Minnesota DOT's Approach to Developing Bridge Cost Models Based on Asset Condition Data

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TRB Asset Management Conference
Rapid Fire Session

We all have a stake in A to B

Background and Purpose

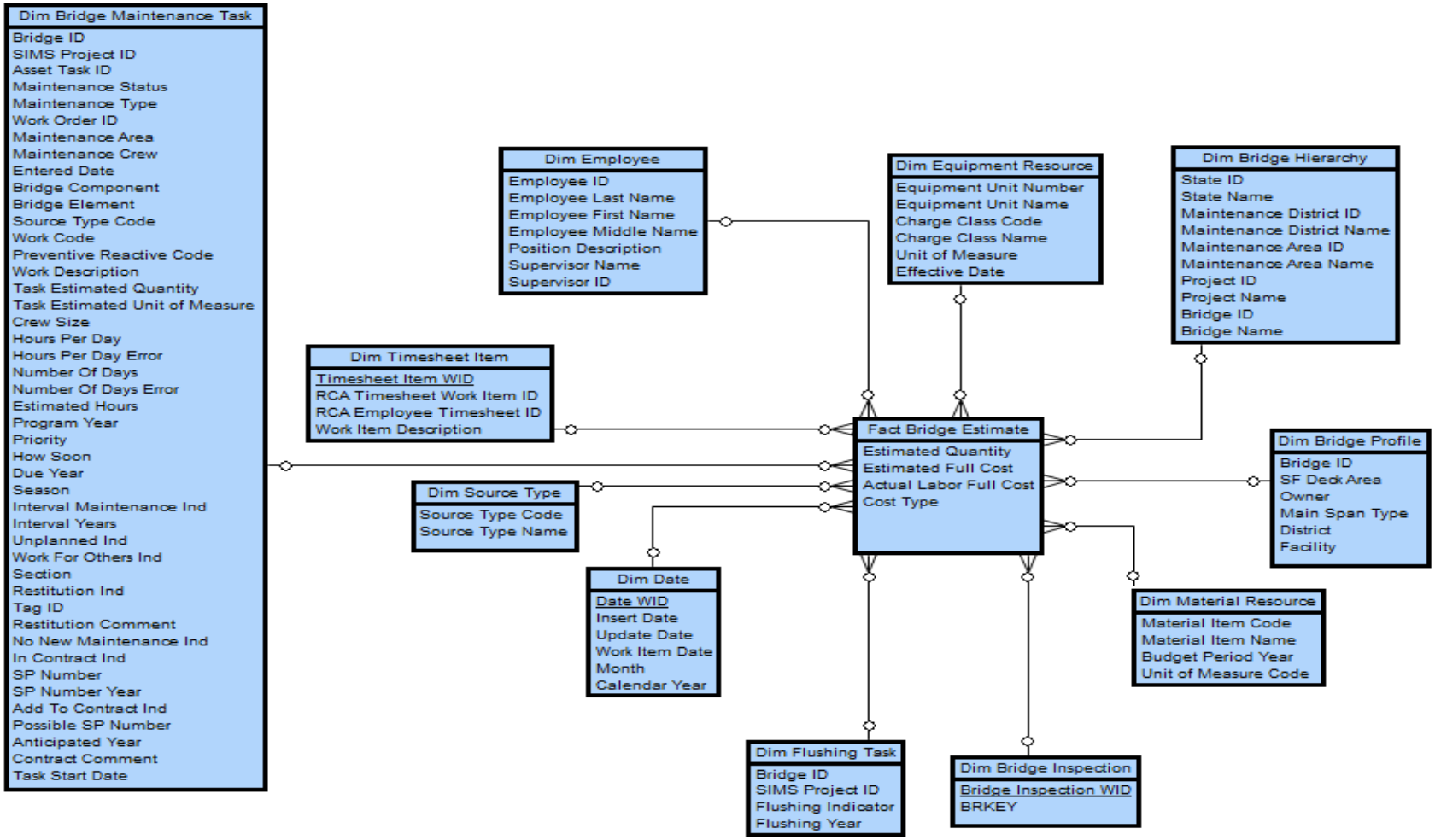
- **MnDOT's Wildly Important Goal**
  - **Enhance Financial Effectiveness**
    - Earn or reinforce stakeholder trust and confidence by demonstrating effective and efficient stewardship of public resources

