The Light at the End of the Tunnel

A Comprehensive Life-Cycle Planning Approach for Tunnel Infrastructure

Presenters:

Chad Allen, HNTB

Trevor Pearce, American Roads

Agenda

- Introduction
- Scope of Services
- Asset Classes
- Asset Inventory & Condition
- Cost Treatment Matrices
- Life-Cycle Cost Analyses
- Cost Model Development

Toll Booths

Introduction to the Detroit Windsor Tunnel

- **Overview:** The DWT is a critical bi-national infrastructure link, **5,160 feet** in length, providing a cross-border connection between Detroit, Michigan, and Windsor, Ontario.

- **Design and Construction:** Opened in 1930, the tunnel features **two 11-foot lanes with 12'8" vertical clearance**. The river section is 75 ft deep. Immersed tubes placed in a trench are protected by armor stone to prevent damage from ship traffic and to provide ballast.

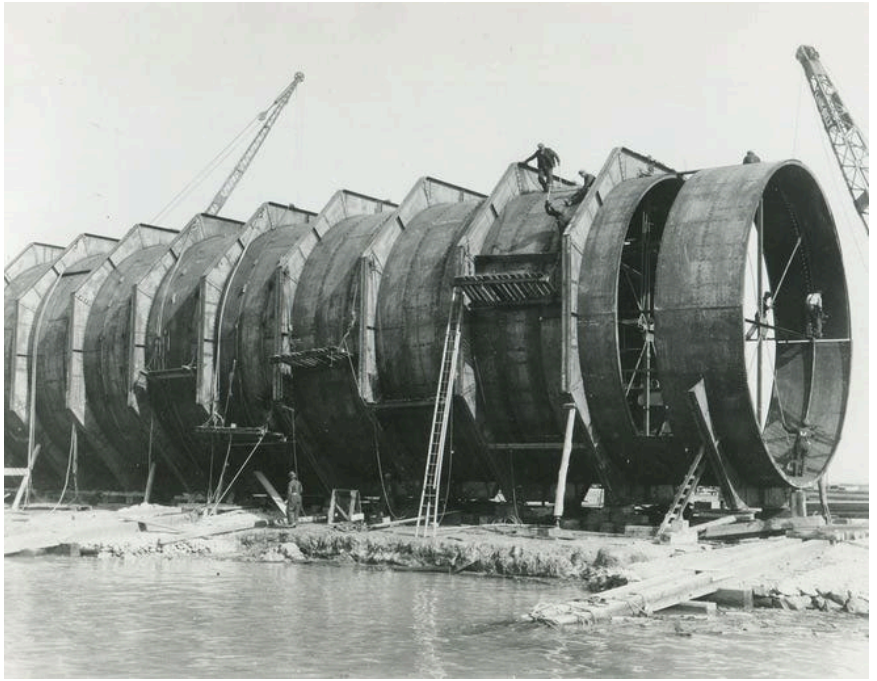
- **Facilities:** Plazas on both sides include toll collection, customs facilities, ventilation systems, and operations offices, with shared emergency services, IT, and customer support.

Introduction to the Detroit Windsor Tunnel

DETROIT WINDSOR TUNNEL

Claim to Fame: Built from 1928 to 1930 - 10 months ahead of schedule

- 3 distinct tunneling techniques
  - ✓ cut and cover for the land section
  - ✓ compressed air shield for the channel approaches
  - ✓ immersed tube for the river sections.
- 65 miles of arc welding - the first major use of arc welding in tunneling history.
- These techniques permitted a shallow tunnel profile which, together with a spiral approach ramp, allowed the connection to Detroit's street system to be located just two blocks from the river.



