4,122,305
2007	2,972,072	4,937,595	7,852,999
2008	2,995,640	4,964,712	8,193,034
2009	2,972,981	4,960,221	8,116,164
2010	2,940,550	4,943,579	8,891,548
2011	2,980,069	4,967,962	11,568,865
2012	2,992,835	4,979,221	10,748,206
2013	2,995,352	4,983,158	24,424,511
2014	2,939,905	4,907,045	21,282,391
Total	**29,649,442**	**49,584,073**	**125,151,003**

CITY OF VINELAND

Database Development

This section provides a description of the database developed for City of Vineland for PMS implementation. This section also summarizes the condition of the network.

Data Sources

City of Vineland HPMA database was developed from various sources. The street names and lengths were extracted from an official road map of the City of Vineland. The condition data used in the HPMA optimization analysis collected by Stantec's RT.

Stantec collected pavement condition data from approximately 320 miles of streets from more than 700-sections within City of Vineland. This data was collected using Stantec's RT survey vehicle, which can simultaneously collect pavement condition, GPS, and Video logging (digital imagery) data. The data collected included the following:

- Surface roughness
- Surface condition in terms of distress severities and extents
- Rut depths
- Longitudinal profiles
- Digital video images of right-of-way attributes
- GPS data and coordinates for location referencing

The roughness data was analyzed in terms of the IRI. IRI is the roughness index obtained from the longitudinal profile of the road, and is used to interpret the roughness/smoothness of each road segment. IRI is then used to calculate NJDOT RQI. The RQI is on a decreasing scale with a maximum value of 5.0, which represent the smoothest possible pavement condition.

Distress data was collected using an automated technique through the use of line scan camera system mounted on the RT. Continuous pavement images of the entire 12-foot lane are collected at 25-foot intervals. These images were then processed in the office, where the imaging program developed by ICC is used to enter distress type, severity, and extent for all identified distresses and to process the data. Figure 73 shows a sample of the images collected from the City of Vineland and used for distress data identification. The distress data was then used to calculate NJDOT SDI. Similar to RQI, the SDI is on a decreasing scale with a maximum value of 5.0, which represent distress-free surface condition.

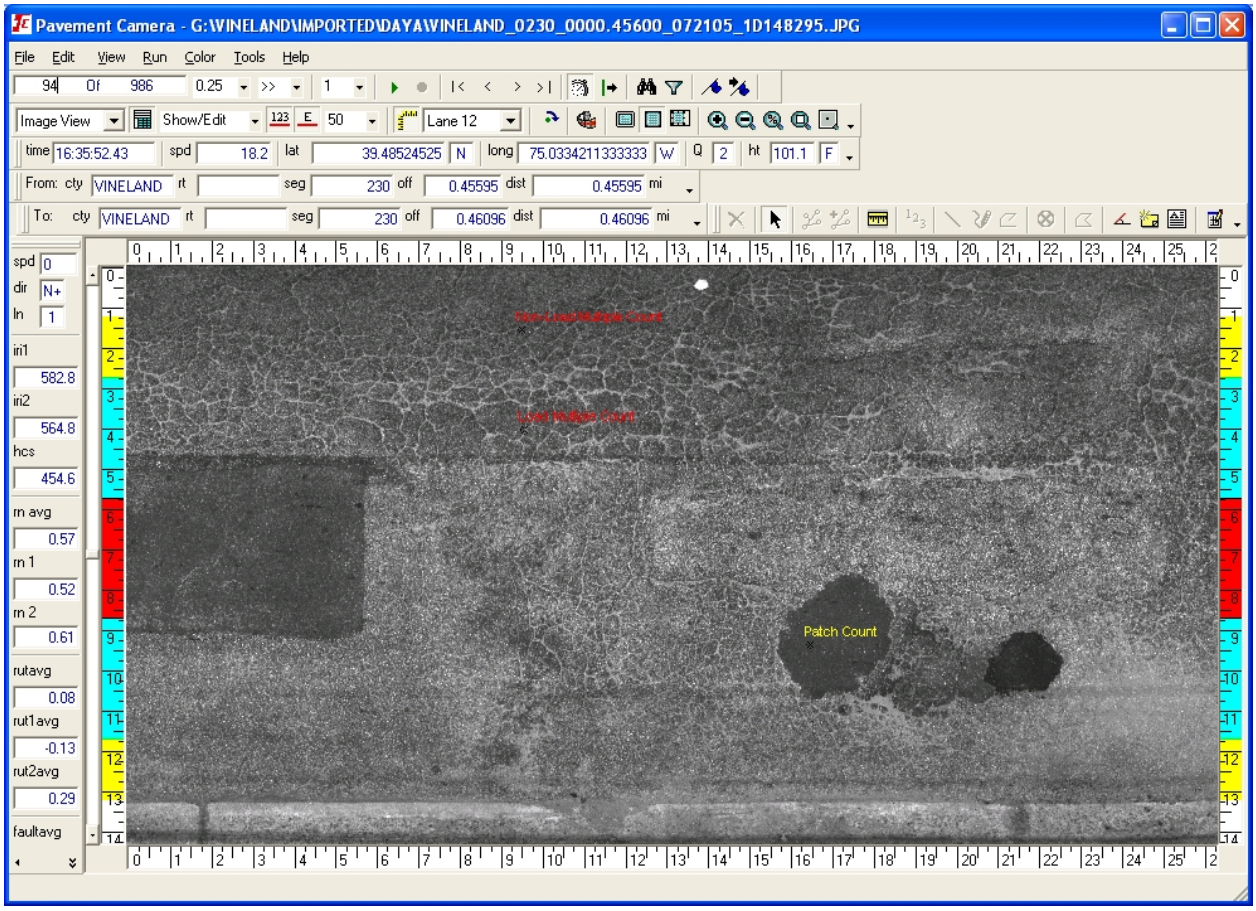

Figure 73: Line Scan Camera Image Processing

Network Condition

The City of Vineland road network condition was evaluated in terms of RQI, SDI, and the NJDOT overall FPR, which is a function of the RQI and SDI on a scale from 0.0 to 5.0, where 5.0 is the best possible pavement condition. Figure 74 through Figure 76 show the condition of the network in terms of RQI, SDI, and FPR, respectively. In the figure, the condition is shown in categories: Poor (0.0 – 2.0), Fair (2.0 – 3.0), Good (3.0 – 4.0), and Excellent (4.0 – 5.0).

