Transportation Asset Management Webinar Series

Webinar 59

Incorporating Maintenance Costs into a TAMP

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U.S. Department of Transportation
Federal Highway Administration

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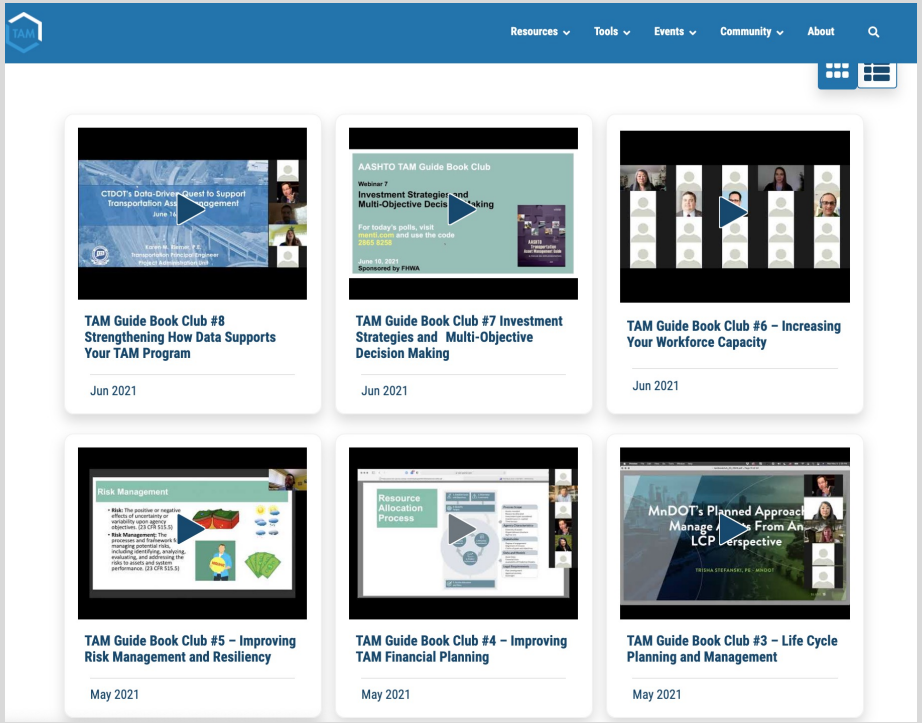
The Voice of Transportation

October 19, 2022

FHWA/AASHTO Asset Management Webinar Series

- This is the 59th in a webinar series that has been running since 2012
- Webinars are held every two months, on topics such as off-system assets, asset management plans, asset management and risk management, and more
  - 3rd Wednesdays, 2PM Eastern
- We welcome ideas for future webinar topics and presentations
- Submit your questions using the webinar's Q&A feature



Incorporating Maintenance Costs into a TAMP

AASHTO TAM WEBINAR SERIES
WEBINAR #59
OCTOBER 19, 2022

Today's Agenda

1. **Introductions** – Anita Bush, Nevada DOT
2. **An Overview of NCHRP 23-08 Findings and Guidance**
   - Brad Allen, Applied Pavement Technology, Inc.
   - Rob Zilay, Dye Management Group, Inc.
3. **Using Maintenance Quality Assurance Data to Support Asset Management** – Morgan Musick, Alabama DOT
4. **The Role of Maintenance in the Life-cycles of Ancillary Assets** – Trisha Stefanski, Minnesota DOT
5. **Maintenance and Ancillary Assets in CDOT's Asset Management Plan** – Toby Manthey, Colorado DOT
6. **Questions and Answers**

NCHRP 23-08: A Guide for Incorporating Maintenance Costs into a TAMP

- **Research Objective:** Develop a guide for state DOTs and other transportation agencies on incorporating maintenance costs in a risk-based TAMP
- **Status:** Final Guide and report submitted for review earlier this month
- **Workshop:** 2023 TRB Annual Meeting, Thursday morning

Many Thanks to the Project Panel!

- Larry Goldstein, TRB
- Jennifer Weeks, TRB
- Anita Bush, Nevada DOT (Chair)
- John Daly, Alpha Infrastructure Management Group
- Chris Diaczoc, Maryland DOTSHA
- Louis Feagans, Indiana DOT
- Dr. Ning Li, Virginia DOT
- Dr. Nadereh Moini, New Jersey Sports & Exposition Authority
- Patrick Norman, North Carolina DOT
- Ken Valentine, Vermont DOT
- Steve Wilcox, New York State DOT

Guide for Incorporating Maintenance Costs into a TAMP

Topics

- Background
  - Challenges to Incorporating Maintenance Costs into a TAMP
  - Intended User Groups
- Framework for Incorporating Maintenance into a TAMP
  - Defining Maintenance
  - Data Needed
  - Life-cycle Planning
  - Risk Management
  - Financial Planning
  - Investment Strategies
- Implementation and Continual Improvement

Challenges to Incorporating Maintenance Costs into a TAMP

OBSTACLES

- Lack of a common definition for maintenance
- Lack of quality data
- Limited understanding of the maintenance and asset life-cycle relationship
- Immature risk management practices
- Separation of maintenance and capital budgets
- Maintenance and asset management have different budget or planning periods
- Unlike other work types, maintenance is applicable at all life-cycle stages

Intended Users

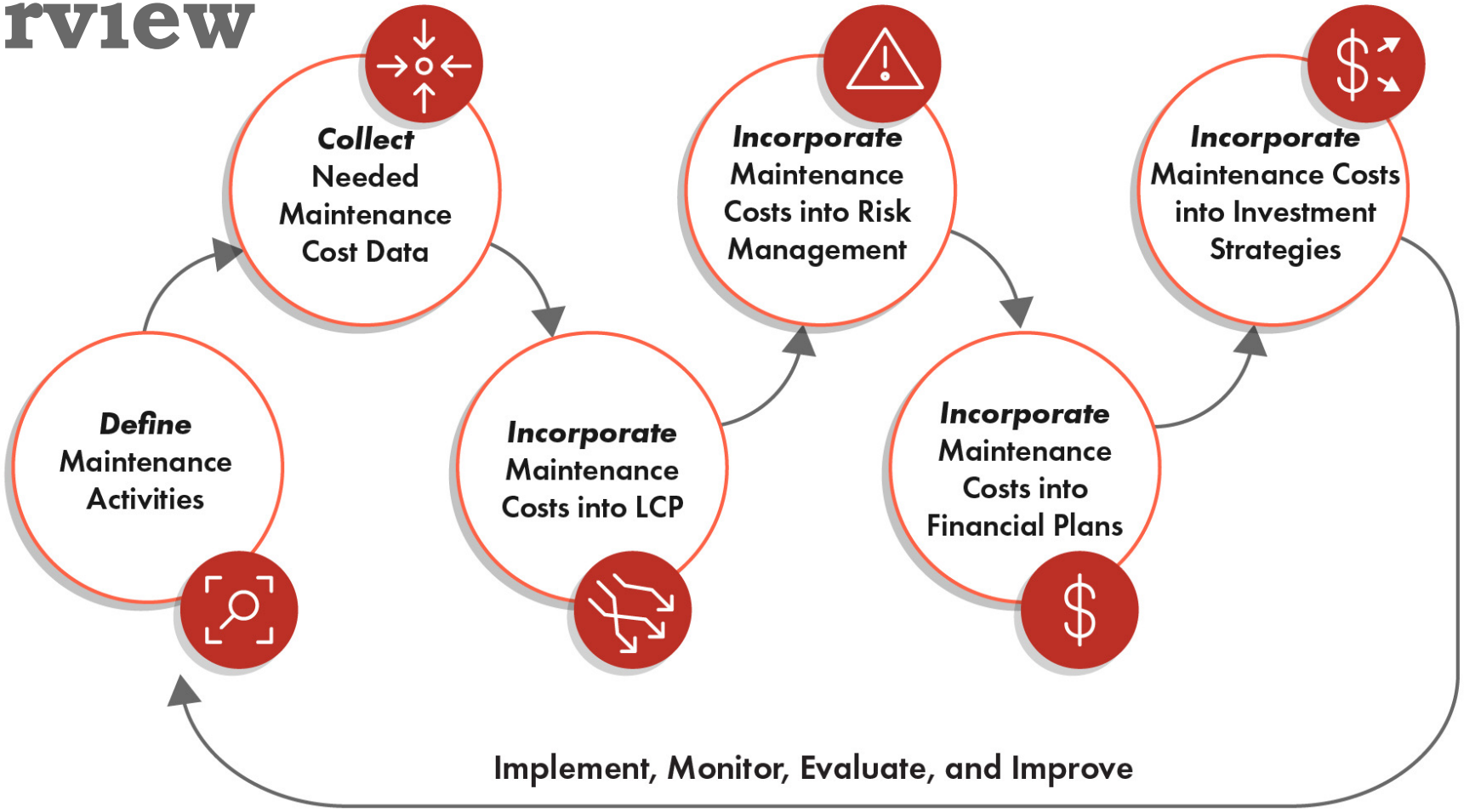
Asset Managers' Concerns

- Long-term planning
- 10-year investment strategies
- Asset condition ratings
- All funding
- Enterprise and programmatic risks

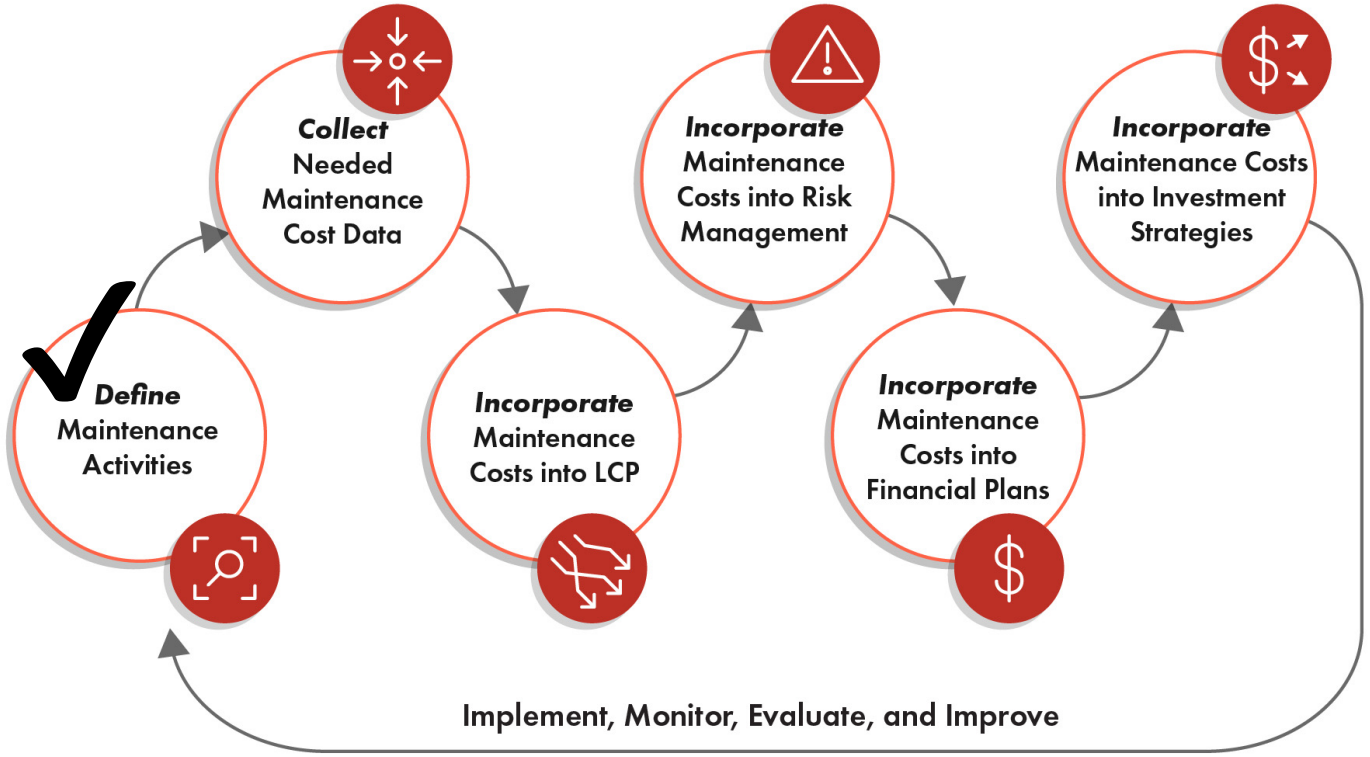
Maintenance Managers' Concerns

- Short-term operations
- Annual budgets
- Maintenance quality assessments
- Maintenance budget
- Implementation of risk mitigation efforts

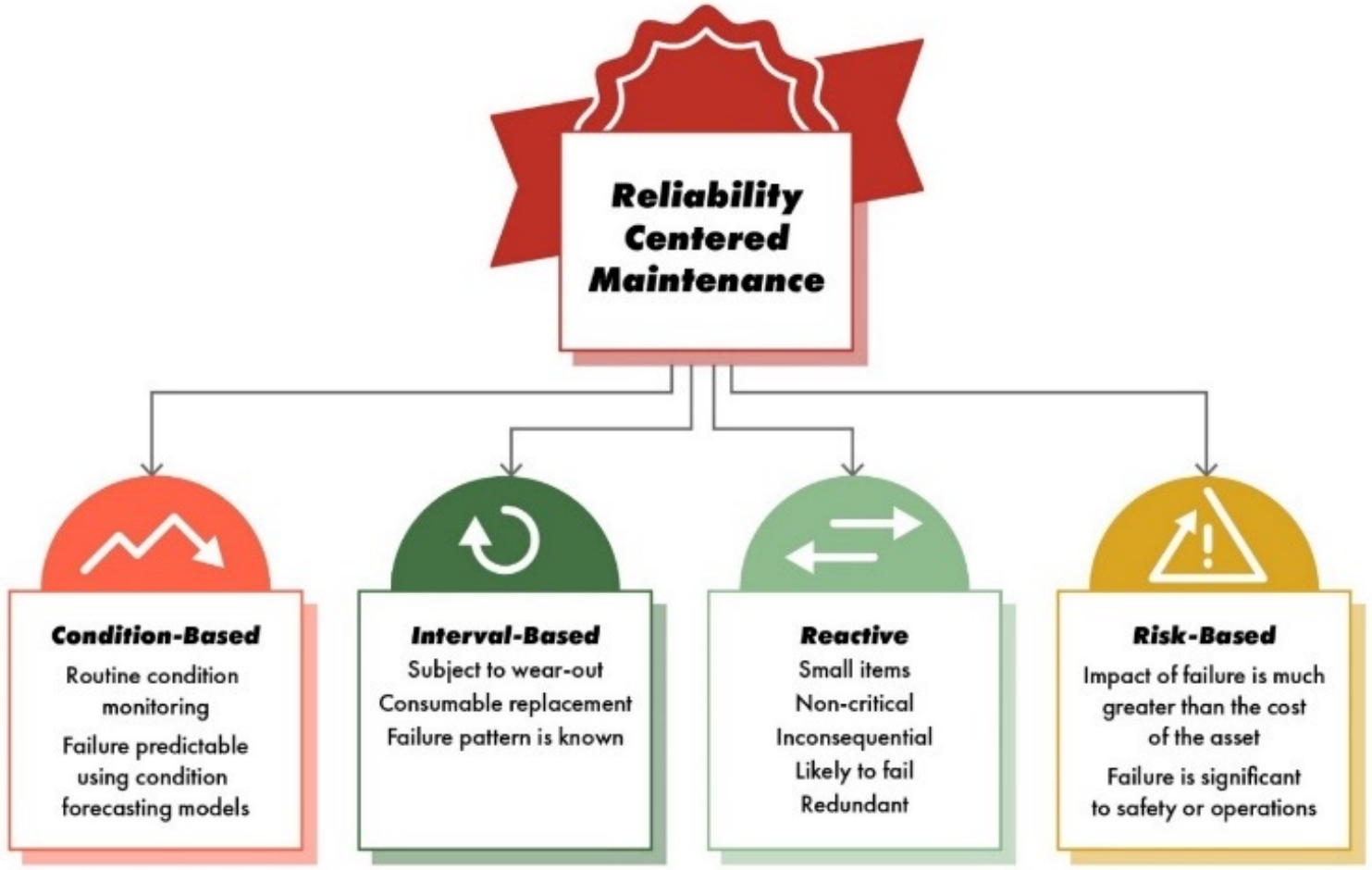
Framework Overview



Defining and Categorizing Maintenance Activities



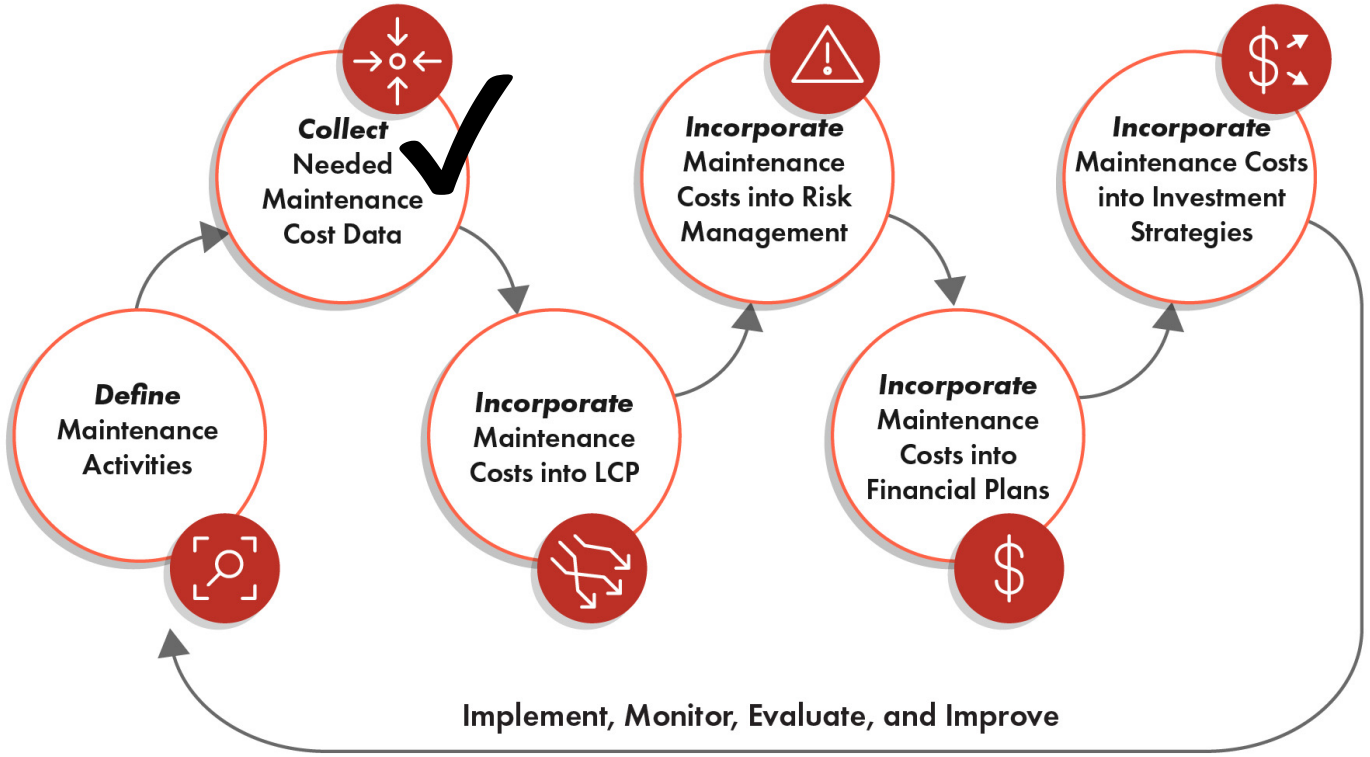
Reliability Centered Maintenance



Categorizing Maintenance Activities

	Category	Activity Examples
	Operations and routine maintenance	Road patrol, mowing, snow and ice control.
	Preventive maintenance	Crack seal, chip seal, sweeping, drain cleaning, bridge washing.
	Repair	Mill and inlay, deck repair, replacement of parts.
	Unit or major component replacement	Sign panel replacement, striping, traffic signal component replacement.
	Organizational strengthening	Training, safety briefings, management system use, planning supervision.

