Development of Next -Generation Pavement Performance Measures

NORTHWEST PAVEMENT MANAGEMENT ASSOCIATION (NWPMA) 2023

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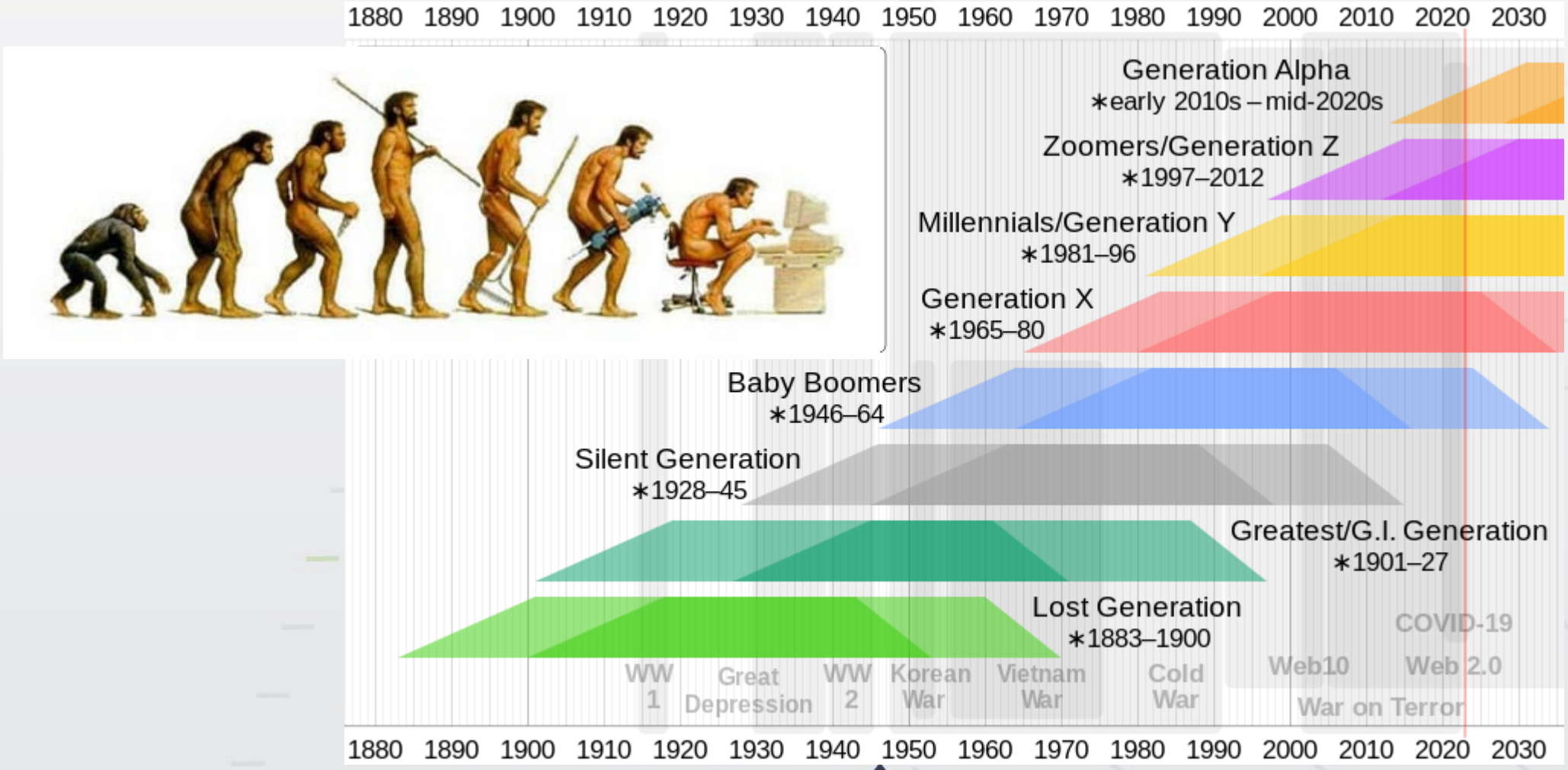
Who am I?

- Prashant V. Ram
- Undergrad in Civil Engg. And Masters in Chemistry in India
- Masters in CivilEngg. at Purdue
- Pavement Engineer,
  Applied Pavement Technology, Inc. (APTech)
- Passionate about sustainability, resilience, pavement/asset management
- I like concrete, have nothing against asphalt
- I like classic rock and heavy metal
- I like riding bikes
- I like lighthouses