- Asset Management Battle
  - **What is the Life-Cycle Cost of Our Major Assets?**
    - Balance system performance and condition
    - Collect and maintain accurate data
    - Risk management analysis
    - Performance based planning
    - Better tradeoff investment decisions

Bridge Data

- Multiple Sources
  - Pontis/BrM – Bridge Inventory and Inspection Data
  - SIMS – Bridge Maintenance Data
  - RCA – Labor, Equipment and Materials (LEM)
  - WOM – Work Order Information, Materials and Other Expenses
  - SWIFT – Project Full Cost and Expenditure Data
  - SEMA4 – Employee/Supervisor Data
- Proportion LEM to Project ID and Source Code
  - where:
    - Project ID is associated with the Bridge Number, and
    - Source Code is associated with the maintenance activity.
- Combine the Data
  - Business Intelligence (BI) Reporting Tool

BI Bridge Maintenance Data Model



Resource Demand Model

- Identify bridge maintenance in terms of:
  - **Component**
    - Deck, Superstructure, Substructure
  - **Work Categories**
    - Flushing, Sealing, Joint Maintenance, Deck Repair, etc.
  - **Bridge Condition**
    - Good, Satisfactory, Fair, Poor
  - **Cost**
    - Dollars Per Square Foot of Deck Area

Resource Demand Model

Example output report from BI (Deck)