Detroit News Archives
Subaqueous Tunnel Section

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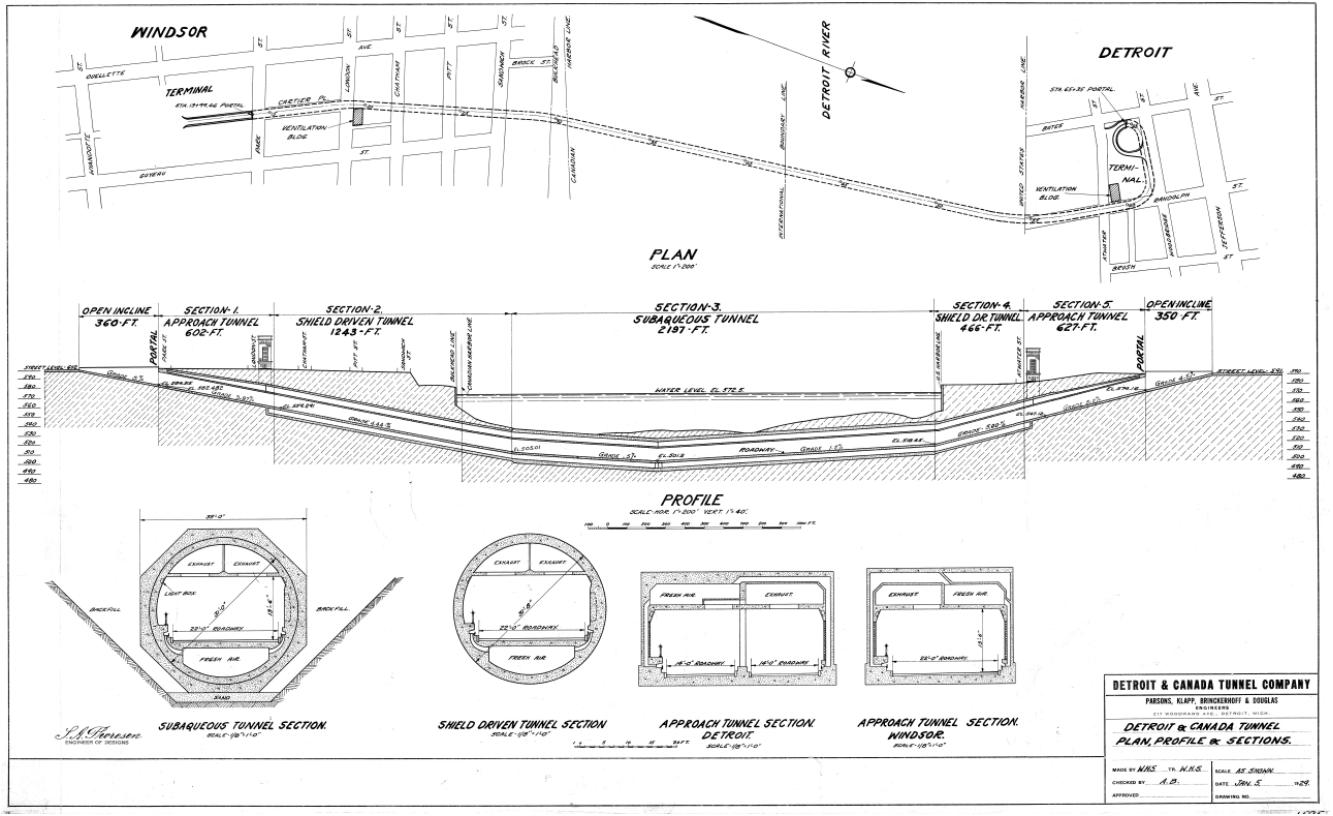
Introduction to the Detroit Windsor Tunnel

DETROIT WINDSOR TUNNEL



S. A. Thoresen
ENGINEER OF DESIGNS

Ingenior S. A. Thoresen

REVISED 2/10/28
SECTION CHANGED FROM SQUARE TO OCTAGONAL.- INTERIOR LINING CHANGED FROM 1'-0" TO 1'-6".- REINFORCEMENT IN LINING CHANGED.-
S.A.T.

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Introduction to the Detroit Windsor Tunnel

DETROIT WINDSOR TUNNEL

Fun Facts

- Ventilation towers rise about 100 feet at each end of the tunnel, on 50-by-90-foot sites. Each tower holds six fresh air fans and six exhaust fans, capable of cycling in a complete change of air every 90 seconds.
- The project pioneered the construction of screeded bed foundation (a technique to ensure proper leveling of poured concrete) for the immersed tube sections.
- Two million granite blocks were used to pave the original roadway, they were removed when the roadway was paved with asphalt in 1977.

Detroit Side – Ventilation Building

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Takeaway #1

Detroit News Archives
Tubes being sunk in Detroit River

Getting to know your asset, how it was made, how it is operated and maintained - helps to inform inspections and guide maintenance & repairs to maintain state-of-good repair.

