#### TRANSPORTATION RESEARCH BOARD

# Methodology for Prioritizing Tunnel Improvements and Developing Capital Plans

## Thursday, October 19, 2017 2:00-3:30PM ET

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### Purpose

Discuss NCHRP Research Report 816.

### Learning Objectives

At the end of this webinar, you will be able to:

- Understand what a tunnel preservation action is and how to develop a list of preservation actions
- Describe how to prioritize improvements for various tunnel systems using a consistent metric
- Explain how the listing can be used to develop multi-year capital plans and to evaluate funding and staffing needs once the improvements are prioritized

**TRB Webinar** 

## Methodology for Prioritizing Tunnel Improvements and Developing Capital Plans

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#### Agenda

- **1.** Project Objectives
- 2. Tunnel Asset Management Process
- **3. Prioritization Process** 
  - a. Identify Preservation Actions
  - b. Measure of Effectiveness Score
  - c. User Prioritization
- 6. Funding Evaluations
- 7. Communicating the Need

*This investigation was sponsored by TRB under the NCHRP Program. The contents of this presentation has not been reviewed by the project panel or NCHRP, nor do they constitute a standard, specification, or regulation.* 

#### NCHRP 14-27 Project Objectives

#### **To Develop:**

- A metric for use by tunnel owners to prioritize tunnel preservation actions
- A metric for evaluating funding scenarios
- A Guide for the Preservation of Highway Tunnel Systems

Inventory

## Less than 614,380 Bridges in the U.S. 473

Tunnels in the U.S.

Tunnels include complex systems; a rational method of prioritizing preservation actions is needed.



# Let's Start with an Example

R ROS

#### Tunnel Inventory

Tunnel #	Average Daily Traffic (x1,000)	Description
1	40	Rural tunnel on a major interstate.
2	100	High traffic urban tunnel downtown in a major city.
3	30	Low traffic urban tunnel outside of city.
4	19	Very low traffic urban tunnel downtown.
5	50	Moderately high traffic tunnel near Tunnel 2.
6	75	High traffic urban tunnel accessing a major city.







Agency Levels of Service (LOS)

Selection of Agency Levels of Service (Goals and Objectives)

**RELIABILITY** | The ability to keep the tunnel open and operational

**SAFETY** | To maintain safe conditions for the traveling public and workers

**SECURITY** | To reduce the vulnerability to technological or natural hazards

**PRESERVATION** | To increase the remaining life of the asset

**QUALITY OF SERVICE** | To improve the experience for the driving public

**ENVIRONMENT** | To reduce the impacts or potential for environmental impacts

Agency Levels of Service (LOS)

#### Weighting of Agency Level of Service and Performance Goals

Example: An agency has defined six levels of service categories as follows:



#### Performance Measures

#### Develop Performance Measures

- Number of Incidents/Accidents per Year | SAFETY
- Condition of Tunnel Structural System | PRESERVATION
- Condition of Tunnel Mechanical and Electrical Systems
   PRESERVATION | RELIABILITY
- Operating Costs | PRESERVATION | RELIABILITY
- Number of Tunnel Closures per Year
   SAFETY | RELIABILITY



#### Inspect Tunnels

• NTIS Inspections per TOMIE and SNTI



#### **Evaluate and Identify Preservation Actions**

- NTIS Inspections
- Maintenance Recommendations
- NFPA 502 Evaluations for Fire Life Safety
- Evaluations to Reduce Maintenance or Energy
  - Replacing fan components to state of the art components for better performance
  - LED lighting





The following preservation actions have been identified and must be evaluated and prioritized based on most recent inspections and evaluations of existing systems.

- 1. Ventilation upgrade to meet NFPA 502. (Tunnel #1)
- 2. Install new LED lights. (Tunnel #1)
- 3. CO System Repair to operating condition. (Tunnel #2)
- 4. Repair active leak in ceiling. (Tunnel #4)
- 5. Remove existing concrete tunnel ceiling. (Tunnel #6)
- 6. Install Flood Gates (Tunnel #6)







**Prioritizing Tunnel Preservation Actions** 

#### NCHRP Report 816 *Guide for the Preservation* of Highway Tunnel Systems

 Provides a metric to prioritize improvements across all tunnel systems and assets



#### Measure of Effectiveness



#### Levels of Service (LOS) Score



Level of Service (LOS) Rating

#### LOS Ratings = Impacts of Preservation Actions on LOS

LOS Rating

The improvement *will have very little impact* in improving the performance associated with the LOS.



