NCHRP 14-20A

Consequences of Delayed Maintenance of Highway Assets

Carlos M. Chang, Ph.D., P.E.

Topics

1. Research Objectives
2. Research Approach
3. Procedure to Quantify the Consequences of Delayed Maintenance
4. Step-by-Step Example for Pavements
5. Summary of the Main Research Contributions
6. Recommendations for Implementation.

Research Objectives

To provide a **set of procedures to quantify the consequences of delayed maintenance** to the highway infrastructure.

The ultimate goal is to **integrate the procedures** developed for individual asset groups **into the asset management process** to support better maintenance funding decisions and improve the communication across management levels.

What is Delayed Maintenance?

Delayed maintenance is defined as the **work needed to preserve the highway system, but postponed in the agency maintenance program.**

This definition applies to all the highway asset groups. However, each asset group has unique characteristics in terms of maintenance policies, condition assessment, deterioration rates, service life, and life-cycle costs.

Research Approach

Task 1: Information review and on-line surveys

Task 2: Focused phone interviews with selected DOTs

Task 3: Perform delayed maintenance scenarios

The methods and analytical tools described in the procedures can be adapted to the agency preservation policies, maintenance resources, and performance standards.

Main Steps of the Procedure to Quantify the Consequences of Delayed Maintenance

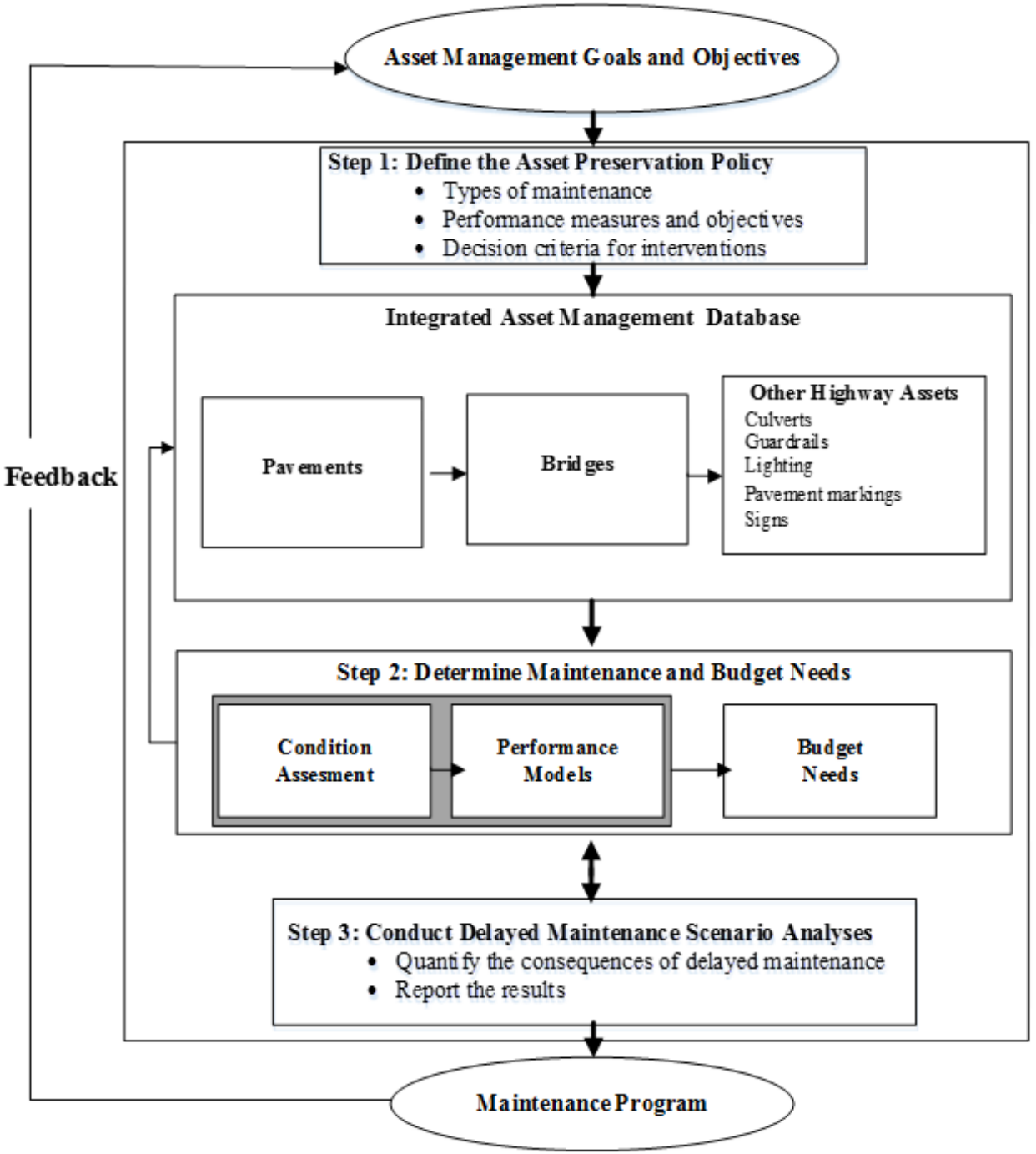
Step 1: Define the asset preservation policy

Step 2: Determine maintenance and budget needs for the asset group

Step 3: Conduct delayed maintenance scenarios analyses

Pavements, Bridges, Culverts, Guardrails, Lighting, Pavement Markings, and Signs.