Scope of Services

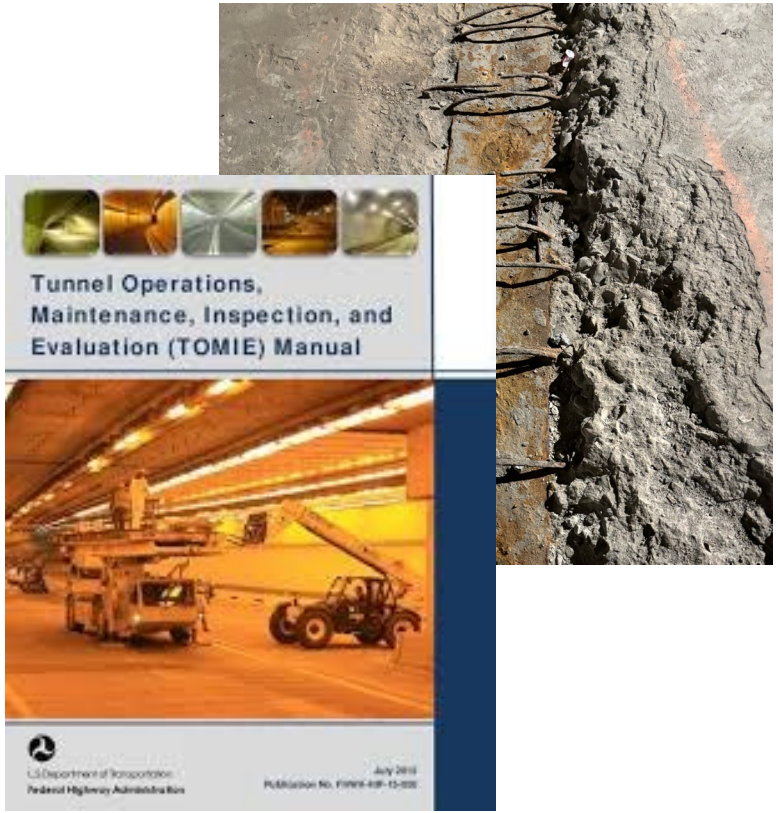
- As a cross-border facility, DWT must demonstrate compliance with both Canadian and U.S. regulatory frameworks
- Review shared services agreement between Detroit & Windsor sides

- **Comprehensive Life Cycle Cost Analysis (LCCA)**
- **Scenario Analyses: 40-year model evaluating capital reinvestment, O&M, and major maintenance. maintaining assets in a State of Good Repair (SOGR)**
- Revenue sensitivity analysis (e.g., GHIB opening impact)

Security Cameras

Scope of Services

- Review and assessment of manuals, procedures, inspection schedules
- Inspect the Detroit Windsor Tunnel and its associated facilities, including all elements: tube, portals, drainage, lighting, ventilations and building, plaza, fire protection, and more.
- Provide a database of asset observations and recommendations based upon our condition assessment
- Assessments were primarily visual, and used handheld tools/methods



Asset Classes

- **Buildings (Architectural)**
  - Roofs, facades, windows, stairs, toll booths, customs booths, interior walls, overhead walkways, roof drains
- **Mechanical**
  - HVAC, blowers, exhaust fans, louvers, roof exhaust fans, pumps, sumps, fresh air supply ducts, exhaust ducts, hot water heater/boiler, etc
- **Electrical**
  - Iso transformers, switchgears, conduit, lighting, junction boxes, power panels, fire alarm panels, power split equipment, motor control center, SCADA, breakers, etc

Asset Classes

DETROIT WINDSOR TUNNEL

- **Tunnel Structures**
  - Subaqueous/ shield driven/ approach
  - Flume rooms, floor beams, aliva drain, ceiling, ducts (fresh air and exhaust), walls, catwalk, curb, tiles
- **Pavement**
  - Parking area, Plaza area, main line pavement, asphalt, concrete, curb, sidewalk
- **Traffic & Security Systems**
  - Security cameras, lane signals & fixtures, traffic signals, traffic signs, rolling gates, toll gates, VMS

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Asset Inventory and Condition

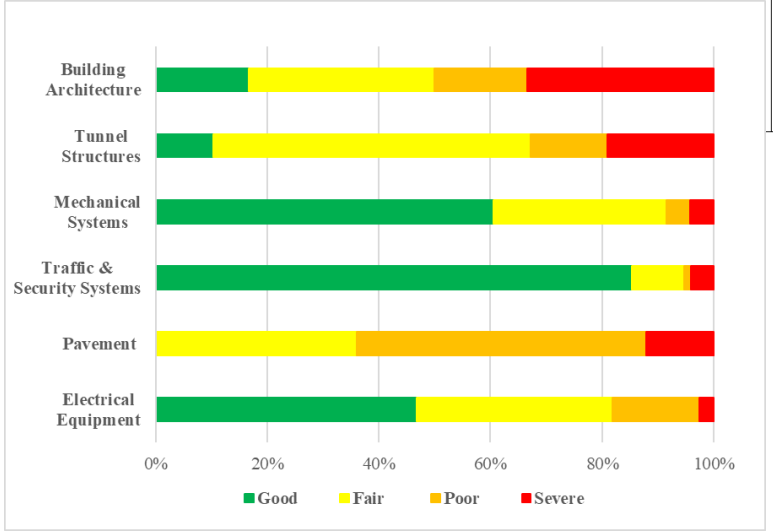
DETROIT WINDSOR TUNNEL

Tabulated asset inspection data, creating a comprehensive inventory that provided a solid foundation for planning and budgeting maintenance and capital expenditures.