The improvement *will greatly impact* the performance associated with the LOS in a positive way.

#### Level of Services (LOS) Score

Preservation Action	Tunnel #	Reliability (20%)	Safety (40%)	Security (5%)	Preservation (18%)	Quality of Service (15%)	Environmental (2%)	LOS Score
Ventilation upgrade to meet NFPA 502	1	1	5	1	5	1	N/A	
Install new LED lights	1	3	4	2	5	4	5	
CO System –Repair to operating condition.	2	2	5	N/A	4	N/A	2	
Repair active leak in ceiling	4	4	5	N/A	5	5	N/A	
Remove existing concrete tunnel ceiling	6	4	5	N/A	4	5	N/A	
Install flood gates	6	4	4	N/A	5	N/A	N/A	

Level of Service (LOS) Score

#### LOS Score =



For Example, if all ratings are 5's, then

 $(W_R^{*5}) + (W_{Sa}^{*5}) + (W_{Se}^{*5}) + (W_P^{*5}) + (W_Q^{*5}) + (W_E^{*5})/5 =$   $5(W_R + W_{Sa} + W_{Se} + W_P + W_Q + W_E)/5 =$ 5(100)/5 = 100

All LOS Scores will be between 0 and 100

#### Level of Services (LOS) Score

Preservation Action	Tunnel #	Reliability (20%)	Safety (40%)	Security (5%)	Preservation (18%)	Quality of Service (15%)	Environmental (2%)	LOS Score
Ventilation upgrade to meet NFPA 502	1	1	5	1	5	1	N/A	66.0
Install new LED lights	1	3	4	2	5	4	5	78.0
CO System –Repair to operating condition.	2	2	5	N/A	4	N/A	2	63.2
Repair active leak in ceiling	4	4	5	N/A	5	5	N/A	89.0
Remove existing concrete tunnel ceiling	6	4	5	N/A	4	5	N/A	85.4
Install flood gates	6	4	4	N/A	5	N/A	N/A	66.0



#### **Calculating Costs - Present Value and Annualization**

Preservation actions not on the same timescale - cannot be compared based on PV alone.

- Annualizing all costs allows for the comparison of very different actions.
- Concept of the time value of money is incorporated using a discount rate term.
   3% is used in examples provided.

#### **Effect of the Number of Users**

- Urban versus rural area
- ADT used
- Cost effectiveness of the preservation action
- Annualized life cycle cost per average daily vehicle



```
Annualized Life Cycle Cost
ALCC = C * [(i * (1+i)<sup>n</sup>)]/[(1+i)<sup>n</sup>-1] – A
```

- C = Capital cost + agency oversight cost (\$)
- i = Discount Rate, 3%
- n = Change in service life resulting from improvement (years)
- A = Annual Change in Costs (\$; maintenance, energy, etc.)

Preservation Action	Tunnel #	Capital Cost	Agency Oversight Cost	Annual Change in Cost	PV of LCC	Remaining Life due to PA	ADT (x 1000)	Annualized Life Cycle Cost	Annual Cost per Daily Vehicle	CE Score
Ventilation upgrade to meet NFPA 502	1	\$5,700,000	\$570,000	\$(152,500)	\$3,614,495	25	40	\$207,573	\$5.19	
Install new LED lights	1	\$3,400,000	\$136,000	\$(71,000)	\$2,479,699	20	40	\$166,675	\$4.17	
CO System – Repair to operating condition.	2	\$32,000	\$3,200	\$0	\$35,200	20	100	\$2,366	\$0.02	
Repair active leak in ceiling	4	\$10,000	\$1,000	\$0	\$11,000	20	19	\$739	\$0.04	
Remove existing concrete tunnel ceiling	6	\$8,000,000	\$800,000	\$(20,000)	\$8,285,405	50	75	\$56,954	\$0.76	
Install flood gates	6	\$8,000,000	\$320,000	\$0	\$8,320,000	100	75	\$263,300	\$3.51	

**Cost Effectiveness Score** 

```
CE Score = 100/[ALCC/ADT)*F
CE Score = 100, if 100/[(ALCC/ADT)*F]>100
```

CE = Cost Effectiveness Score ADT = Average Daily Traffic (no. of vehicles) ALCC/ADT = Annual Life Cycle Cost/Daily Vehicle F = Cost Factor, 10