Collecting Needed Data



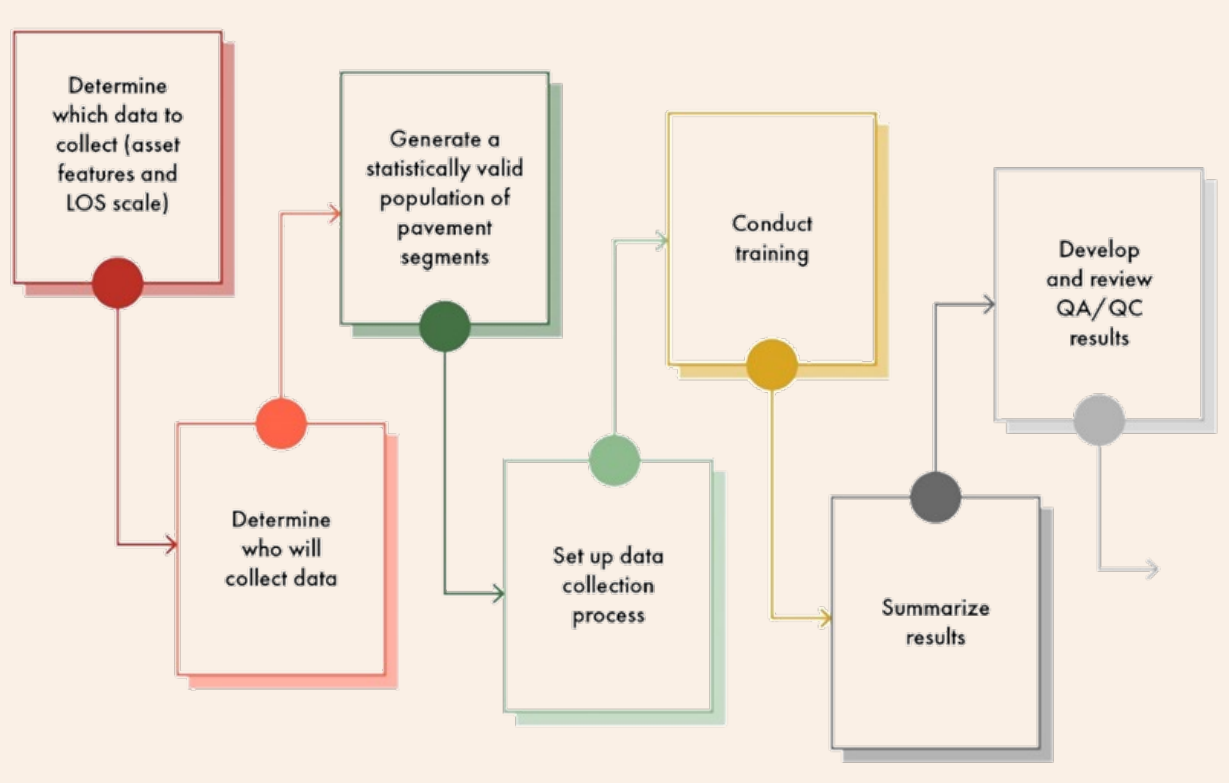
Defining Performance for Different Maintenance Strategies

Approaches	Condition Data	Age / Last Treatment	Risk Data
Condition	✓	✓	Optional
Interval	Optional	✓	Optional
Reactive	Optional	Optional	Optional
Risk Based	Optional	Optional	✓

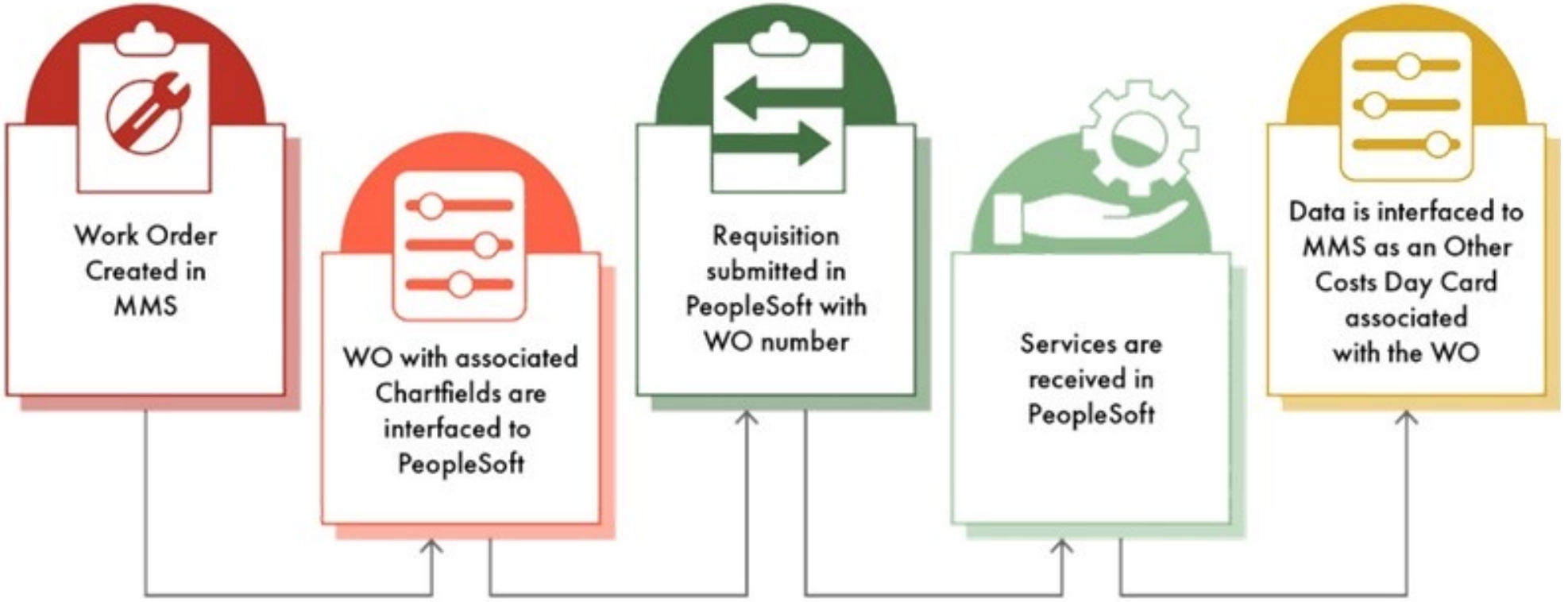
Maintenance Quality Assurance Program

ALABAMA DOT EXAMPLE

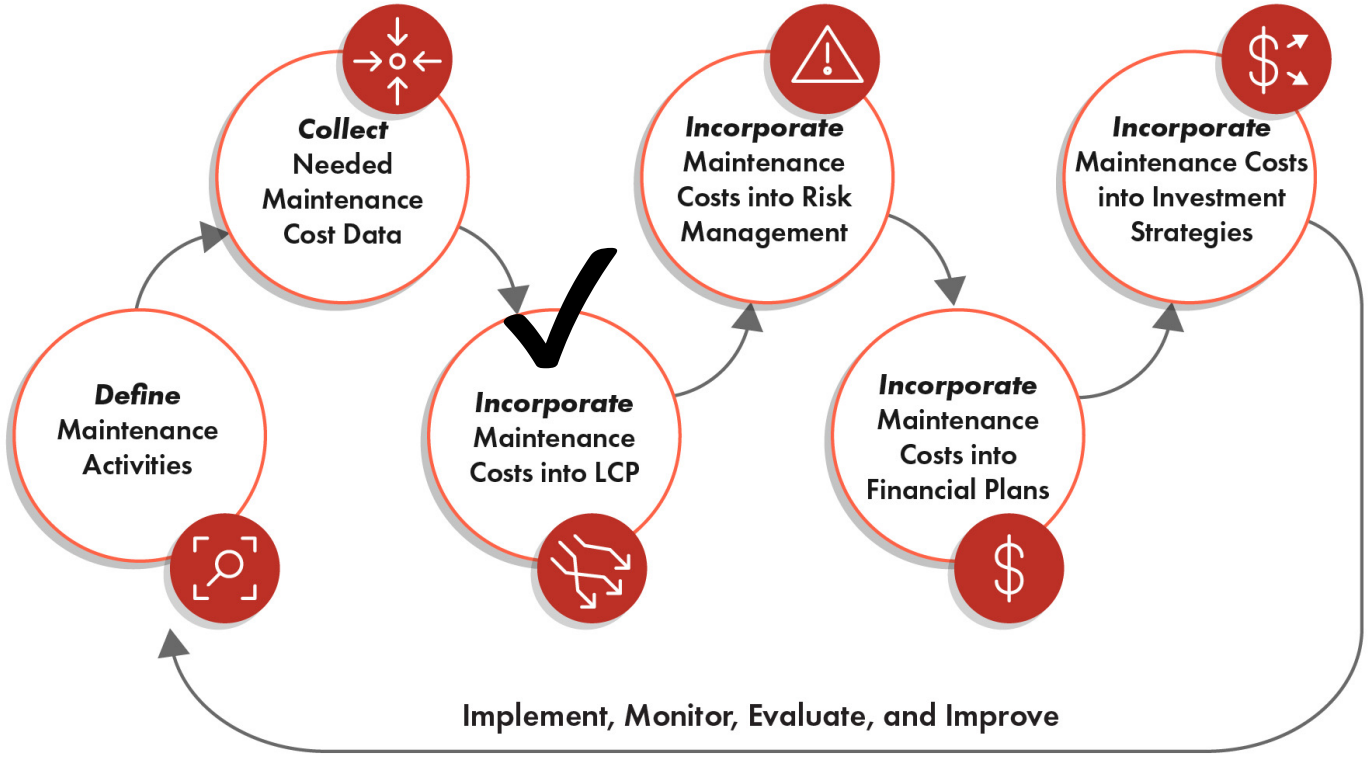
MQA program enables ALDOT to compare asset condition over time and across organizational units in a consistent manner.



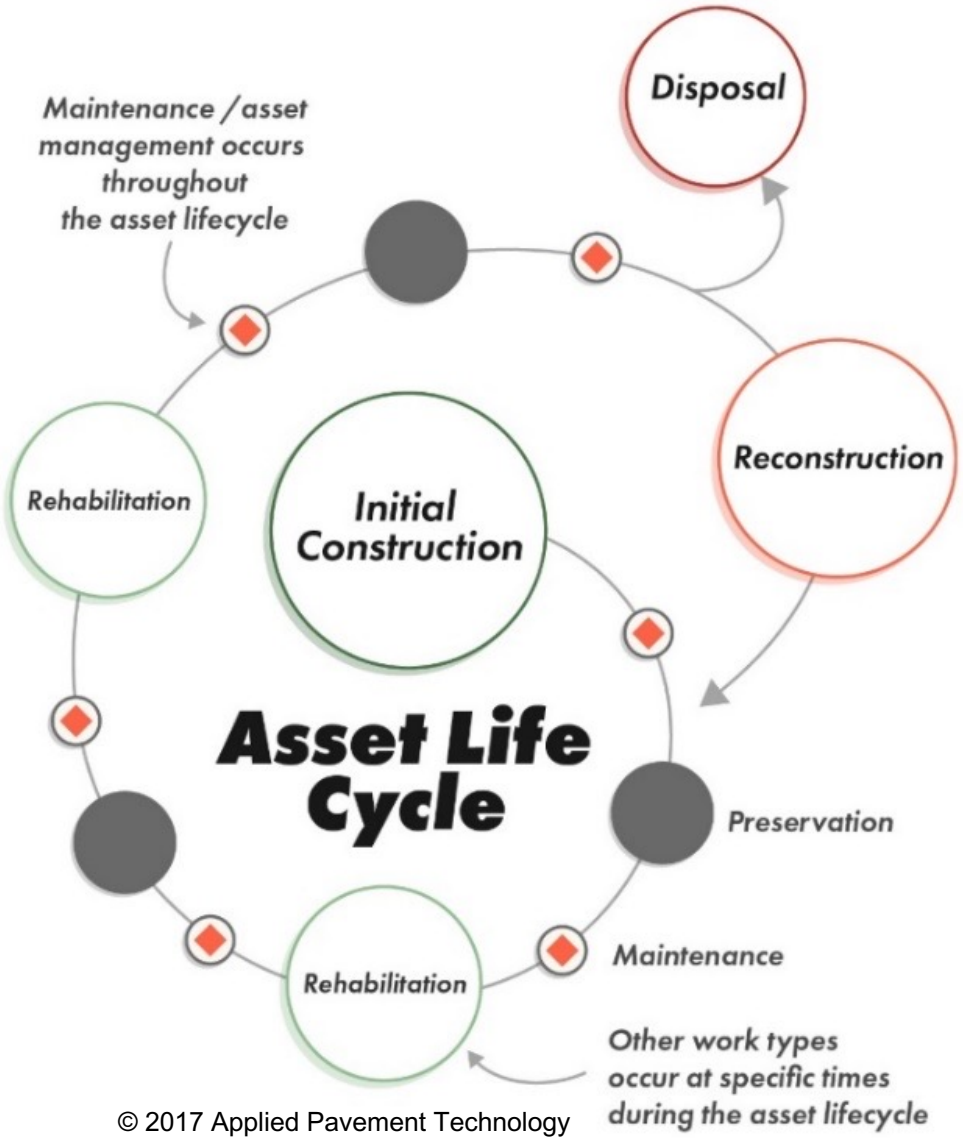
Tracking Maintenance by Contract Costs



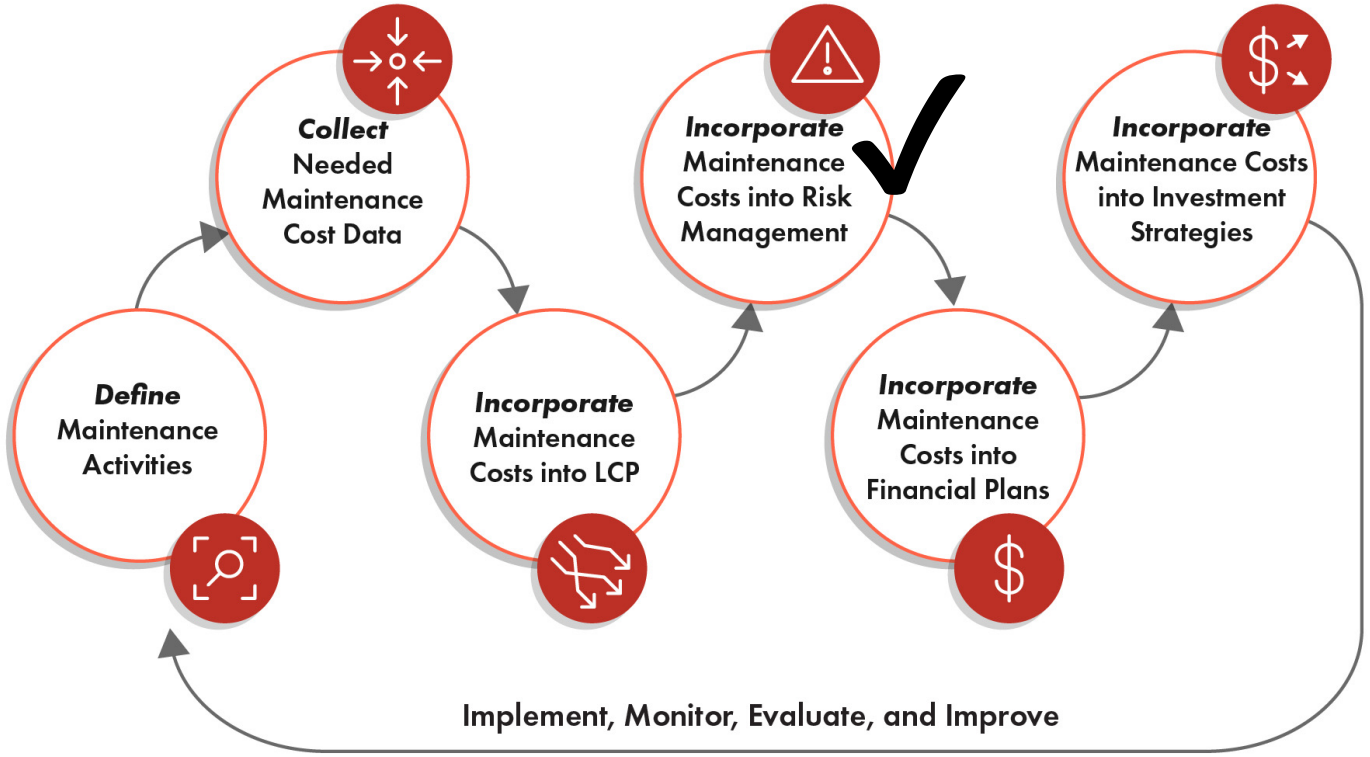
Supporting Life-Cycle Planning (LCP)