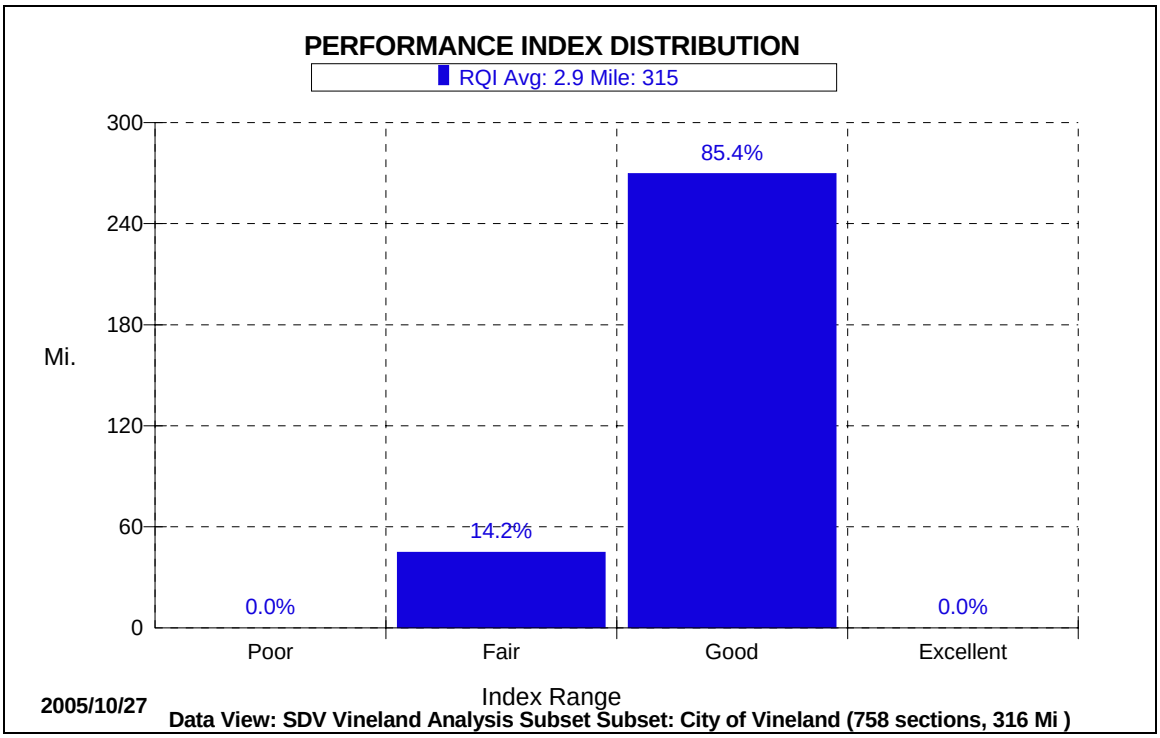

Figure 74: The City of Vineland Network Condition in Terms of RQI

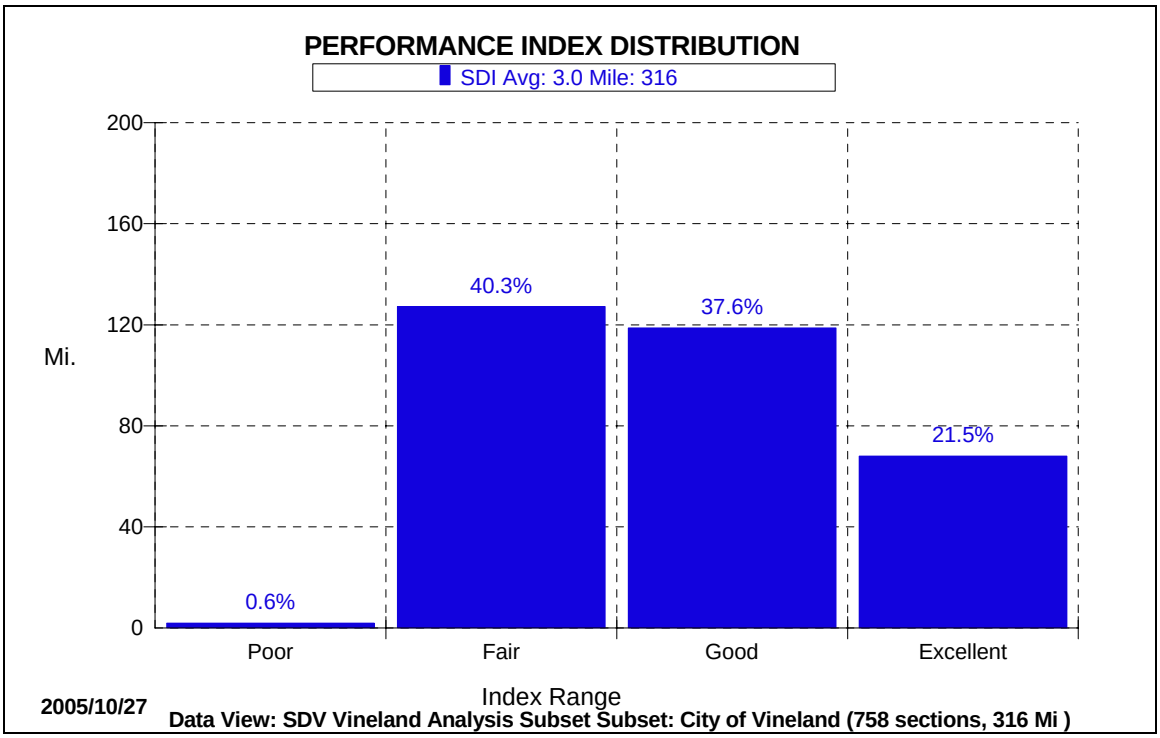

Figure 75: The City of Vineland Network Condition in Terms of SDI

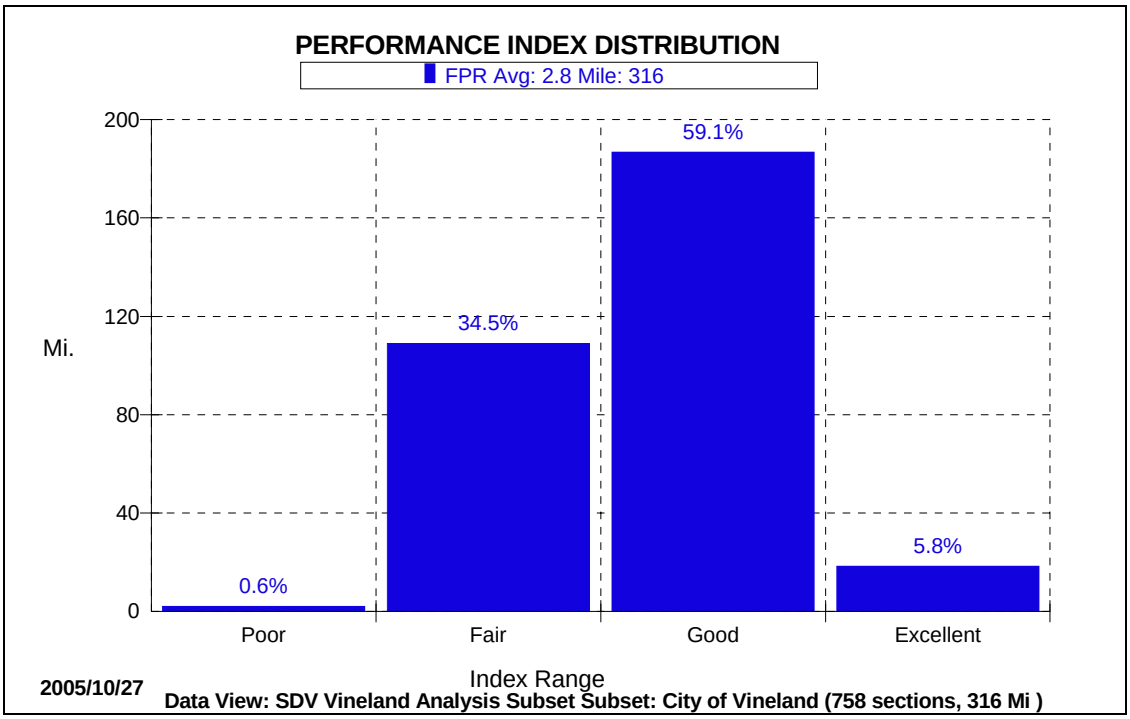

Figure 76: The City of Vineland Network Condition in Terms of FPR

Analysis Models

In this section, the analysis models used for the optimization analysis are presented. These models include the decision trees and the performance prediction models.