Detroit Asset Categories	Good	Fair	Poor	Severe	Total Number of Elements
Building Architecture	4	8	4	8	24
Tunnel Structures	6	33	8	11	58
Mechanical Systems	72	37	5	5	119
Electrical Equipment	72	54	24	4	154
Traffic & Security Systems	128	14	2	6	150
Pavement		9	13	3	25
Total	**282**	**155**	**56**	**37**	**530**

Tunnel Structures	Good	Fair	Poor	Severe	Total Number of Elements
Land Section		5	3	1	9
Flume Room		1	1	2	4
Landside Exhaust Duct		5			5
Landside Supply Duct		5			5
River Exhaust Duct	4	2			6
River Supply Duct		8	2		10
Shield Driven Section	1	3	2	4	10
Subaqueous Section	1	4		4	9
Total	**6**	**33**	**8**	**11**	**58**

Defect	Condition State 1 (CS1)	Condition State 2 (CS2)	Condition State 3 (CS3)	Condition State 4 (CS4)
Element-specific defect as defined in SNTI.	*Good condition*- no notable distress.	*Fair condition*- isolated breakdowns or deterioration.	*Poor condition*- widespread deterioration or breakdowns without reducing load capacity.	*Severe condition*- warrants a structural review to determine the impact on strength or serviceability of the element or tunnel, OR a structural review has been completed and the defects impact strength and serviceability of the element or tunnel.



Note: *Data shown represents the assets owned and maintained by American Roads (Detroit side)*

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Cost Treatment Matrices

- Includes data and information necessary to develop a cost model that details the timing and cost of required intervention activities to maintain safe and reliable operations,
  - Catalog of activities established to provide an overall investment framework. [Inspection/Evaluation/Monitoring Activities and Studies, Maintenance Activities (Reactive & Proactive), Rehabilitation, and Replacement]
  - Cost estimating – RSMeans, DOT Statewide unit averages, known subcontract pricing, and crew builds (with SME insights)

Cost Treatment Matrices

Activity / Treatment	Applies To	Estimated Cost (2024)	Unit Quantity	Frequency
Investigation / Evaluation / Monitoring				
Land & River Section Fresh Air Supply and Exhaust Ducts: Conduct volume flow measurements during test run of each fan. Three-person crew ($708.75/hour) for 4 days, special equipment anemometers and data storage - (equipment rental $1000/day), turn each fan on for 15 minutes, achieve steady state, measure air flow in tunnel. $26,680 cost is assumed to be split between DWT and WDBL.	Entire Tunnel	$13,340	Per Activity	5 years
General Maintenance				
Fan Maintenance: Conduct cleaning, visual inspection, conduct test runs with measurement of vibration, check motors, measure motor resistance, open and clean housing, lubricate bearings. Motors should be checked for excess temperatures and unusual vibrations. Includes fan belt replacement.	Blowers and Exhaust Fans	$2420	Each	5 years
Fan Bearing Replacement: Replace fan bearings. Includes testing and cost for bearings.	Blower and Exhaust Fans	$3,260	Each	10 years
Roof Exhaust Fan Maintenance: Check motors for noise, which is indication that they will need to be replaced. Blow out and clean housing. Motors should be checked for excess temperatures and unusual vibrations. Service belts twice per year.	Roof Exhaust Fans	$475	Per Activity	6 months
Intake Louver Maintenance: clean and remove any obstructions. Perform necessary maintenance to ensure proper operation.	Intake Louvers	$4,050	Each	3 years