Approaches for Considering Maintenance Costs in LCP



Addressing Risk



Incorporating Maintenance Costs into Risk Management

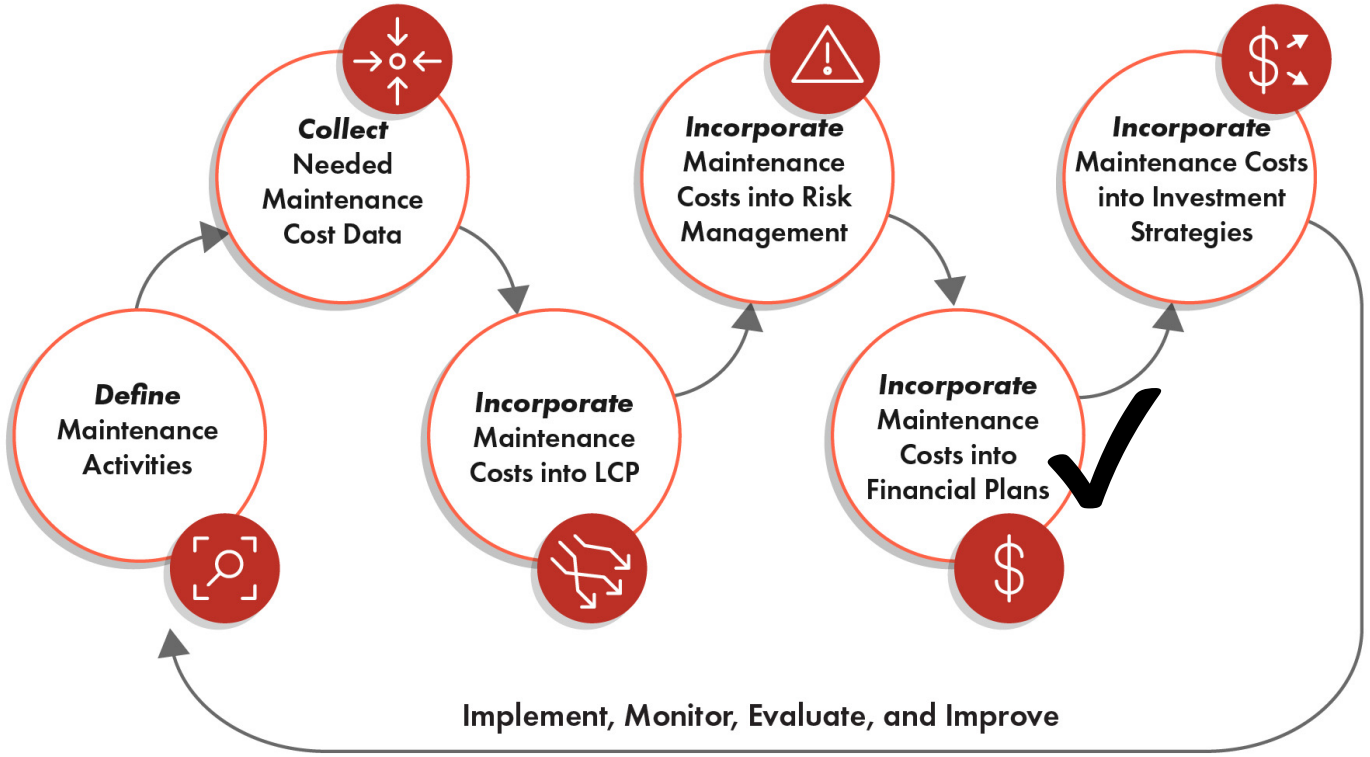
TRENDS

- Funding fluctuation
- Aging infrastructure
- Staffing
- New infrastructure
- Environmental changes

EVENTS

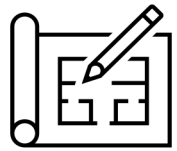
- Extreme weather (emergency events and 23 CFR 667)
- Economic disruption
- Regulations or requirements

Financial Planning



Financial Plan Development Process

The 7-step process helps agencies to list maintenance sources and uses to forecast maintenance costs for TAMP financial plan.



1. Determine TAM scope

2. Identify funding sources

3. Establish fund uses

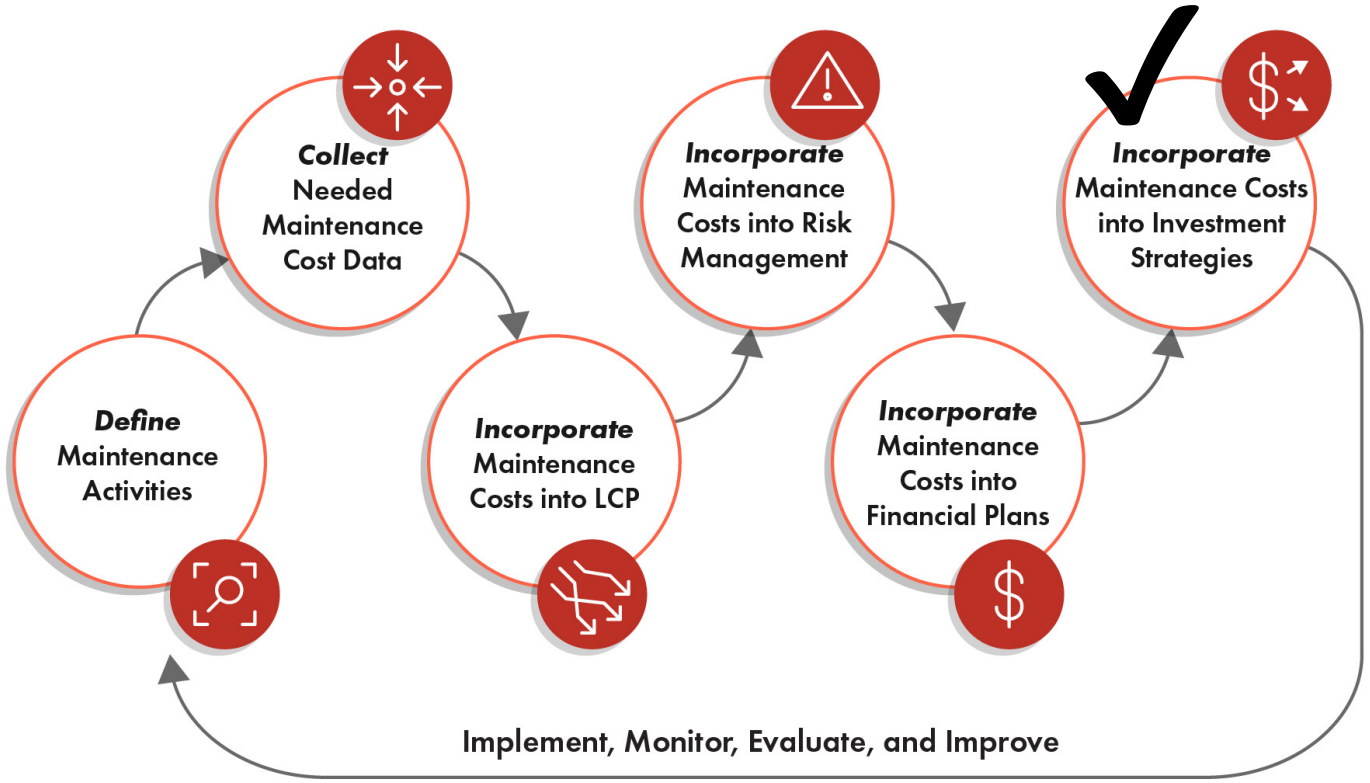
4. List fund sources and uses

5. Validate list

6. Document constraints

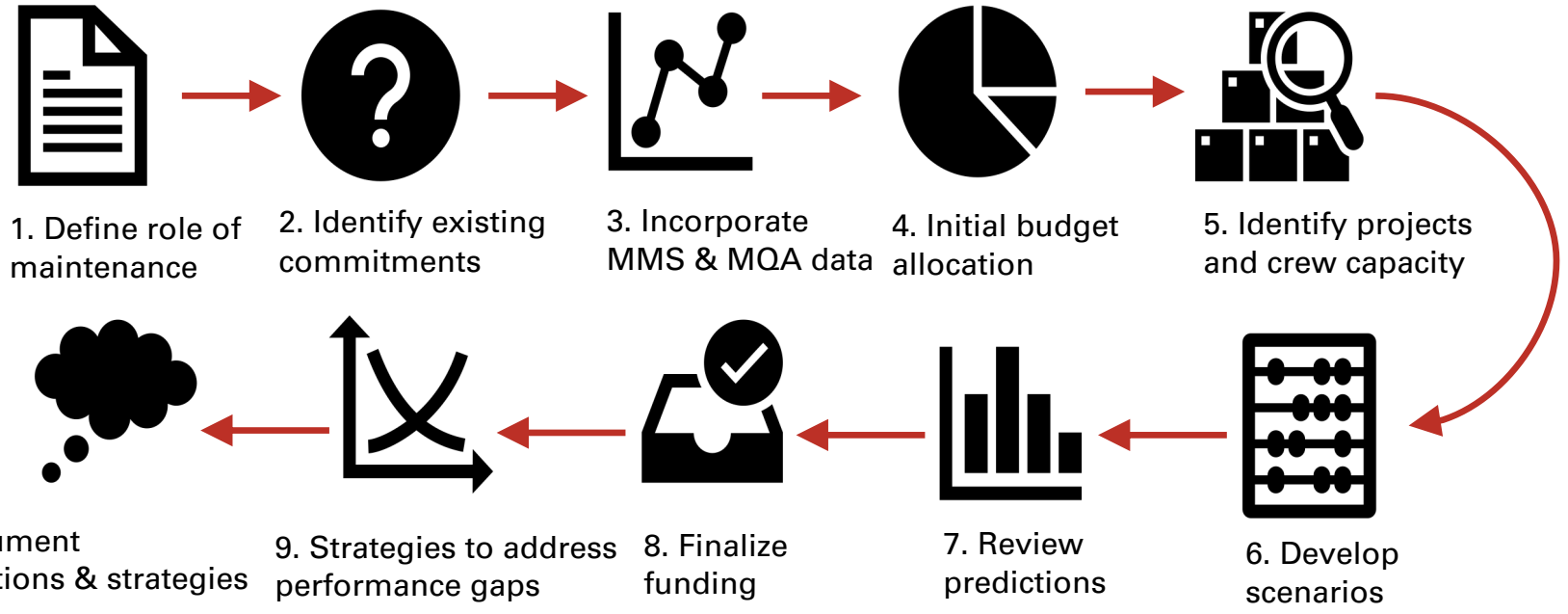
7. Document fixed cost

Financial Planning

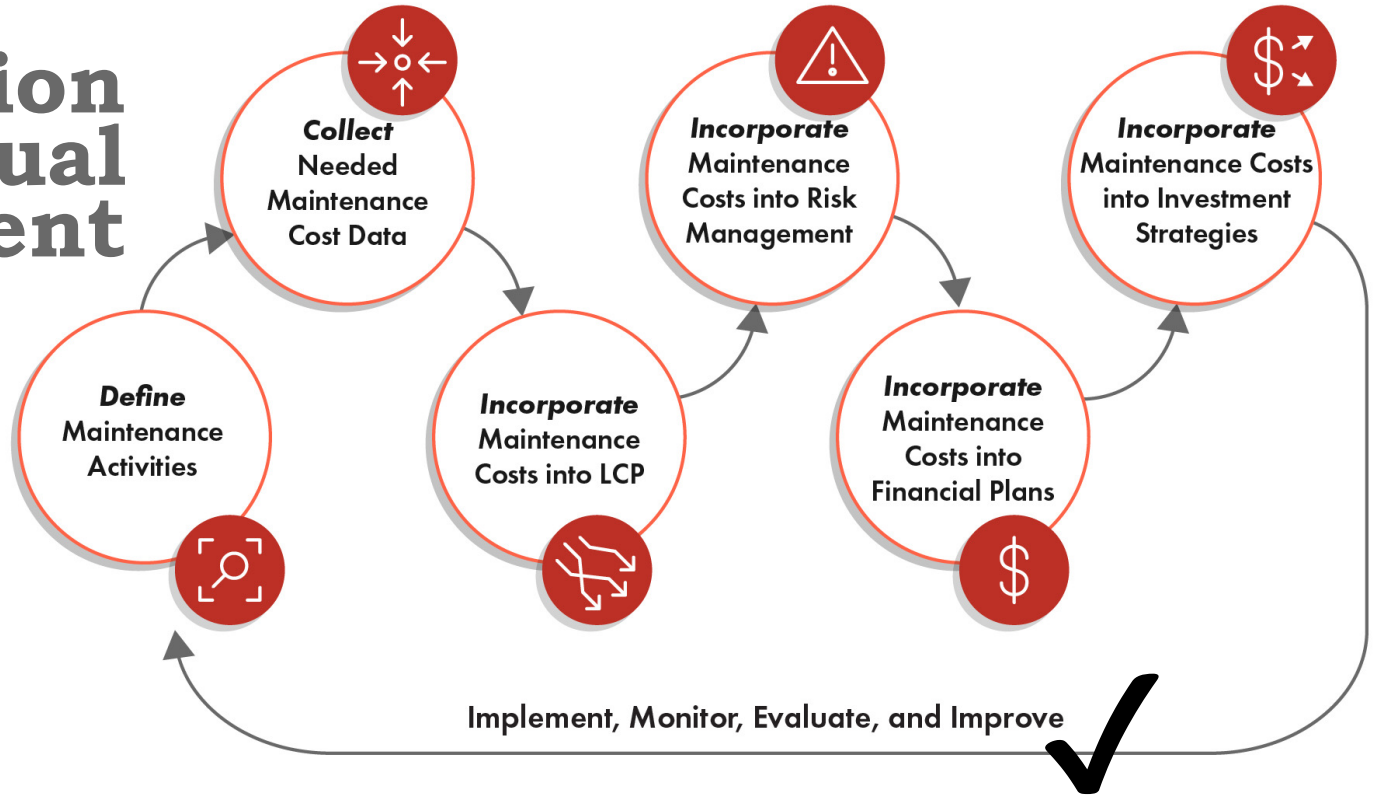


Investment Strategy Development Process

This guidance adjusted the 10-step process established in NCHRP 898 and FHWA guidance for maintenance activities that are not delivered through construction project.



Implementation and Continual Improvement



Keys to Success

- Coordination with capital program
  - ALDOT's maintenance contracting
  - NYSDOT's innovative maintenance contracting
- Coordinate timing of maintenance delivery
  - TDOT's coordination among maintenance, safety, and operations
- Training, equipping, and supplying
  - NYSDOT's investment in organizational development

NCHRP 23-08 Products

- A Guide for Incorporating Maintenance Costs into a TAMP
- Executive Summary
- Tech Memo
- Presentation
- Workshop (To be held at the 2023 TRB Annual Meeting)

Contact Information

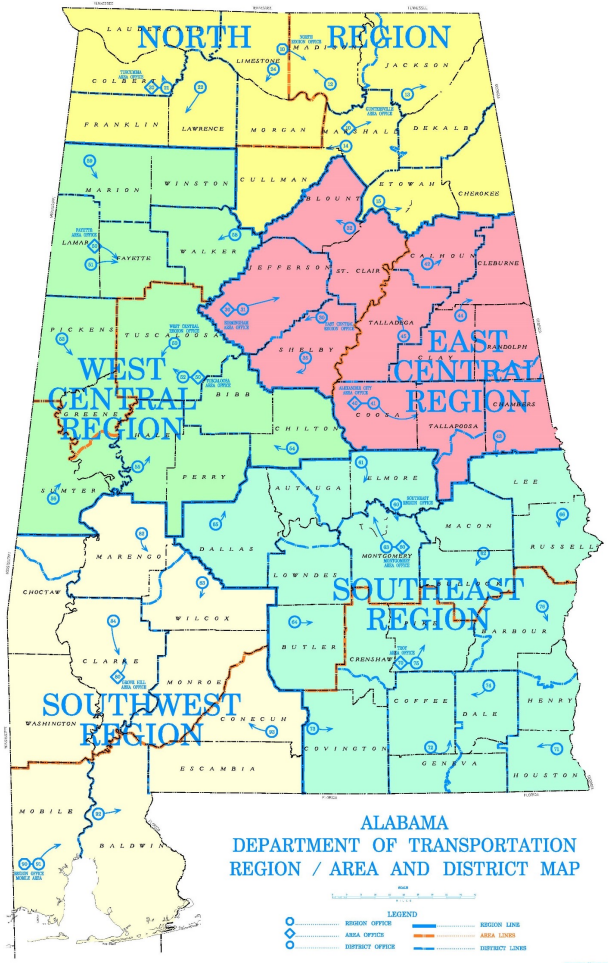
- Brad Allen, PE
  - ballen@appliedpavement.com
- Rob Zilay, PMP
  - rzilay@dyemanagement.com