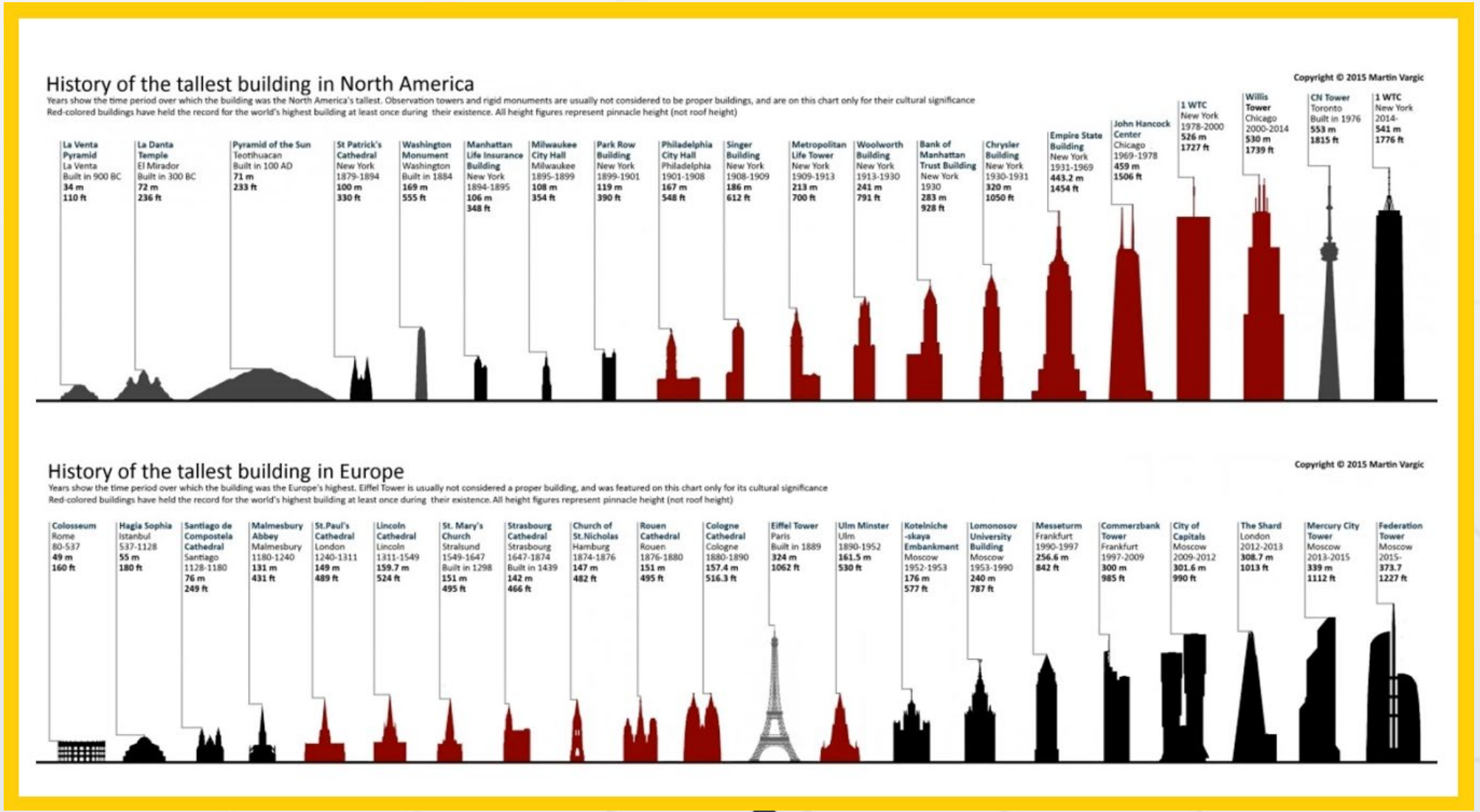
Human Generations



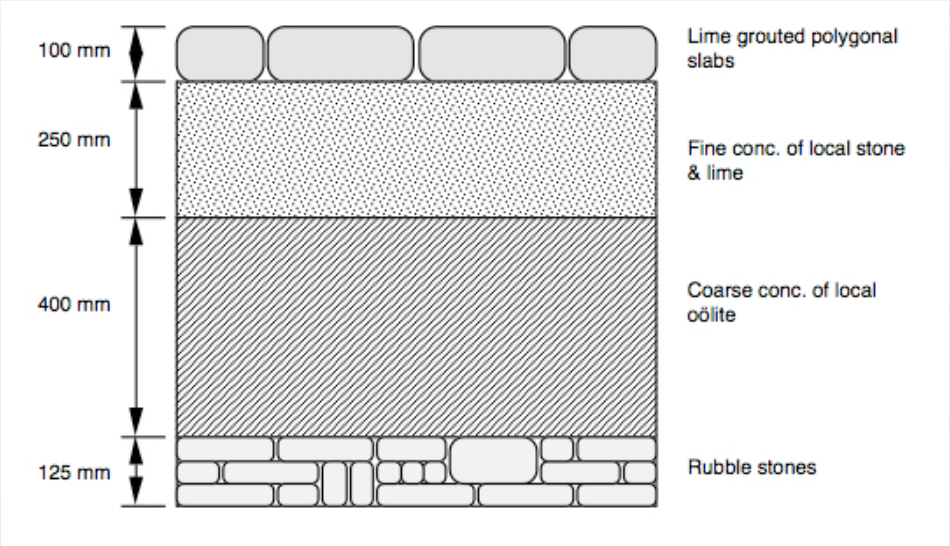
Generations of Rock Music

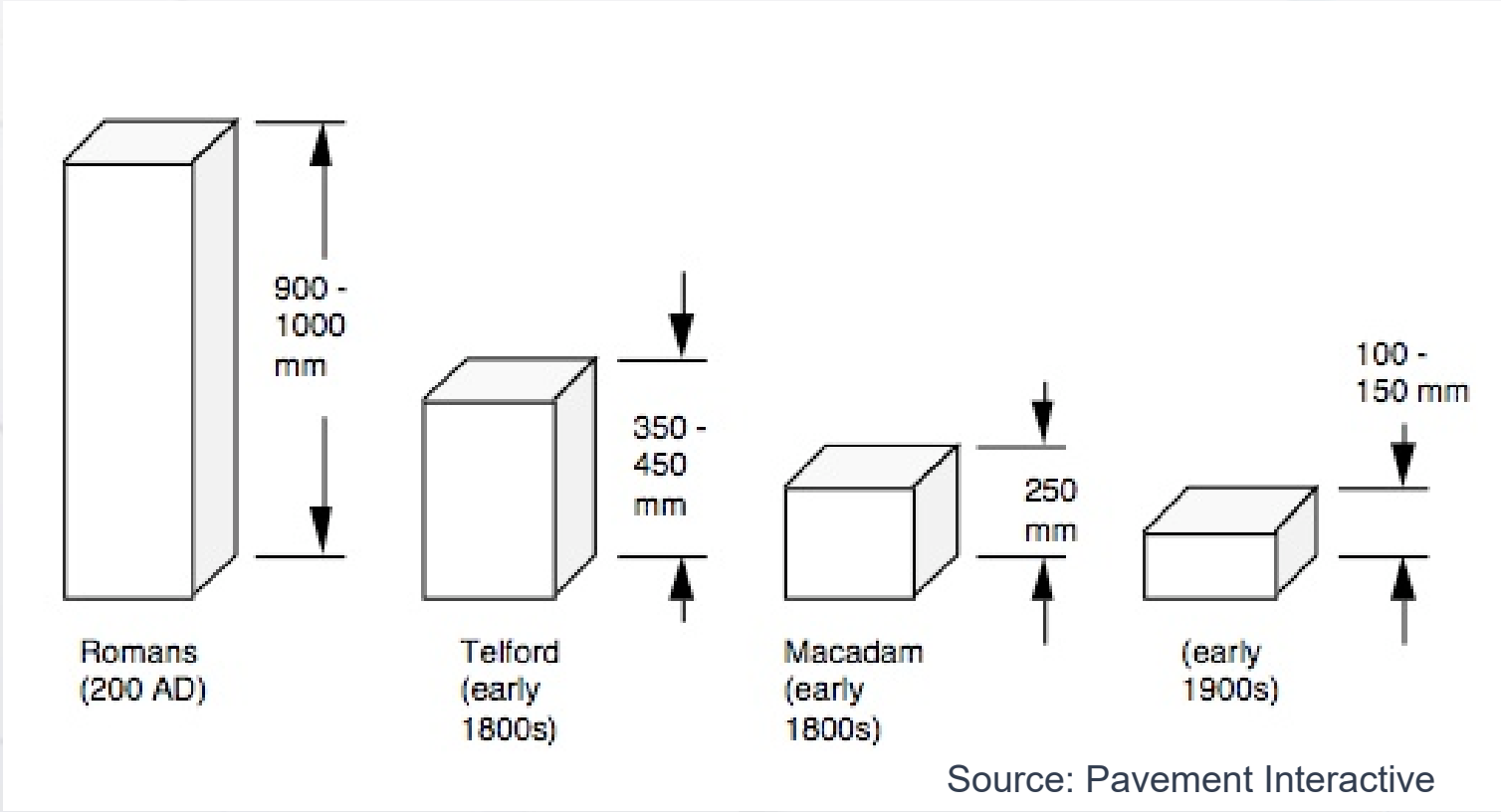
- 1960s: Beatles, Rolling Stones, The Doors, Led Zeppelin, Bob Dylan
- 1970s: Queen, Pink Floyd, Black Sabbath, Creedence
- 1980s: Metallica, Guns N Roses, AC/DC
- 1990s: Nirvana, Pearl Jam, Foo Fighters, Alice in Chains
- 2000s: Linkin Park, Green Day, Tool

Building Generations



Pavement Generations





Source: Pavement Interactive

Presentation Topics

- Background
- Next-Generation Pavement Performance Measures
- State Validation Efforts
- Findings, Conclusions, and Implementation Considerations

Project Background

- Study initiated by FHWA in September 2015
  - Phase I: Conceptual Development (Sep 2015 to Sep 2016)
  - Phase II: Pilot Testing and Validation (Oct 2017 to Sep 2022)
- Objectives:
  - Further develop, test, and validate :
    - Promising pavement performance measures
    - Promising methodologies to enable a full implementation of a comprehensive asset management plan
  - Provide input on modifications needed to existing asset management systems

Next-Generation Pavement Performance Measures (NGPPMs)

What's Your Story?

- Is there a different story we can tell using performance measures that are not just based on asset condition?
- Is our current pavement management strategy sustainable over the long-term?

Open Source Images from Pixabay

Source: Posteritati

Pavement Performance Measures Evaluated

- **Life-cycle performance measures** :
  - Remaining service interval (RSI)
  - Annualized unit cost ratio (AUCR)
  - Cost accrual ratio (CAR)
- **Financial performance measures** :
  - Asset sustainability index (ASI)
  - Asset sustainability ratio (ASR)
  - Asset consumption ratio (ACR)
  - Stewardship liability ratio (SLR)

- How feasible is the measure?
- What data is needed?
- What are the use cases?
- How do we calculate the measure?

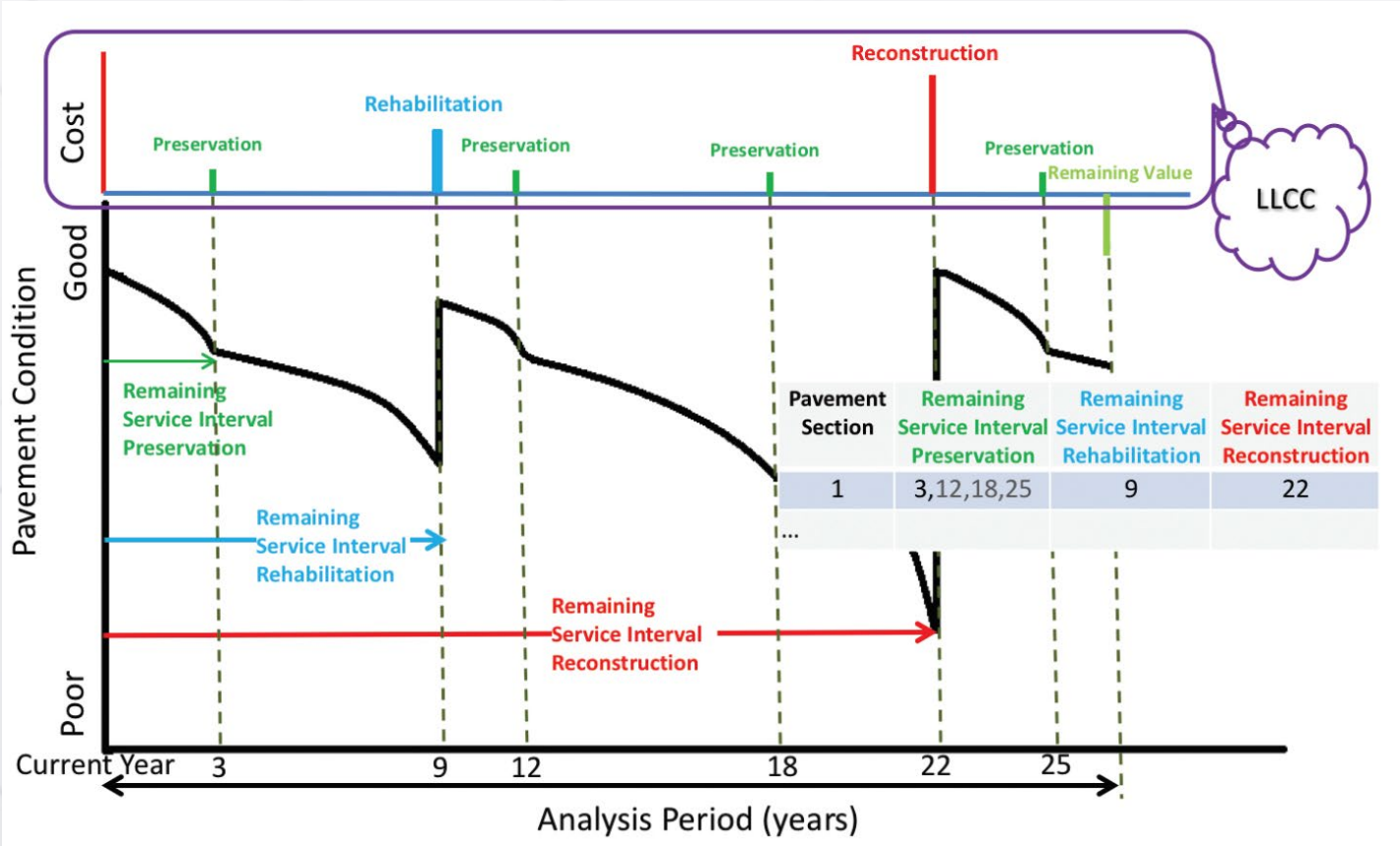
Life-Cycle Performance Measures

Remaining Service Interval (RSI)
Concepts

- Identify a structured sequence of type and timing of various pavement treatment options to provide the desired performance over the life cycle at minimum practicable costs
- Apply any treatment, at any year, for each pavement segment in a network subject to constraints and acceptable level of service (LOS)
- Use any performance measure to establish LOS criteria and impart other desired performance constraints