Framework to Integrate the Delayed Maintenance Procedures into the Asset Management Process



Step-by-Step Example for Pavements

Step 1
Define the Asset Preservation Policy

1.1 Identify the types of maintenance for the asset group

1.2 Establish performance objectives for the asset group

1.3 Formulate decision criteria for maintenance activities

1.1 Identify the Types of Maintenance

Asphalt Pavements

- Chip seals
- Cold in-place recycling
- Cold milling
- Crack filling or sealing
- Fog seal
- Hot in-place recycling
- Microsurfacing
- Patching
- Profile milling
- Thin asphalt overlays
- Scrub seals
- Slurry seals
- Ultra-thin asphalt overlay
- Ultra-thin bonded wearing course
- Ultra-thin concrete overlay

Concrete Pavements

- Crack sealing
- Diamond grinding
- Diamond grooving
- Dowel bar retrofit
- Full-depth concrete patching
- Joint resealing
- Partial-depth concrete patching
- Thin asphalt overlay
- Ultra-thin bonded wearing course

AASHTO 2007, Peshkin et al. 2011

1.2 Establish Performance Objectives

- Maximum International Roughness Index (IRI) of the pavement network
- Minimum pavement condition of the pavement network
- Minimum Present Serviceability Index (PSI) of the pavement network
- Minimum Remaining Service Life (RSL) of the pavement network
- Minimum percent of the pavement network in good condition
- Maximum percent of the pavement network in poor condition
- Minimum Skid Number (SN) of the pavement network
- Minimum International Friction Index (IFI) of the pavement network

1.3 Formulate Decision Criteria for Maintenance Activities

Pre-schedule maintenance based on time-intervals

Pavement Type	Treatment	Recommended Year of Initial Treatment	Treatment Timing Cycle
Bituminous-surfaced	Crack Sealing	1 to 3	2 to 6 years
	Fog Seals	0 to 3	1 to 2 years
	Scrub Seals	1 to 6	1 to 3 years
	Slurry Seals	2 to 6	3 to 5 years
	Microsurfacing	3 to 7	4 to 7 years
	Chip Seals	2 to 5	4 to 7 years
	Ultrathin Friction Course	2 to 6	7 to 10 years
	Thin Overlays	5 to 8	7 to 10 years
PCC-surfaced	Joint and Crack Sealing	4 to 10	7 to 8 years
	Diamond Grinding	5 to 10	5 to 10 years

Source: adapted from Peshkin et al. 2004

Maintenance activities based on condition trigger values

Surface Type	Class	IRI (in/mi)	Cracking		Rutting (inch)	Faulting (inch)
			Percent	Length (ft/mi)		
Flexible, Composite	Interstate	80	0	250	0.25	N/A
	Primary	100	0	1000	0.25	N/A
	Secondary	125	5	1000	0.25	N/A
Rigid	Interstate	100	0	N/A	N/A	0.10
	Primary	100	0	N/A	N/A	0.10
	Secondary	125	0	N/A	N/A	0.10.