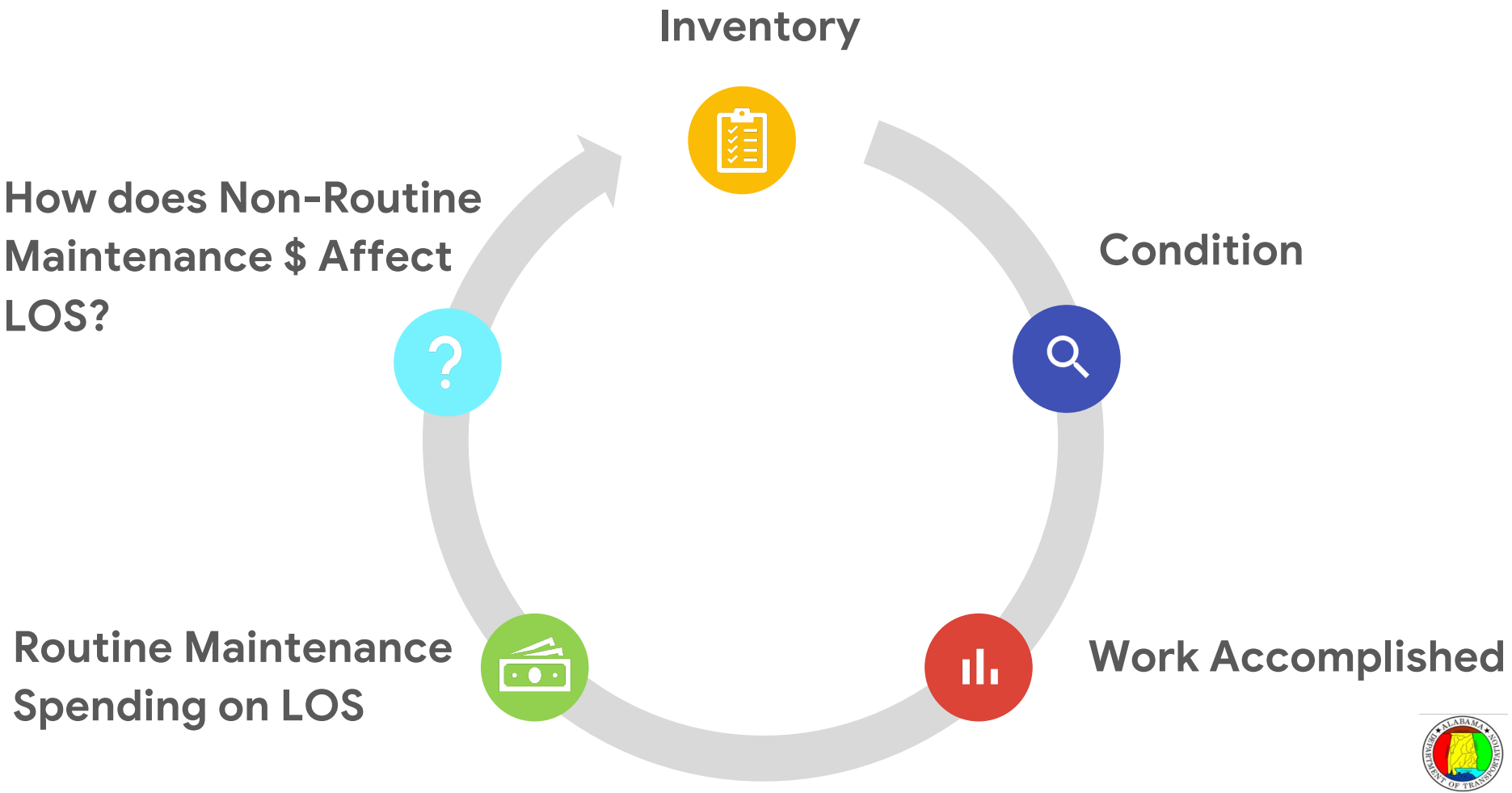
Collecting Inventory and Condition Data

NCHRP 23-08 Peer Exchange
November 12, 2022

Morgan Musick, PE

- Assistant Maintenance Management Engineer
- Responsible for the MMS and all data it contains
- Manages MQA Program & Condition Assessment Project
- Responsible for Routine and Special Maintenance Expenses


NORTH REGION
WEST CENTRAL REGION
EAST CENTRAL REGION
SOUTHEAST REGION
SOUTHWEST REGION
ALABAMA
DEPARTMENT OF TRANSPORTATION
REGION / AREA AND DISTRICT MAP
LEGEND
REGION OFFICE
AREA OFFICE
DISTRICT OFFICE
REGION LINE
AREA LINES
DISTRICT LINES
EFFECTIVE:
September 3, 2020


Inventory
Condition
Work Accomplished
Routine Maintenance Spending on LOS
How does Non-Routine Maintenance $ Affect LOS?

Data We Collect

Asphalt Pavement

- Potholes
- Raveling
- Shoving

Concrete Pavement

- Spalling
- Faulting
- Joint Sealing
- Punchouts
- Pumping
- Potholes

Paved/Unpaved Shoulders

- Edge Raveling
- Sweeping
- Drop Off
- High Shoulder

Drainage

- Drains
- Ditches
- Drop Inlets
- Curb & Gutter

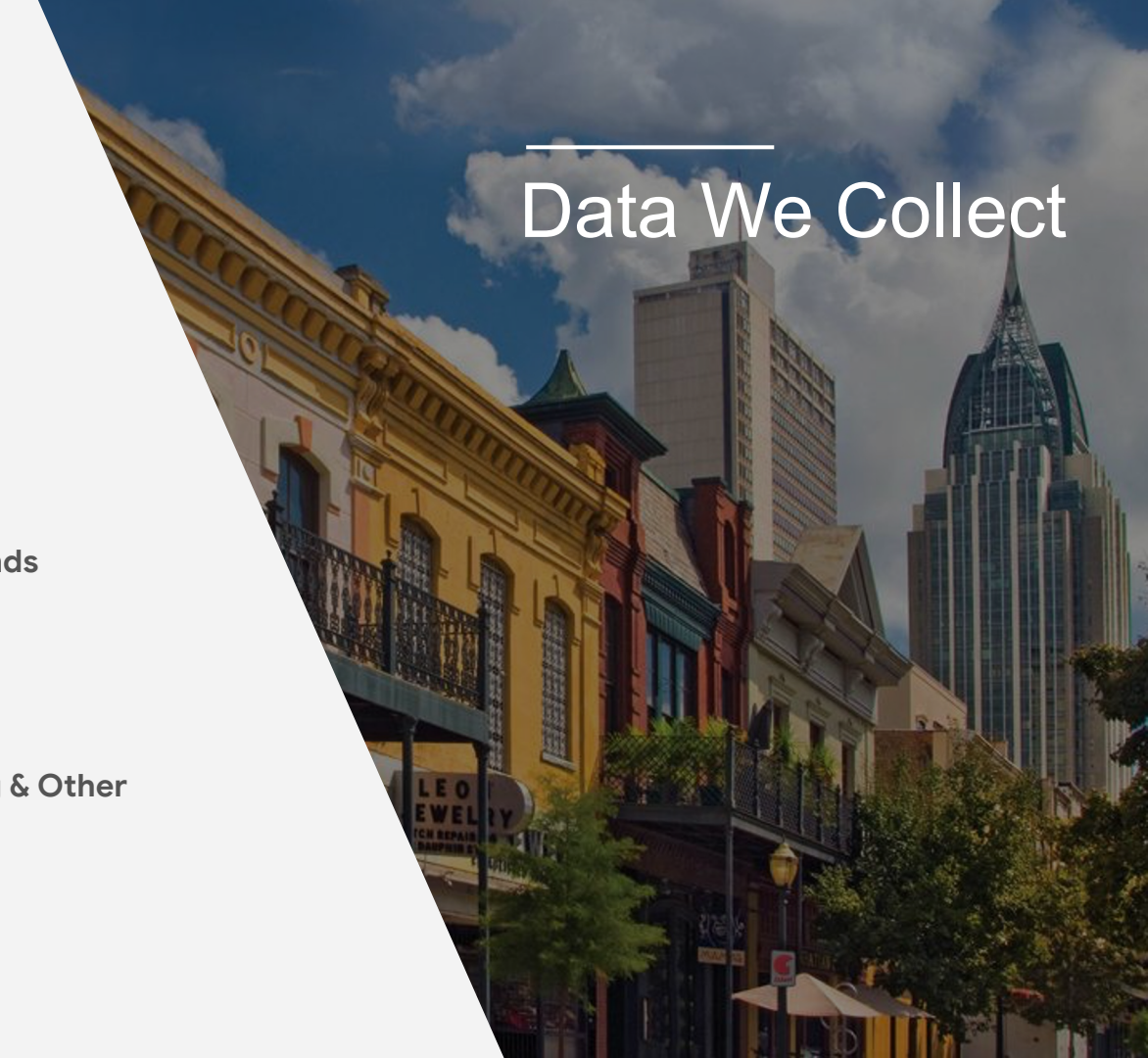
Data We Collect

Roadside

- Erosion Control – Slopes
- Vegetation
- Fences
- Litter

Traffic Services

- Pavement Markings & Legends
- Pavement Striping
- Raised Pavement Markers
- Delineators
- Object Markers
- Signals
- Signs – Regulatory, Warning & Other
- Guardrail
- Cable Rail
- Impact Attenuators
- Barrier Walls



Condition Assessment Overview

Annual Process – In-house and Vendor

Collect for 38 asset features
- 8,019 samples collected in 2022

Sample-based approach:
- 95% confidence interval for INT routes
- 90% confidence interval for NHS & OSH

Final product: Asset Condition Scorecards at District Level

Data Collection – Paper Form

ALABAMA DEPARTMENT OF TRANSPORTATION

Maintenance Bureau

Maintenance Feature Inventory and Condition Rating Form

Sample Number		Begin MP	40.3	Div/District	5/2	Route	AL0006	Direction	NE
Number of Lanes	2	End MP	40.4	Crew	BIRMINGHAM			Date	1-8-16

ASPHALT PAVEMENT

Features	Measure	Condition
Potholes	Number of potholes (≥ 6"x6"x1")	0
Raveling	Surface area distressed (total sq. ft.)	0
Shoving	Deficient surface area (total sq. ft.)	0

CONCRETE PAVEMENT

Features	Measure	Condition
Spalling	Number of spalls (≥ 6"x6"x1")	0
Faulting	Number of faulted slabs (≥ 1/4" high)	0
Joint Sealing	Lin. ft. of joints requiring sealing (≥ 1/4" wide)	0
Pumping	Number of slabs deficient	0
Punchouts	Number of punchouts (≥ 6"x6")	0

SHOULDERS

Features	Inventory (Total Must Not Exceed 2112, 1056' Unpaved/1056' Paved)		Measure (Must Not Exceed Inventory Length)	Condition
Paved Shoulder	Lin. ft. of paved shoulder	528	N/A	
Potholes	N/A		Number of potholes	0
Edge Raveling	N/A		Lin. ft. of edge raveling	0
Sweeping (Incl. Curb)	Lin. ft. of shoulder/curb subject to sweeping	0	Lin. ft. of shoulder/curb needing sweeping	0
Unpaved Shoulder	Lin. ft. of unpaved shoulder	0	N/A	
Shoulder Drop-Off	N/A		Lin. ft. of low shoulder (≥ 2")	0
High Shoulder	N/A		Lin. ft. of high shoulder (> 1")	0

DRAINAGE

Data Collection – Fillable PDF

ALABAMA DEPARTMENT OF TRANSPORTATION
Maintenance Bureau
Maintenance Feature Inventory and Condition Rating Form

Sample Number	1	**Begin MP**	307.1	**Area/District**	12	**Route**	AL0053	**Direction**	N	**Date**	3/6/2019
Number of Lanes	2	**End MP**	307.2	**Road Class**	NHS	**Adjacent Section (Y/N)**	Y	**Bifurcated Section (Y/N)**		Y	
Reference Number		**Company Name**		Neel-Schaffer Inc.		**Crew Name**		3			

ASPHALT PAVEMENT

Features	Measure	Condition
Potholes	Number of potholes (≥ 6"x6"x1")	1
Raveling	Surface area distressed (total sq. ft.)	60
Shoving	Deficient surface area (total sq. ft.)	0

CONCRETE PAVEMENT

Features	Measure	Condition
Spalling	Number of spalls (≥ 6"x6"x1")	-
Faulting	Number of faulted slabs (≥ 1/4" high)	-
Joint Sealing	Lin. ft. of joints requiring sealing (≥ 1/4" wide)	-
Pumping	Number of slabs deficient	-
Punchouts	Number of punchouts (≥ 6"x6")	-

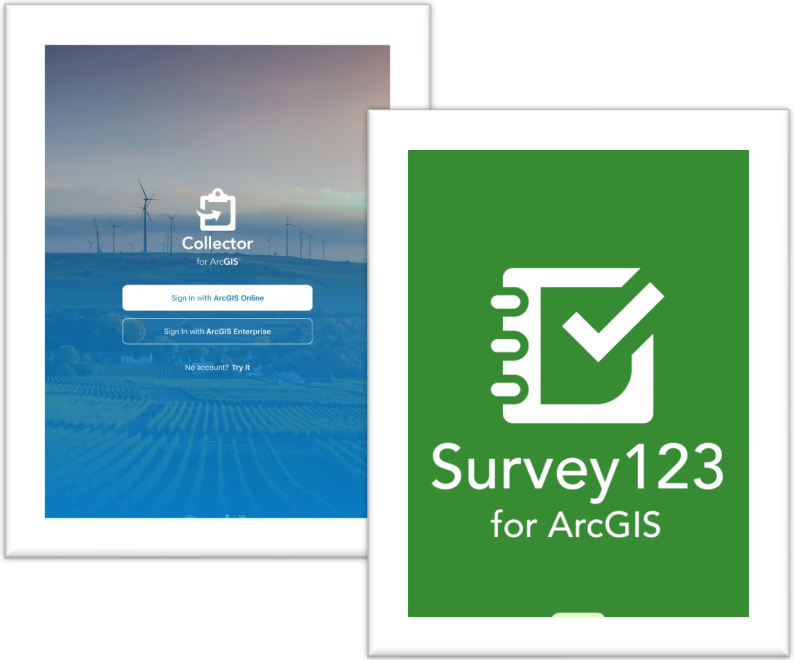
SHOULDERS

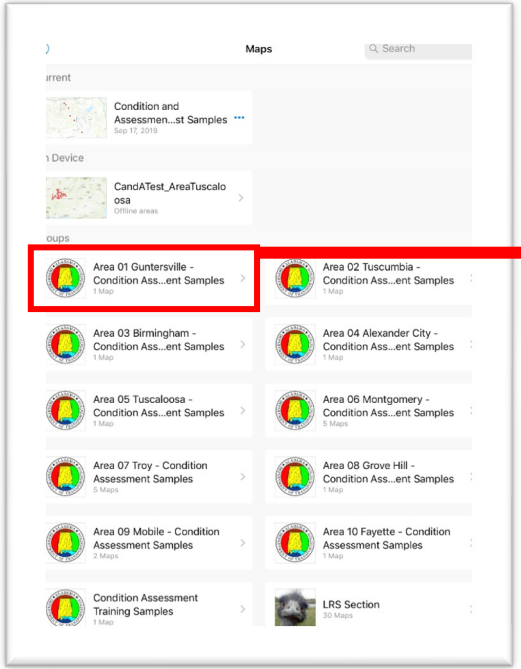
Features	Measure (Must Not Exceed 2112', 1056' Unpaved/1056' Paved)	Inventory	Measure (Must Not Exceed Inventory Length)	Condition
Paved Shoulder	Lin. ft. of paved shoulder	528	N/A	
Potholes	N/A		Number of potholes	0
Edge Raveling	N/A		Lin. ft. of edge raveling	0
Sweeping (Incl. Curb)	Lin. ft. of shoulder/curb subject to sweeping	-	Lin. ft. of shoulder/curb needing sweeping	-
Unpaved Shoulder	Lin. ft. of unpaved shoulder	976	N/A	
Shoulder Drop-Off	N/A		Lin. ft. of low shoulder (≥ 2")	41
High Shoulder	N/A		Lin. ft. of high shoulder (> 1")	0