Remaining Service Interval (RSI)
Analysis Outputs

- Identify the lowest life-cycle cost (LLCC) solution (optimal) and other options (suboptimal) that achieve the performance goals
- Treatment types and timings are **outputs** from the process; outputs include a set of all feasible strategy options



Source: FHWA

Annualized Unit Cost Ratio (AUCR)

- Ratio of the annualized cost of all planned/actual expenditures over the pavement lifecycle to the annualized cost of expenditures under the optimized strategy

$$AUCR = \frac{EUAC_{actual\ or\ planned}}{EUAC_{optimized\ strategy}}$$

Cost Accrual Ratio (CAR)

- Ratio of net present value (NPV) of actual/planned costs to date against the NPV of the agency's optimized life-cycle strategy

$$Short - Term\ CAR = \frac{NPV_{actual\ or\ planned\ costs\ to\ date}}{NPV_{of\ all\ costs\ in\ optimized\ strategy\ to\ date}}$$

$$Long - Term\ CAR = \frac{NPV_{actual\ or\ planned\ costs\ to\ date}}{Overall\ NPV_{of\ all\ costs\ in\ optimized\ strategy}}$$

Financial Performance Measures

Asset Sustainability Index (ASI)

- Ratio of amount of budget allocated to amount needed to meet the desired state of good repair (DSOGR)

$$ASI = \frac{Amount\ Budgeted}{Amount\ Needed}$$

Amount budgeted = Treatment cost from pavement management system (PMS) analysis runs

Amount needed = Budget needed to meet DSOGR

- Helps determine adequacy of investments to address needs identified by PMS

Asset Sustainability Ratio (ASR)

- Ratio of asset maintenance, preservation, and replacement expenditure to asset value depreciation over a given period

$$ASR = \frac{Asset\ Renewal\ Expenditure}{Asset\ Value\ Depreciation}$$

- Helps evaluate adequacy of agency investments to offset asset value depreciation

Asset Consumption Ratio (ACR)

- Ratio of depreciated asset replacement cost to the current replacement value

$$ASR = \frac{Depreciated\ Replacement\ Cost}{Current\ Replacement\ Cost}$$

- Highlights average proportion of as-new/as-built condition left

Stewardship Liability Ratio (SLR)

- Ratio of unfunded treatment needs to the current replacement cost

$$SLR_{Year\ n} = \frac{Unfunded\ PMS\ Treatments_{Year\ n}}{Replacement\ Cost}$$

- Helps track progression of backlog over time when compared to a baseline established by the agency

State Validation

Validation Objectives

- Validate through pilot implementation:
  - Next-generation pavement performance measures
  - Proposed transportation asset management methodology
- What is “validation”?
  - Implemented with available data and tools
  - Practical for use by agency in the decision-making process
  - Methodology can improve outcomes

States Selected for Validation

- Idaho Transportation Department (ITD)
- South Dakota Department of Transportation (SDDOT)
- Texas Department of Transportation (TxDOT)

ITD Validation

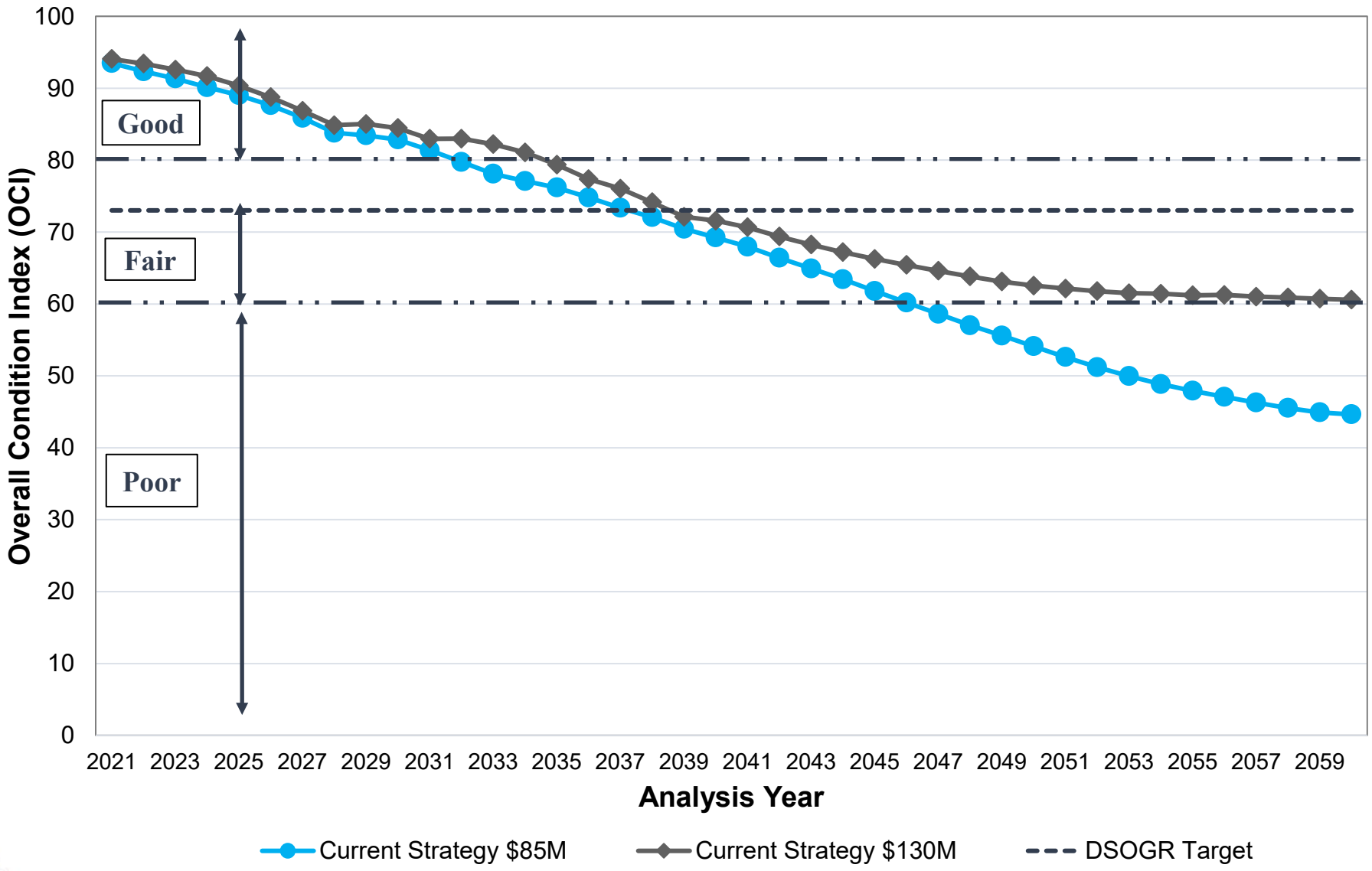
NEXT-GENERATION PAVEMENT PERFORMANCE MEASURES

Analysis Parameters

- Analysis period: 40 years
- Discount rate: 2 percent
- Pavement network: entire state system (12,265 lane-mi)
- Life-cycle strategies: current and worst-first
  - Only current strategy was used calculate measures
- Annual budget levels: Seven budget levels between $70 and $270M investigated
  - $85M and $130M scenarios analyzed further