Preservation Action	Tunnel #	Project Cost	Agency Oversight Cost	Annual Change in Cost	PV of LCC	Remaining Life due to PA	ADT (x 1000)	Annualized Life Cycle Cost	Annual Cost per Daily Vehicle	CE Score
Ventilation upgrade to meet NFPA 502	1	\$5,700,000	\$570,000	\$(152,500)	\$3,614,495	25	40	\$207,573	\$5.19	1.9
Install new LED lights	1	\$3,400,000	\$136,000	\$(71,000)	\$2,479,699	20	40	\$166,675	\$4.17	2.4
CO System – Repair to operating condition.	2	\$32,000	\$3,200	\$0	\$35,200	20	100	\$2,366	\$0.02	100.0
Repair active leak in ceiling	4	\$10,000	\$1,000	\$0	\$11,000	20	19	\$739	\$0.04	100.0
Remove existing concrete tunnel ceiling	6	\$8,000,000	\$800,000	\$(20,000)	\$8,285,405	50	75	\$56,954	\$0.76	2.3
Install flood gates	6	\$8,000,000	\$320,000	\$0	\$8,320,000	100	75	\$263,300	\$3.51	2.8

#### Risk-Based Urgency Score



#### **Determination of Risk-Based Urgency Score**

- Subjective, by AAMT
- Takes into consideration age, remaining life, condition, risk of unplanned events, and PA upgrades needed for code compliance

Assign a Risk-Based Urgency Rating of 1 to 10.

#### Risk-Based Urgency Score

Preservation Action	Tunnel #	Remaining Life	Theoretical Service Life	% Life Expended	Condition (1 to 4)	Regulatory Compliance Issue? (Y/N)	Risk of Unplanned Event (1 to 3)	RBU Rating (1 to 10)	RBU Score
Ventilation upgrade to meet NFPA 502	1	1	25	96	2	Y	3	8	
Install new LED lights	1	5	20	75	3	Y	1	3	
CO System –Repair to operating condition.	2	2	20	90	4	Y	1	7	
Repair active leak in ceiling	4	5	50	90	3	Ν	1	7	
Remove existing concrete tunnel ceiling	6	0	50	100	3	Ν	1	10	
Install flood gates	6	N/A	100	N/A	N/A	N	3	6	

Assigning RBU Ratings	_	
Risk Factors	Urgency	<b>RBU Rating</b>
At least one area suggests the need for immediate action.	Extreme	10
Multiple areas of consideration are of concern or one area of concern is		9
highly probable and would have significant impact on the LOS	High	8
Thighly probable and would have significant impact on the LOS.		7
		6
At least one area of consideration is of concern.	Medium	5
		4
		3
No areas of consideration are considered critical.	Low	2
		1
No indication of urgency.	Non-Existent	0

#### Risk-Based Urgency Score

Preservation Action	Tunnel #	Remaining Life	Theoretical Service Life	% Life Expended	Condition (1 to 4)	Regulatory Compliance Issue? (Y/N)	Risk of Unplanned Event (1 to 3)	RBU Rating (1 to 10)	RBU Score
Ventilation upgrade to meet NFPA 502	1	1	25	96	2	Y	3	8	80
Install new LED lights	1	5	20	75	3	Y	1	3	30
CO System –Repair to operating condition.	2	2	20	90	4	Y	1	7	70
Repair active leak in ceiling	4	5	50	90	3	Ν	1	7	70
Remove existing concrete tunnel ceiling	6	0	50	100	3	Ν	1	10	100
Install flood gates	6	N/A	100	N/A	N/A	Ν	3	6	60

#### Measure of Effectiveness Score



#### Measure of Effectiveness Score

Preservation Action	Tunnel #	LOS Score	Cost Effectiveness Score	Risk-Based Urgency Score	Measure of Effectiveness Score
		35%	20%	45%	100%
Ventilation upgrade to meet NFPA 502	1	66.0	1.9	80	59.5
Install new LED lights	1	78.0	2.4	30	41.3
CO System –Repair to operating condition.	2	63.2	100.0	70	73.6
Repair active leak in ceiling	4	89.0	100.0	70	82.7
Remove existing concrete tunnel ceiling	6	85.4	2.3	100	75.4
Install flood gates	6	66.0	2.8	60	50.7



#### **Factors Affecting Final Agency-Preferred Prioritization:**

- Owners may choose "low hanging fruit" as top priority
- Group PA's in one tunnel or regionally to minimize disruptions
- Group PA's to be performed in one contract (i.e. mechanical) at multiple tunnels
- Internal staffing resources availability
- Plan PA in accordance with Capital Plan Budgets