Source: O'Toole et al. 2013

Step 2
Determine Maintenance and Budget Needs

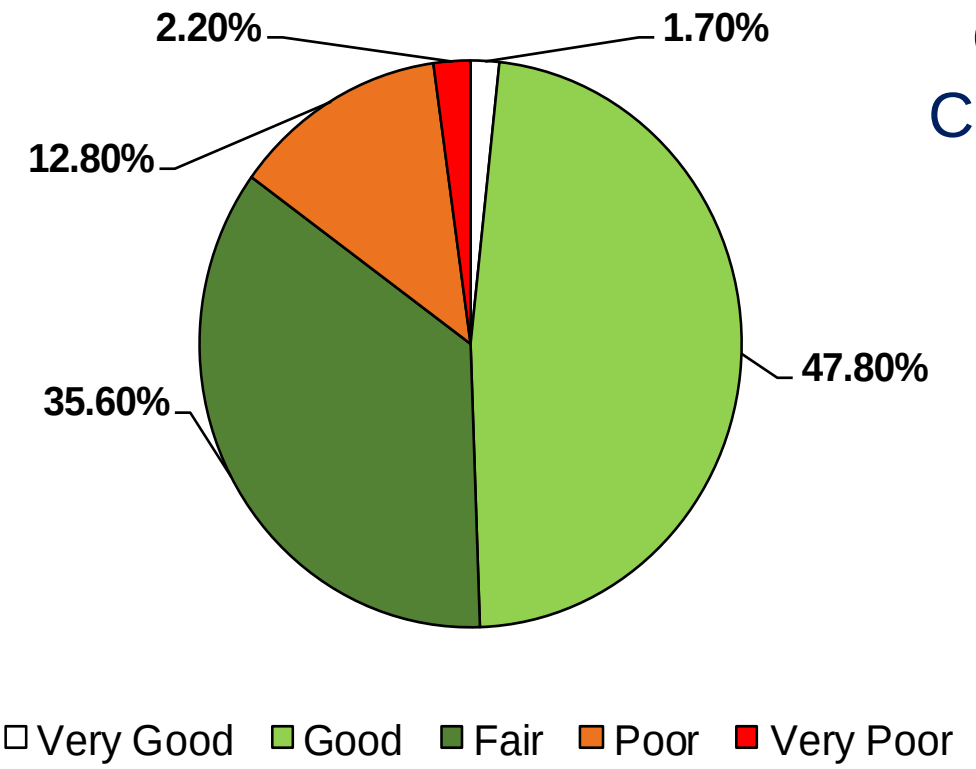
2.1 Asses the asset group condition

2.2 Select performance models to forecast the asset group condition and/or remaining life

2.3 Perform the needs analysis

2.1 Asses Pavement Network Condition

Before Treatment

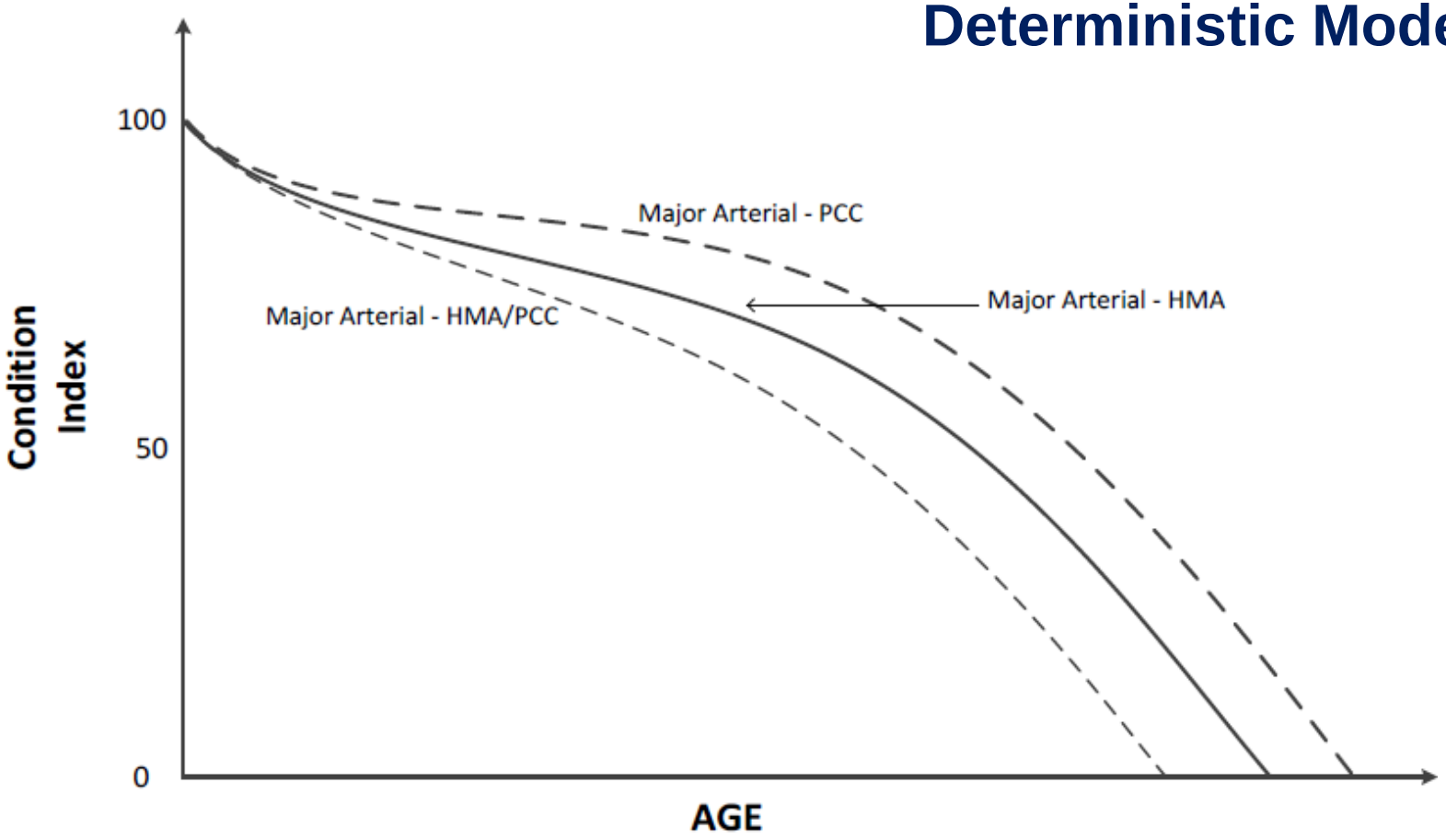


Current Average Condition Index (CI)

65

2.2 Select Performance Models to Forecast Condition

Deterministic Model



Example of family pavement performance curves

2.3 Perform the Needs Analysis to Identify Maintenance Activities to Meet the Objectives

To identify maintenance activities needed to meet the established goals over the period of analysis.

This analysis should be based on applying the right treatment, to the right asset, and the right time; in other words, it should reflect applying the "best engineering" practices related to maintenance treatments.

Step 3
Maintenance Scenarios Analyses

3.1 Formulate delayed asset maintenance scenarios

3.2 Perform the delayed maintenance scenarios analyses

3.3 Determine the impact and report the consequences of delayed maintenance

3.1 Formulate Delayed Maintenance Scenarios

1. All needs includes the agency-preferred maintenance policy with no funding constraints. A baseline budget is estimated from this scenario
2. Do nothing in which no treatments are applied over the analysis period.
3. Delayed maintenance by a given number of years that varies for each highway asset group due to their expected service life, decision criteria, and consequences of postponing maintenance activities.
4. Budget-driven with limited funds for maintenance activities.

Summary of Performance Models and Analytical Tools for the Highway Assets

Asset Group	Data	Performance Models	Analytical Tools
Pavements	Pavement network inventory with condition assessment	Deterministic Probabilistic Bayesian Expert-based model	Pavement Manageme Systems (PMS)
Bridges	Bridge network inventory with condition assessment Example: NBI data for all 50 states	Probabilistic- Markov models. Example: NBIAS default performance models.	Bridge Management Systems (BMS)
Culverts	NBI data on bridge-length culverts with condition assessment	Prediction of culvert rating (0-9) using a probabilistic approach similar to the bridge mode.	Culvert Management Systems (CMS) Spreadsheet based analytical tool
Guardrails	Guardrail System inventory with condition assessment	Transition probability matrices to model the increase/decrease of deficient guardrails.	Spreadsheet based analytical tool
Lighting	Lighting System inventory with condition assessment	Weibull models for predicting likelihood of lamp or electrical failure. Straight-line loss of service life based on expected life.	Spreadsheet based analytical tool
Pavement Markings	Pavement Markings inventory with condition assessment	Weibull models for predicting pavement marking retroreflectivity failure. Straight-line deterioration model.	Spreadsheet based analytical tool
Signs	Sign System inventory with condition assessment	Transition probability matrices to model the increase/decrease of deficient signs.	Spreadsheet based analytical tool

3.2 Delayed Maintenance Scenarios Analyses

Summary of Results

Scenario	Description	Total Agency Cost[1,2]	Backlog Cost[1,2]	Percent Pavements in Very Poor Condition[1]
1	All Needs	$325 M	$0	0
2	Do Nothing	$0	$593.5 M	45.1
3	Delayed Maintenance by 2 years	$192 M	$209.7 M	18.6
4	Budget-driven with limited funds 0 percent of baseline budget for maintenance	$181 M	$310.9 M	35.8

[1] At the end of the analysis period.
[2] Total cost using a 3 percent interest and inflation rate.