Deck

Preventive Reactive	Work Category	NBI	Labor Hours	Labor Hours / SF Deck Area	Estimated Labor Full Cost	Estimated Labor Full Cost / SF Deck Area	Estimated Equipment Full Cost	Estimated Equipment Full Cost / SF Deck Area	Estimated Material Full Cost	Estimated Material Full Cost / SF Deck Area	Estimated Work Order Material Full Cost	Estimated Work Order Material Full Cost / SF Deck Area	Estimated Work Order Other Full Cost	Estimated Work Order Other Full Cost / SF Deck Area	**SF Deck Area**	**Estimated Full Cost**	**Estimated Full Cost / SF Deck Area**	# Bridges Maintained
Preventive	Flushing	Good (NBI >= 7)	9,749.09	0.0008	$450,036	$0.0364	$247,777	$0.0200	$5,699	$0.0005					**12,373,218**	**$703,512**	**$0.0569**	851
		Satisfactory (NBI = 6)	2,996.40	0.0007	$138,098	$0.0318	$81,910	$0.0188	$794	$0.0002					**4,346,938**	**$220,802**	**$0.0508**	233
		Fair (NBI = 5)	984.35	0.0007	$41,895	$0.0317	$20,891	$0.0158	$437	$0.0003					**1,322,049**	**$63,223**	**$0.0478**	48
		Poor (NBI <= 4)	86.25	0.0010	$3,846	$0.0432	$2,749	$0.0308							**89,138**	**$6,595**	**$0.0740**	12
	Joint Maintenance	Good (NBI >= 7)	6,187.84	0.0013	$288,866	$0.0601	$124,010	$0.0258	$24,688	$0.0051	$16,350	$0.0263	$12,532	$0.0340	**5,495,953**	**$466,446**	**$0.0263**	417
		Satisfactory (NBI = 6)	3,554.63	0.0013	$175,431	$0.0636	$56,313	$0.0204	$10,837	$0.0039	$24,697	$0.0480	$2,675	$0.0055	**3,288,206**	**$269,953**	**$0.0480**	140
		Fair (NBI = 5)	161.33	0.0007	$7,523	$0.0328	$2,452	$0.0107	$60	$0.0003	$272	$0.0113			**253,604**	**$10,307**	**$0.0113**	18
	Sealing	Good (NBI >= 7)	7,607.75	0.0025	$340,600	$0.1126	$100,302	$0.0332	$160,304	$0.0530	$14,302	$0.0407	$3,075	$0.0010	**3,422,743**	**$618,583**	**$0.0407**	246
		Satisfactory (NBI = 6)	3,792.75	0.0022	$174,839	$0.1012	$54,019	$0.0313	$74,001	$0.0428	$27,469	$0.0335	$2,369	$0.0261	**2,577,112**	**$332,698**	**$0.0335**	73
		Fair (NBI = 5)	295.00	0.0012	$14,066	$0.0592	$3,730	$0.0157	$7,456	$0.0314	$2,916	$0.1217			**261,746**	**$28,168**	**$0.1217**	17
		Poor (NBI <= 4)	64.00	0.0116	$3,197	$0.5810	$1,373	$0.2496	$54	$0.0099					**5,502**	**$4,624**	**$0.8404**	2
Reactive	Approach, Curb, Walk, Rail Maintenance	Good (NBI >= 7)	9,414.50	0.0038	$437,700	$0.1768	$154,152	$0.0623	$70,058	$0.0283	$20,560	$0.1012	$19,671	$0.0221	**2,768,282**	**$702,141**	**$0.1012**	170
		Satisfactory (NBI = 6)	2,569.00	0.0013	$124,743	$0.0630	$32,047	$0.0162	$10,818	$0.0055	$4,128	$0.0359	$1,276	$0.0024	**2,452,717**	**$173,012**	**$0.0359**	59
		Fair (NBI = 5)	1,209.50	0.0023	$56,994	$0.1107	$20,031	$0.0389	$6,421	$0.0125			$176	$0.0033	**567,390**	**$83,622**	**$0.0033**	18
		Unknown	28.50	0.0270	$1,480	$1.4012	$497	$0.4703							**1,056**	**$1,976**	**$1.8715**	1
	Deck Repair	Good (NBI >= 7)	3,334.00	0.0019	$161,144	$0.0900	$49,709	$0.0278	$13,820	$0.0077	$2,842	$0.0144	$4	$0.0003	**2,001,289**	**$227,519**	**$0.0144**	117
		Satisfactory (NBI = 6)	4,086.00	0.0014	$202,267	$0.0716	$54,999	$0.0195	$13,267	$0.0047	$13,897	$0.0137	$30	$0.0005	**3,870,125**	**$284,460**	**$0.0137**	106
		Fair (NBI = 5)	1,566.75	0.0021	$77,508	$0.1039	$17,186	$0.0230	$6,862	$0.0092	$3,523	$0.0294			**865,393**	**$105,080**	**$0.0294**	31
		Poor (NBI <= 4)	3,175.50	0.0748	$161,883	$3.8145	$21,187	$0.4992	$2,425	$0.0571			$63,726	$0.3720	**47,941**	**$249,221**	**$0.3720**	7
	Miscellaneous Deck Maintenance	Good (NBI >= 7)	3,042.86	0.0008	$148,348	$0.0403	$61,874	$0.0168	$15,513	$0.0042	$625	$0.0014	$5	$0.0008	**4,130,322**	**$226,365**	**$0.0014**	205
		Satisfactory (NBI = 6)	1,300.09	0.0006	$65,235	$0.0324	$25,862	$0.0128	$2,162	$0.0011	$970	$0.0017			**2,583,451**	**$94,229**	**$0.0017**	98
		Fair (NBI = 5)	122.25	0.0009	$6,000	$0.0433	$3,601	$0.0260	$2	$0.0000	$18	$0.0003			**193,847**	**$9,620**	**$0.0003**	19
		Poor (NBI <= 4)	20.50	0.0001	$935	$0.0048	$472	$0.0024			$14	$0.0001			**388,794**	**$1,421**	**$0.0001**	6

Life Cycle Cost Analysis
Key Components

- **Deterioration Model**
  - 2014 Research Project Results
    (Olson and Nesvold Engineers, P.S.C.)
  - Engineering Judgement
- **Categories of Work**
  - Preventive
  - Reactive
  - Rehab/Replacement
- **Number of Bridges Acted Upon**
  - BI Resource Demand Model
- **Cost per Square Foot Deck Area**
  - BI Resource Demand Model