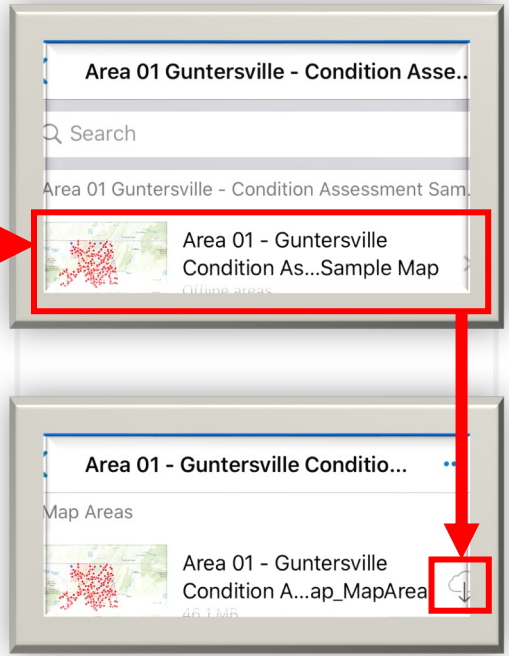
DRAINAGE

Features	Measure	Inventory	Measure	Condition

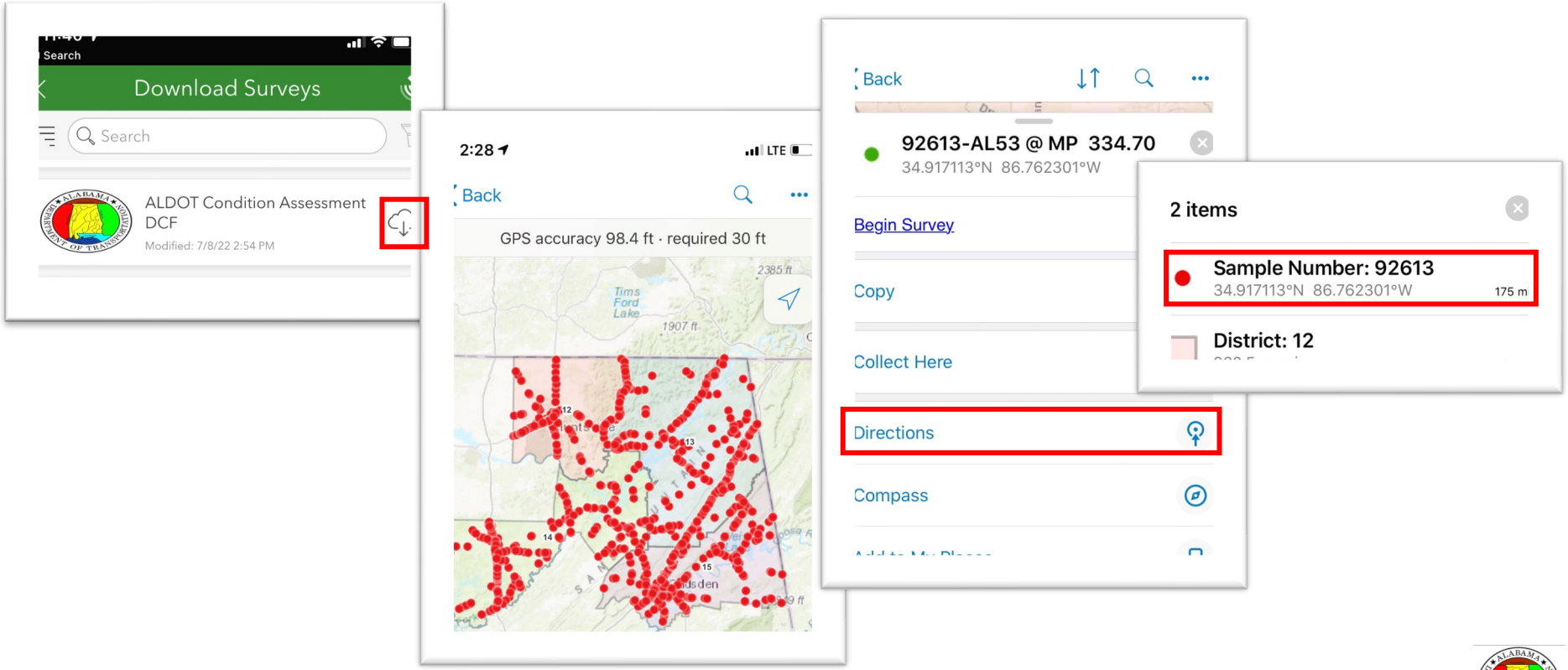
Data Collection: ArcGIS Utilization







Data Collection: ArcGIS Utilization



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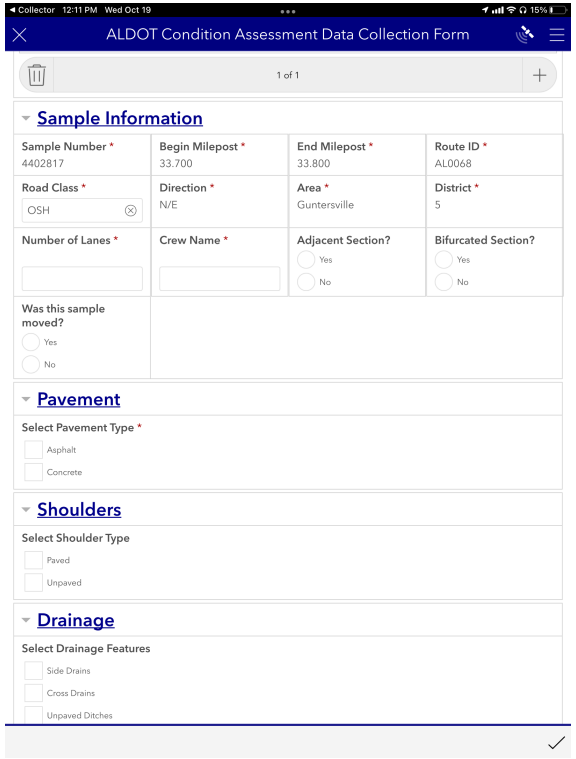
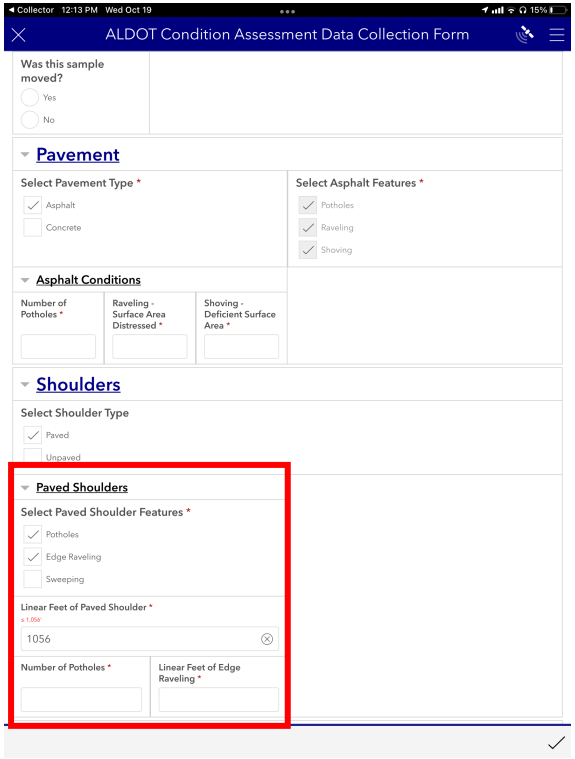
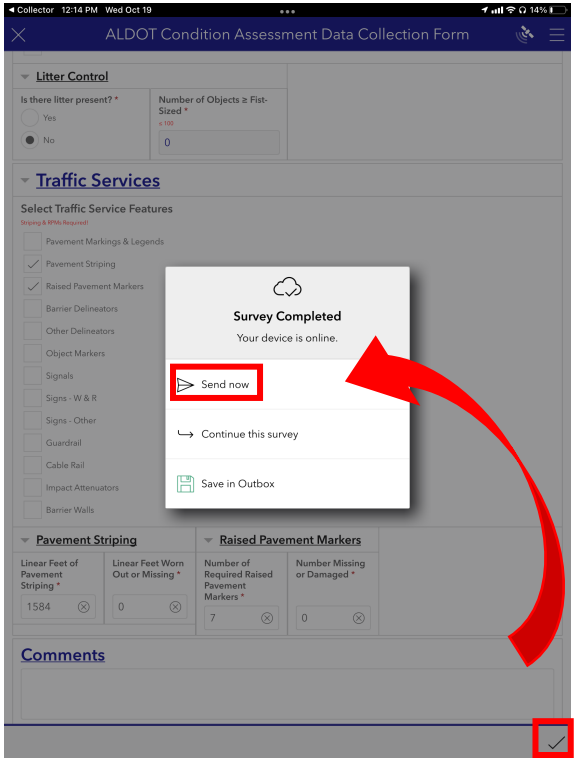
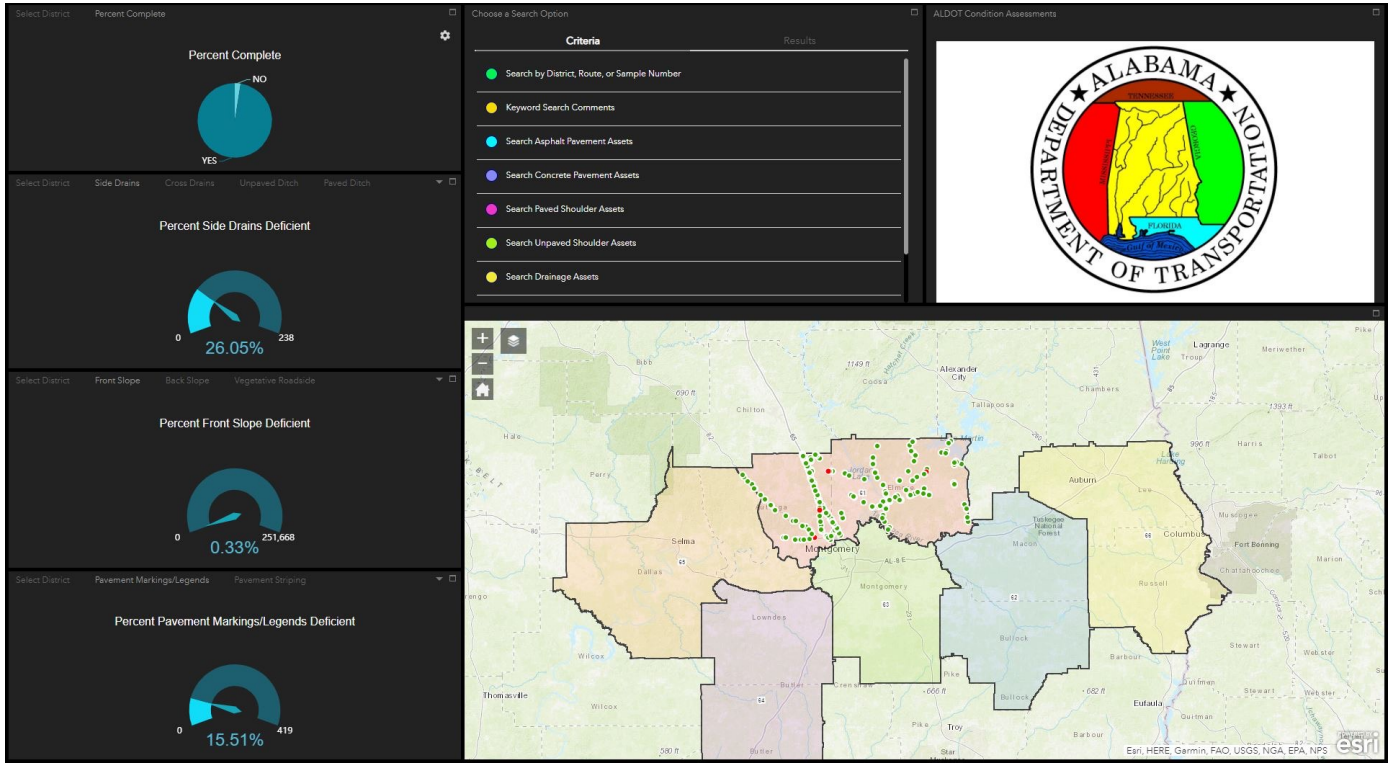






Dashboard


Select District
Percent Complete
Percent Complete
NO
YES
Select District
Side Drains
Cross Drains
Unpaved Ditch
Paved Ditch
Percent Side Drains Deficient
0
238
26.05%
Select District
Front Slope
Back Slope
Vegetative Roadside
Percent Front Slope Deficient
0
251,668
0.33%
Select District
Pavement Markings/Legends
Pavement Striping
Percent Pavement Markings/Legends Deficient
0
419
15.51%
Choose a Search Option
Criteria
Results
Search by District, Route, or Sample Number
Keyword Search Comments
Search Asphalt Pavement Assets
Search Concrete Pavement Assets
Search Paved Shoulder Assets
Search Unpaved Shoulder Assets
Search Drainage Assets
ALDOT Condition Assessments
ALABAMA
DEPARTMENT OF TRANSPORTATION
Montgomery
Auburn
Selma
Esri, HERE, Garmin, FAO, USGS, NGA, EPA, NPS
esri

Condition Assessment Process

- Determine what you want to collect – asset features and LOS scale
- Determine who will collect data
- Generate samples
- Set up data collection process
- Conduct training
- Summarize Results
- QA/QC Results

Condition Assessment Preparation

Establish Assets, Units, & Grade Ranges

			Average Level Of Service Grade Ranges				
Group	Feature	Units	A	B	C	D	F
Paved Surfaces	Potholes	Count / Ln Mi Def.	0 - 0.2	0.2 - 1	1 - 3	3 - 5	>5
	Raveling	% Deficient	0 - 2	2 - 5	5 - 10	10 - 20	>20
Drainage	Ditches	% Deficient	0 - 2	2 - 5	5 - 10	10 - 20	>20
Roadside	Litter Patrol	Pieces/Shoulder Mile	0 - 50	50 - 100	100 - 300	300 - 500	>500
Traffic	Guardrail	% Deficient	0 - 1	1 - 3	3 - 5	5 - 10	>10
Vegetation	Noxious Weeds	% Deficient	0 - 2	2 - 5	5 - 10	10 - 20	>20

Condition Assessment Results: Five Year Trend

Benefits

- **Consistent scorecard format year after year allows for comparison of assets over time and across organizational units**

Sample LOS Scorecard						
Group	Feature	2016	2017	2018	2019	2020
Asphalt Pavement	Asphalt - Potholes	A	A-	B+	A+	A+
	Raveling	B-	B-	B+	B+	B+
	Shoving	C	F	D-	F	D-
Concrete Pavement	Spalling	A-	A	A	A	A+
	Faulting	A-	A	A	A	A+
	Joint Sealing	A-	A	A	A	A+
	Punchouts	A-	A	A	A	A+
	Pumping	A	A	A+	A+	A+
Paved Shoulders	Potholes	A+	A+	A+	A+	A+
	Edge Raveling	B+	B-	A	A	B
	Sweeping	B-	A	A+	A+	D-
Unpaved Shoulders	Drop Off	C	D	C	D	D
	High Shoulder	D	D-	C	D-	F
Drainage	Side Drains	B	B-	B-	C	C
	Cross Drains	B	B-	B-	C	C
	Unpaved Ditches	B	B+	B+	B+	B
	Paved Ditches	C	C	F	F	D
	Drop Inlets	B-	B-	B-	C+	F
	Curb & Gutter	F	C-	C	C+	C
Roadside	Erosion Control - Front Slopes	A+	C	B+	A	B+
	Erosion Control - Back Slopes	A-	C	B-	A-	A
	Undesirable Vegetation	A+	A+	A	A	B-
	Brush/Tree Control	C	C	D+	D	F
	ALDOT Fence	C+	C+	B+	A+	C
	Litter Control	D+	C	C	C	C
Traffic Services	Pavement Markings & Legends	D	B-	B+	B	C+
	Pavement Striping	B+	A-	A+	A	C+
	Raised Pavement Markers	B-	C-	C-	D+	C
	Delineators-Guardrail/Cable/BarrierWall	C	B-	B-	B	B-
	Delineators-Other	C	A-	C+	B+	B-
	Object Markers	D-	D-	F	F	F
	Signals	A+	A+	A	A+	A+
	Signs - Regulatory and Warning	B-	B+	B	C+	A-
	Signs - Other	B	A-	A-	C+	A-
	Guardrail	C	B-	C	C	D

In-House vs. Outsourcing

PROS

Consultants

- Rating Consistency
- Easier to QC data
- Easier to track budget
- Finite budget (time and $)
- Train the trainer worked well

In-House

- Less expensive
- Educational for newer staff; learn to identify what needs to be fixed

CONS

Consultants

- More expensive than in-house staff
- Major time commitment for ALDOT project manager (at least in Year 1)

In-House

- Ratings less consistent than consultants
- Due to staff availability, difficult to train everyone

Lessons Learned/Where to Begin

- **Accurate asset inventory is necessary for this approach to work**
- **# of Samples – Able to decrease the number of samples but maintain same statistical significance with 90% confidence level on NHS and OSH routes while keeping 95% on INT.**
- **Incorporate field training from the start**
- **Begin by reviewing best practice state manual to determine:**
  - **Which data/assets to collect?**
  - **How to generate the number of samples?**
  - **What would you like your grade ranges to be?**
  - **Who will collect the data and how?**

Questions?

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DEPARTMENT OF TRANSPORTATION

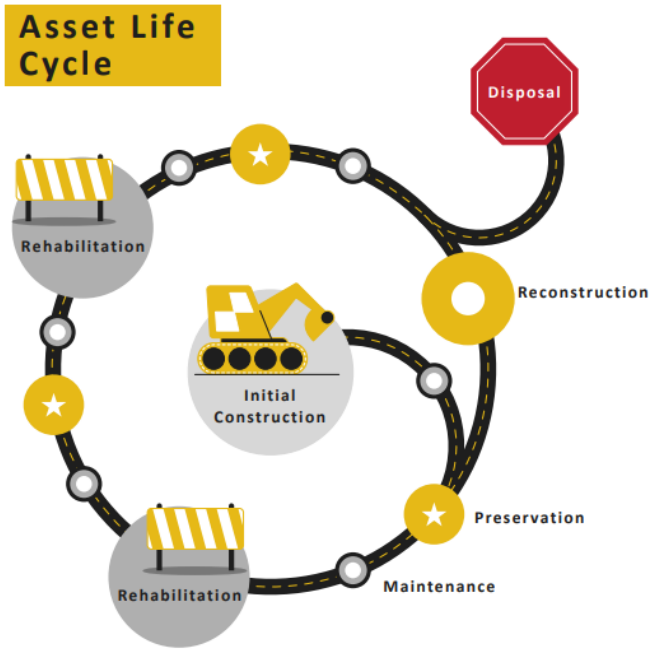
Connecting Maintenance to Life Cycle Planning

Trisha Stefanski, P.E.

Asset Management Program Office Director

What is Life Cycle Planning?

LCP is the process of developing and ***comparing strategies*** to *"estimate the cost of managing an* ***asset network*** *over its* ***whole life****, with consideration for* ***minimizing cost*** *while* ***preserving or improving conditions****."*



MnDOT Life Cycle Planning Objectives

- Establish a long-term focus for improving and preserving the system.
- Improve infrastructure asset resilience to climate change & extreme weather events.
- Determine the conditions that can be achieved for different levels of funding.
- Reduce the annual *cost of system preservation* without impacting asset conditions.
- Provide objective data to support investment decisions.
- Demonstrate good stewardship to internal and external stakeholders.
- **Determine investment funding needed to achieve the desired state of good repair.**
- **Develop maintenance strategies that consider long-term investment needs.**

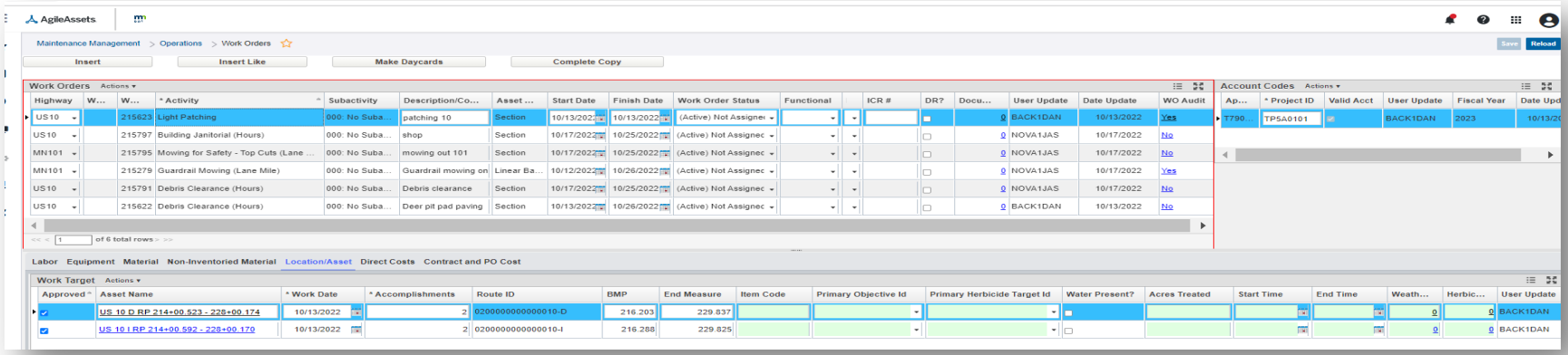
MnDOT Life Cycle Planning Process Improvements