Detroit River Exhaust Fan 1

Cost Treatment Matrices

DETROIT WINDSOR TUNNEL

Activity / Treatment	Applies To	Estimated Cost (2024)	Unit Quantity	Frequency
Fan Variable Frequency Drive Replacement	Fan variable Frequency Drives	$87k - (3) 200 hp $75k - (3) 100 hp $10k - (6) 10 hp	Each	Replace over 8 years, then every 15 years
Transformer Replacement	Transformers	$15,000	Each	40 years
Switchboard Replacement	Switchboards	$500,000	Each	40 years
Replace Switchgears when breakers are no longer available.	Switchgears	$2,000,000	Each	40 years
Replace Universal Power Supply (UPS) batteries	Universal Power Supply (UPS)	$3,000	Each	2 years
Lighting System Upgrades – Service Tunnel: Assumes 20 new fixtures ($300 each), to replace existing fixtures and associated conduit AND/OR install fixtures and conduit in areas with poor lighting. This is in addition to the conduit replacement treatment. Includes 500 ft of conduit.	Lighting System Fixtures Lighting System Conduit	$6,00 $27,700	Per Activity	7 years (fixtures) 75 years (conduit)

Junction Boxes

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Cost Treatment Matrices

DETROIT WINDSOR TUNNEL

Activity / Treatment	Applies To	Estimated Cost (2024)	Unit Quantity	Frequency
Investigation / Evaluation / Monitoring				
Land & River Section Fresh Air Supply and Exhaust Ducts: Conduct volume flow measurements during test run of each fan. 3-person crew ($708.75/hour) for 4 days, special equipment anemometers and data storage - (equipment rental $1000/day), turn each fan on for 15 minutes, achieve steady state, measure air flow in tunnel. $26,680 cost is assumed to be split between DWT and WDBL.	Entire Tunnel	$13,340	Per Activity	5 years
General Maintenance				
Pump Maintenance: Check motors, measure resistances, and check cables. When performing maintenance checks, the motors should be checked for excess temperatures and unusual vibrations. Typically, the pump is controlled by an electrode or float switches in the sump. Examine the check valves and discharge piping.	Mechanical Pumps	$3,780	Each	5 years
HVAC, AC, Water Heaters, and Boiler Maintenance: Thorough cleaning of coils, drains, and elements. Inspecting connections, motor operations, and thermostat functionality.	HVAC, AC Units, Water Heaters, and Boilers	$26,625	Contract	Annual
Supply & Exhaust Drainage Pipe Maintenance: Inspect for leaks and excessive corrosion.	Supply & Exhaust Drainage Pipes	$14,175	Per Activity	Annual
Roof Maintenance: Ensure that drains are free from obstructions and are not clogged.	Roof Top Storm Drains	$473	Each	6 months
Rehabilitation				
Repair broken or damage intake louvers and perform the necessary repairs to ensure proper function for the next 20 years.	Intake Louvers	$50,000	Each	50 years

HVAC Unit No.4

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Takeaway #2

Don’t just do a desktop analysis. Get out in the field. See how things are made. (Takeaway 1) and observe and communicate with the teams that maintain and operate the assets. This opens lines of communication, builds relationships, and provides insights that can be used to;

- Schedule the right time for the right treatment
- Provide reasonable cost treatment matrices and more accurate LCCAs,
- Increases trust, credibility, and overall confidence

Main Centrifugal Pump

Life-Cycle Cost Analyses

- Maintain the **tunnel in a safe, operable condition.**
- Extend the useful life of the tunnel to at least **125 years** . [2055]
- Conduct LCCA for a 41-year period through 2065.
- **Scenario 1:** Achieve / maintain a "CS1" condition ("Good") for all DWT assets by 2065
- **Scenario 2:** Maintain a State of Good Repair: All critical assets are in a safe, reliable, and sustainable condition - will be in CS1 or CS2 condition by the end of 2065.

Electrical Equipment

Life-Cycle Cost Analyses

Considerations

- Analysis based on current traffic and revenue patterns.
- Potential revenue impacts from the planned 2025 opening of the Gordie Howe International Bridge (GHIB) – analyses assumed a 10% reduction in traffic was considered.
- Large capital project – Land Section Tunnel Ceiling Replacement forecasted in the outyears.

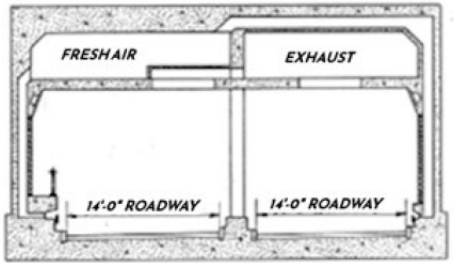
Detroit News
Gordie Howe International Bridge

Life-Cycle Cost Analyses

Land Section Tunnel Ceiling Replacement

Hanger Plate

A project to replace the nearly 4,000-foot-lon ceiling in the combined subaqueous and shiel driven sections of the tunnel was started in 2017 and completed in 2020. **Cost $23M**



LAND SECTION DETROIT

The ceilings in the subaqueous and shield-driven sections were not structural, however the Land Section ceiling provides structural support to the tunnel complicating repairs **= Increased replacement cost**

The condition of the Land Section steel structural beams encased in the ceiling concrete was uncertain.