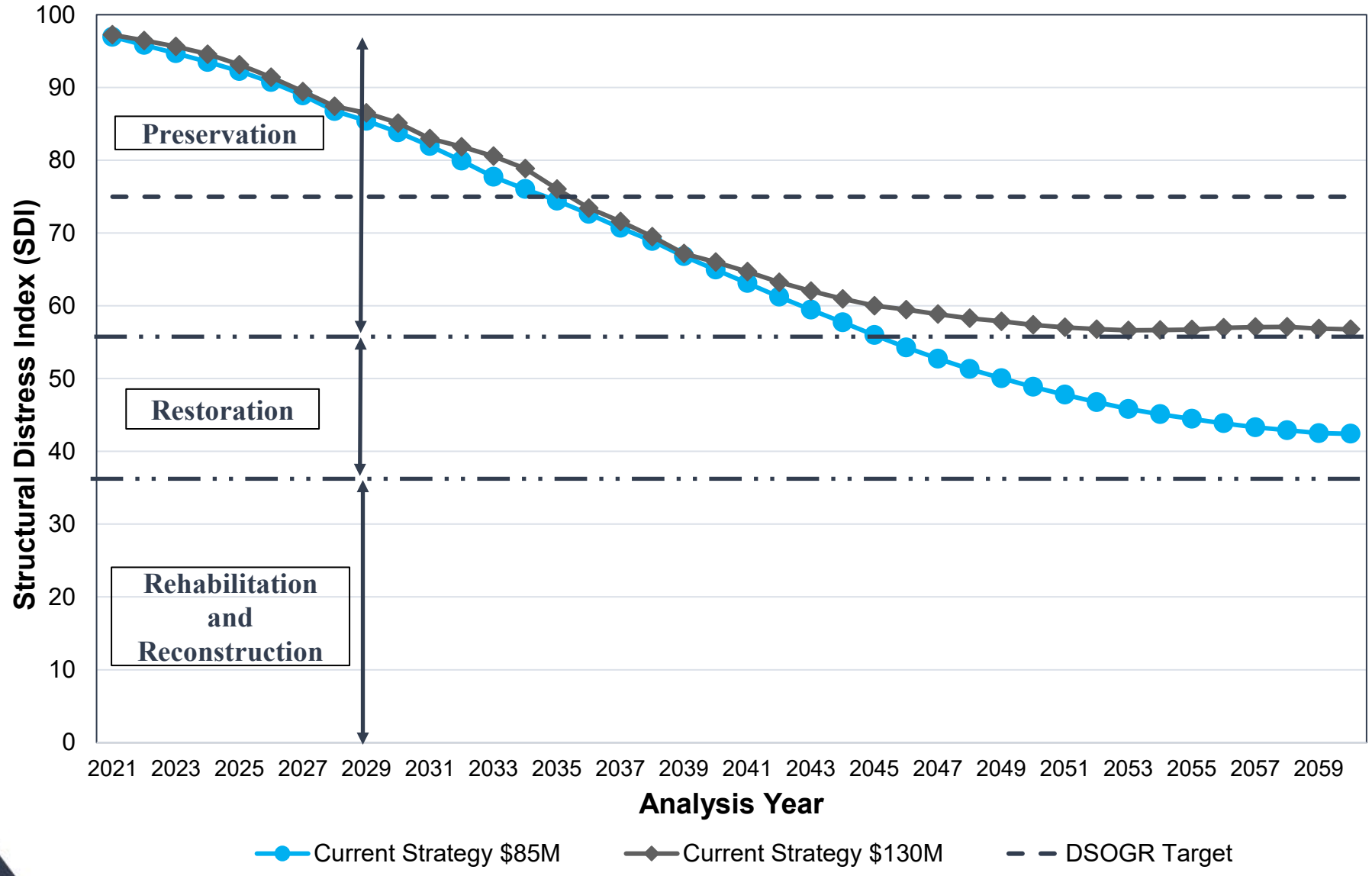
Pavement Condition Trends

Overall Condition Index (OCI)



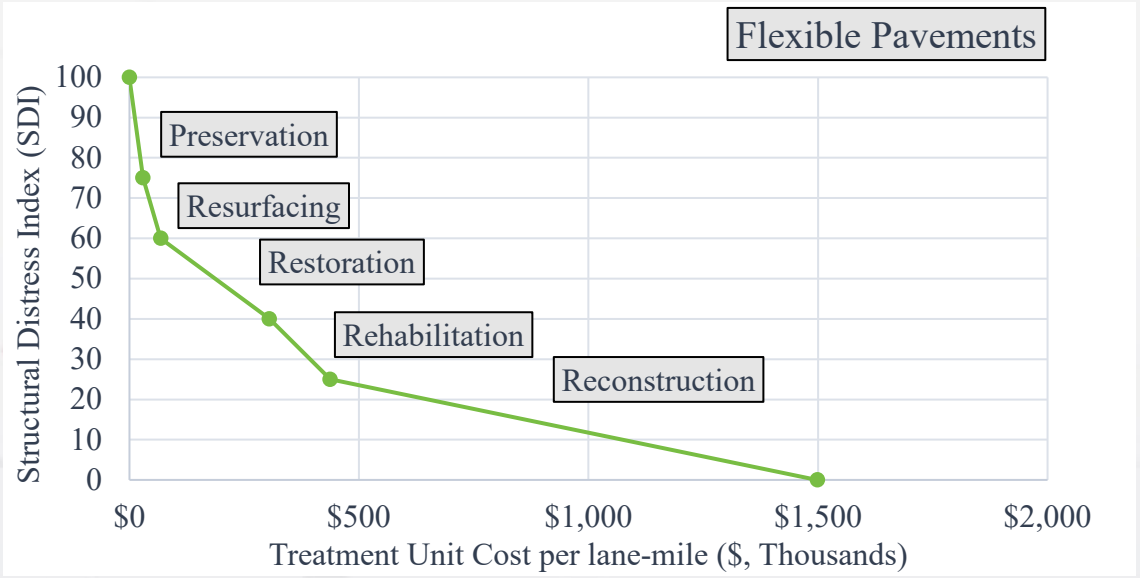
Pavement Condition Trends

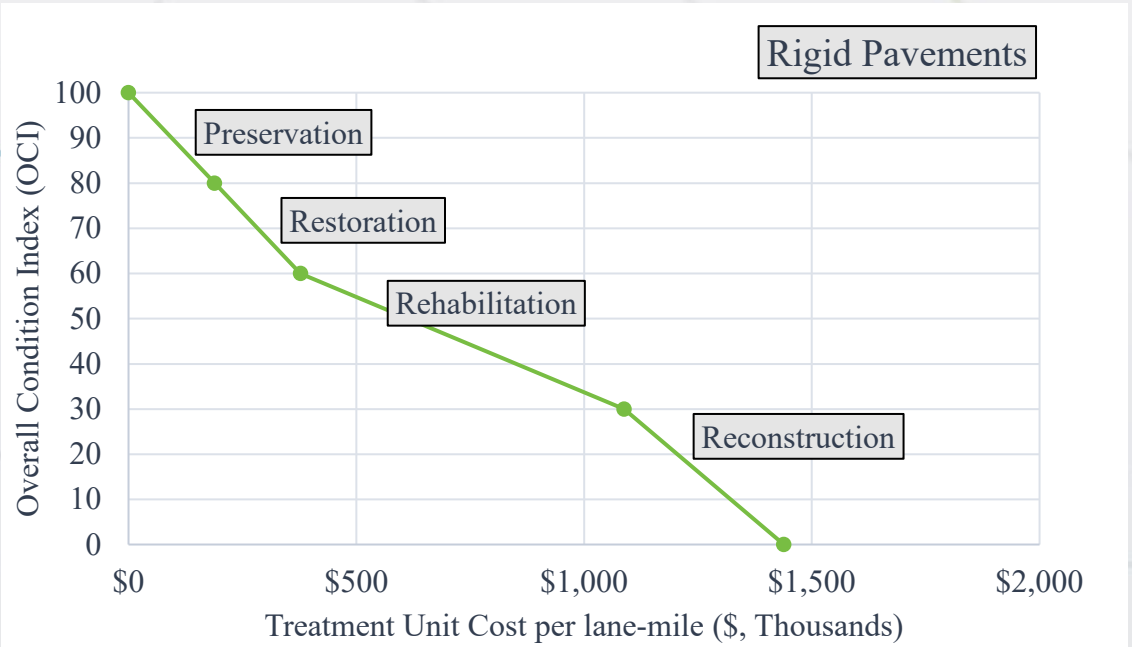
Structural Distress Index (SDI)



Modeling Depreciation

- Depreciation model developed based on pavement condition:
  - SDI for flexible pavements
  - OCI for rigid pavements
- Cost of treatment required to restore the pavement segment close to an as-built condition