20-year analysis period

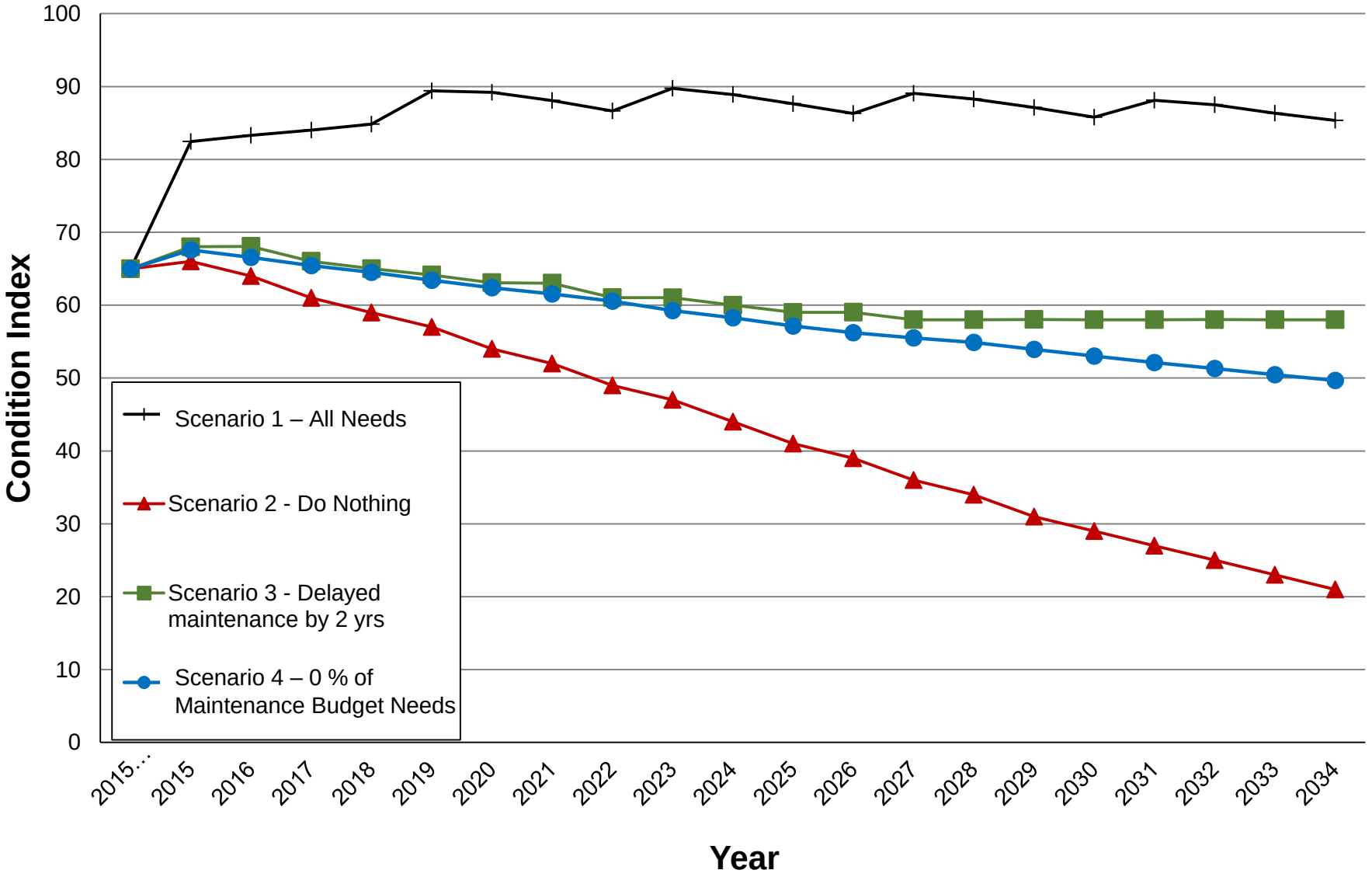
3.3 Determine the Impact of Delayed Maintenance and Report the Consequences

The procedure to quantify the consequences of delayed maintenance of highway assets involves comparing changes in:

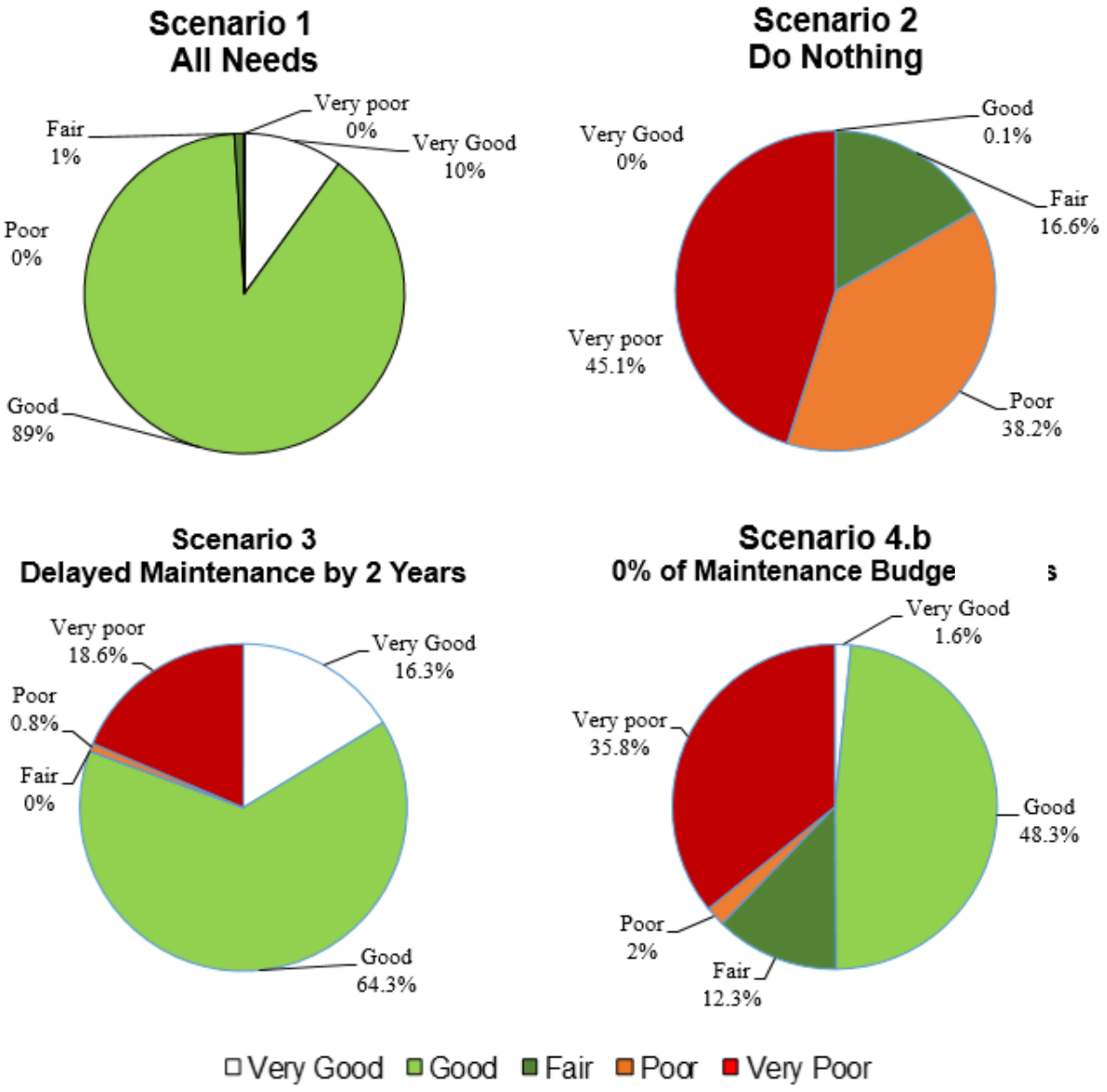
- Asset condition
- Remaining service life
- Agency costs in terms of:
  - Budget needs
  - Backlogged costs
  - Asset value