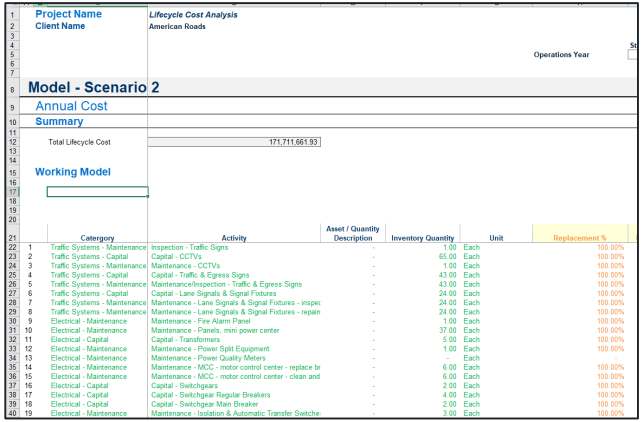
Land Section Tunnel Ceiling Replacement

- Because of the uncertain scope of beam replacement, a range of potential costs were evaluated. Replacement costs varied from $75M to $150M.
- Our recommended next steps included;
  - ✓ Performing reactive maintenance
  - ✓ Conducting a detailed inspection
  - ✓ Conduct destructive testing to evaluate integrity of steel beams
- Land Section Ceiling Replacement represented a large, variable future capital cost.

Exposed Beams Under Evaluation

Cost Model Development

- Two cost models were developed, one for the Canadian Operator and one for US Operator.
- Activities, Quantities, Work Curves, and Unit cost estimates were derived from the Cost Treatment Matrices.
- Developed a set of “rules” to guide adjustments to the timing of the treatments based on each scenario.
- These adjustments replaced or rehabilitated assets based on the predicted condition state and the percentage of remaining service life.



Project Name
Client Name

Lifecycle Cost Analysis
American Roads

Operations Year

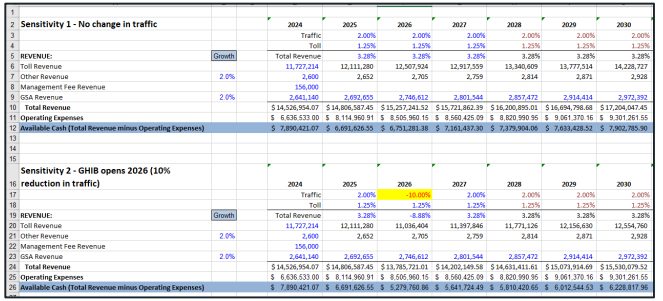
Model - Scenario 2

Annual Cost
Summary

Total Lifecycle Cost: 171,711,661.93

Working Model

	Catergory	Activity	Asset / Quantity Description	Inventory Quantity	Unit	Replacement %
1	Traffic Systems - Maintenance	Inspection - Traffic Signs	-	1.00	Each	100.00%
2	Traffic Systems - Capital	Capital - CCTVs	-	65.00	Each	100.00%
3	Traffic Systems - Maintenance	Maintenance - CCTVs	-	1.00	Each	100.00%
4	Traffic Systems - Capital	Capital - Traffic & Egress Signs	-	43.00	Each	100.00%
5	Traffic Systems - Maintenance	Maintenance/Inspection - Traffic & Egress Signs	-	43.00	Each	100.00%
6	Traffic Systems - Capital	Capital - Lane Signals & Signal Fixtures	-	24.00	Each	100.00%
7	Traffic Systems - Maintenance	Maintenance - Lane Signals & Signal Fixtures - inspec	-	24.00	Each	100.00%
8	Traffic Systems - Maintenance	Maintenance - Lane Signals & Signal Fixtures - repain	-	24.00	Each	100.00%
9	Electrical - Maintenance	Maintenance - Fire Alarm Panel	-	1.00	Each	100.00%
10	Electrical - Maintenance	Maintenance - Panels, mini power center	-	37.00	Each	100.00%
11	Electrical - Capital	Capital - Transformers	-	5.00	Each	100.00%
12	Electrical - Maintenance	Maintenance - Power Split Equipment	-	1.00	Each	100.00%
13	Electrical - Maintenance	Maintenance - Power Quality Meters	-	-	Each	-
14	Electrical - Maintenance	Maintenance - MCC - motor control center - replace br	-	6.00	Each	100.00%
15	Electrical - Maintenance	Maintenance - MCC - motor control center - clean and	-	6.00	Each	100.00%
16	Electrical - Capital	Capital - Switchgears	-	2.00	Each	100.00%
17	Electrical - Capital	Capital - Switchgear Regular Breakers	-	4.00	Each	100.00%
18	Electrical - Capital	Capital - Switchgear Main Breaker	-	2.00	Each	100.00%
19	Electrical - Maintenance	Maintenance - Isolation & Automatic Transfer Switche	-	3.00	Each	100.00%