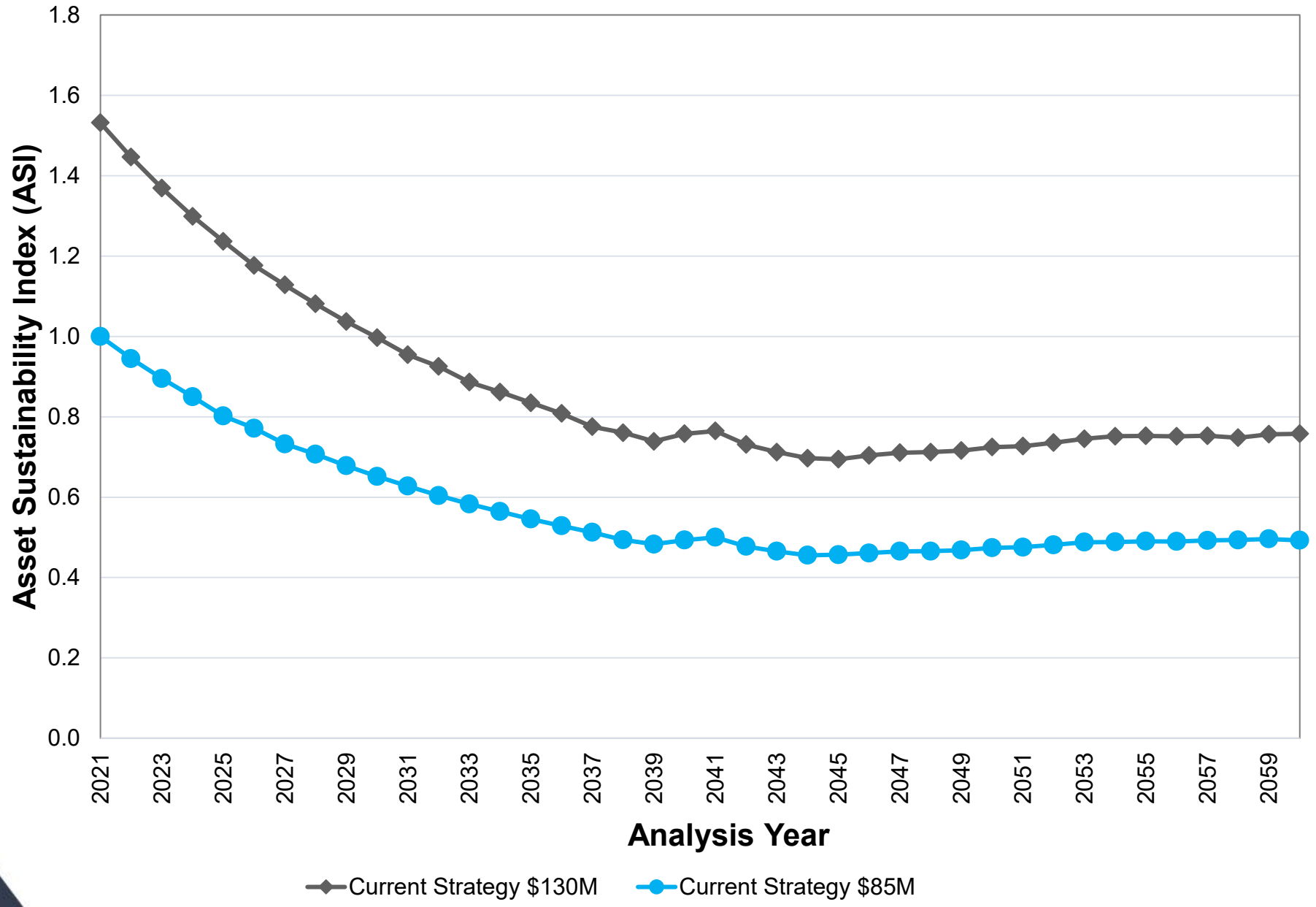




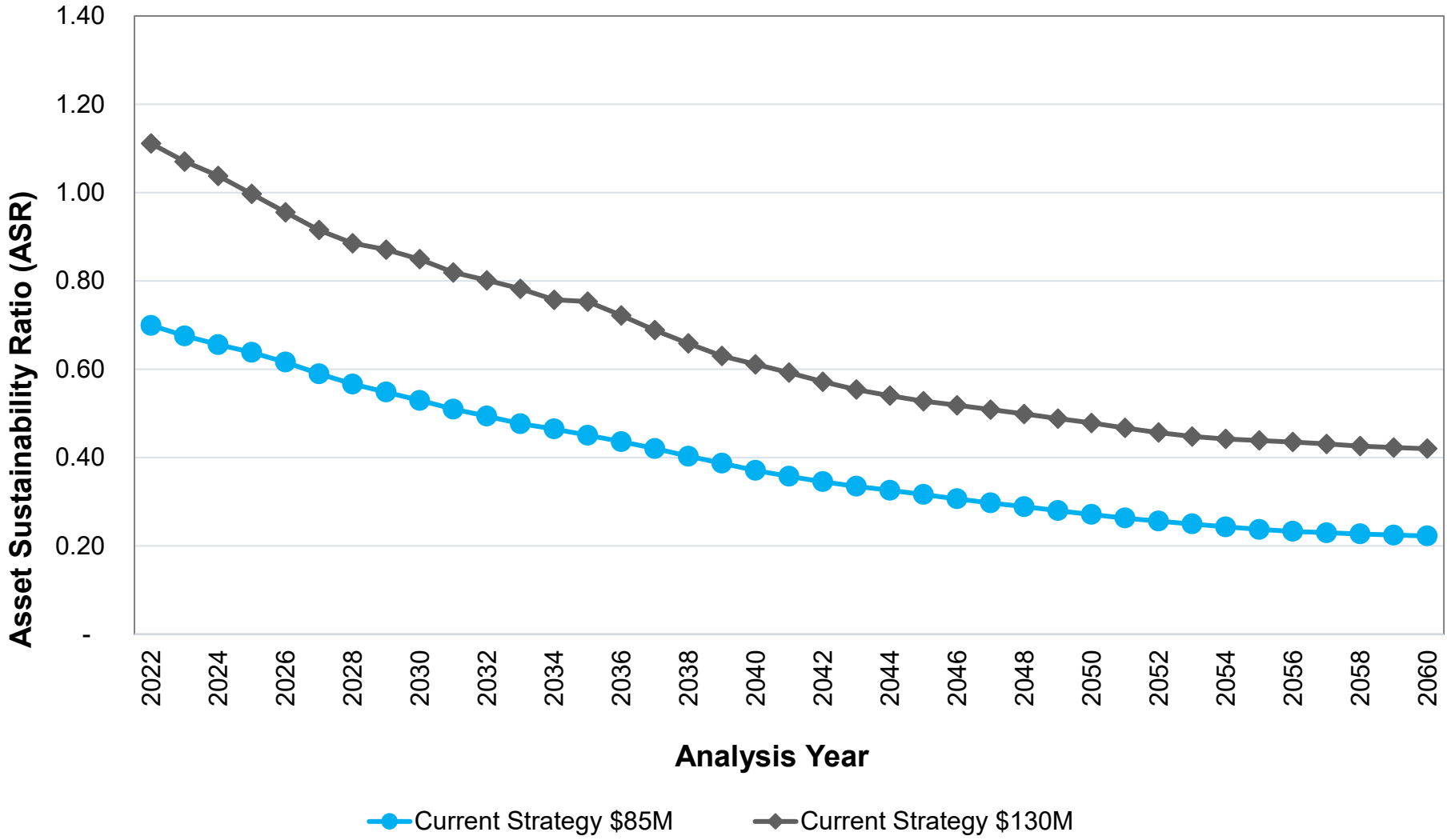
Calculating “Pavement Need”

- Annual funding level to meet the desired state of good repair
  - Functional DSOGR: OCI ⩾ 73
  - Structural DSOGR: SDI ≥ 75
- Results of $85M, $130M, $200M, and $270M analysis runs analyzed to establish “pavement need” over the analysis period

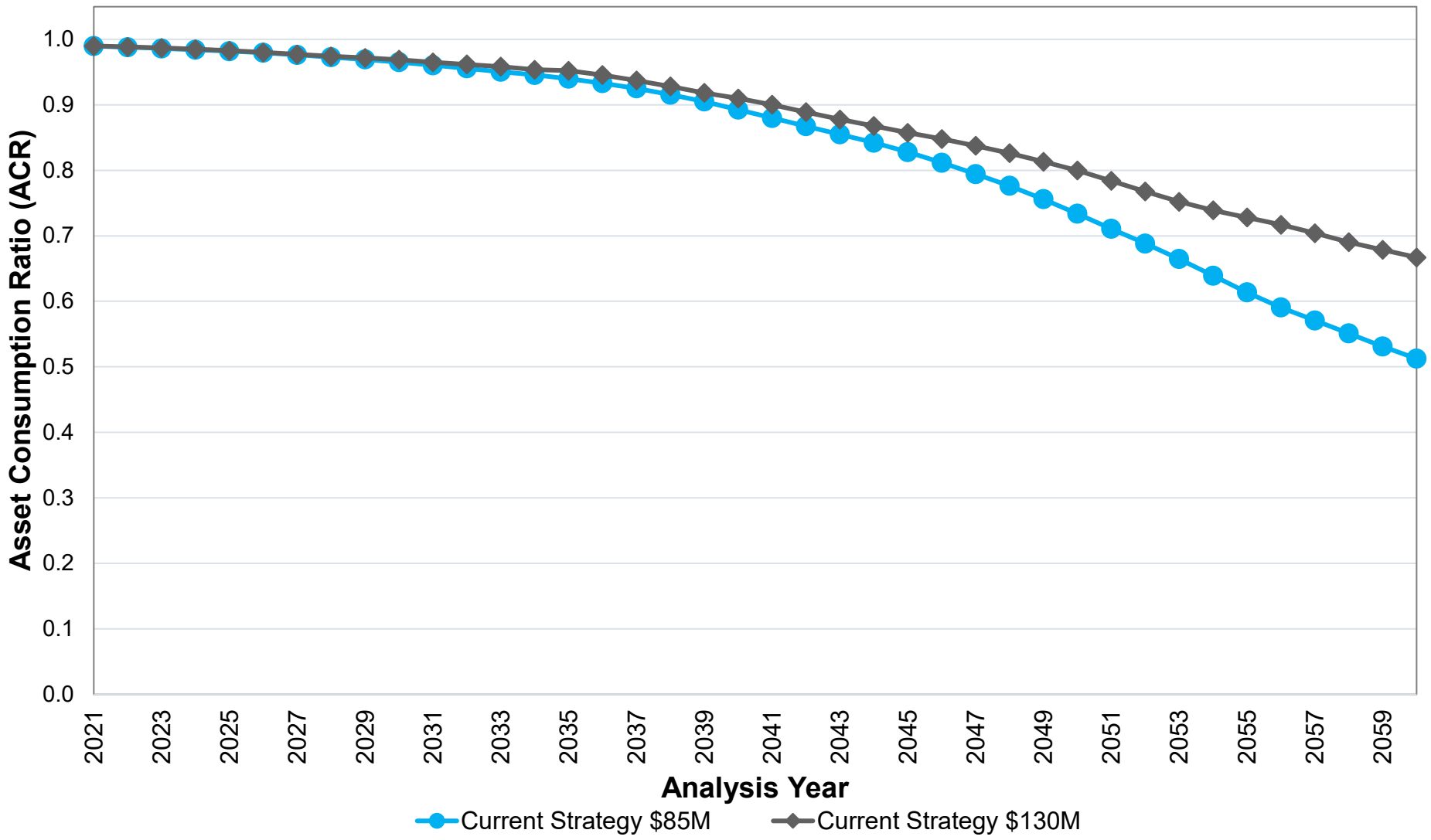
Asset Sustainability Index (ASI)