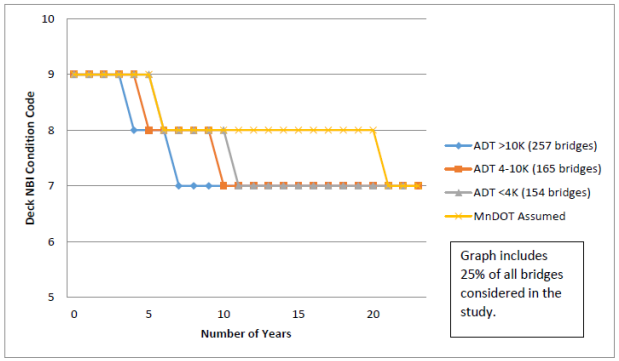


Figure 4.1: Deck Deterioration for Bridges Built During or After 1990 with a Concrete Overlay

Life Cycle Cost Analysis

Example (Deck)

Life Cycle Cost Inputs - Bridge Decks

General	Good	Satis	Fair	Poor	Total				
Number of bridges	2176	609	143	19	2947	2947	Deck area	47.495	million sq.ft
NBI	9	6	5	0					
Health index weight	100	80	50	0			Joint quantity	558620	LF
Discount rate	1.7%						Rail quantity	1818934	LF

Deterioration Model (without preservation)

	Years	Good	Satis	Fair	Poor
Good	18	96.2%	3.8%	0.0%	0.0%
Satis	5		87.1%	12.9%	0.0%
Fair	5			87.1%	12.9%
Poor	--				100%

Deterioration Model (with preventive maintenance)

	Years	Good	Satis	Fair	Poor	
Good	23	97.0%	3.0%	0.0%	0.0%	Good
Satis	10		93.3%	6.7%	0.0%	Satis
Fair	7			90.6%	9.4%	Fair
Poor	--				100%	Poor

Deterioration Model (with preservation)

	Years	Good	Satis	Fair	Poor
	25	97.3%	2.7%	0.0%	0.0%
	15		95.5%	4.5%	0.0%
	11			93.9%	6.1%
	--				100%

Inpection

Treatment	Units	$/unit	Unit/br	$k/br	# bridges acted upon in a year: Good	Satis	Fair	Poor	% bridges acted upon in a year: Good	Satis	Fair	Poor	Real ✓ $M/yr
Inspection (2824)	SF	$0.03	16116	0.5					54.0%	57.0%	57.0%	100.0%	0.8
Annual cost per bridge - no preservation ($k)									0.3	0.3	0.3	0.5	0.8

SF Check / From BI

Million SF	Million SF	SF
0.00	0.00	

Preventive Maintenance

Treatment *(DOT Maintenance Crews)*	Units	$/unit	Unit/br	$k/br	# bridges acted upon in a year: Good	Satis	Fair	Poor	% bridges acted upon in a year: Good	Satis	Fair	Poor	Real ✓ $M/yr
Flushing (2120, 2837)	SF	$0.05	16116	0.8	1286	418	93	13	59.1%	68.6%	65.0%	68.4%	1.5
Joint Sealing/Maintenance (2827, 2847)	SF	$0.07	16116	1.2	356	120	15	0	16.4%	19.7%	10.5%	0.0%	0.6
Reestablish Joint (2846)	SF	$0.22	16116	3.5	18	11	0	0	0.8%	1.8%	0.0%	0.0%	0.1
Deck Sealing (2836)	SF	$0.12	16116	1.9	40	16	1	0	1.8%	2.6%	0.7%	0.0%	0.1
Crack Sealing (2838)	SF	$0.13	16116	2.1	162	48	15	2	7.4%	7.9%	10.5%	10.5%	0.5
Rail Sealing (2844)	SF	$0.24	16116	3.9	76	22	3	0	3.5%	3.6%	2.1%	0.0%	0.4
Total percent acted upon									89%	104%	89%	79%	
Annual cost per bridge - with preservation ($k)									1.3	1.5	1.2	1.3	3.9