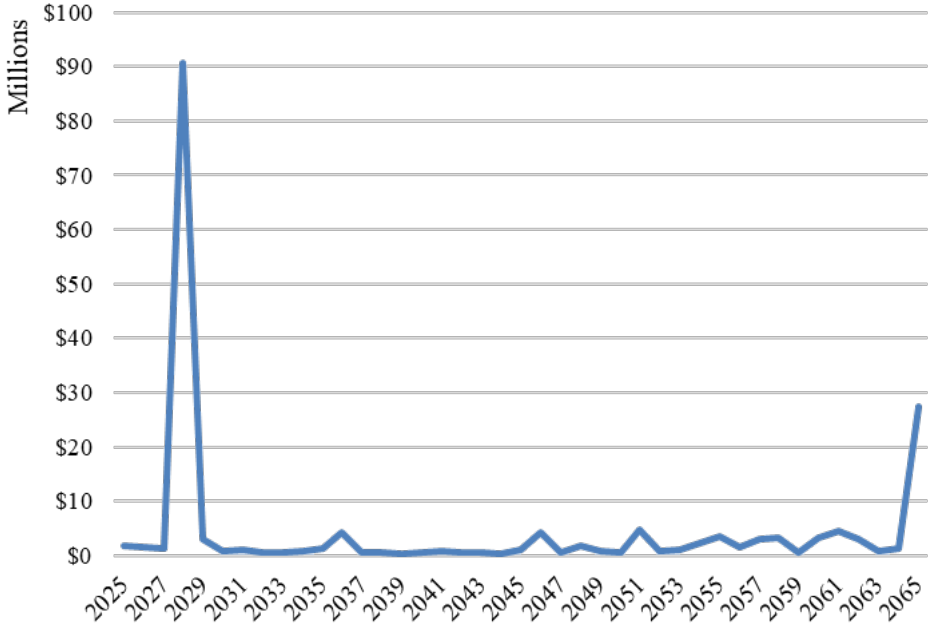
Sensitivity 1 - No change in traffic

		2024	2025	2026	2027	2028	2029	2030
		Traffic	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%
		Toll	1.25%	1.25%	1.25%	1.25%	1.25%	1.25%
REVENUE:	Growth	Total Revenue	3.28%	3.28%	3.28%	3.28%	3.28%	3.28%
Toll Revenue		11,727,214	12,111,280	12,507,924	12,917,559	13,340,609	13,777,514	14,228,727
Other Revenue	2.0%	2,600	2,652	2,705	2,759	2,814	2,871	2,928
Management Fee Revenue		156,000						
GSA Revenue	2.0%	2,641,140	2,692,655	2,746,612	2,801,544	2,857,472	2,914,414	2,972,392
Total Revenue		$ 14,526,954.07	$ 14,806,587.45	$ 15,257,241.52	$ 15,721,862.39	$ 16,200,895.01	$ 16,694,798.68	$ 17,204,047.45
Operating Expenses		$ 6,636,533.00	$ 8,114,960.91	$ 8,505,960.15	$ 8,560,425.09	$ 8,820,990.95	$ 9,061,370.16	$ 9,301,261.55
Available Cash (Total Revenue minus Operating Expenses)		$ 7,890,421.07	$ 6,691,626.55	$ 6,751,281.38	$ 7,161,437.30	$ 7,379,904.06	$ 7,633,428.52	$ 7,902,785.90

Sensitivity 2 - GHIB opens 2026 (10% reduction in traffic)