How to Report the Consequences of Delayed Maintenance?

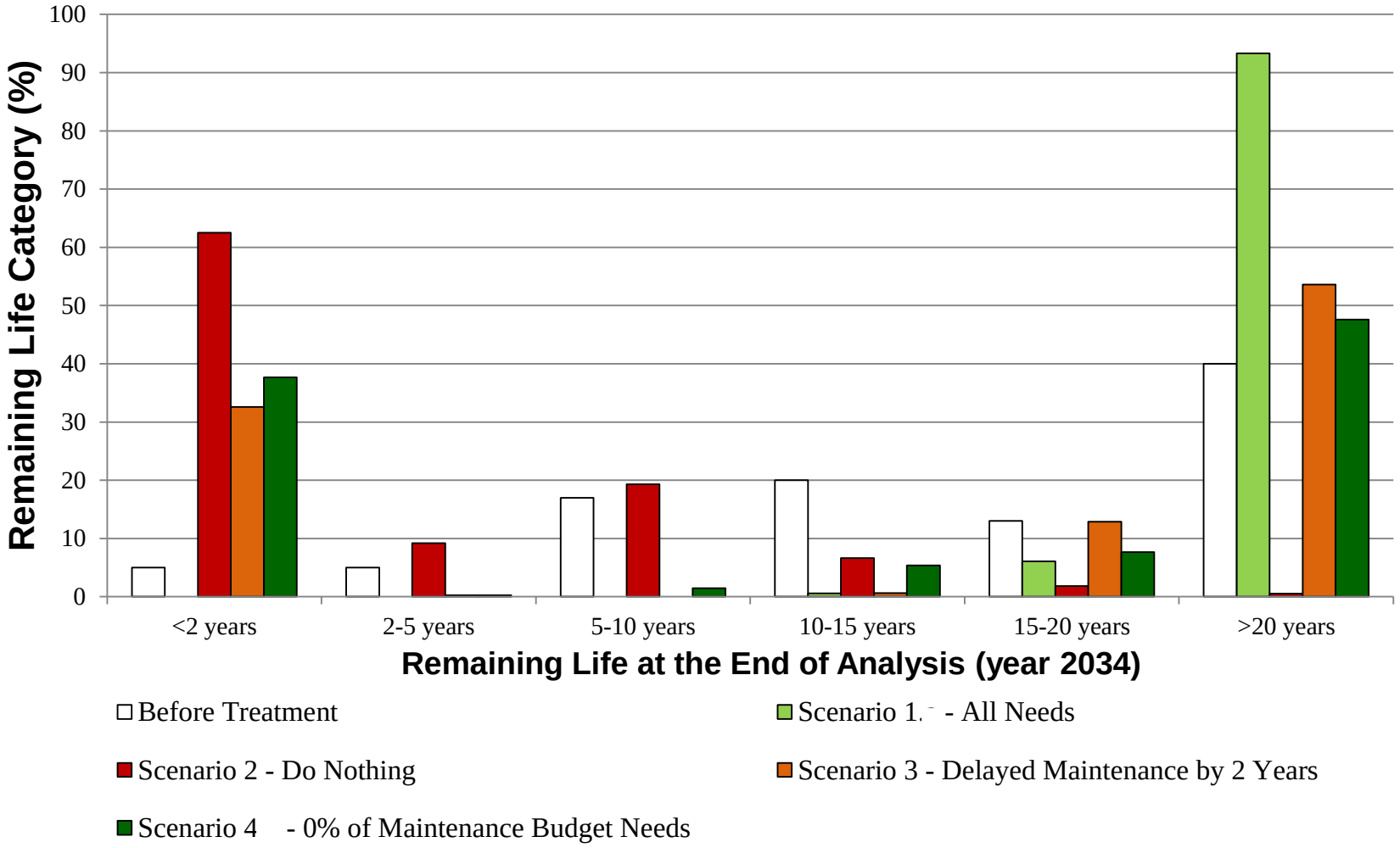
Impact on Pavement Condition



Pavement Network Condition At the End of 20 Years

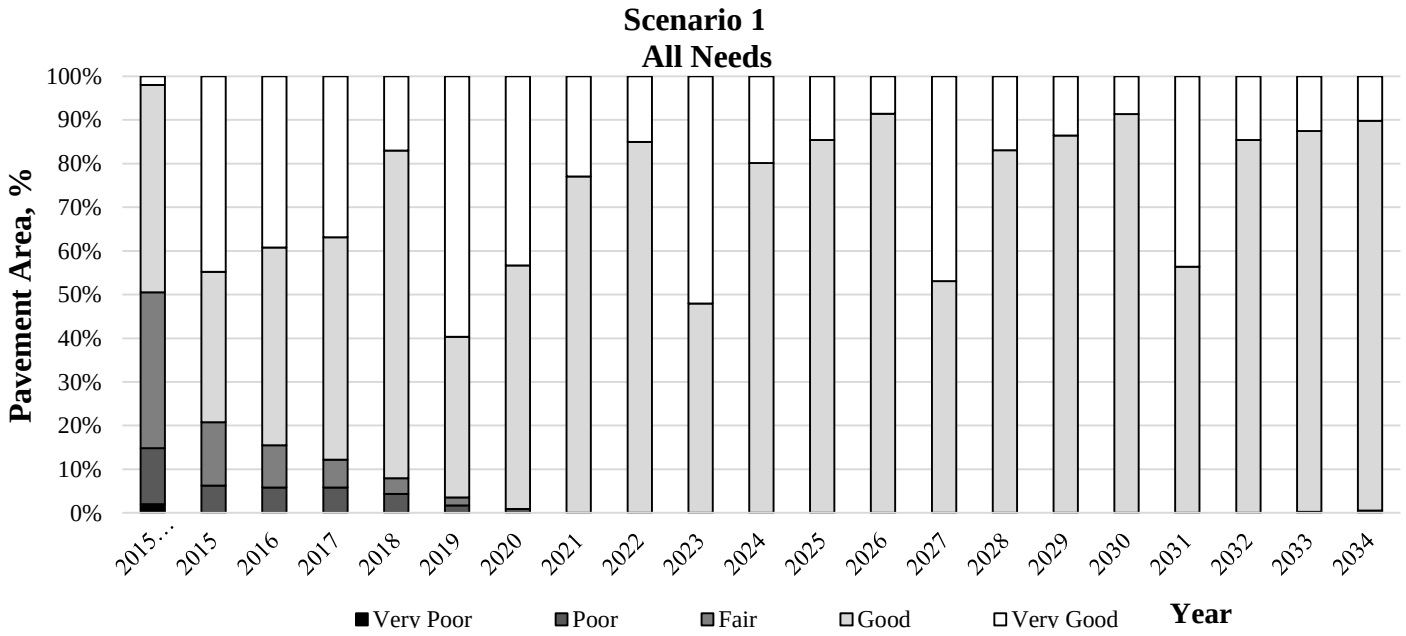


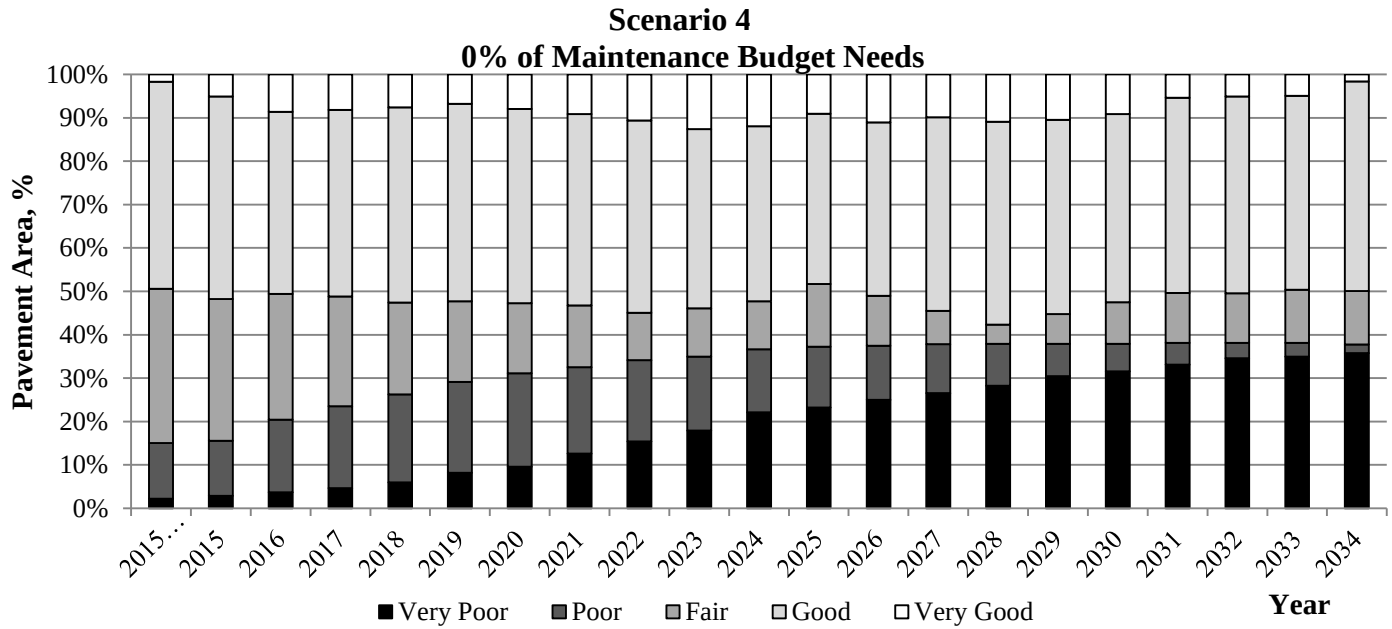
Remaining Service Life



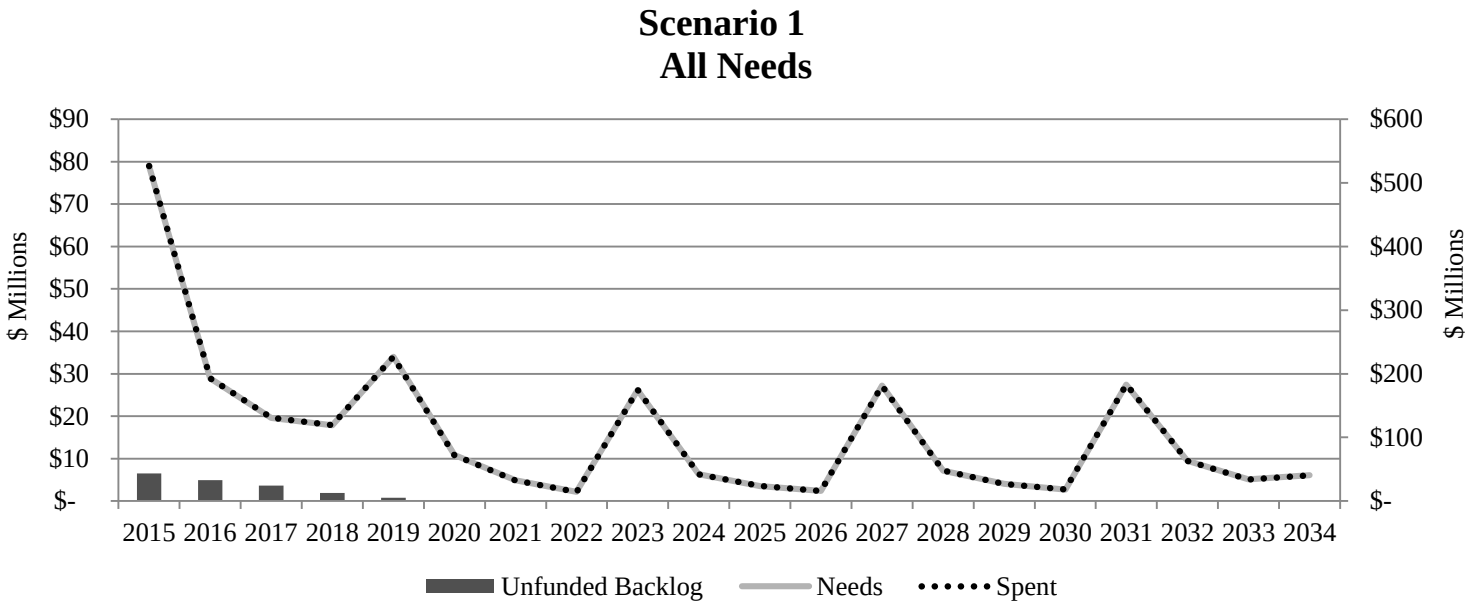
20-year analysis period

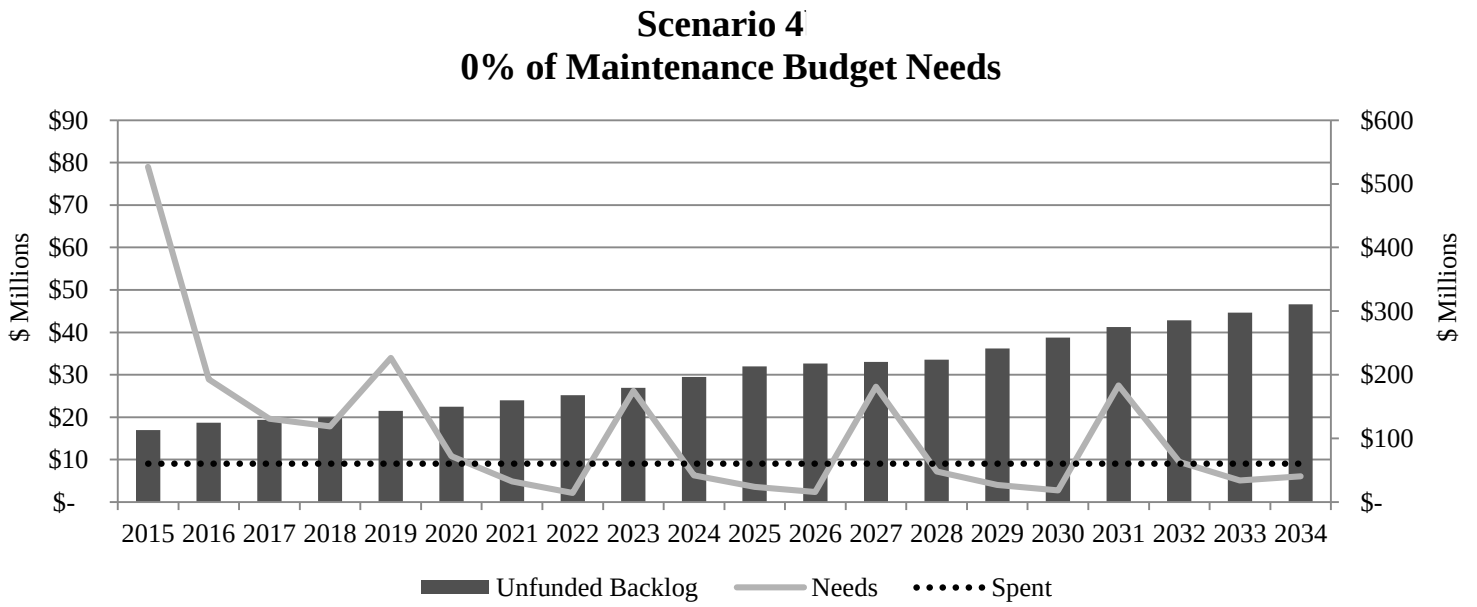
Budget Needs





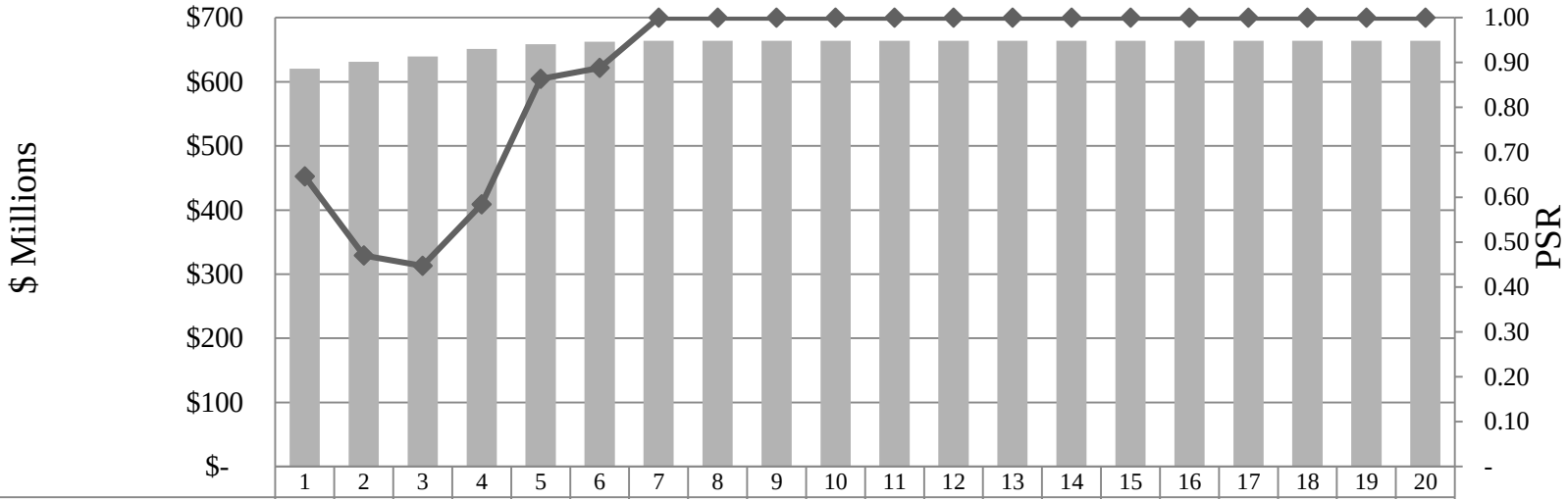
Backlogged Cost





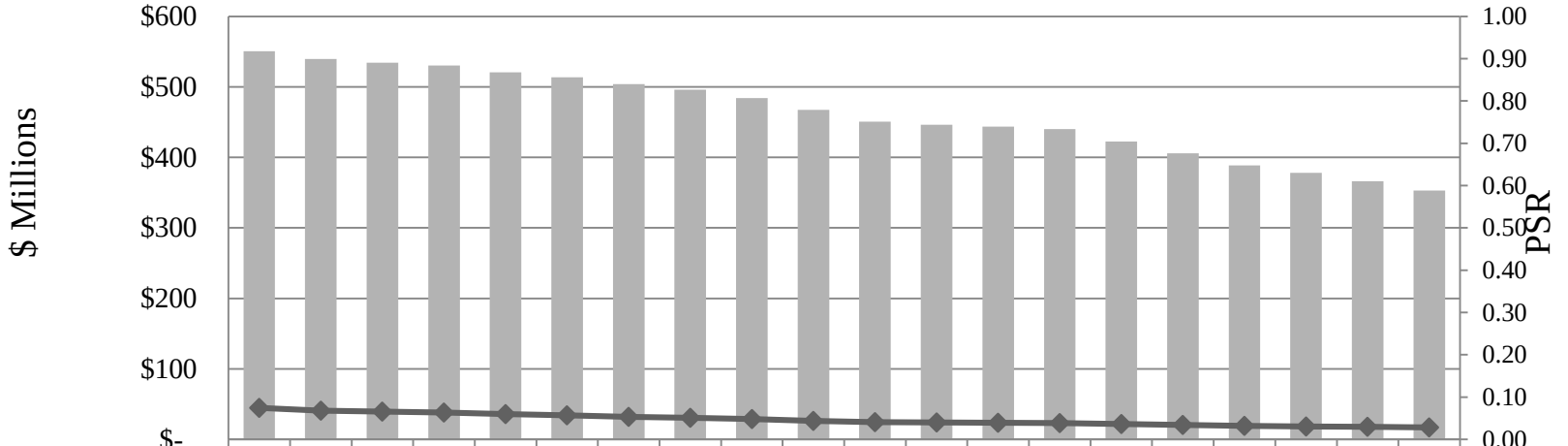
Pavement Network Value

Scenario 1 - All Needs



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Network Value (US $ million)	$621	$631	$640	$651	$658	$662	$664	$664	$664	$664	$664	$664	$664	$664	$664	$664	$664	$664	$664	$664
Sustainability Ratio	0.65	0.47	0.45	0.58	0.86	0.89	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Scenario 4 - 0% of Maintenance Budget Needs