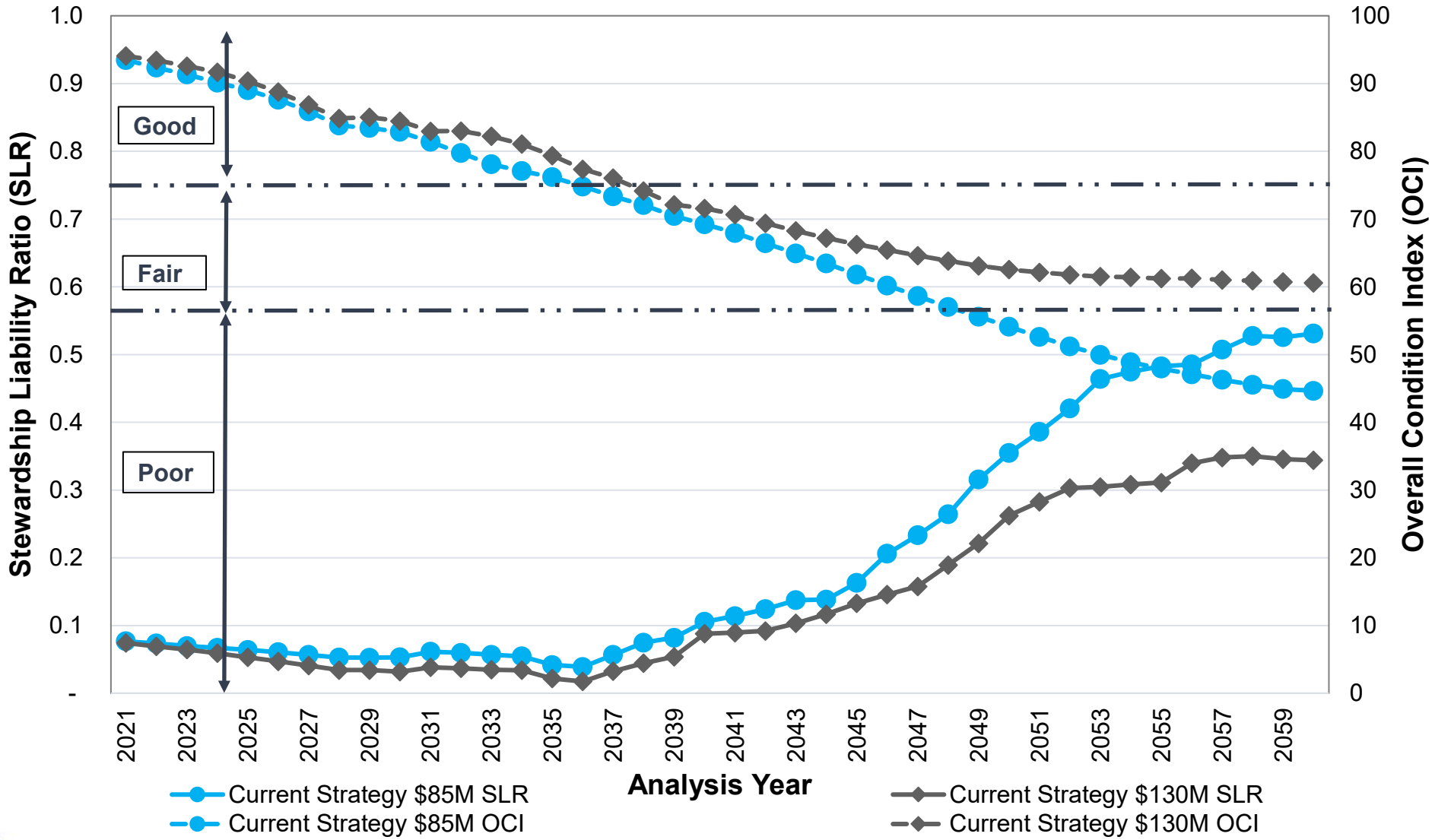
Asset Sustainability Ratio (ASR)



Asset Consumption Ratio (ACR)



Stewardship Liability Ratio (SLR)



SD DEPARTMENT OF TRANSPORTATION

South Dakota DOT Validation

NEXT-GENERATION PAVEMENT PERFORMANCE MEASURES

Analysis Parameters

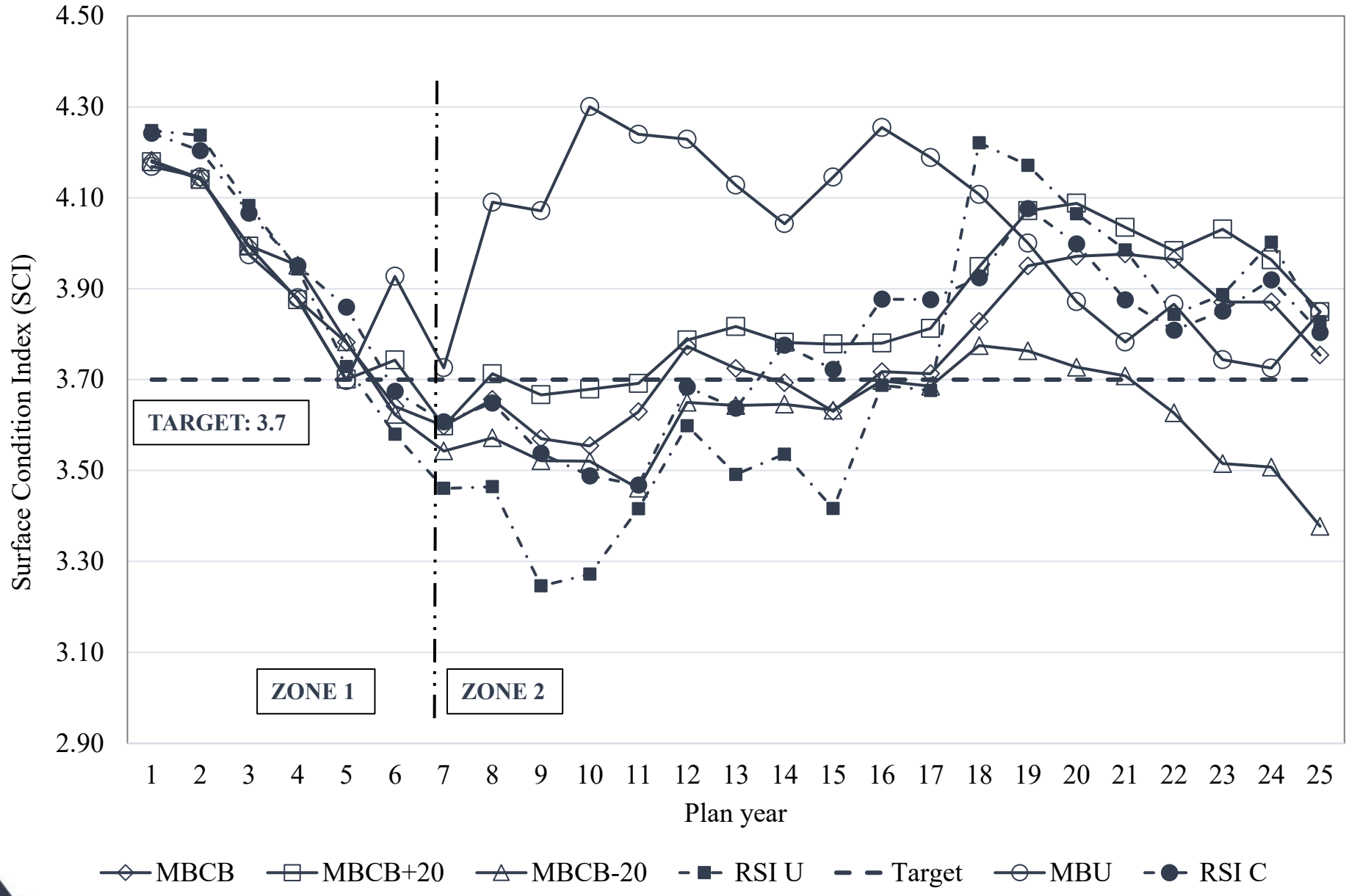
- Analysis period: 25 years
- Discount rate: 3.32 percent
- Analysis Corridor: US-14 (rural minor arterial, 579 l-mi)
- Budget levels evaluated using PMS:
  - Current: $16.7 average annual budget (MBCB)
  - 20% higher that current budget (MBCB+20)
  - 20% lower than current budget (MBCB-20)
  - Unlimited budget (MBU)

Additional Analysis for RSI Validation

- Conducted outside PMS environment (using PMS data) to:
  - Identify sequence of type and timing of various treatment options to provide desired performance at lowest life-cycle cost (LLCC)
  - Composite Index used as performance constraint
  - IRI used as LOS criteria
- Two RSI alternatives with LCC lower than SDDOT alternatives chosen for further analysis:
  - RSI-C: Annual budget constraints imposed
  - RSI-U: Unconstrained analysis