Decision Trees

Two decision trees were developed, with one for flexible pavements and the second for rigid pavements. These decision trees are similar to the decision tree used by NJDOT for pavement analysis at the county level. The two trees used for the analysis are:

Flexible Pavements:

FPR < 1.5
- Y: Reconstruction
- N: 1.5 ≤ FPR ≤ 3.5
  - Y: SDI or RQI ≤2.0
    - Y: M2O4
    - N: M2O2
  - N: Crack seal/fill

Rigid Pavements:

FPR < 1.5
- Y: PPCC R, ACPC (AC Overlay)
- N: 1.5 ≤ FPR ≤ 3.5
  - Y: SDI or RQI ≤2.0
    - Y: 4PCII
    - N: 2PCII
  - N: Crack seal, or surface texturing.

Where,

FPR	=	Final Pavement Rating
SDI	=	Surface Distress Index
RQI	=	Ride Quality Index
M2O2	=	Mill 2", Overlay 2"
M2O4	=	Mill 2", Overlay 4"
PPCC R	=	Partial PCC Reconstruction
ACPC	=	Asphalt Concrete Overlay over Portland Cement Concrete
2PCII	=	Overlay 2" over PCC (II)
4PCII	=	Overlay 4" over PCC (II)

Performance Prediction Models

The NJDOT prediction models were customized to reflect the expected service life of pavements based on discussions with the local agencies engineers and our own experiences. Figure 77 through Figure 82 presents the prediction models for each of the three indices (SDI, RQI and FPR) for each rehabilitation activity listed within the decision trees based on pavement type studied.

It should be noted that the performance models shown in the figures are based on the performance models used by NJDOT HPMA used for the Interstate and state routes. However, these models were revised to extend the service life the pavements by 2 to 3 years, such that it would better reflect the conditions of local roads, within the local agencies.