2018 TAMP LCP was project-level perspective.

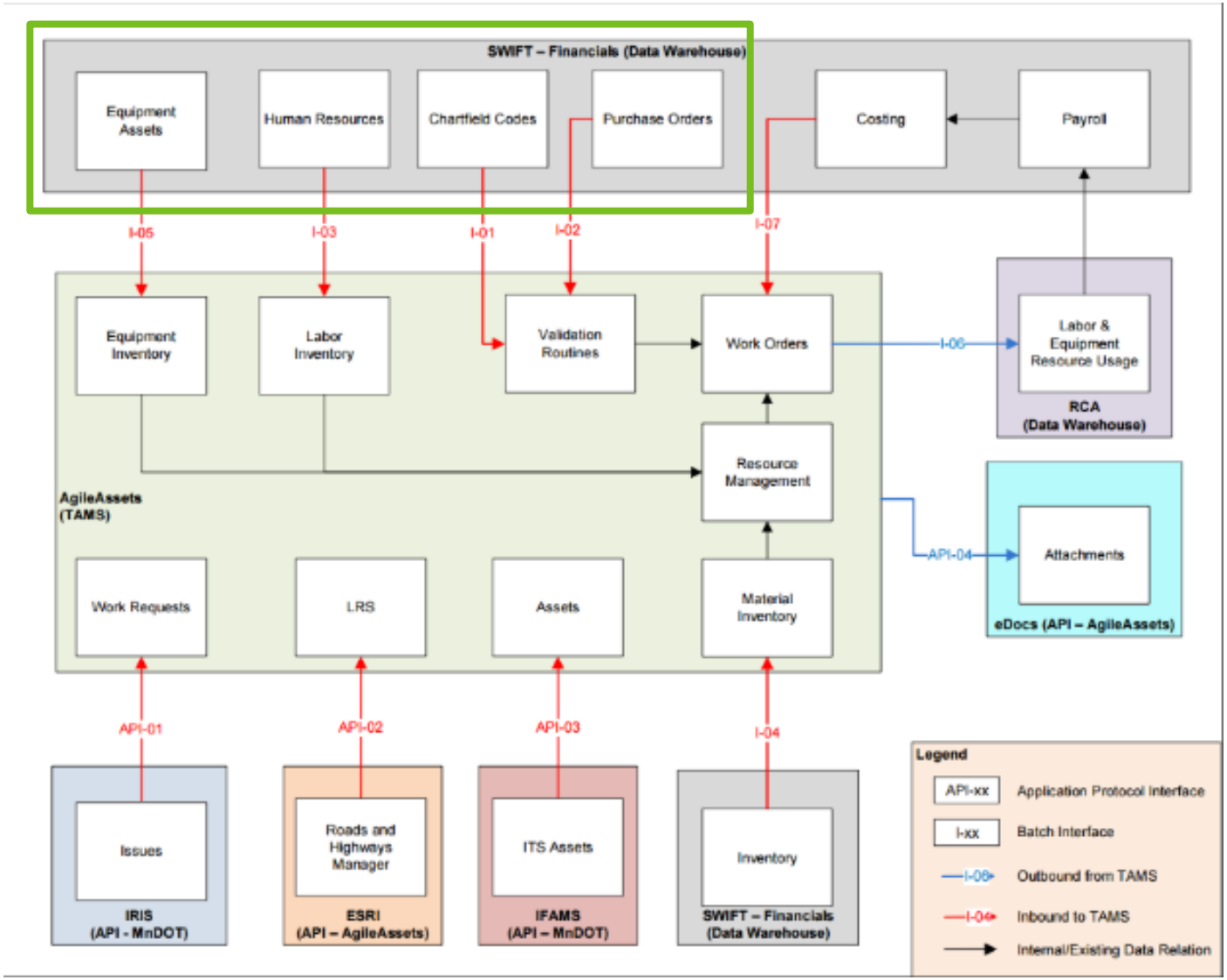
- Two Treatment Strategies.
- Ancillary Asset Did Not Include Network Condition.
- Maintenance Costs Were Estimated For Most Ancillary Assets.

2022 TAMP LCP network-level analysis of system performance

- Additional LCP Strategies.
- Considers Current and Predicted Asset Network Condition.
- Utilize Historical Cost Data
  - Maintenance Management System (TAMS)
    - ➢ Labor$, Equipment$, Materials$



Ancillary Maintenance Management System Integration Diagram



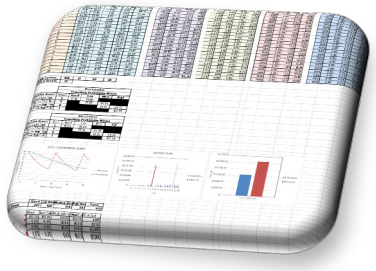
Life Cycle Planning Details By Asset Class

Asset Class	Tool	Strategies	Maintenance Costs Included?
Pavements	Highway Pavement Management Application	Baseline, Low-Volume Roads, Concrete Pavement, No Preservation	Yes
Bridges	Bridge Replacement and Improvement Management Application	Preservation, Worst-First	Yes
Buildings	Archibus System and Analysis	Facilities 20-year Strategic Plan	Yes
Highway Culverts	Thank you! Applied Pavement Technology	Desired and Current	Yes
Deep Stormwater Tunnels			
ITS Assets			
Noise Walls*			
Signs			
Signals			
Lighting			
Pedestrian Facilities			

*The analysis utilized actual deterioration curve data from inspections

Ancillary Assets
Advanced LCP Spreadsheet Inputs

- Percent of Current Asset Network In Good/Fair/Poor Condition
- The Number of Assets Added Each Year
- Length of Time To Transition From One Condition State To Another
- Maintenance or Inspection Activity, Frequency, Cost, & Impact To Asset Condition
- Capital% Versus Maintenance% Funding

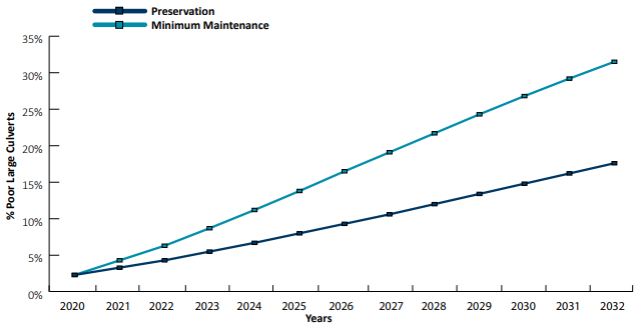


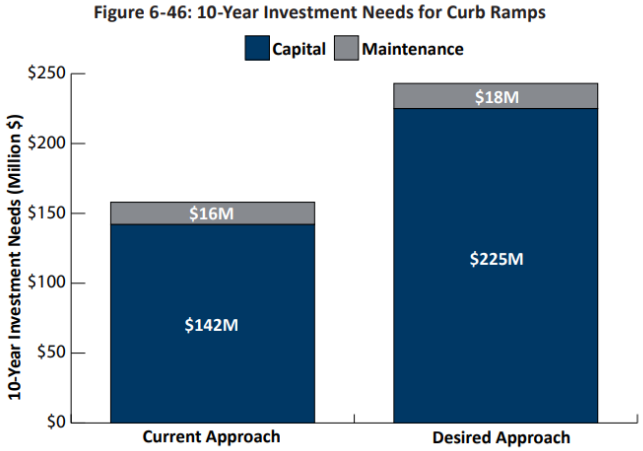
TREATMENT	% ANNUALLY TREATED IN GOOD CONDITION	% ANNUALLY TREATED IN FAIR CONDITION	% ANNUALLY TREATED IN POOR CONDITION	UNIT COST ($/ ASSET
Reactive Maintenance	1%	2%	3%	$90,000
Inspection	20%	20%	20%	$200
Major rehab	0%	0%	5%	$19,000
Replacement	0%	0%	3%	$125,000

CURRENT CONDITION	REACTIVE MAINTENANCE	INSPECTION	MAJOR REHAB	REPLACEMENT
Good	Good	Good	N/A	N/A
Fair	Fair	Fair	N/A	N/A
Poor	Poor	Poor	75% to Good and 25% to Fair	Good

MnDOT Life Cycle Planning Results

- 10 Year Projected Condition - Each Strategy
- 10 Year Investment Need - Each strategy
  - Maintenance Bucket
  - Capital Bucket
- Key Takeaways





Pavement Treatments and Costs

- ✓ Treatment Decision Tree's programmed into PMS
- ✓ Cost Information Coming from Pay Items and TAMS MMS

Figure 6-3: Typical Treatments and Associated Costs for Asphalt-Surfaced Pavements

TREATMENTS	FHWA TREATMENT CATEGORY	COST PER LANE-MILE
Reclaim and Overlay, Urban Regrade, Rural Regrade, Concrete Replacement, Unbonded Concrete Overlay	Reconstruction	$268,000 - $2,615,000
Medium Mill and Overlay, Major CPR and Grinding, Cold In-Place Recycling, Thin Mill and Overlay, Crack/Seal and Thick Overlay, Major CPR, Medium Overlay, Micro-mill and UTBWC, Minor CPR and Grinding, Reclaim and Whitetopping, Thick Mill and Overlay, Thin Overlay, UTBWC, Whitetopping, Hot In-Place Recycling	Rehabilitation	$101,000 - $640,000
Chip Seal, Crack Seal, Crack Fill, Joint Seal	Preservation	$3,000 - $31,000

CPR: Concrete Pavement Restoration; UTBWC: Ultra-thin bituminous wearing course

<u>Future Improvements Pavements</u>

- New Pavement Management System Project Underway
- TAMS MMS integration with AASHTOware Capital Project Costs (Pay Items)

Bridge Treatments and Costs

- Internal Staff Perform Preventive Maintenance Activities
  - Flushing – Annually To Reduce Corrosion
  - Crack sealing – 5 Year Cycle
  - Joint maintenance/Minor Repairs – Response to Inspection/Element Condition
- Inspection/Maintenance Activity Recorded in Bentley Structural Inspection & Maintenance System.
- Internal Maintenance Cost By Activity Come From MnDOT Timesheet System.

Figure 6-9: Cost of Bridge Treatments and Actions

TREATMENTS AND ACTIONS	FHWA TREATMENT CATEGORY	COST
Culvert	Reconstruction	$144 Sq. Ft.
Early Materials	Reconstruction	N/A
New Bridge	Reconstruction	$174 – $302 Sq. Ft.
Pedestrian Bridge	Reconstruction	$1M - $4M per bridge
Temporary Bridge	Reconstruction	N/A
Deck Replacement	Rehabiliation	$74.40 Sq. Ft.
Major Widening	Rehabiliation	$229 Sq. Ft.
Superstructure Replacement	Rehabiliation	$131.60 Sq. Ft.
Bridge Painting	Preservation	$18.60 - $21.70 Sq. Ft.
Deck Overlay	Preservation	$9.70 Sq. Ft.
End Posts	Preservation	$9000 Corner of Bridge
Joint Replacements	Preservation	$1144 - $3432 Linear Foot
Railing or Median Barrier Replacement	Preservation	$225 - $350 Linear Foot
Substructure Repairs or Pier Struts	Preservation	$160 - $200 Linear Foot Substructure. Pier Struts $1100 Linear Foot
Preventive Maintenance (Set aside in STIP and CHIP)	Maintenance	$5.70 - $13.70 Sq Ft
Bridge Portion of BARC (Set aside in STIP and CHIP)	Maintenance	N/A
Crack Sealing	Maintenance	$3.00 Linear Foot

Life Cycle Planning Process
Highway Culverts

TREATMENT	MAINTENANCE FUNDING	CAPITAL FUNDING
Inspection	100%	0%
Cleaning	70%	30%
Reset ends	20%	80%
Joint repair	15%	85%
Pave invert	75%	25%
Replace ends	33%	67%
Slipliner	45%	55%
Cured in-place pipe	0%	100%
Replace-Trench	10%	90%
Replace-Jack	0%	100%

UNIT COST ($ PER ASSET)
$100
$1,000
$3,900
$3,440
$1,840
$5,630
$14,000
$19,500
$31,500
$91,000

Figure C-6: Deterioration Models for Highway Culverts

APPROACH	TRANSITION STATES	YEARS	GOOD	FAIR	POOR	VERY POOR
Current	Good to Fair	10	93.3%	6.7%	N/A	N/A
Current	Fair to Poor	14	N/A	95.2%	4.8%	N/A
Current	oor to Very Poor	6	N/A	N/A	89.1%	10.9%
Desired	Good to Fair	10	93.3%	6.7%	N/A	N/A
Desired	Fair to Poor	16	N/A	95.8%	4.2%	N/A
Desired	oor to Very Poor	8	N/A	N/A	91.7%	8.3%

% Treatment Distribution (How many culverts treated in each condition state) By Condition State

Life Cycle Planning Process
Intelligent Transportation System

Figure 6-26: ITS Infrastructure Assets and Typical Treatment Actions

ITS ASSET	TYPICAL TREATMENT ACTIONS
Fiber Network Shelters	Routine, Preventive Maintenance, and Minor Rehabilitation Actions: Filter change, fan checks and replacement, power supply check and replacements, infestation and leak checks, debris removal. Major Rehabilitation: Power supply replacement, fan replacement, HVAC system maintenance. Replacement: Shelter and foundation replacement
Traffic Management System Cabinets	Routine and Preventive Maintenance: Filter replacement, general cleaning, inspection. Minor Rehabilitation: Fan replacement. Major Rehabilitation: Door and lock replacement. Replacement: Cabinet replacement
Dynamic Message Signs	Routine and Preventive Maintenance: Filter change, fan check, pixel board and power supply check, infestation and leak checks, debris removal. Minor Rehabilitation: Fan replacement, power supply replacement. Major Rehabilitation: Pixel board replacement. Replacement: Walk-in DMS and post-mounted DMS installation
Traffic Monitoring Cameras	Routine and Preventive Maintenance: Tilt camera up (to let rain wash the lens of camera). Minor Rehabilitation: Wiper blade replacement. Major Rehabilitation: Repair of internal and external camera components. Replacement: Replacement or upgrade of camera
E-ZPass Readers	Routine and Preventive Maintenance: Annual inspection (five years after installation) to ensure mounting brackets on antennae are in good condition. Minor Rehabilitation: N/A. Major Rehabilitation: N/A. Replacement: Complete replacement of device
Reversible Road Gates	Routine and Preventive Maintenance: Lubrication, hydraulic oil draining and replacement. Minor Rehabilitation: Flasher unit, orange flag replacement. Major Rehabilitation: Hydraulic pump and arm replacement. Replacement: Complete replacement
Ramp Meters	Routine and Preventive Maintenance: None. Minor Rehabilitation: LED bulb replacement. Major Rehabilitation: New indicators (signal body). Replacement: Complete replacement
Fiber Communication Network	Routine and Preventive Maintenance: None. Minor Rehabilitation: Splice in connectors. Major Rehabilitation: Fixing severed cable. Replacement: Complete replacement
Traffic Detection	Routine and Preventive Maintenance: None. Minor Rehabilitation: Splice (loops); recalibration (radar). Major Rehabilitation: Wire pulls (loops); new eletrical wires (radars). Replacement: Complete replacement

Helped to Document and Communicate Consistent Routine & Preventive Maintenance Activities and Costs!!

Life Cycle Planning Results
Highway Culverts

Figure 6-19: 10-Year Performance Trends for Highway Culverts

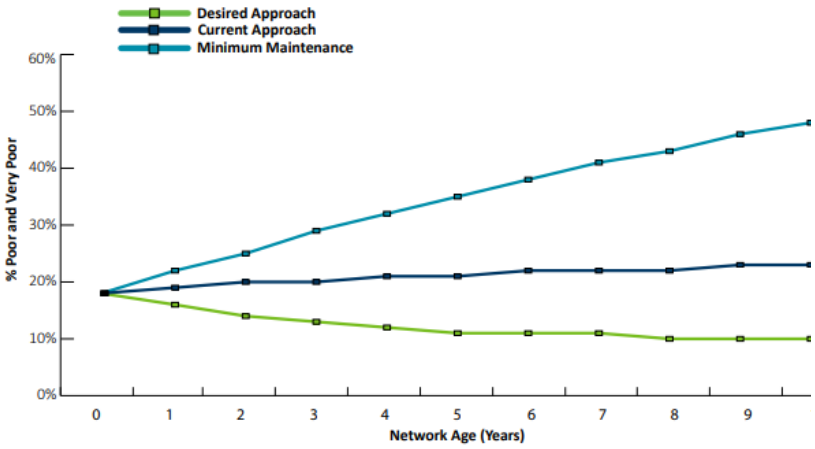
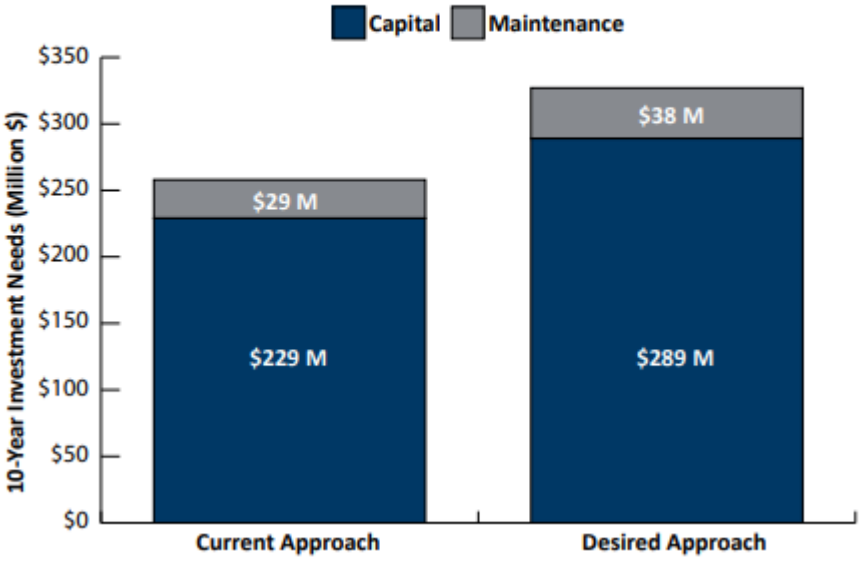


Figure 6-21: 10-Year Investment Needs for Highway Culverts



- As The Network Age Increase; Desired Approach Obtains 10% Network Level Condition.
- Funding Investment Needs to Increase By 31% Under Desired Approach.

Life Cycle Planning Results
Maintenance + LCP

ITS Assets

- Routine and preventive maintenance actions have no impact on asset condition.

Overhead Sign Structures

- An increase in out-of-cycle inspections, helps identify and monitor issues before causing structures to deteriorate. In addition, increase the frequency of nut tightening, rehabilitation, and replacement.

Signals and Lighting

- Utilizing age-based condition and performance targets, thus limiting preventive maintenance's impact to extend asset service life.
- MnDOT staff believe that electrical and structural inspections could extend service life.
- Investing in strategic preventive maintenance for High-Mast Lighting will maintain the assets in a good state of repair over their design life.

Summary

- Incorporating maintenance and capital activities = complete picture of life cycle planning for each asset.
- Data speaks louder than words, generating culture and funding shifts. This data may be used for future maintenance distribution across MnDOT Districts.
- Utilization of Maintenance Cost data for better decision-making reinforcing dedication and accuracy in enterprise asset management systems.