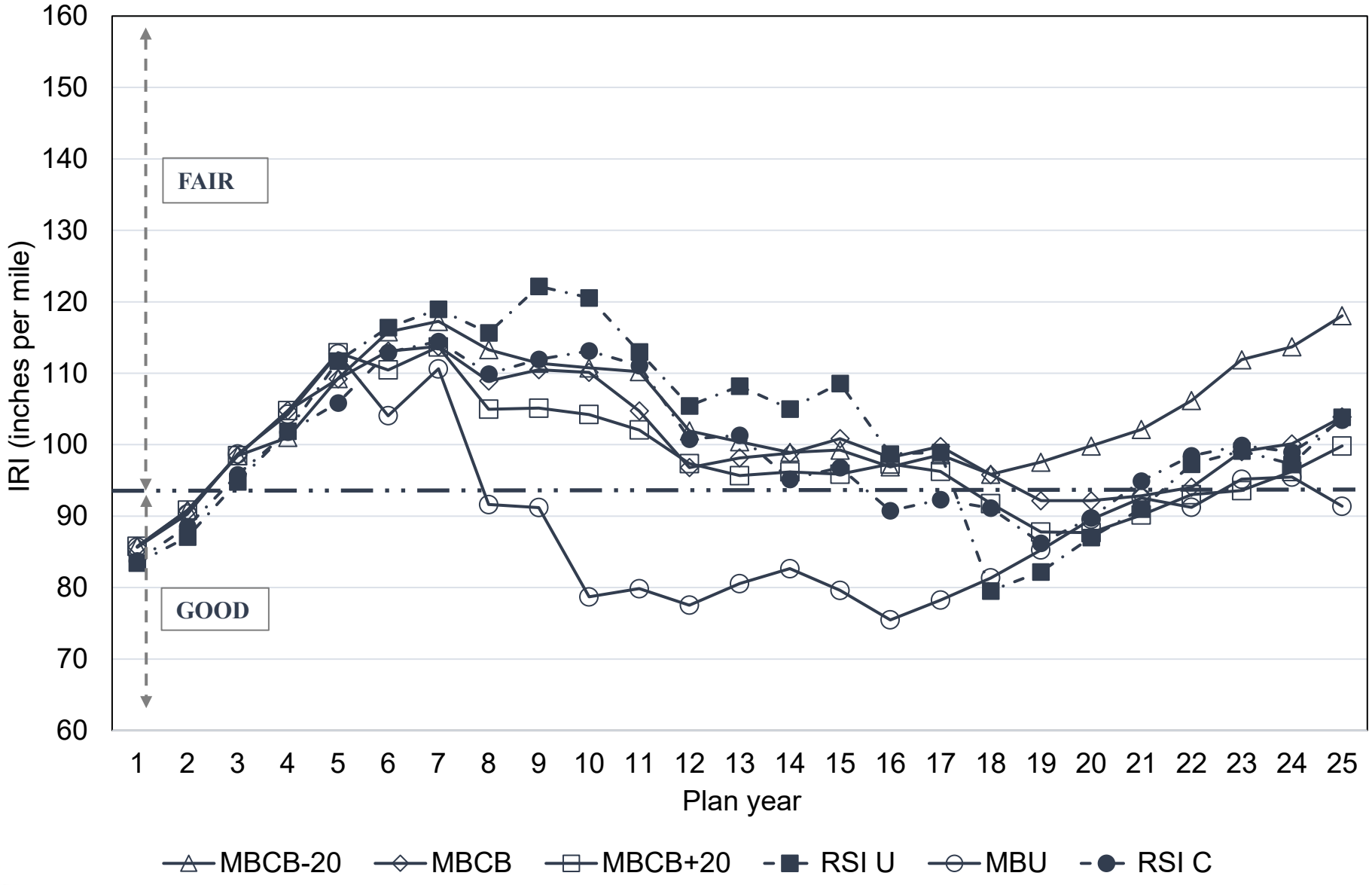
Pavement Condition Trends

Surface Condition Index (SCI)



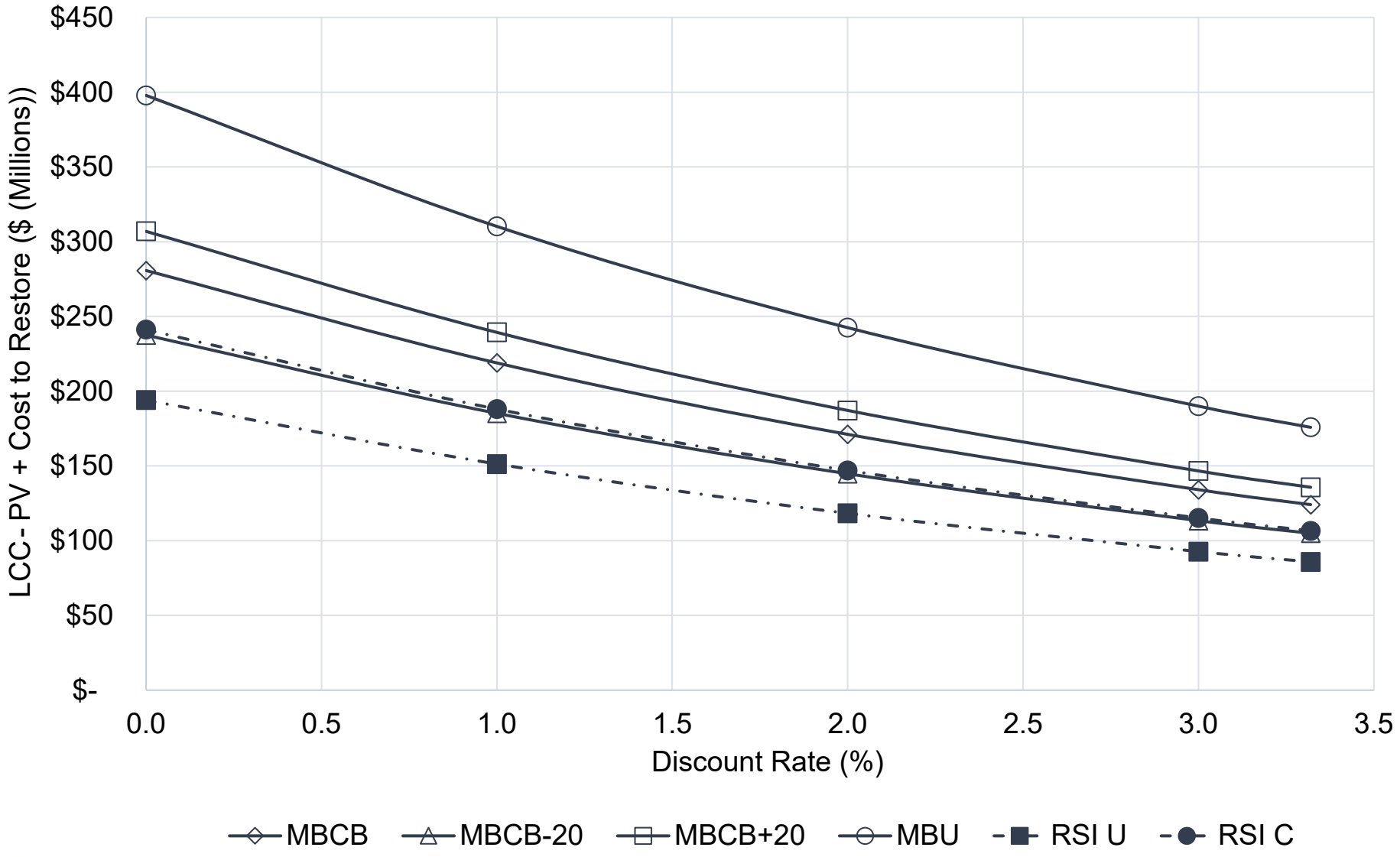
Pavement Condition Trends

International Roughness Index (IRI)