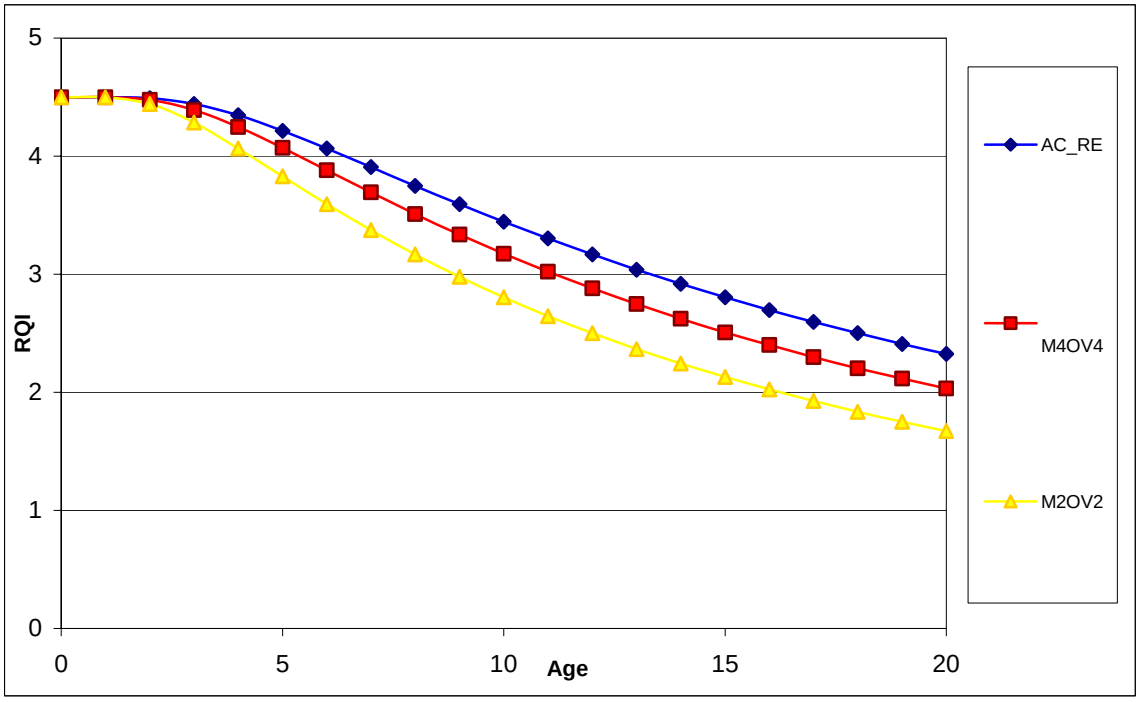

Figure 77: Performance RQI Model for AC Rehabilitation Activities

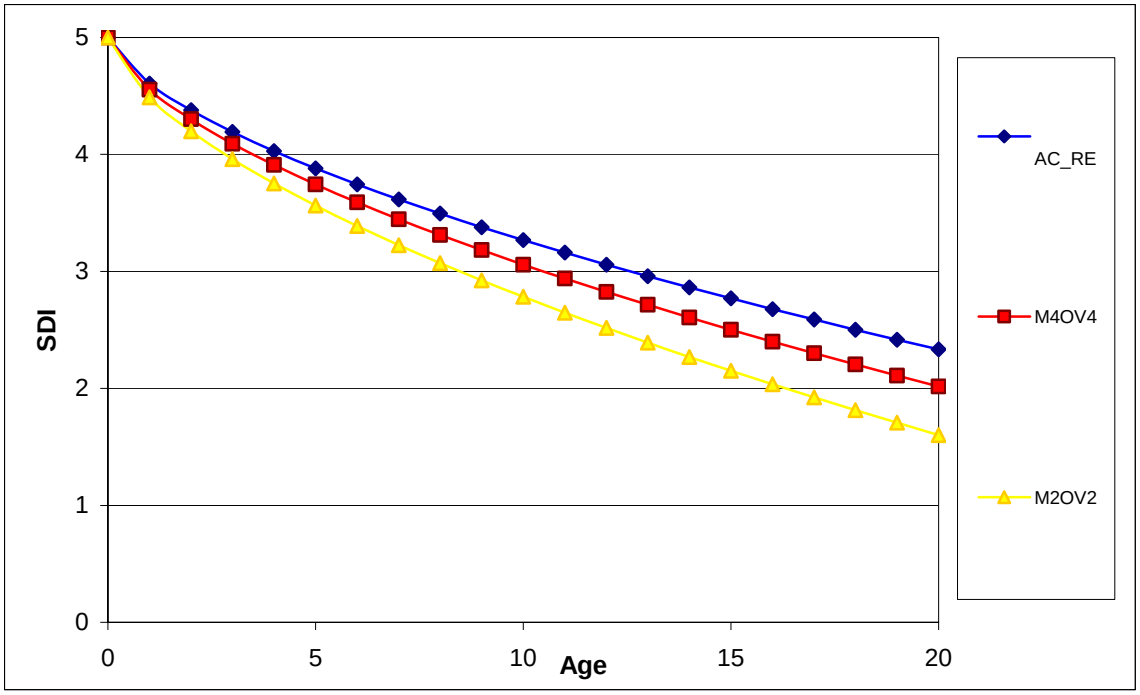

Figure 78: Performance SDI Model for AC Rehabilitation Activities

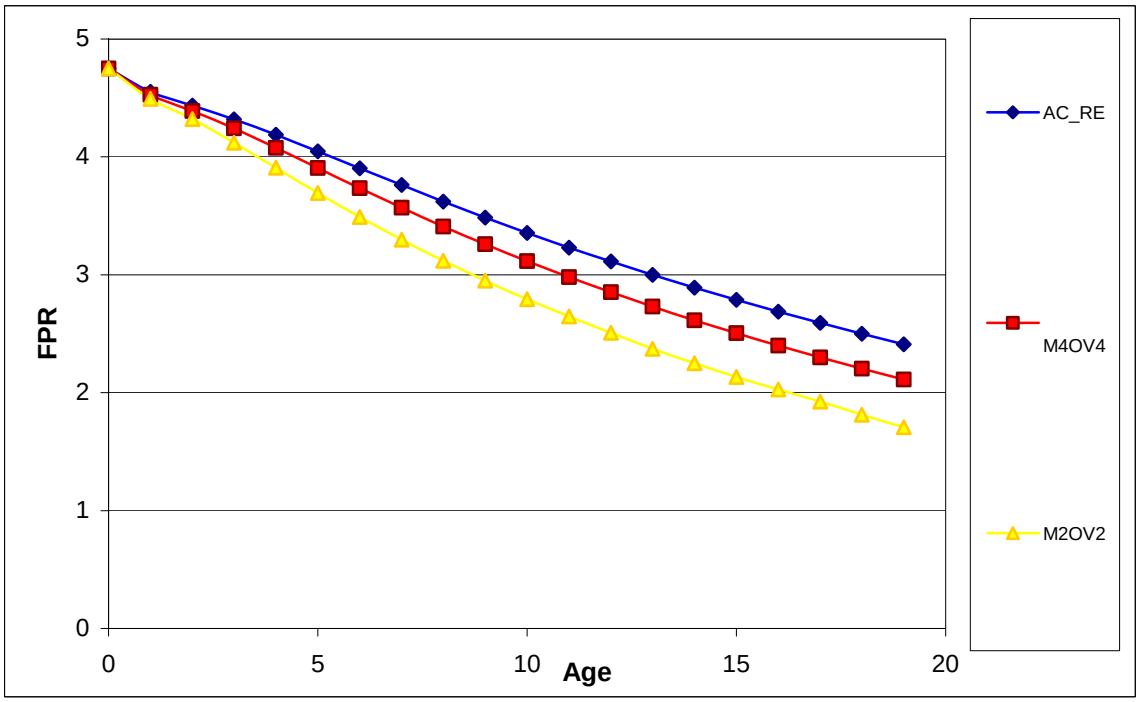

Figure 79: Performance FPR Model for AC Rehabilitation Activities

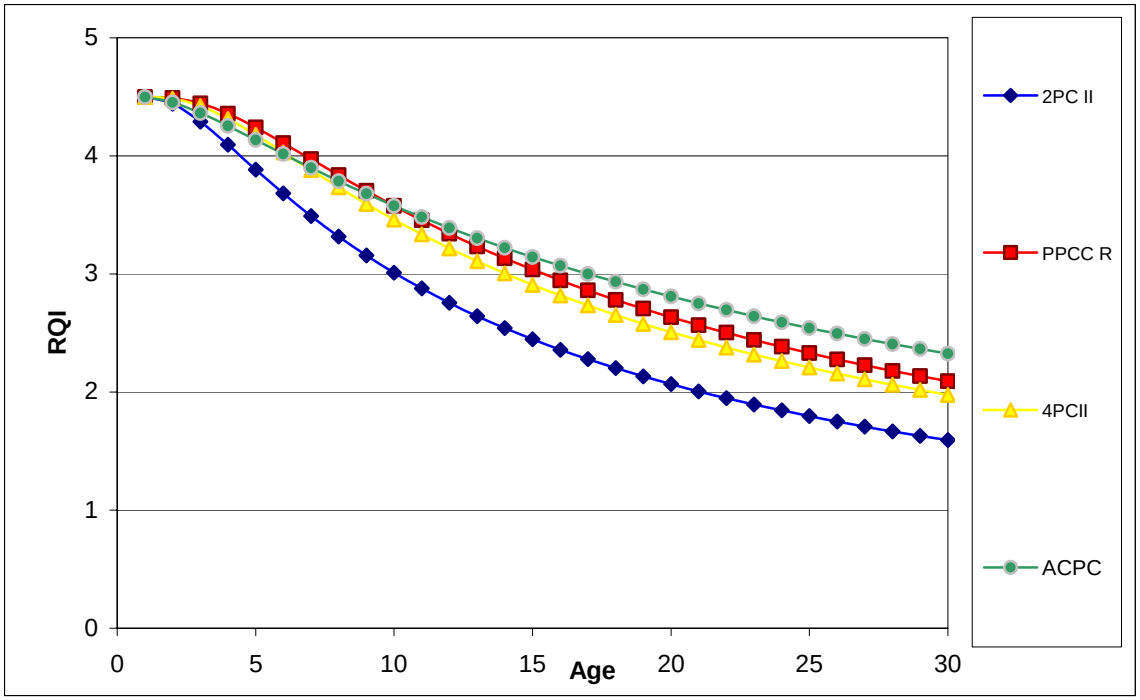

Figure 80: Performance RQI Model for PCC Rehabilitation Activities

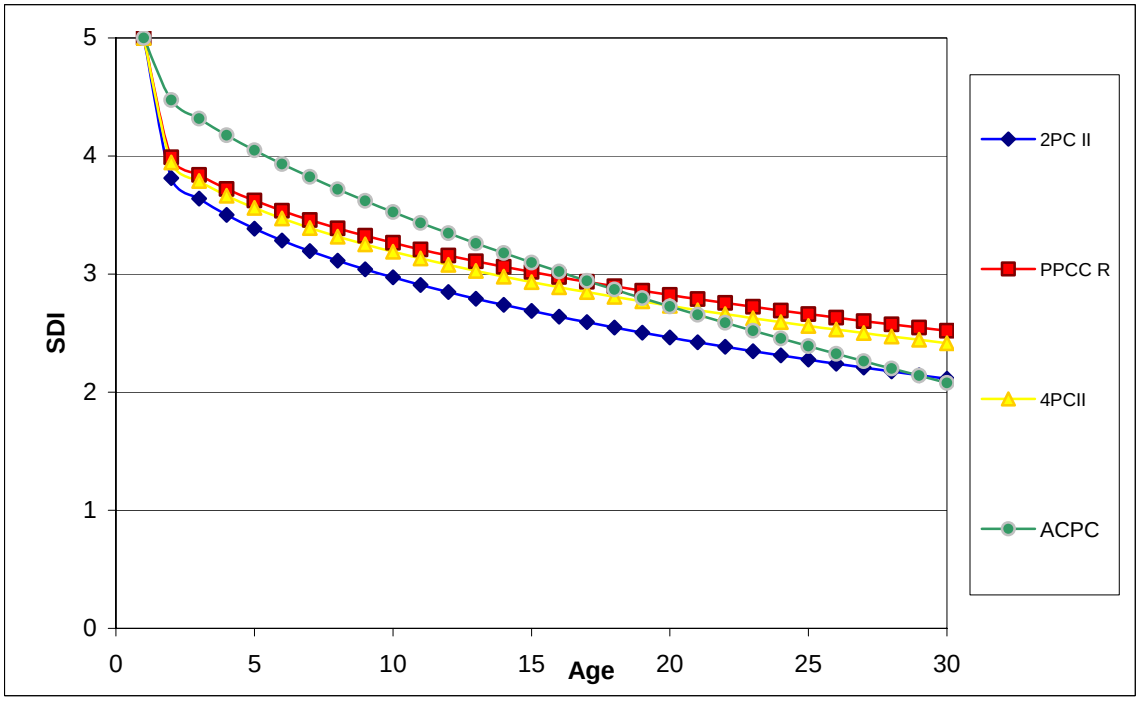

Figure 81: Performance SDI Model for PCC Rehabilitation Activities

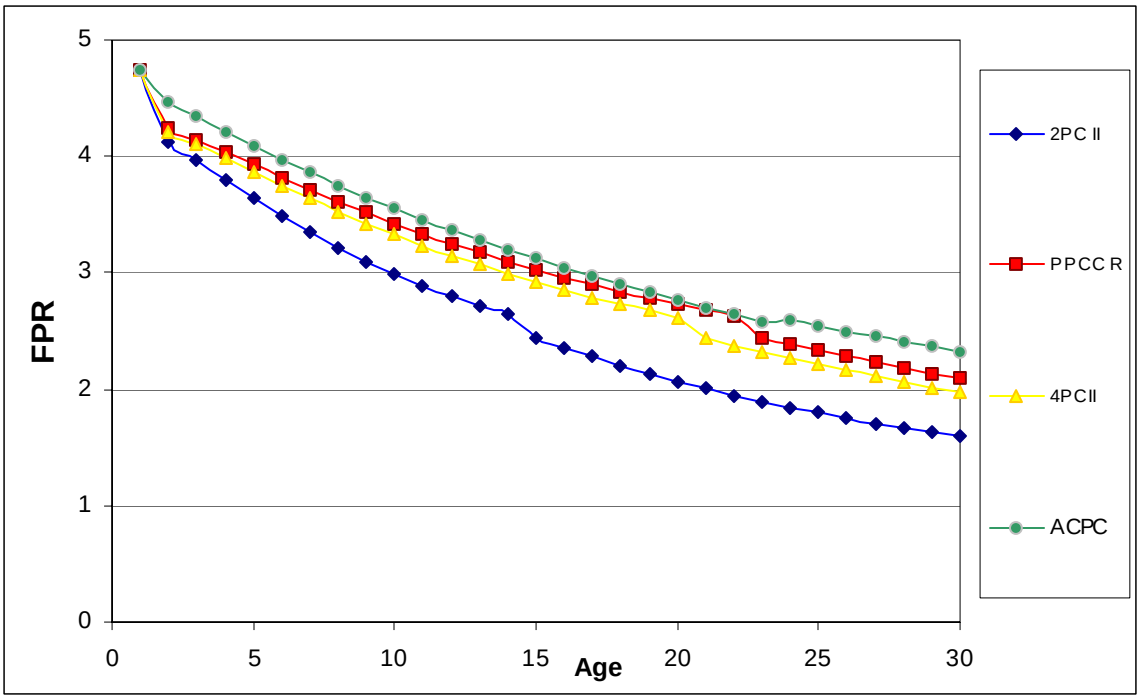

Figure 82: Performance FPR Model for PCC Rehabilitation Activities

Budget Scenario Analysis

For the City of Vineland analysis, three budget scenarios were considered. The three budget scenarios are:

1. UN03 – 3 million dollars per year starting from 2005 through 2014.

2. UN05 – 5 million dollars per year starting from 2005 through 2014.

3. ND01 –Needs-based analysis, where the budget needed to maintain the average FPR at a level of 3.0 starting from 2005 through 2014 is estimated.

Analysis Parameters

The analysis parameters were based on Stantec's past project experiences in New Jersey. The parameters used in the analysis are as follows:

- The trigger levels for analysis for FPR are 2.0 for all streets. This trigger level is also used to define the deficiency level for any street, such that if the FPR is less that 2.0, the street will be considered deficient.