MnDOT's 2022 TAMP is…

More Informative, Compelling, and Useful.

http://www.dot.state.mn.us/assetmanagement/tamp.html

Thank You!

Trisha Stefanski
MnDOT Asset Management
Program Office Director

COLORADO
Department of Transportation

Incorporating Maintenance

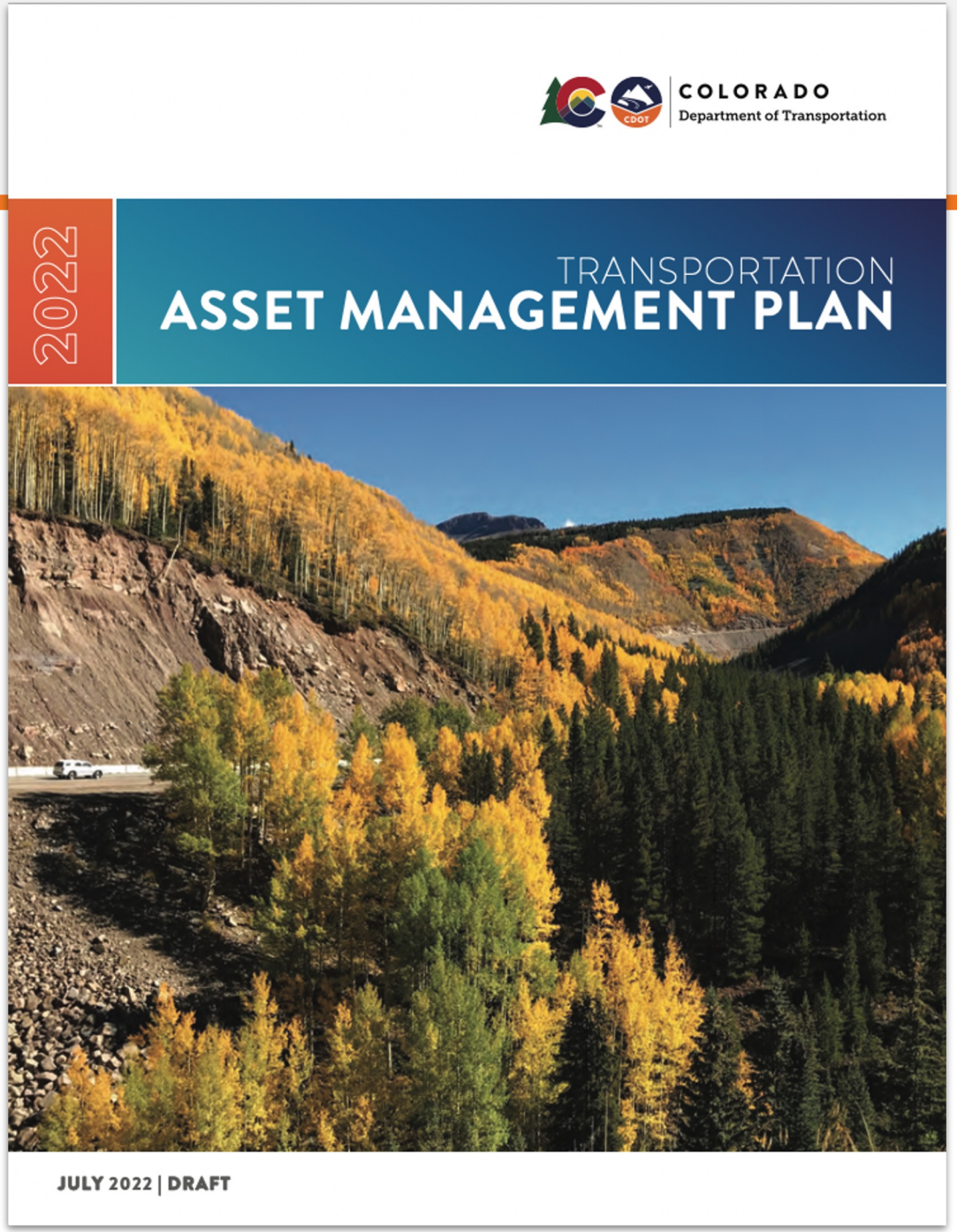
for Main and Ancillary Assets in CDOT's TAMP

October 2022

2022 TAMP Overview:

- 12 asset classes featured
- Total page count will be about 250.
- Built in a modular fashion.
- Very graphical executive summary

- Today's focus:
  - Asset Plans for smaller asset classets (culverts, walls, tunnels, etc.)
  - Incorporation of maintenance



Executive Summary

Executive Summary:

- Gives a quick ***graphical*** look at:
  - What we do
  - Asset performance vs. targets
  - Asset-management process
  - Top risks
  - Future improvements
  - Letter from the Executive Director

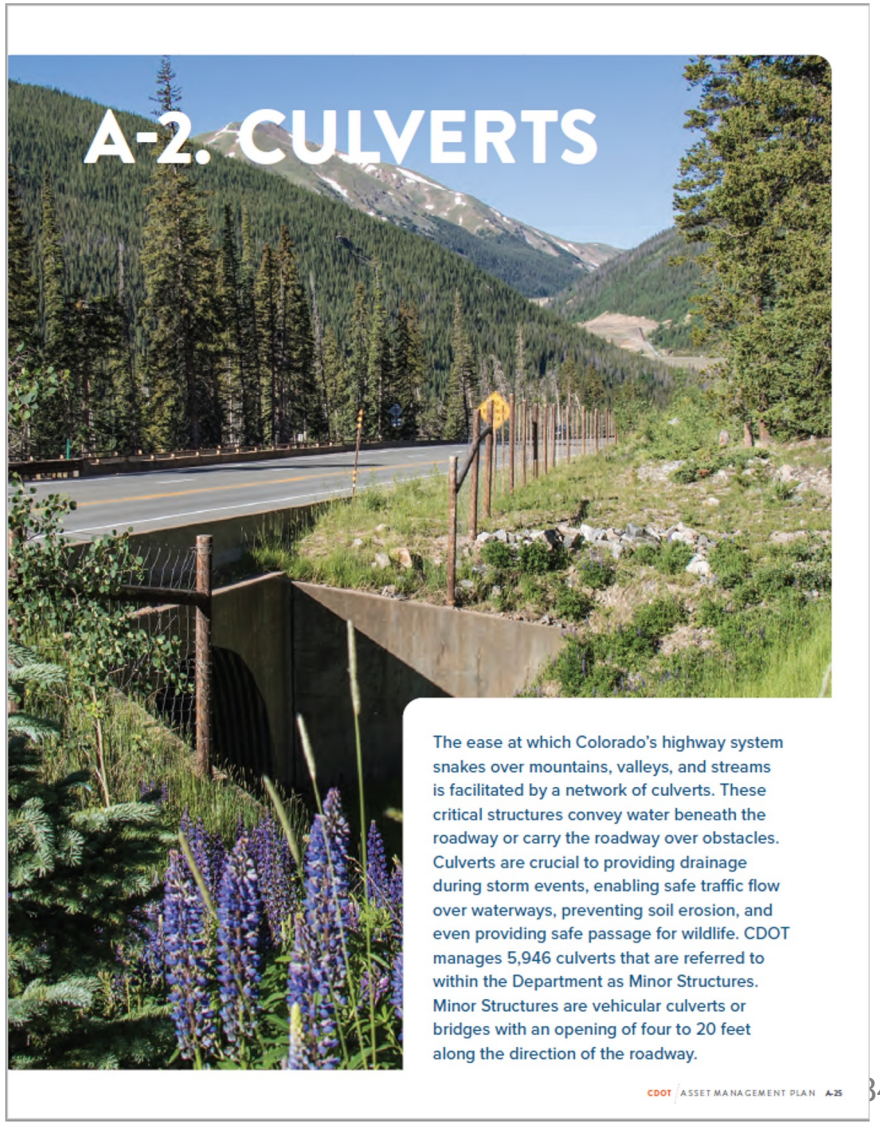
TAMP Development

Status:

- Working with WSP.
- Status: Submitted main TAMP to FHWA.
- Finalizing ancillary asset plans.
- Will submit all 12 assets to FHWA next month.

Federal Minimum Requirements:

- Summary of NHS pavements & bridges
- Asset management objectives/metrics
- Performance gaps
- Life-cycle planning
- Risk-management analysis
- Financial plan, minimum 10 years
- Investment strategies



Plan Elements 1/3

INVENTORY AND CONDITION

CDOT owns and maintains 3,219 units of rolling-stock[1] fleet assets that are divided into four categories: Essential, Road, Off-Road, and Support. CDOT tracks these fleet assets within the SAP Equipment Database, which includes data on age, utilization, and cost of maintenance that are used to determine each asset's condition.

INVENTORY

Of the 3,219 vehicles in the fleet, 978 are classified as Essential vehicles, critical for important missions. These include snowplow trucks and other snow-removal vehicles (e.g., snowcats and snow blowers), as well as aerial-lift trucks for signal maintenance. The fleet asset inventory is provided in **Table A.3-2**.

Table A.3-2 *Current Inventory and Condition of Fleet Assets*

Asset Type	Current Count	Useful Life (Years)	Average Age (Years)	Percent Useful Life Expended
ESSENTIAL	*978*	*15*	*12.00*	*80%*
Snowplow trucks	868	12	12.00	100%
Snowcats	5	15	10.4	70%
Others	105	15	9.1	60%
ROAD	1069	10	10.08	108%
One-Ton Trucks	377	10	9.6	96%
Mechanic Trucks	69	10	11.1	111%
Others	623	10	11.6	116%
OFF-ROAD	*667*	*15*	*12.92*	*86%*
Dozers	10	15	13.1	87%
Motor Graders	85	12	15.9	133%
Loaders	263	15	13.7	91%
Others	309	15	11.4	76%
FLEET SUPPORT	*505*	*15*	*9.99*	*66%*
Personnel Lifts (Scissor Lifts)	5	10	14.2	142%
Large Welders	8	15	20.5	137%
Others	492	15	9.7	65%
Total	3219	13.2	12.23	93%

1 This number changes weekly, based on fleet turns and up-fit schedule.

PERFORMANCE GAP ANALYSIS

CDOT uses a performance-driven approach to manage traffic signals. This section describes the projected performance of these assets given the planned funding and investment strategies described in the previous two sections. The section then compares projected performance against the performance target. CDOT's ability to close performance gaps largely depends on receiving additional funding. For traffic signals, CDOT also is assessing additional opportunities to close performance gaps that focus on adjustments to life-cycle planning strategies.

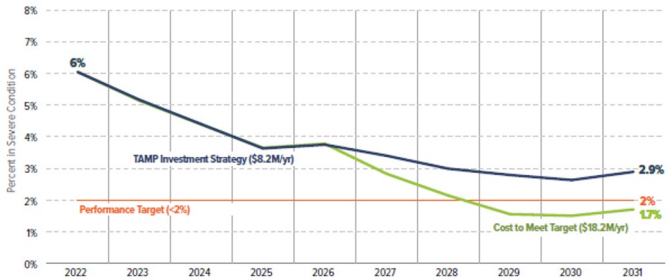
NEEDS AND PROJECTED CONDITION

CDOT's AIMS model predicts the long-term performance of signals given expected funding. Signal components deteriorate in the model using step functions based on the expected life cycle of each component (i.e., assembly, controller, and cabinet). The components deteriorate from Good to Fair, then to Poor, and then to Severe based on the expected life of each component. The model assumes that 80 percent of planned budgets is dedicated to signal assemblies, while 10 percent is dedicated to cabinets, and 10 percent to controllers.

At planned funding levels (about $8.2 million annually), traffic signals are not expected to meet the performance target of having no more than 2 percent of signals in Severe condition by 2031. As shown in **Figure A.8-3**, an additional $10 million in annual budget is required to meet CDOT's performance target by 2029 and sustain that state until year 2033. At that point in time, a significant number of signals owned by CDOT will begin reaching the end of their designed service lives. To sustain the targeted performance beyond 2033, an additional $25-$50 million in annual budget will be required to replace signals.

Figure A.8-3 *Forecasted Percentage of Signals in Severe Condition*

The anticipated annual budget of $8.2 million will not meet the performance target of ensuring that less than 2 percent of traffic signals are in severe condition. The annual cost of meeting the target by 2031 is about $18.2 million, or an additional $10 million per year.



FINANCIAL PLAN

CDOT sets planning budgets for its asset programs four years in advance. The plan below assumes that funding for the Culverts program will remain static for the foreseeable future, at the level most recently set ($8.2 million for fiscal year 2025). These budget assumptions, combined with CDOT's life-cycle management approaches discussed in the subsequent section, inform the investment strategies for culverts that CDOT plans to leverage to achieve system-wide asset performance goals while minimizing life-cycle costs.

FUNDING SOURCES

The culverts portion of the Transportation Asset Management (TAM) program supports the life-cycle management for culvert assets. Of the allocated funding, approximately $1 million per year is used for inspections. Meanwhile, preservation and maintenance provided by the Maintenance Levels of Service (MLOS) program is budgeted separately, in the MLOS Financial Plan.

PLANNED FUNDING

Table A.2-7 summarizes the projected funding levels for the Culverts program for fiscal years 2022-31.

Table A.2-7 *Culverts 10-Year Financial Plan Budgets FY22-31 (in Millions)*

FY22	FY23	FY24	FY25	FY26	FY27	FY28	FY29	FY30	FY31
$8.3	$8.3	$8.2	$8.2	$8.2	$8.2	$8.2	$8.2	$8.2	$8.2

Plan Elements 2/3

LIFE-CYCLE PLANNING

CDOT analyzes its wall inventory and inspection data to forecast investment needs and set work priorities. This process is known as life-cycle planning and accounts for the whole-life costs of planning, constructing, and maintaining walls, with consideration for minimizing long-term costs while preserving or improving the condition. Currently, the main driver for applying life-cycle strategies to wall assets is condition. CDOT leverages the findings from its annual condition-assessment report and employs various treatments to address the needs of walls in different conditions. Major rehabilitation and reconstruction restore walls that are identified as Emergency Repair Findings or in Poor condition. Walls in Good and Fair condition receive routine maintenance, as needed.

LIFE-CYCLE PLANNING

CDOT uses a condition-based approach to the life-cycle management of a wall. This means condition data is used to determine the appropriate type and timing of work and to prioritize potential work within available budgets. CDOT identifies damaged walls that diminish the resiliency and reliability of the highway system and prioritizes these assets. Impacts of poorly functioning walls on CDOT's highway system are discussed in the section named Impacts of Insufficient Funding. CDOT prioritizes wall projects for maintenance to minimize such safety, mobility, environmental, public perception, public health, and asset management risks.

The Walls program maintains, repairs, rehabilitates, and replaces walls. Some design work is performed in-house, but most construction is performed by contractors. CDOT's Maintenance Levels of Service (MLOS) program delivers routine maintenance, preservation treatments, and repairs that do not require engineering.

The current program approach for managing wall assets is typically reactive in nature. CDOT's wall-maintenance program prioritizes addressing walls that pose substantial risks, (i.e., are identified with Emergency Repair Findings). As a result, most repairs and wall maintenance are carried out in response to inspection findings. Examples of inspection findings requiring repair include deterioration due to water, vehicle-impact damage, or observed deterioration reported by maintenance staff or periodic inspections.

PROGRAM DECISION-MAKING

CDOT uses several different treatments to address wall deterioration. Wall treatments can range from vegetation removal to patching or replacement, depending on the wall condition and availability of funds. Definitions of the wall treatment work types are summarized below. A list of wall treatments and their typical costs are shown in **Table A.10-5**.

- **Preservation** consists of activities that prolong the life of the structure without changing the condition rating (i.e., preventative maintenance). Examples include vegetation removal and drainage cleanout.
- **Maintenance** includes patching and other repair treatments that do not have the potential to change condition but provide an expected extension of service life.
- **Rehabilitation** includes repairs or replacements of portions of walls that provide a change in wall condition and expected extension of service life. Examples include replacing deteriorated blocks, resetting bulging or rotated concrete panels, or patching extensive cracks or spalls.

RISK MANAGEMENT

Aligned with CDOT's overall risk-management approach, the Traffic Signals program manages risk across multiple levels—agency, programmatic, and project/asset. Section 6 of the overall TAMP provides more information about CDOT's risk-management methodology and processes.

The Traffic Signals program maintains a register of risks to its overall program and projects. Top risks to the Traffic Signals program are presented in **Table A.8-6**.