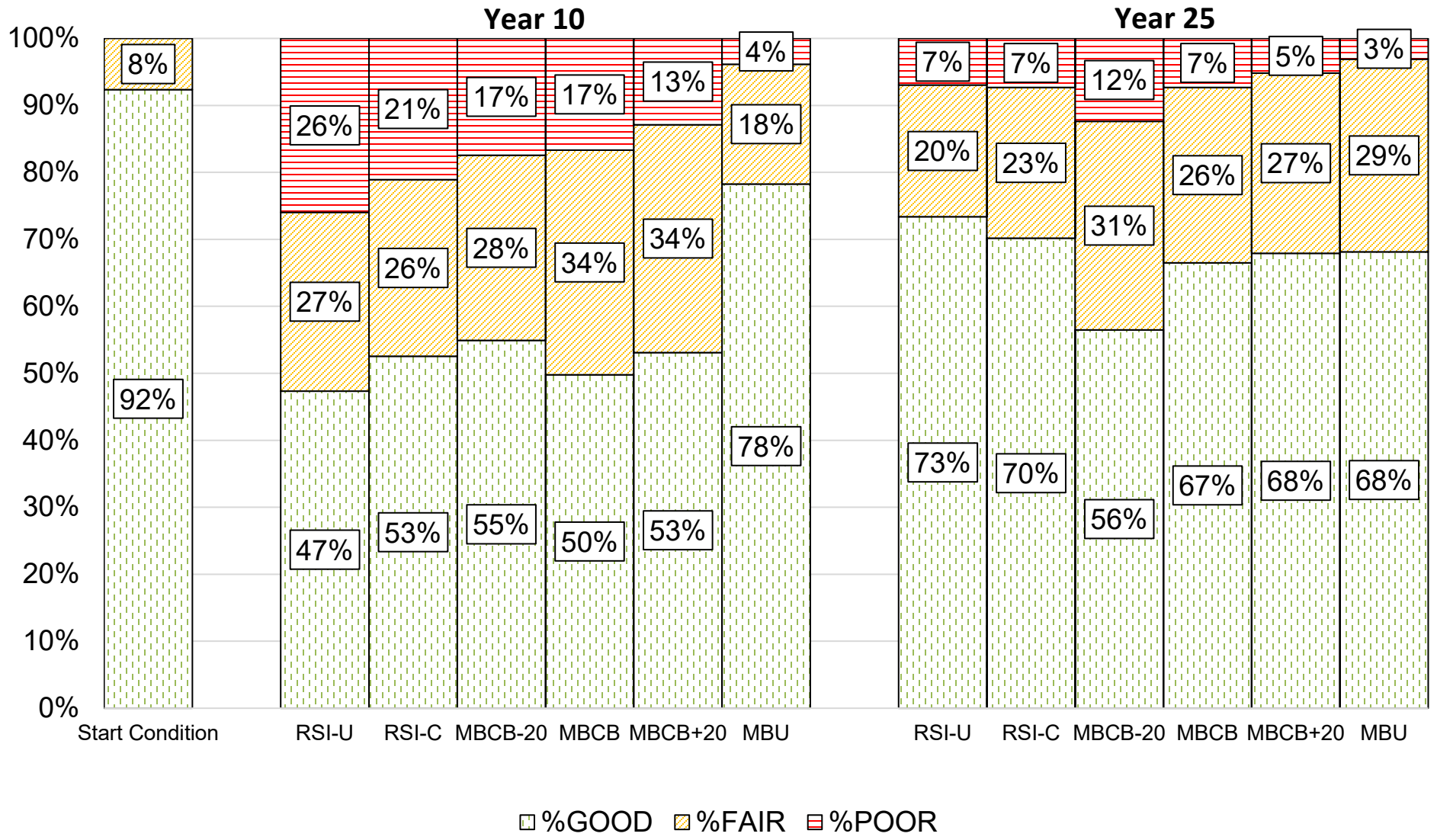
RSI Analysis

Life-Cycle Cost Comparison

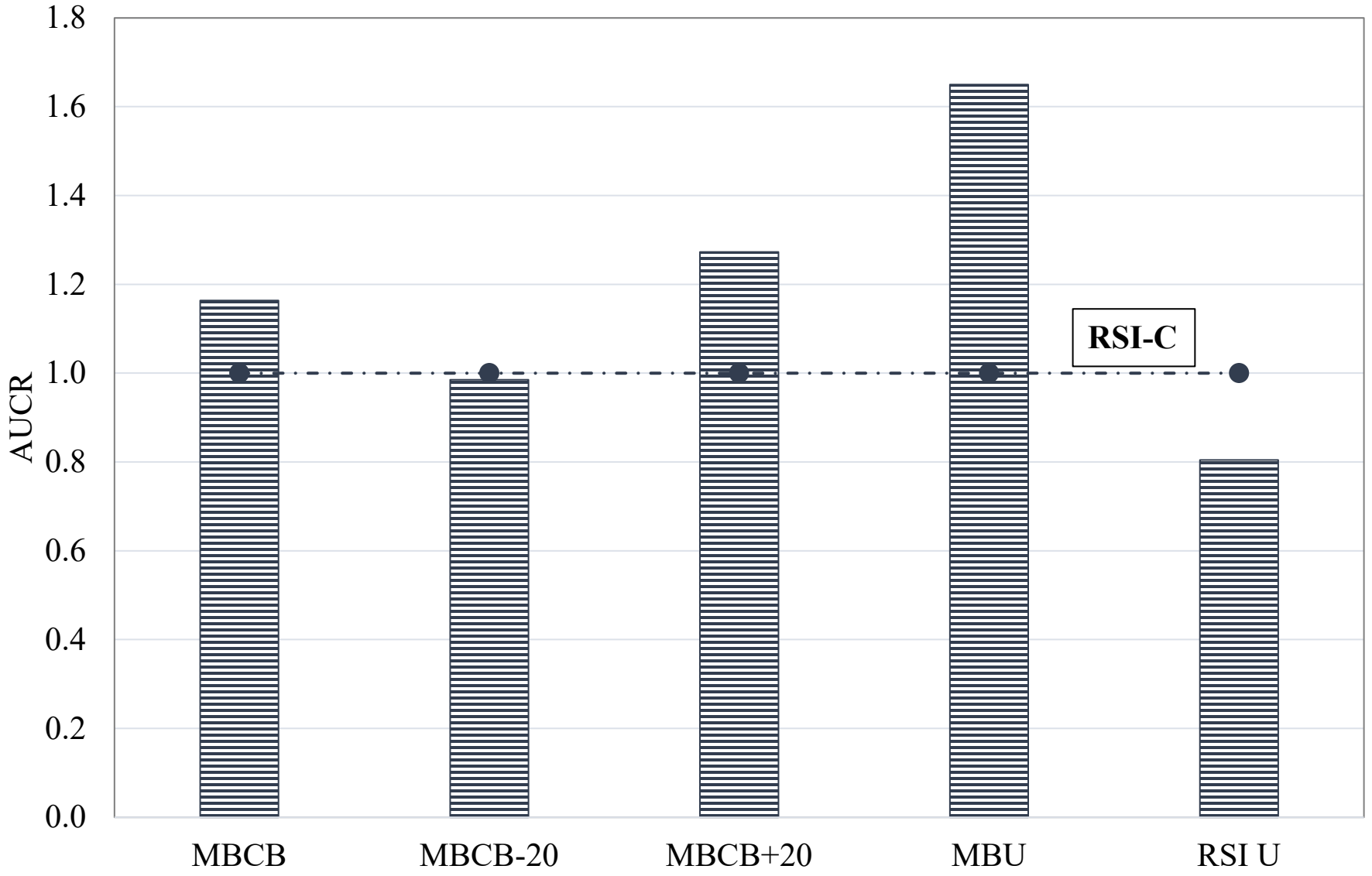


RSI Analysis

Comparison of Condition Outcomes

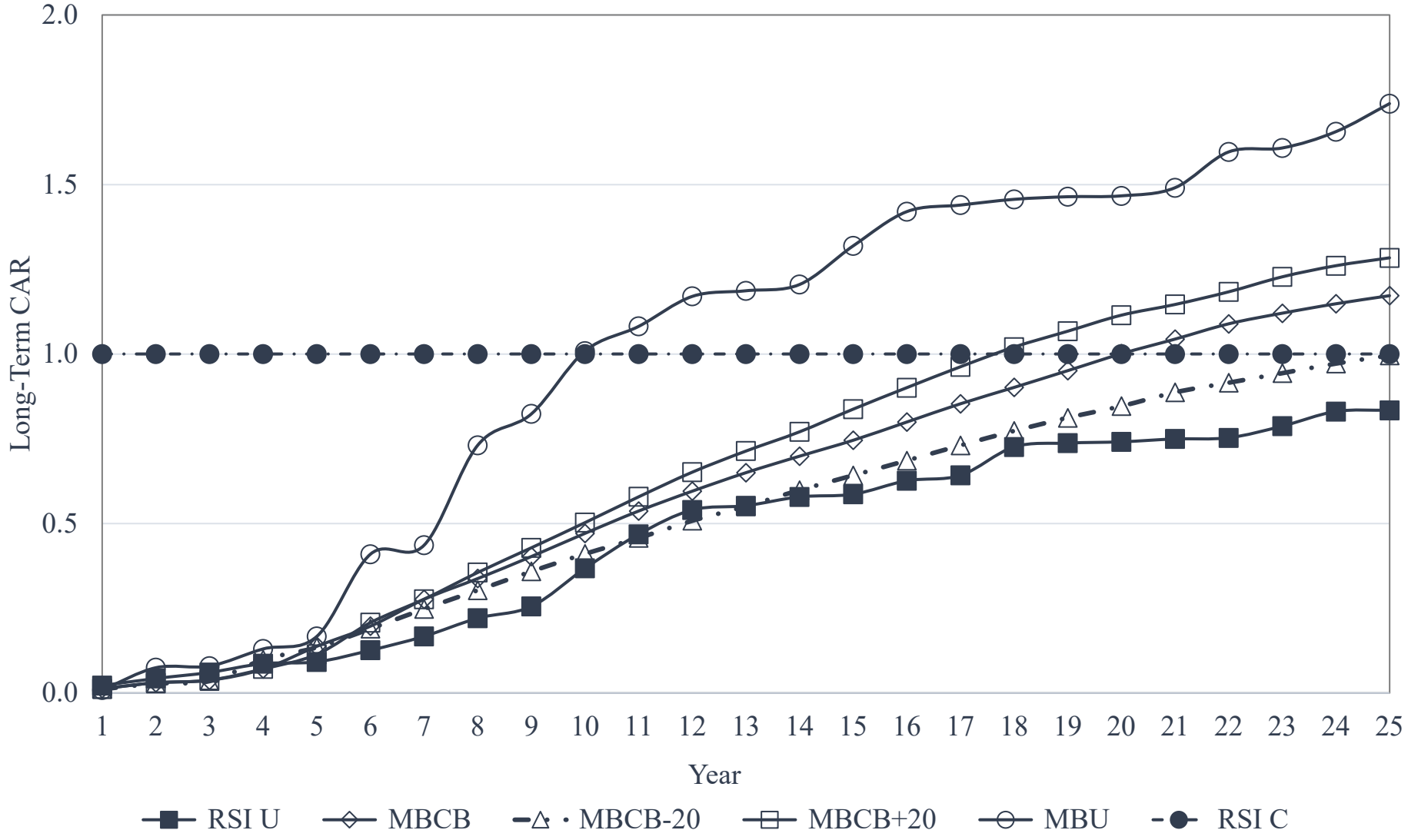


Annualized Unit Cost Ratio (AUCR)



Cost Accrual Ratio (CAR)

Long-Term CAR Trends



Concluding Remarks

Summary (1/2)

- To make sound, long-term investment decisions, performance indicators in multiple areas are needed:
  - Condition measures specific to asset class and agency (e.g. rutting, cracking, roughness)
  - Life-cycle measures that provide information on life-cycle cost of managing a pavement network
  - Financial measures that describe the financial sustainability of an agency's pavement management program

Summary (2/2)

- RSI framework helps agencies establish longterm treatment strategies
  - Life-cycle measures (CAR and AUCR) based on RSI analysis help visualize how different life-cycle strategies compare to the optimized strategy
- ASI, ASR, and SLR proved to be the most useful financial performance measures to help answer following questions:
  - How much do we need to invest to achieve/maintain DSOGR?
  - How much needs to needs to be invested to offset depreciation?
  - Are we investing in right type of treatments?
  - When might a significant shift in strategies be required?

Implementation Considerations

- Short-term strategies (< 5 years)
  - Compare NGPPMs to existing agency-based measures
  - Communicate differences between various treatment strategies and funding levels
  - Pilot NGPPMs within a district or region
  - Conduct training for PMS practitioners
- Long-term strategies (5 to 10 years)
  - Work with PMS vendors to enable calculation of NGPPMs
  - Use financial measures to validate PMS decision trees

Thank you!

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