#### Planning – Final Prioritization

Preservation Action	Tunnel #	LOS Score	Cost Effectivenes s Score	Urgency Score	Measure of Effectiveness Score	Calculated Priority	User Defined Priority
		35%	20%	45%	100%		
Ventilation upgrade to meet NFPA 502	1	66.0	1.9	80	59.5		
Install new LED lights	1	78.0	2.4	30	41.3		
CO System –Repair to operating condition.	2	63.2	100.0	70	73.6		
Repair active leak in ceiling	4	89.0	100.0	70	82.7		
Remove existing concrete tunnel ceiling	6	85.4	2.3	100	75.4		
Install flood gates	6	66.0	2.8	60	50.7		

#### Planning – Final Prioritization

Preservation Action	Tunnel #	LOS Score	Cost Effectivenes s Score	Urgency Score	Measure of Effectiveness Score	Calculated Priority	User Defined Priority
		35%	20%	45%	100%		
Ventilation upgrade to meet NFPA 502	1	66.0	1.9	80	59.5	4	
Install new LED lights	1	78.0	2.4	30	41.3	6	
CO System –Repair to operating condition.	2	63.2	100.0	70	73.6	3	
Repair active leak in ceiling	4	89.0	100.0	70	82.7	1	
Remove existing concrete tunnel ceiling	6	85.4	2.3	100	75.4	2	
Install flood gates	6	66.0	2.8	60	50.7	5	

#### Planning – Final Prioritization

Preservation Action	Tunnel #	LOS Score	Cost Effectivenes s Score	Urgency Score	Measure of Effectiveness Score	Calculated Priority	User Defined Priority
		35%	20%	45%	100%		
Ventilation upgrade to meet NFPA 502	1	66.0	1.9	80	59.5	4	3
Install new LED lights	1	78.0	2.4	30	41.3	6	5
CO System –Repair to operating condition.	2	63.2	100.0	70	73.6	3	2
Repair active leak in ceiling	4	89.0	100.0	70	82.7	1	1
Remove existing concrete tunnel ceiling	6	85.4	2.3	100	75.4	2	4
Install flood gates	6	66.0	2.8	60	50.7	5	6

#### **Funding Evaluations**



#### Top Down Funding

Preservation Action	Tunnel #	User Defined Priority	Total Project Cost (\$)	Cumulative Annual Cost (\$)	Year Implemented		Budget for
Repair active leak in ceiling	4	1	11,000	11,000	1		Year 1=\$7 M
CO System – Repair to Operating Condition	2	2	35,200	46,200	1		Total: \$6,316,200
Ventilation upgrade to meet NFPA	1	3	6,270,000	6,316,200	1		
Remove existing concrete tunnel ceiling	6	4	1,980,000	1,980,000	2		
Install New LED Lights	1	5	3,740,000	3,740,000	3		
Install flood gates	6	6	8,320,000	12,060,000	3	]	

#### Bottom Up Funding

Preservation Action	Tunnel #	User Defined Priority	Total Project Cost (\$)	Cumulative Annual Cost (\$)	Year Implemented	
Repair active leak in ceiling	4	1	11,000	11,000	1	
CO System – Repair to Operating Condition	2	2	35,200	46,200	1	Total: \$6,316,200
Ventilation upgrade to meet NFPA	1	3	6,270,000	6,316,200	1	
Remove existing concrete tunnel ceiling	6	4	1,980,000	2,039,400	2	Budget required for Year 1=\$6.32 M
Install New LED Lights	1	5	3,740,000	3,967,766	3	
Install flood gates	6	6	8,320,000	12,794,454	3	

### **Communicate Needed Funding for Desired Performance**

Critical to Safety (Safety Rating = 4 or 5)



\$20.8 M

needed to fund

#### **Communicate Needed Funding for Desired Performance**

Assets in Severe Condition (Condition = 3 or 4)

Preservation Action	Tunnel #	Condition	Project Cost (\$)	Priority	Year Implemented	
Repair active leak in ceiling	4	3	11,000	1	1	<u>]</u>
CO System –Repair to operating condition.	2	4	35,200	2	1	Total:
Ventilation upgrade to meet NFPA 502	1	2	6,270,000	3	1	\$5.8 M
Remove existing concrete tunnel ceiling	6	3	1,980,000	4	2	$\mathcal{V}$
Install new LED lights	1	3	3,740,000	5	3	
Install flood gates	6	N/A	8,800,000	6	3	



## **Questions?**

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# **Today's Participants**

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