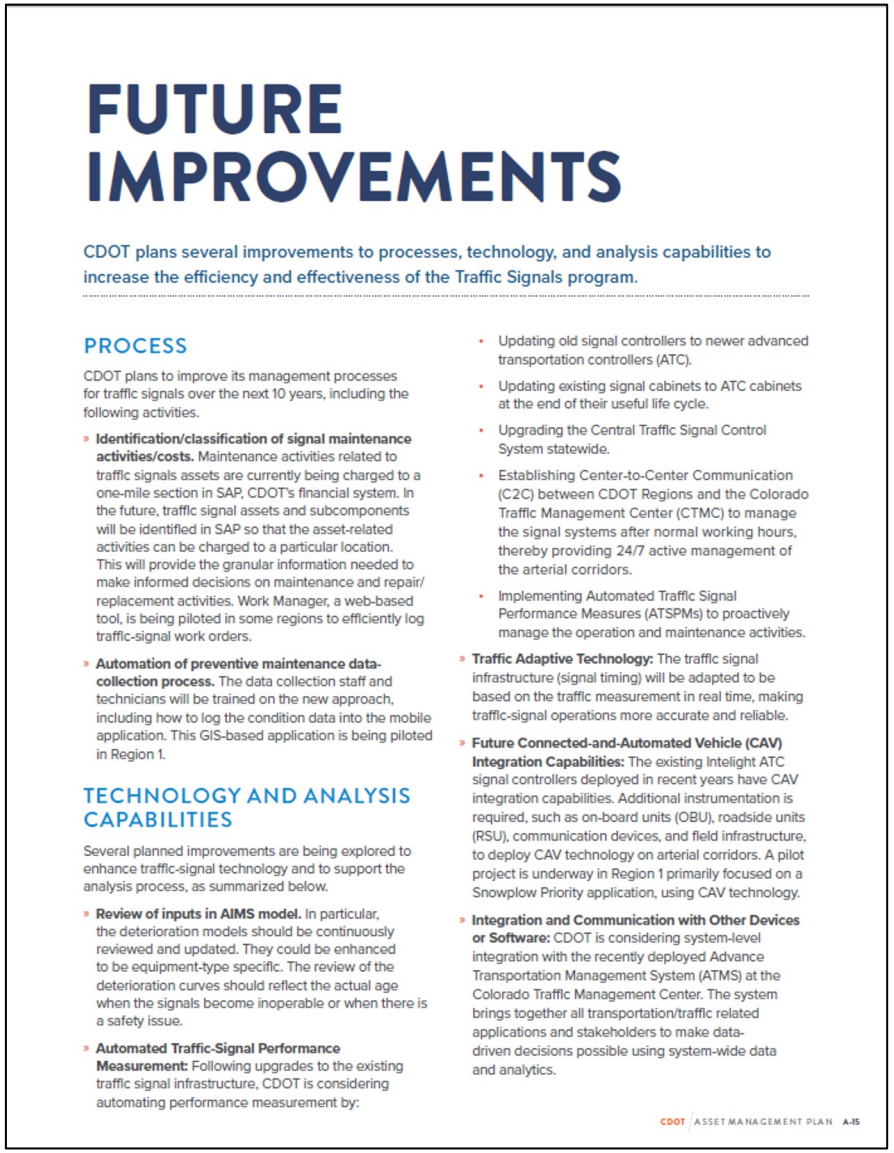
Table A.8-6 *Top Traffic Signal Risks*

Risk Level	Threat/Opportunity	Risk Score	Risk-Management Strategy
Program	Changing federal and state laws, policies, standards, and specifications in the near future (e.g., Update to the Manual on Uniform Traffic Control Devices [MUTCD], ADA requirements, multi-modal considerations).	39.6 (L)5 * (C)3.9 * (V)2[1]	Treat, tolerate—maintain existing infrastructure, replace/upgrade to the latest standards when asset treatment is required.
Project	Loss of communication due to fiber damage or utility-line damage (e.g., loss of power, fiber cuts).	37.4 (L)5 * (C)3.7 * (V)2	Treat by location. Tolerate—repair, replace, where required. Collect damages from utility operators.
Project	Signal components (cabinets, poles) damaged by vehicles.	37.4 (L)5 * (C)3.7 * (V)2	Treat, tolerate, terminate. Repair, replace based on post-event inspection.
Program	Increased construction costs and labor/material shortages.	36.0 (L)5 * (C)3.6 * (V)2	Treat, tolerate—maintain existing infrastructure, implement innovative project-delivery methods.

Table A.10-5 *Wall Life-Cycle Management Activities*

FHWA Treatment Work Type	Activity	Typical Costs/Square Foot
Preservation	Vegetation Removal	$15
Maintenance	Patching	$180
Rehabilitation	Replacing Deteriorated Blocks	$250
Reconstruction (Replacement)	Replacement	$300

Plan Elements 3/3



FUTURE IMPROVEMENTS

CDOT plans several improvements to processes, technology, and analysis capabilities to increase the efficiency and effectiveness of the Traffic Signals program.

PROCESS

CDOT plans to improve its management processes for traffic signals over the next 10 years, including the following activities.

- **Identification/classification of signal maintenance activities/costs.** Maintenance activities related to traffic signals assets are currently being charged to a one-mile section in SAP, CDOT's financial system. In the future, traffic signal assets and subcomponents will be identified in SAP so that the asset-related activities can be charged to a particular location. This will provide the granular information needed to make informed decisions on maintenance and repair/replacement activities. Work Manager, a web-based tool, is being piloted in some regions to efficiently log traffic-signal work orders.
- **Automation of preventive maintenance data-collection process.** The data collection staff and technicians will be trained on the new approach, including how to log the condition data into the mobile application. This GIS-based application is being piloted in Region 1.

TECHNOLOGY AND ANALYSIS CAPABILITIES

Several planned improvements are being explored to enhance traffic-signal technology and to support the analysis process, as summarized below.

- **Review of inputs in AIMS model.** In particular, the deterioration models should be continuously reviewed and updated. They could be enhanced to be equipment-type specific. The review of the deterioration curves should reflect the actual age when the signals become inoperable or when there is a safety issue.
- **Automated Traffic-Signal Performance Measurement:** Following upgrades to the existing traffic signal infrastructure, CDOT is considering automating performance measurement by:
  - Updating old signal controllers to newer advanced transportation controllers (ATC).
  - Updating existing signal cabinets to ATC cabinets at the end of their useful life cycle.
  - Upgrading the Central Traffic Signal Control System statewide.
  - Establishing Center-to-Center Communication (C2C) between CDOT Regions and the Colorado Traffic Management Center (CTMC) to manage the signal systems after normal working hours, thereby providing 24/7 active management of the arterial corridors.
  - Implementing Automated Traffic Signal Performance Measures (ATSPMs) to proactively manage the operation and maintenance activities.
- **Traffic Adaptive Technology:** The traffic signal infrastructure (signal timing) will be adapted to be based on the traffic measurement in real time, making traffic-signal operations more accurate and reliable.
- **Future Connected-and-Automated Vehicle (CAV) Integration Capabilities:** The existing Intelight ATC signal controllers deployed in recent years have CAV integration capabilities. Additional instrumentation is required, such as on-board units (OBU), roadside units (RSU), communication devices, and field infrastructure, to deploy CAV technology on arterial corridors. A pilot project is underway in Region 1 primarily focused on a Snowplow Priority application, using CAV technology.
- **Integration and Communication with Other Devices or Software:** CDOT is considering system-level integration with the recently deployed Advance Transportation Management System (ATMS) at the Colorado Traffic Management Center. The system brings together all transportation/traffic related applications and stakeholders to make data-driven decisions possible using system-wide data and analytics.

STRATEGIC USE OF ADDITIONAL REVENUE

Should CDOT receive additional revenue to fund the Walls asset class, the Department's first priority is to eliminate any funding gaps related to achieving the PD-14 performance target. Once goals are achieved, the Department will reduce Poor backlog with a priority towards the most critical and/or vulnerable assets to improve system resilience. CDOT estimates the current "Poor" backlog for Walls could be eliminated with about $216 million.

Work Types Memo for Bridges

1. **Bridge:**
    - **Preservation** consists of activities that prolong the life of the structure by arresting deterioration or re-establishing element protection without changing the condition rating. Examples include painting, replacing joints, installing waterproof membranes, and cleaning.
    - **Maintenance** consists of repairs that prolong the life of the structure by arresting deterioration or re-establishing element protection without changing the condition rating. Examples include minor patching, crack arrest, and deck repair.
    - **Rehabilitation** consists of repairs expected to prolong the life of the structure and improve an element- or component-condition rating. Examples include deck rehabs, substructure rehabs, superstructure rehabs, and split-timber girder rehabs.
    - **Reconstruction** consists of replacement of an existing structure.
    - **Initial Construction** consists of:
        - Construction of a bridge where no bridge has ever been built, such as new interchanges.
        - Widening of the structure to accommodate the addition of any lanes (e.g., turn lanes, accel/decel lanes, additional general purpose or managed lanes, multi-use pathways)
        - Widening of the structure to accommodate construction phasing.
        - Initial construction does not include shoulder widening or addition of a new shoulder to meet current design standards.

Note: All work types include preconstruction costs.

Bridge Investment Strategies

Chapter describes our investment strategies for pavement and bridges, shown through distribution among five work types:

1. Maintenance
2. Preservation
3. Rehabilitation
4. Reconstruction
5. Initial Construction (Estimating new construction remains a work in progress. Figures averages of the early years of the 10-Year Plan.

Table 19 *Bridge Investment Strategy*, FY 2022–31 (in Millions)

Work Type	FY 22	FY 23	FY 24	FY 25	FY 26	FY 27	FY 28	FY 29	FY 30	FY 31
Maintenance*	$5.4	$5.2	$5.0	$5.1	$5.3	$5.4	$5.6	$5.8	$5.9	$6.3
Preservation	$19.39	$22.15	$22.96	$16.76	$19.08	$20.92	$24.20	$38.15	$38.30	$31.88
Rehabilitation	$7.02	$15.15	$15.34	$21.54	$1.73	$0	$20.08	$0.15	$33.12	$32.39
Reconstruction	$108.65	$54.24	$86.17	$84.90	$134.61	$93.81	$110.27	$121.38	$90.95	$102.69
Initial Construction	$93.2	$93.2	$93.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
TOTAL	$233.3	$189.94	$222.67	$128.30	$160.72	$120.13	$160.15	$165.48	$168.27	$173.26

Maintenance Activities for Bridges

Bridge activities delivered by Maintenance Levels of Service (MLOS) Program.

Bridge Maintenance Program Area is about $5M per year.

Activity	Activity Description	Accomplishment UOM
STRUCTURE MAINTENANCE (350)		
351	Inspections	Each
352	Bridge Structure- Cleaning	Each
353	Bridge Deck Repair	Square Yard
354	Superstructure Maintenance & Repair	Each
355	Painting	Gallon
356	Curb, Guardrail, & Railing	Linear Foot
357	Bearing Maintenance & Repair	Each
358	Substructure Maintenance & Repair	Each
359	Approach/Departure Slabs & Slope Protection	Each
360	Rotomilling Asphalt on Bridge Deck	Square Yard
361	Rotomilling Concrete on Bridge Deck	Square Yard
362	Crack and Joint Sealing Concrete on Bridge Deck	Pounds
363	Crack and Joint Sealing Asphalt on Bridge Deck	Pounds
364	Deck Expansion Device (Sealing Joints)	Linear Foot

Work Types for Culverts

Culvert-treatment work types are defined as follows:

Preservation includes cleaning, brush clearing, and similar treatments that help the culvert function properly.

Maintenance includes scour repair and miscellaneous repairs. These treatments do not provide a change in culvert condition but do extend service life.

Rehabilitation includes slip lining, spray lining (i.e., lining a deteriorated pipe with a layer of protective material such as grout), and other repair treatments. These treatments restore culvert condition and extend service life. To receive a slip lining, a culvert cannot have begun collapsing. This treatment is considered a preservation or rehabilitation action, depending on the condition of the existing pipe.

Reconstruction consists of replacing the existing structure with a new structure. This results in a resetting of expectations regarding culvert condition and service life. Culverts with Essential Repair Findings are most commonly replaced. Replacement is typically accomplished by excavating through the overlying pavement and placing a new structure, although new pipe installation methods that do not require digging an open trench may also be used. The most cost-effective approach is selected as part of the design process. Hydraulic analysis is required as part of the design process to make sure the final culvert is properly sized.

Culvert Investment Strategies

Culverts Maintenance Program Area (MPA) is No. 202.

ROADWAY FACILITIES (200)	
202	Drainage Structure- Clean, Repair, Replace, Remove Dirt
206	Ditches & Streambeds
207	Salt & Sand Removal
210	Slope Repair
215	Road Kill Clean-up
216	Fence, Gates, Road Closures, Cattle Guard
217	Sound Barrier Maintenance
218	Litter Barrel and Trash Clean-up
219	Rock Run
220	Sweeping-Machine
222	Sweeping-Hand
223	Environmental Temporary BMP
224	Environmental Permanent BMP
225	Environmental Inspection

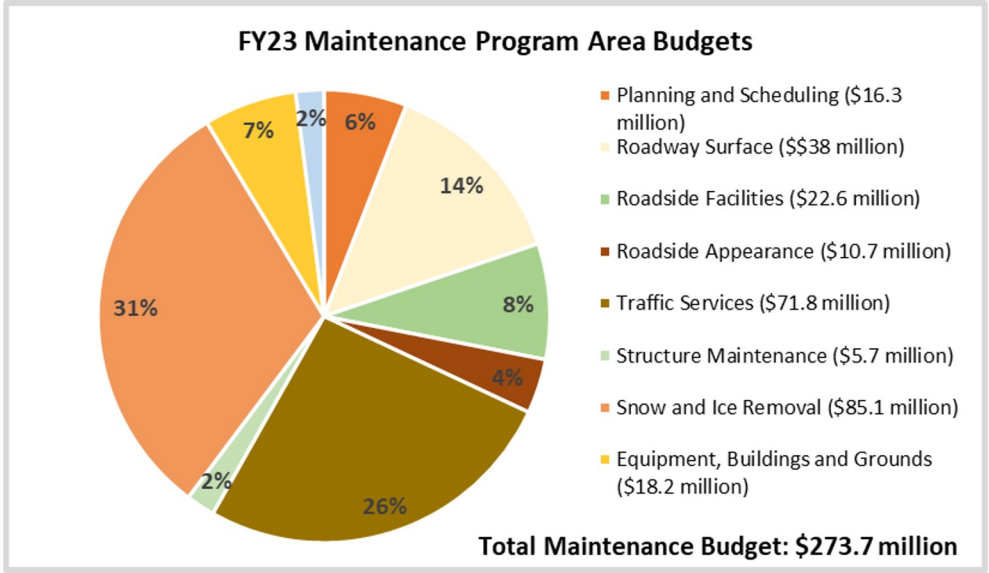
- About $2.3 million spent on culverts maintenance annually through Maintenance Levels of Service (MLOS) program. Activities that do not require engineering, including routine maintenance, preservation treatments, and repairs.
- Culverts asset program spends $8.2 million annually. Funds routine inspection ($1M annually), repair, rehabilitation, reconstruction, and replacement of culverts that's not covered under the MLOS program.

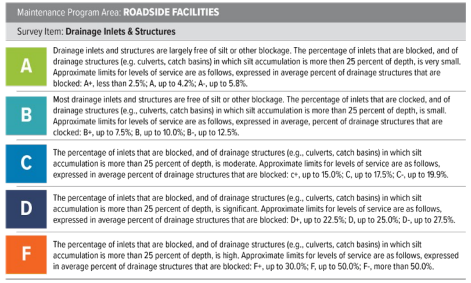
Maintenane (MLOS) Section of TAMP

ASSETS AT A GLANCE

MLOS

6,911,813 linear feet Metal Guardrail	2,581,538 linear feet Concrete Guardrail	838,727 linear feet Cable Guardrail	211,738 count Signs	48,928 miles Striping	34,735 count Pavement Markings
752 count High Mast Lighting	26,984 Light Poles count Roadway Lighting	22,878 count Crash/Energy Attenuators	23,427 count End Treatments	493,000 count Delineators	58,462,326 linear feet Fence



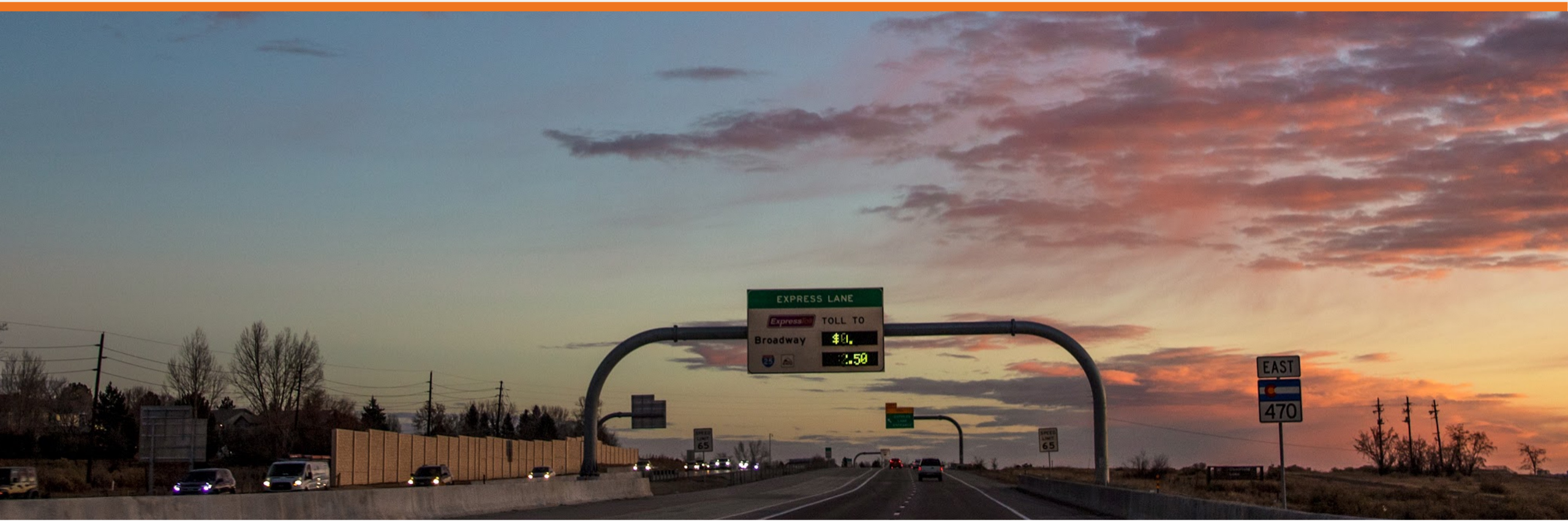


Maintenance Program Area: **ROADSIDE FACILITIES**

Survey Item: **Drainage Inlets & Structures**

A	Drainage inlets and structures are largely free of silt or other blockage. The percentage of inlets that are blocked, and of drainage structures (e.g. culverts, catch basins) in which silt accumulation is more then 25 percent of depth, is very small. Approximate limits for levels of service are as follows, expressed in average percent of drainage structures that are blocked: A+, less than 2.5%; A, up to 4.2%; A-, up to 5.8%.
B	Most drainage inlets and structures are free of silt or other blockage. The percentage of inlets that are clocked, and of drainage structures (e.g., culverts, catch basins) in which silt accumulation is more than 25 percent of depth, is small. Approximate limits for levels of service are as follows, expressed in average, percent of drainage structures that are clocked: B+, up to 7.5%; B, up to 10.0%; B-, up to 12.5%.
C	The percentage of inlets that are blocked, and of drainage structures (e.g., culverts, catch basins) in which silt accumulation is more than 25 percent of depth, is moderate. Approximate limits for levels of service are as follows, expressed in average percent of drainage structures that are blocked: C+, up to 15.0%; C, up to 17.5%; C-, up to 19.9%.
D	The percentage of inlets that are blocked, and of drainage structures (e.g., culverts, catch basins) in which silt accumulation is more than 25 percent of depth, is significant. Approximate limits for levels of service are as follows, expressed in average percent of drainage structures that are blocked: D+, up to 22.5%; D, up to 25.0%; D-, up to 27.5%.
F	The percentage of inlets that are blocked, and of drainage structures (e.g., culverts, catch basins) in which silt accumulation is more than 25 percent of depth, is high. Approximate limits for levels of service are as follows, expressed in average percent of drainage structures that are blocked: F+, up to 30.0%; F, up to 50.0%; F-, more than 50.0%.

Questions?



Thank You!

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