- The rehabilitation treatments unit cost used in the analysis were based on the standard unit costs used by NJDOT, which were defined in 2003. However, to reflect the reduction of overhead costs including engineering cost, traffic control, etc. Therefore, the NJDOT standard unit costs were reduced by a factor of 25%, as shown in Table 13:

Table 13: Rehabiliation Treatments Unit Costs

Pavement Type	ID	Description	NJDOT Cost ($/s.y.)	Vineland Cost ($/s.y.)
Flexible Pavements	M2+OV2	Mill 2"+ Overlay2"	18.60	13.95
	M4+OV4	Mill 4"+ Overlay4"	36.00	27.00
	AC Re	AC Reconstruction	86.8	65.10
Rigid Pavements	2PC II	Overlay2" over PC II	59.50	44.63
	PPCC R	Partial PCC Reconstruction	61.10	45.83
	4PCII	Overlay4" over PC II	63.30	47.48
	ACPC	Pubb PCC+OV6"	65.10	48.83

- The analysis was based on the latest performance data available for each section, which is the data collected in 2005.
- Since the analysis period extends to 2014, some projects might need to be rehabilitated more than once within the analysis period, depending on the first rehabilitation treatment performance prediction model.

Analysis Results

The results of the City of Vineland Budget Scenario are presented in the following graphs. Figure 83 shows the total cost per year for City of Vineland for an analysis period of 10 years in terms of the budget scenarios ND01 (average FPR=3.0 by 2008). Figures 84 through 89 show the network average and network percentage deficiency in terms of the three indices.