		2024	2025	2026	2027	2028	2029	2030
		Traffic	2.00%	-10.00%	2.00%	2.00%	2.00%	2.00%
		Toll	1.25%	1.25%	1.25%	1.25%	1.25%	1.25%
REVENUE:	Growth	Total Revenue	3.28%	-8.88%	3.28%	3.28%	3.28%	3.28%
Toll Revenue		11,727,214	12,111,280	11,036,404	11,397,846	11,771,126	12,156,630	12,554,760
Other Revenue	2.0%	2,600	2,652	2,705	2,759	2,814	2,871	2,928
Management Fee Revenue		156,000						
GSA Revenue	2.0%	2,641,140	2,692,655	2,746,612	2,801,544	2,857,472	2,914,414	2,972,392
Total Revenue		$ 14,526,954.07	$ 14,806,587.45	$ 13,785,721.01	$ 14,202,149.58	$ 14,631,411.61	$ 15,073,914.69	$ 15,530,079.52
Operating Expenses		$ 6,636,533.00	$ 8,114,960.91	$ 8,505,960.15	$ 8,560,425.09	$ 8,820,990.95	$ 9,061,370.16	$ 9,301,261.55
Available Cash (Total Revenue minus Operating Expenses)		$ 7,890,421.07	$ 6,691,626.55	$ 5,279,760.86	$ 5,641,724.49	$ 5,810,420.66	$ 6,012,544.53	$ 6,228,817.96

Cost Model Development – Sample Outputs



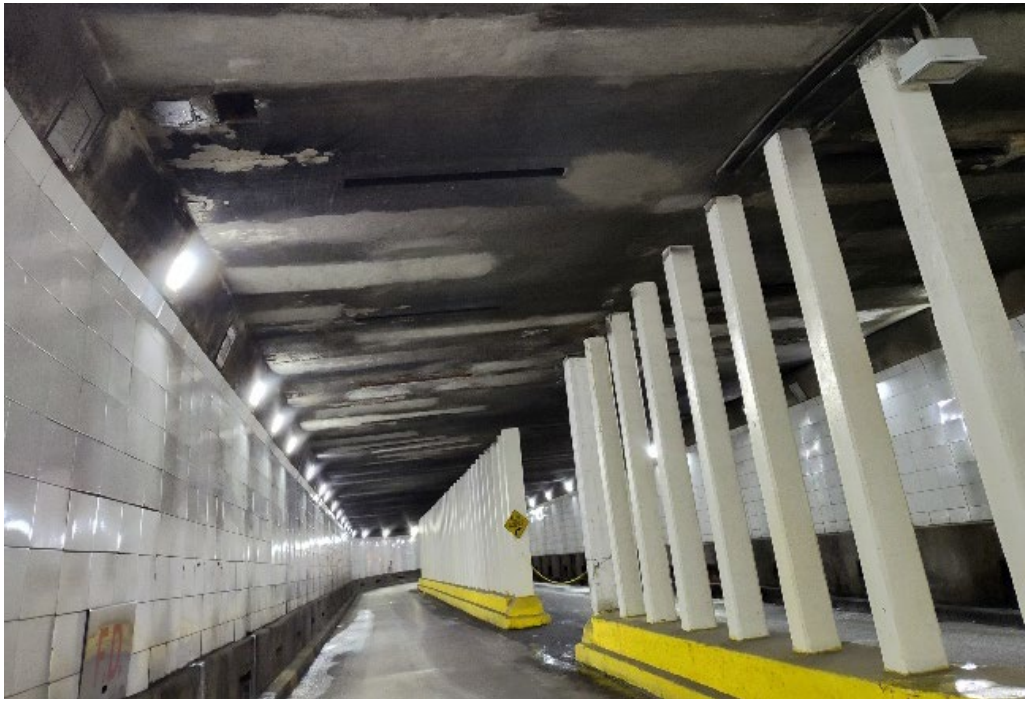
Annual Total Lifecycle Costs

Category	41-year Totals
Traffic Systems - Maintenance	$3,477,308
Traffic Systems - Capital	$3,700,158
Electrical - Maintenance	$2,928,257
Electrical - Capital	$25,892,972
Pavement - Maintenance	$3,854,662
Pavement - Capital	$14,600,607
Building Architecture Maintenance	$1,008,583
Building Architecture - Capital	$14,576,008
Structural - Maintenance	$1,659,077
Structural - Capital	$101,999,705
Mechanical - Maintenance	$8,280,061
Mechanical - Capital	$5,301,508
Maintenance Subtotal	**$21,207,948**
Capital Subtotal	**$166,070,958**
Grand Total	**$187,278,906**

Total Lifecycle Costs thru 2065

Takeaway #3

Defining the outcomes ahead of time helped to minimize the number of investment scenarios and kept the lifecycle cost analyses focused.



Detroit Land Section

DETROIT WINDSOR TUNNEL

Thank you

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