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Network Value (US $ million)	$551	$539	$534	$530	$521	$514	$504	$496	$484	$467	$451	$446	$444	$440	$423	$406	$389	$378	$366	$353
Sustainability Ratio	0.07	0.07	0.07	0.06	0.06	0.06	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03

Summary of Performance Measures for Strategic and Network Level Reports

Performance Measure Report Category		Pavement	Bridge	Culvert	Guardrail	Lighting	Pavement Marking	Signs
Asset condition		✓	✓	✓	✓	✓	✓	✓
Remaining service life		✓	✓	✓			✓	
Agency costs		✓	✓	✓	✓	✓	✓	✓
Asset value		✓	✓	✓	✓		✓	✓
Sustainability ratio		✓	✓	✓	✓	✓	✓	✓
Sustainability and user's costs [1]	Safety (e.g. Accident costs)	✓	✓					
	Mobility (e.g. Travel time, operating costs)	✓	✓					
	Environmental (e.g. CO_2 emissions)	✓	✓					

[1] Reports may include user costs or sustainability performance measures only if data and analytical tools are available to estimate these parameters.

Summary of Main Research Contributions

1. The procedures describe preservation policies, maintenance practices, inventory data, condition assessment methods, analytical tools for analyses, and reports to assist agencies in quantifying the consequences of delayed maintenance.
2. The procedures have been prepared in a practical, adaptable, and easy-to-follow format with focus on implementation. Therefore, the procedures can be implemented using agency-specific analysis tools from existing management systems

Recommendations for Implementation

1. Make the decision to proceed with the implementation
2. Integrate the preservation policies into an overall asset management process
3. Periodic update of the asset group inventory, condition assessment, and service life data. The procedures rely on up-to-date records with reliable maintenance and inspection data to develop or calibrate performance models
4. Select appropriate analytical tools to perform the needs and scenario analyses
5. Select reports to facilitate the interpretation of the results from the scenario analyses

Acknowledgments

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Research Team

The University of Texas at El Paso

Carlos M. Chang, Ph.D., P.E.
Soheil Nazarian, Ph.D., P.E.
Marketa Vavrova, Ph.D., E.I.T.

Research Assistants

Luis Valdez
Erick Munoz
John Padilla
Sandra Gutierrez
Shahrouz J. Ghadimi
Oscar Ortega
Edgar Rodriguez

Nichols Consulting Engineers, Chtd

Margot T. Yapp, P.E.
Linda M. Pierce, Ph.D., P.E.
Timin Punnackal, E.IT.
Jason Puccinelli, P.E.
Mei-Hui Lee, Ph.D.

Spy Pond Partners, LLC

William Robert

Consultant

Roger E. Smith, Ph.D., P.E.

Thank You!

Carlos M. Chang, Ph.D., P.E.

cchangalbitres2@utep.edu