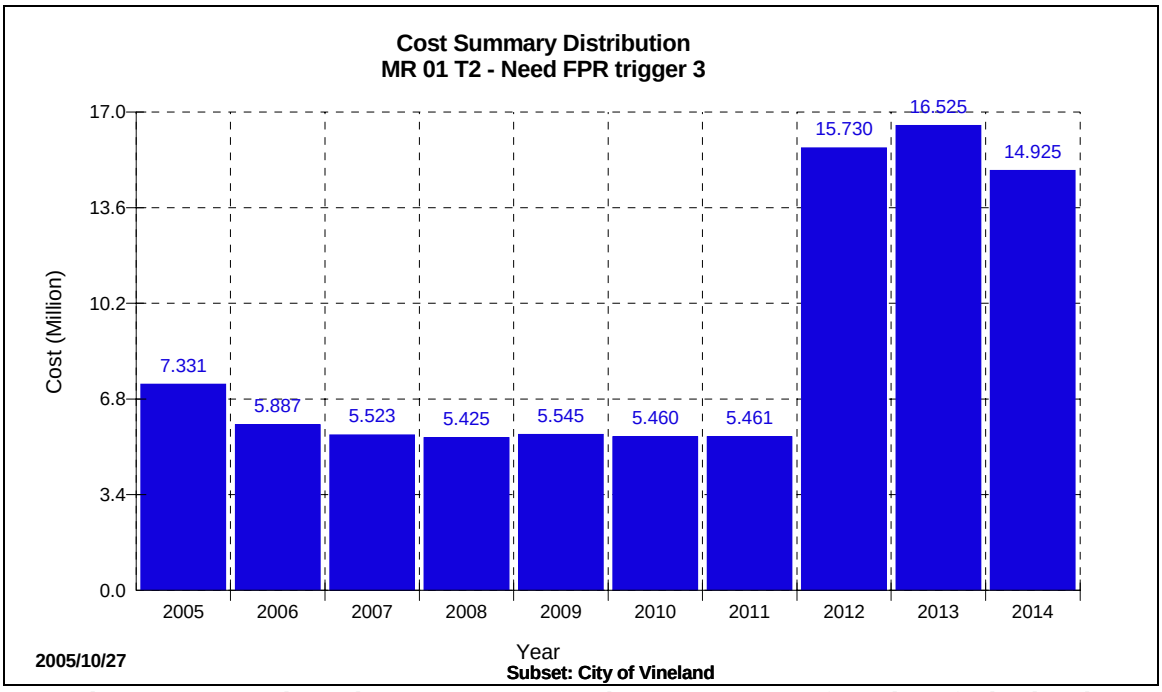

Figure 83: Need Analyses Costs - Total Cost Per Year for City of Vineland

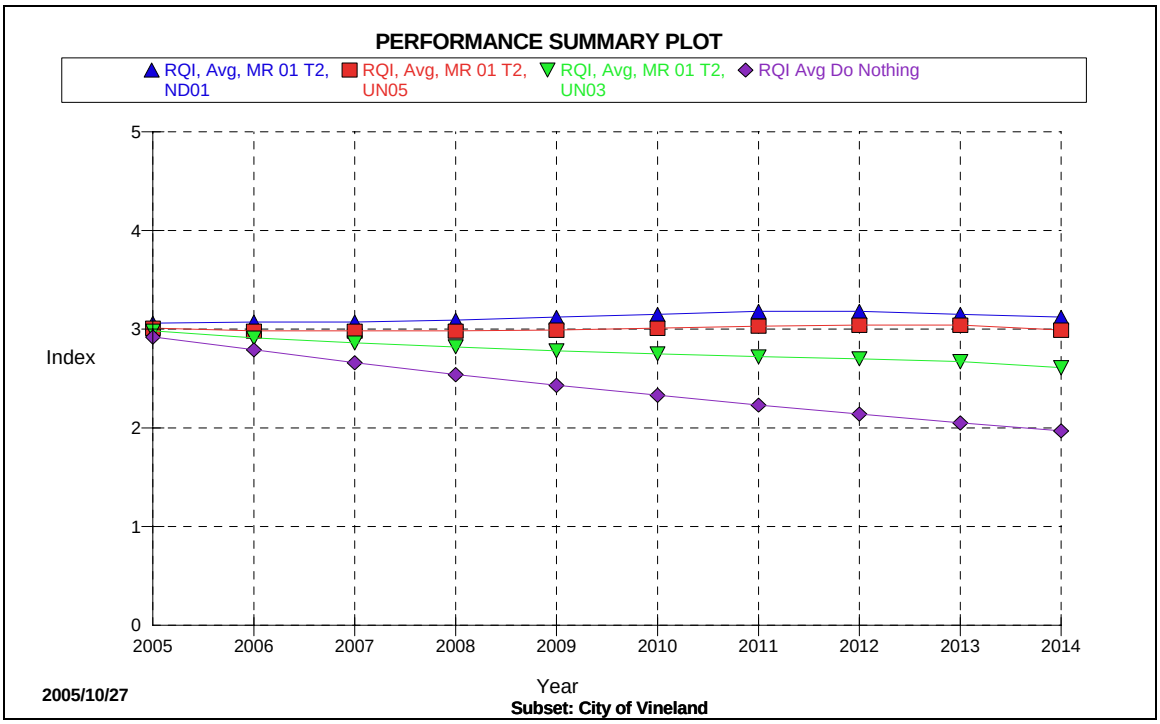

Figure 84: City of Vineland Network Average RQI

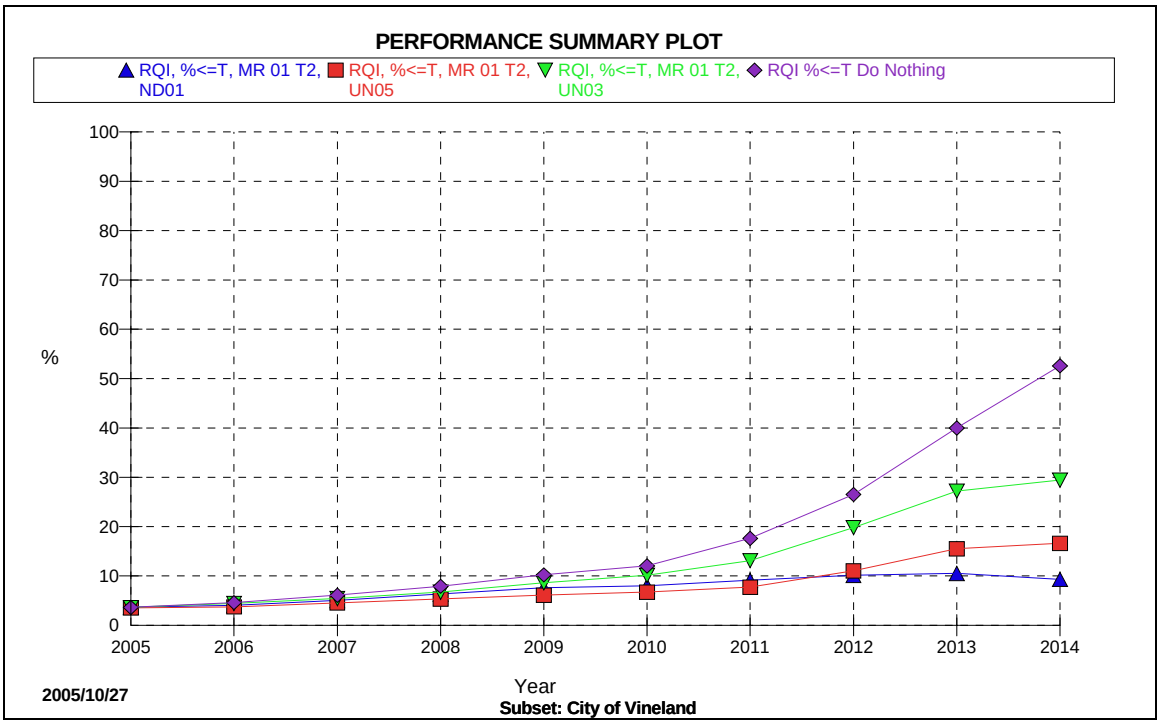

Figure 85: City of Vineland Network Percentage Deficiency in Terms of RQI

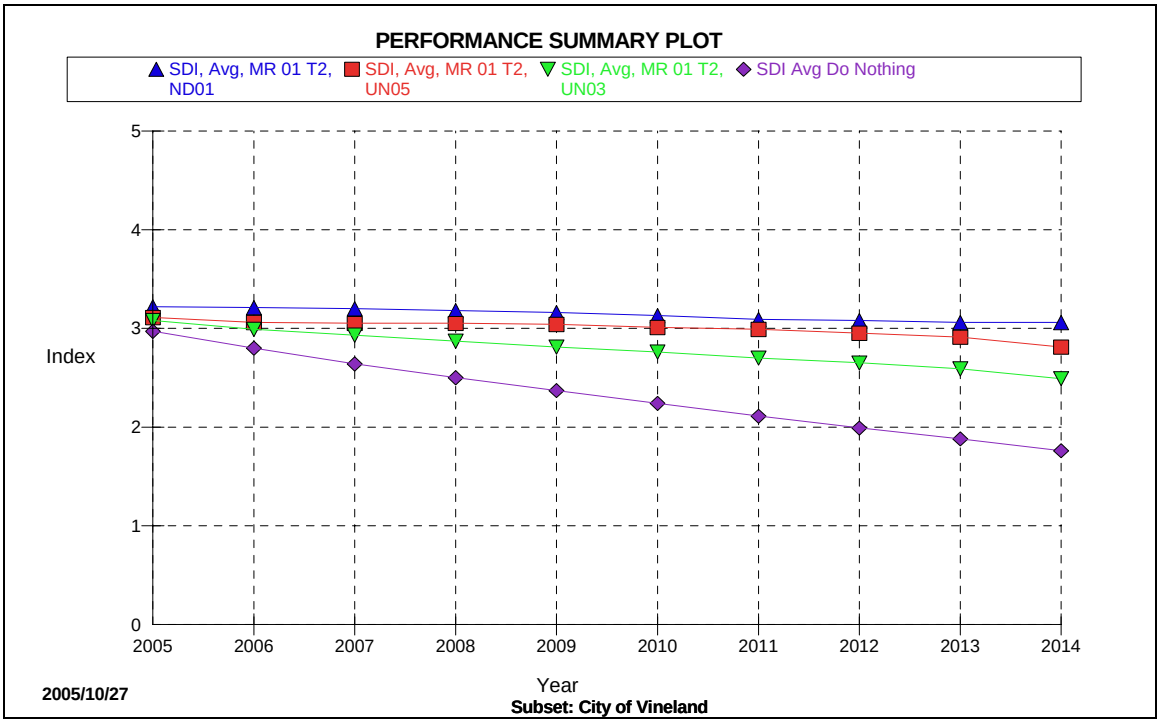

Figure 86: City of Vineland Network Average SDI

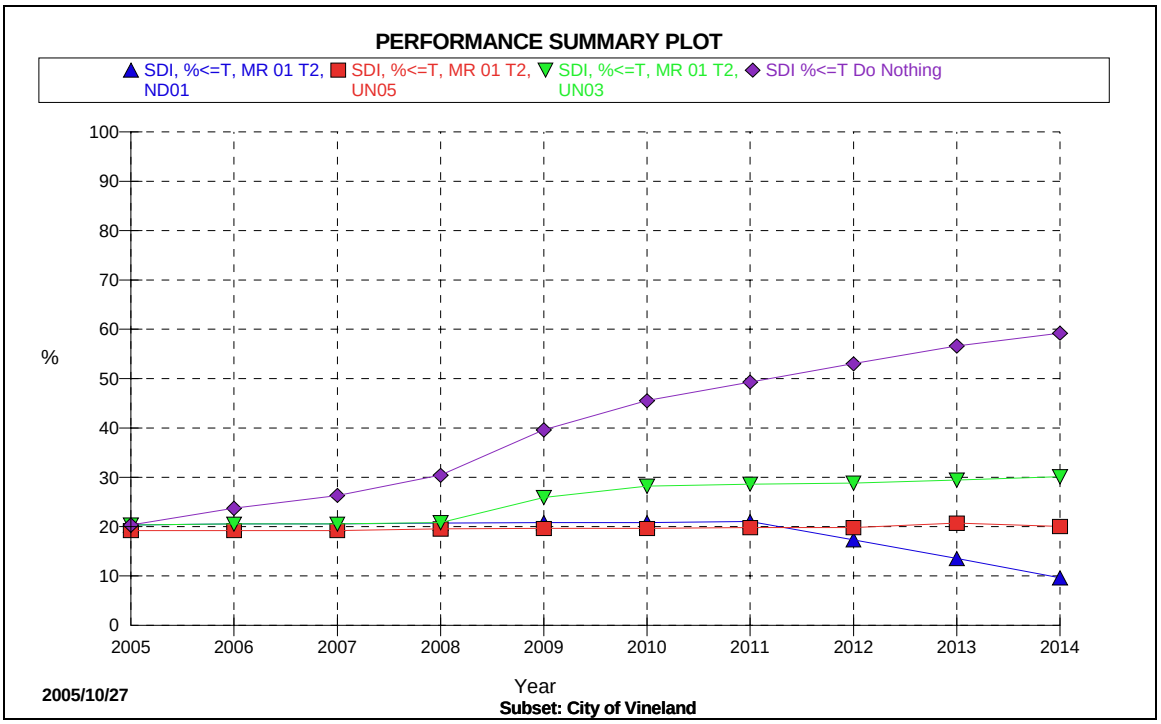

Figure 87: City of Vineland Network Percentage Deficiency in Terms of SDI

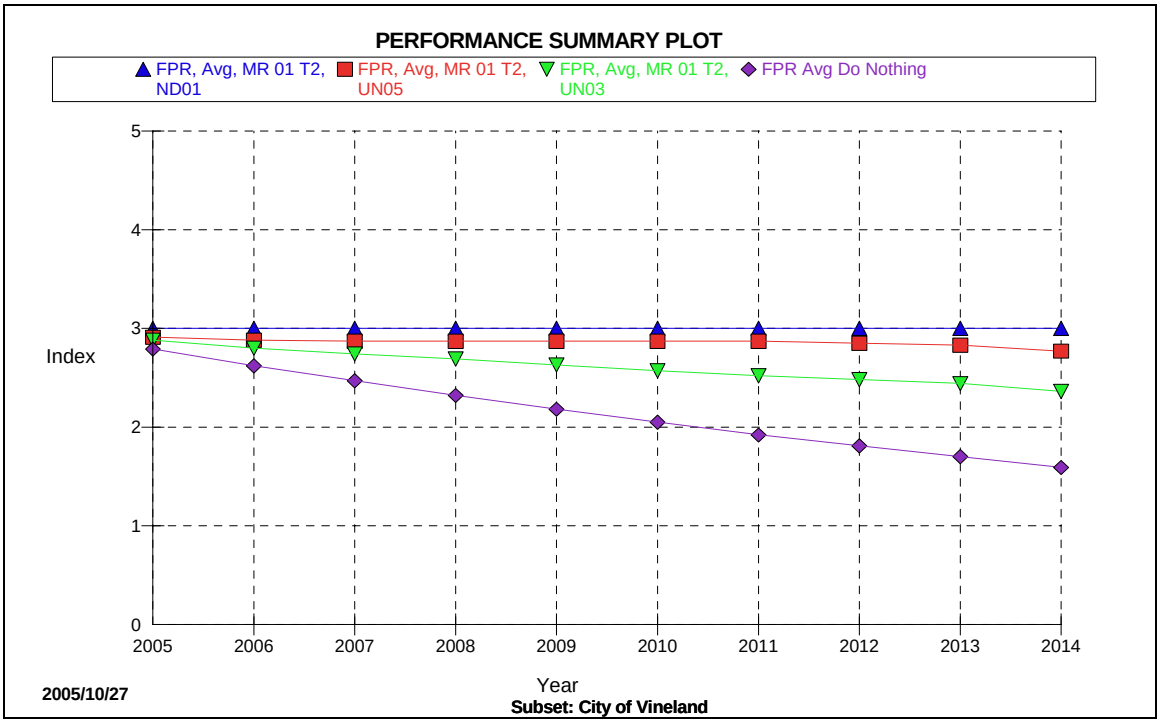

Figure 88: City of Vineland Network Average FPR

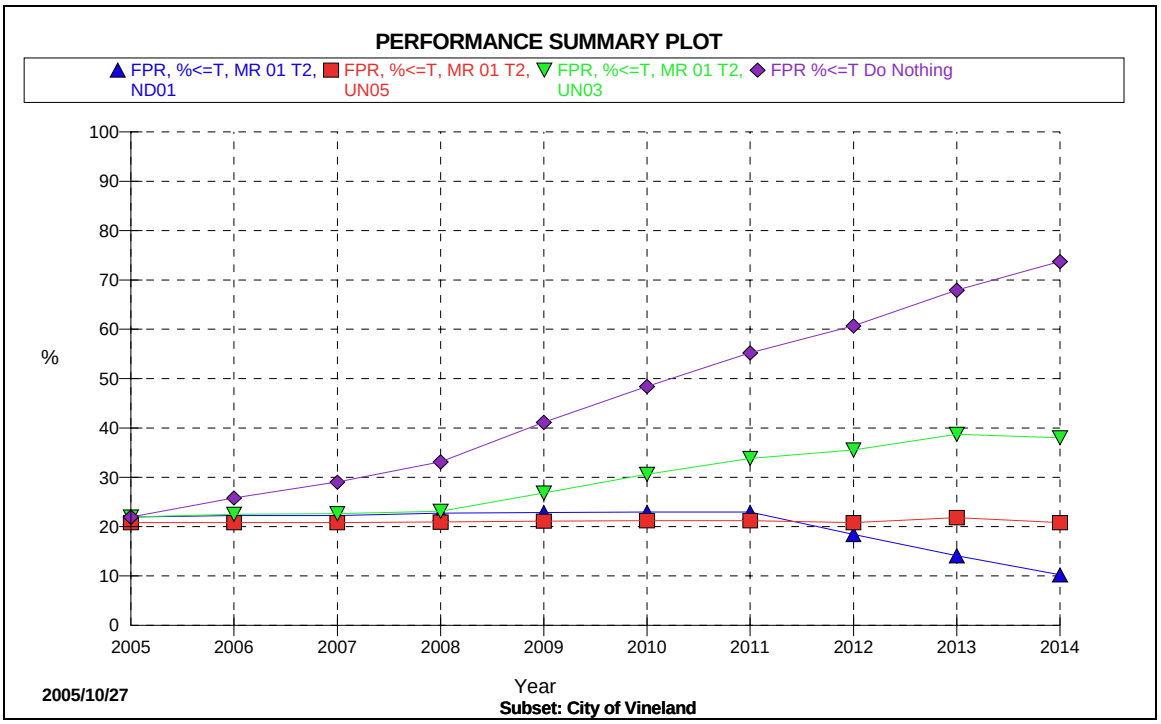

Figure 89: City of Vineland Network Percentage Deficiency in Terms of FPR

Budget Summary

As mentioned earlier, four budget scenarios were run for the entire City of Vineland network. These budget scenarios are UN03 ($3.0 million per year), UN05 ($5.0 million per year), and ND01 (needs-based analysis to maintain the average RQI, SDI and FPR at 3.0).

The analysis results of these scenarios were described in the previous section. The budgets spent within each of these scenarios over the analysis period are summarized in Table 14.

Table 14: Budget Summaries

Year	UN03	UN05	ND01
2005	2,998,131	4,780,370	7,330,787
2006	2,998,292	4,966,221	5,886,567
2007	2,992,859	4,986,536	5,523,481
2008	2,990,499	4,987,665	5,424,751
2009	2,995,740	4,997,047	5,545,485
2010	2,996,262	4,984,923	5,459,578
2011	2,992,597	4,994,411	5,461,152
2012	2,990,499	4,982,978	15,729,535
2013	2,998,091	4,985,155	16,524,616
2014	2,997,185	4,997,840	14,924,829
Total	**29,950,155**	**49,663,146**	**87,810,781**

CONCLUSIONS AND RECOMMENDATIONS