SF Check / From BI

Million SF	Million SF	SF
29.17	0.00	
7.91	0.00	
0.47	0.00	
0.92	0.00	
3.66	0.00	
1.63	0.00	

Reactive Maintenance

Treatment *(DOT Maintenance Crews)*	Units	$/unit	Unit/br	$k/br	# bridges acted upon in a year: Good	Satis	Fair	Poor	% bridges acted upon in a year: Good	Satis	Fair	Poor	Real ✓ $M/yr
Deck Repair (2820)	SF	$0.16	16116	2.6	105	82	25	5	4.8%	13.5%	17.5%	26.3%	0.6
Rail Repair/Replace (2819)	SF	$0.18	16116	2.8	64	23	9	0	2.9%	3.8%	6.3%	0.0%	0.3
Treatment *(Contract Work)*													
Replace Joint	SF	$5.50	16116	88.6		5	10		0.0%	0.8%	7.0%	0.0%	1.3
Low Slump Overlay	SF	$7.00	16116	112.8		10	12		0.0%	1.6%	8.4%	0.0%	2.5
Total percent acted upon									7.8%	19.7%	39.2%	26.3%	
Annual cost per bridge ($k)									0.2	3.0	16.3	0.7	2.2
Approximate interval (years)													8.4

Percent improved

Effect	Good	Satis	Fair	Poor
0.1	0.5%	1.3%	1.7%	2.6%
0	0.0%	0.0%	0.0%	0.0%
0	0.0%	0.0%	0.0%	0.0%
1	0.0%	1.6%	8.4%	0.0%
	0.5%	3.0%	10.1%	2.6%

Rehab/Replacement

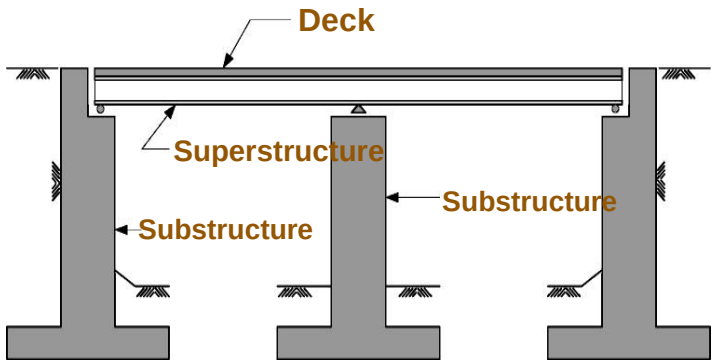
Treatment	Units	$/unit	Unit/br	$k/br	# bridges acted upon in a year: Good	Satis	Fair	Poor	% bridges acted upon in a year: Good	Satis	Fair	Poor	Real ✓ $M/yr	
Redeck	SF	$60.00	16116	967.0			7	3	0.0%	0.0%	4.9%	15.8%	9.7	21%
Replace Structure	SF	$0.00	16116	0.0					0.0%	0.0%	0.0%	0.0%	0.0	0%
Total percent acted upon									0.0%	0.0%	4.9%	15.8%		21%
Annual cost per bridge ($k)									0.0	0.0	47.3	152.7	9.7	

Resulting condition

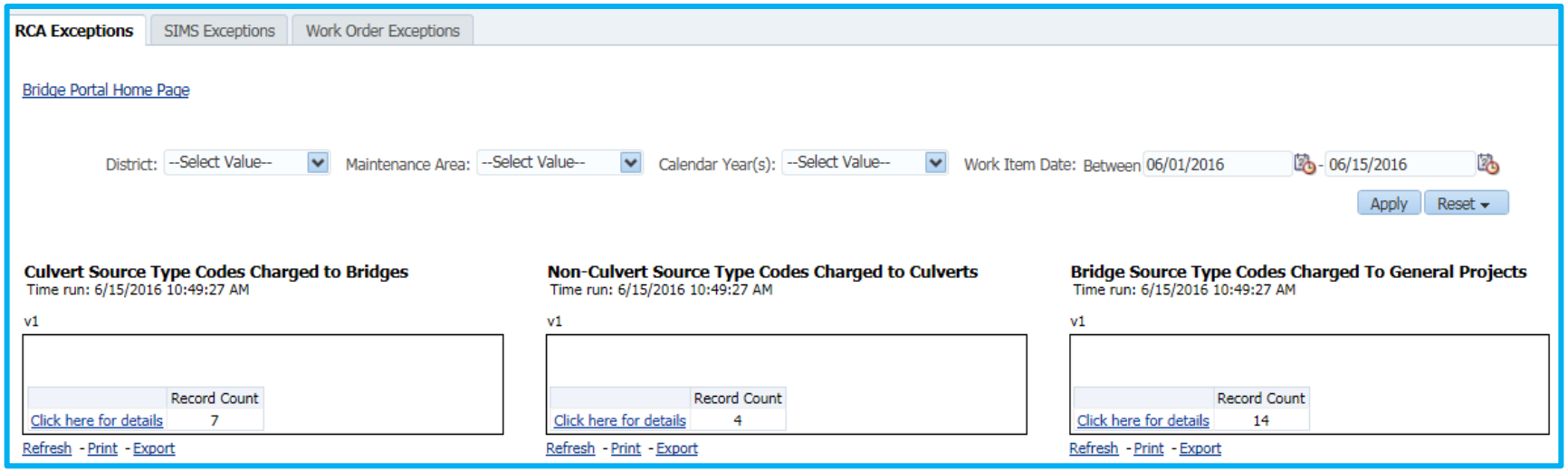
Good	Satis	Fair	Poor
100%	0%	0%	0%
100%	0%	0%	0%
100.0%	0.0%	0.0%	0.0%

Challenges

- **Quality Data**
  - LEM to each **Bridge** **AND** each **Activity**
    - Timesheet Improvements
    - Exception Reports
    - Timesheet Validation Reports
- **Combining Data**
  - Different Units
    - Cost/SF Deck Area
- **Developing LCCA for bridges**
  - Three distinct components that deteriorate differently



Exception Reports



Culvert Source Type Codes Charged to Bridges - Details
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District Name	Maintenance Area Name	RCA Timesheet Work Item ID	Work Item Date	Cost Type Name	Resource	Source Type Code - Name	Bridge ID	Design Main Description	Project ID	Project Name
D3-Baxter	Maintenance Area 3A	35890526	6/2/2016	Labor	01172210 -	2823 - Bridge Culvert Inspection	6712	02 Stringer/Girder	TS006712	7.4 MI E OF LASTRUP
		35890527	6/2/2016	Labor	01172210 -	2823 - Bridge Culvert Inspection	6737	02 Stringer/Girder	TS006737	11.7 MI W OF ONAMIA
		35890528	6/2/2016	Labor	01172210 -	2823 - Bridge Culvert Inspection	33001	02 Stringer/Girder	TS033001	0.4 MI N OF JCT TH 23
		35890529	6/2/2016	Labor	01172210 -	2823 - Bridge Culvert Inspection	01006	02 Stringer/Girder	TS001006	RICE RIVER
		35890530	6/2/2016	Labor	01172210 -	2823 - Bridge Culvert Inspection	11005	02 Stringer/Girder	TS011005	T.H. 6 - ROOSEVELT LAKE
		35890531	6/2/2016	Equipment	TM207061 - DODGE RAM 1500	2823 - Bridge Culvert Inspection	9099	02 Stringer/Girder	TS009099	IN BRAINERD
				Labor	01172210 -	2823 - Bridge Culvert Inspection	9099	02 Stringer/Girder	TS009099	IN BRAINERD

Timesheet Validation Report

District: D6 (continued)