A base Pavement Management System (PMS) was developed and implemented, on a pilot basis, for six local agencies within the state of New Jersey. As part of this pilot implementation, a database containing section attribute and pavement condition data was compiled for each of the six selected agencies. These databases were delivered to the agencies during the Joint FHWA 2005 Northeast Pavement Management Conference and NJDOT Local PMS Workshop in held in November 2005.

The pilot implementation also involved the development of limited performance prediction models and decision trees. In addition, budget scenario analyses were performed using the base PMS to demonstrate some of the potential benefits of adopting a PMS. A final report for each of the six agencies considered in the pilot implementation was prepared and delivered. In this report, details of the parametric setup, performance models, and decision trees were provided.

The pilot implementation demonstrated that a single PMS software can accommodate the basic needs of multiple NJ local government agencies and can be adopted with very limited effort. It also illustrated and documented the benefits of adopting a PMS. The final product of this pilot implementation can be delivered in the form of a fully functioning PMS (Stantec's Highway Pavement Management Application (HPMA) adopted by NJDOT) or in the form of an Access database with customized reports, which has already been delivered to the six selected agencies. The Access database can also be linked to a Geographic Information System (GIS), as demonstrated by Stantec at the Joint FHWA 2005 Northeast Pavement Management Conference and NJDOT Local PMS Workshop.

The project highlighted the problems local agencies face in terms of lack of resources, especially manpower, which restrict the personnel that can be dedicated to maintaining and running the system and collating pavement data electronically. Taking this factor into consideration, the following recommendations are made for the six pilot agencies:

1. Adoption of main HPMA software from NJDOT – NJDOT have offered to make their full HPMA application available at no license cost to the local agencies. If an agency decides to take this option, they will need to contact Stantec to arrange for installation and staff training, as well as for a maintenance and support agreement.

2. PMS services, including reporting, provided to local agency by consultant – the consultant provides PMS services using raw pavement data supplied by the agency. This will include running the required analyses and presenting the agency with hard and digital copies of the appropriate reports.

3. Above services, enhanced by use of the HPMA web-based application – in this option, the results of the analyses are loaded into the HPMA web-based application. The results can then be accessed remotely from any internet terminal by authorized personnel and can be viewed in various formats and combinations. This enables the desired information to be found quickly and in the format of most use to the viewer. Please note that the web-based application is not a part of Stantec's agreement with

NJDOT and agencies that select to utilize this feature will have to enter into an agreement with Stantec, including the license cost of the web-based application.

For other local agencies not involved in the pilot implementation, the project has had the benefit of producing a base PMS with parametric set-up that is available for utilization. These other agencies can also take advantage of the PMS models developed for the pilot agencies, which will provide a good starting point for implementation into their own system. The three above noted options could either be undertaken by each of these agencies individually, or by an MPO for all agencies under its jurisdiction.