Project ID: TS009706 **Project Name:** 7.5 MI SW OF JCT TH 63

RCA LABOR							RCA EQUIPMENT			RCA MATERIALS		
Fin Dept ID	Employee ID	Supervisor Name	Date	Earn Cd	Hours	Equipment Number & Desc	Equipment Usage	Unit	Material Item Nbr	Material Description	Qty	Unit
Source Type Code: 2838 - BRIDGE DECK CRACK SEALING												
T7949624	01019820	Dahl,Carroll D	Waletzki,Lawrence B	08/26/2015	REG	2.00	TM211458 - FORD F250 EXT CAB 2WD	18.00	MILE	-		
T7949624	01158693	Hovden,Adam Ryan	Waletzki,Lawrence B	08/26/2015	REG	2.00	-			-		
T7949624	01173235	Lockwood,Kevin C	Waletzki,Lawrence B	08/26/2015	REG	2.00	-			-		
T7949624	01143948	Patzner,Eric B	Waletzki,Lawrence B	08/26/2015	REG	4.00	-			-		
T7949624	01134056	Roeder,Jonathan C	Waletzki,Lawrence B	08/26/2015	REG	2.00	TM203081 - AIR COMPRESSOR TM97863 - TRUCK; W/CRANE & FLATBED	1.00 HOUR 15.00 MILE		-		
T7949624	01172635	Sigrist,Dakota T	Waletzki,Lawrence B	08/26/2015	REG	2.00	-			-		
T7949624	01158662	Troutman,Jeremiah	Waletzki,Lawrence B	08/26/2015	REG	2.00	TM213205 - RAM 5500 CREW CAB 2WD TRUCK	16.00	MILE	-		
						Labor Hours SubTotal for Source Type Code:		**16.00**				

Work Order: 7664

Work Order Materials Usage

Expense ID & Description	Quantity	Unit
17328-SAND,BLASTING 12/40 GR 80 LB BAG	7.00	BAG
20902-SEALER,PENETRANT PATCH SEALANT TYPE A, TE2501 A	3.50	GAL
20903-SEALER,PENETRANT PATCH TYPE B, TE2501 B	3.50	GAL

Work Order Other Expenses

Expense Description	Source Type	Quantity	Cost / Unit
FAST SET EPOXY PART A #50577	2838	2.00	$76.43
FAST SET EPOXY PART B #50578	2838	2.00	$76.43

Source Type Code: 2844 - BRIDGE CONC BARRIER/RAIL SEAL												
T7949624	01019820	Dahl,Carroll D	Waletzki,Lawrence B	08/26/2015	REG	6.00	TM211458 - FORD F250 EXT CAB 2WD	18.00	MILE	-		
T7949624	01158693	Hovden,Adam Ryan	Waletzki,Lawrence B	08/26/2015	REG	6.00	-			-		
T7949624	01173235	Lockwood,Kevin C	Waletzki,Lawrence B	08/26/2015	REG	6.00	-			-		
T7949624	01143948	Patzner,Eric B	Waletzki,Lawrence B	08/26/2015	REG	6.00	-			-		
T7949624	01134056	Roeder,Jonathan C	Waletzki,Lawrence B	08/26/2015	REG	6.00	TM203081 - AIR COMPRESSOR TM97863 - TRUCK; W/CRANE & FLATBED	1.00 HOUR 15.00 MILE		-		
T7949624	01172635	Sigrist,Dakota T	Waletzki,Lawrence B	08/26/2015	REG	6.00	-			-		
T7949624	01158662	Troutman,Jeremiah	Waletzki,Lawrence B	08/26/2015	REG	6.00	TM213205 - RAM 5500 CREW CAB 2WD TRUCK	17.00	MILE	-		
						Labor Hours SubTotal for Source Type Code:		**42.00**				

Work Order: 7664

Work Order Materials Usage

Expense ID & Description	Quantity	Unit
17328-SAND,BLASTING 12/40 GR 80 LB BAG	16.00	BAG
20889-SEALER,THOROSHEEN	14.00	GAL
Z1527-MISC/UNIQUE/OTHER MATERIAL, $25 LOT	1.00	EACH

Work Order Other Expenses

Expense Description	Source Type	Quantity	Cost / Unit

Future Outcomes

- Continue to improve data accuracy and quality
- Optimize investment strategies
- Identify and implement additional BI reporting
- Improve maintenance and operations resource planning
  - Apply Resource Demand Model costs to Bridge Maintenance Work Plans

Questions?

Thank you!