CA4PRS Use in Washington State

by

Jeff Uhlmeyer, State Pavement Engineer

UNIVERSITY OF WASHINGTON

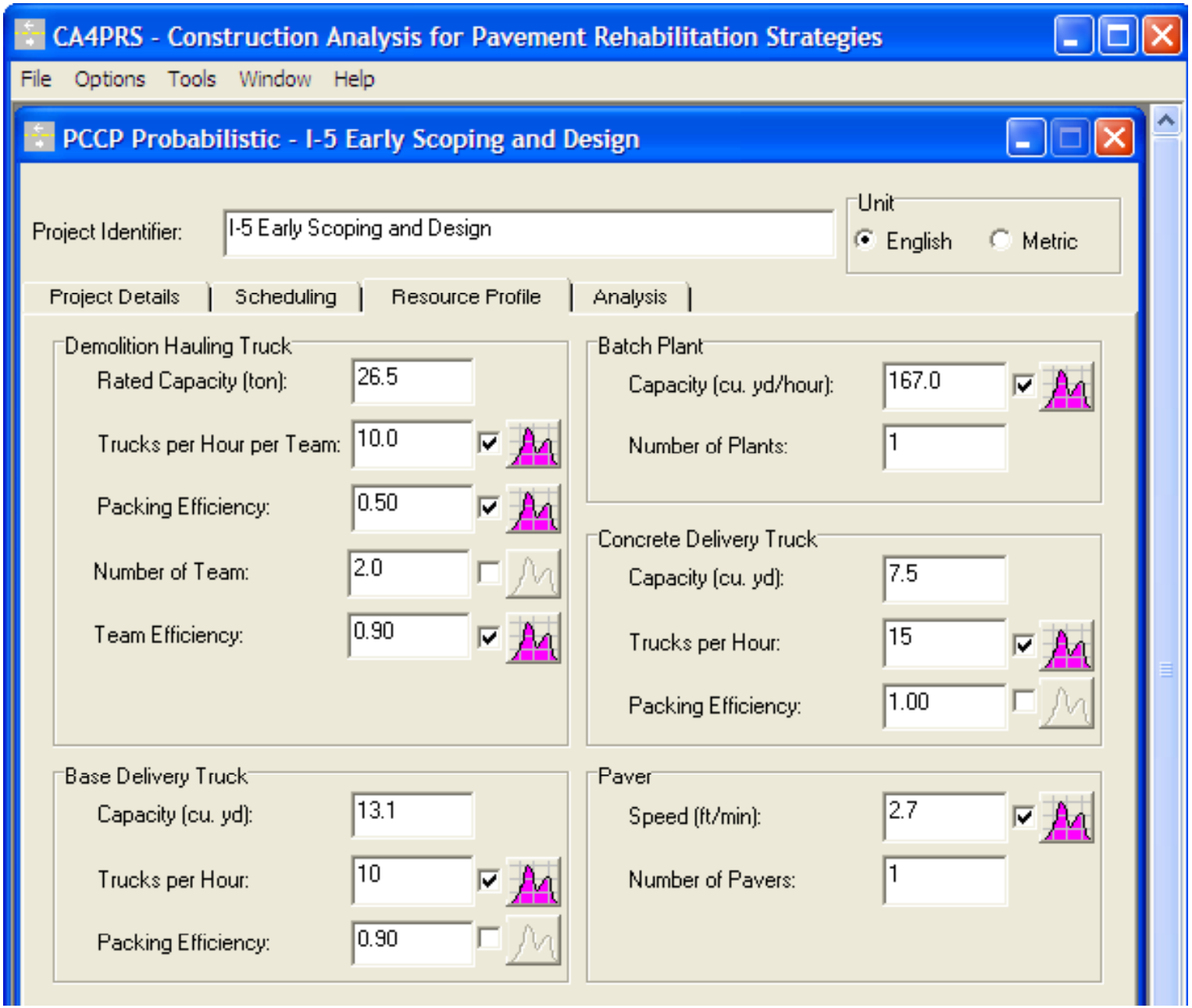
Washington State Department of Transportation

WSDOT Efforts to Mitigate Construction Impacts:

- Alternative contracting
- Rapid construction strategies
- Alternative closure windows
- Specialized materials
- Training and education

CA4PRS: A tool for estimating contractor productivity

- Estimates contractor productivity given:
  - Traffic closure window
  - Lane availability and use for construction
  - Construction materials
  - Pavement structure
  - Scheduling constraints
  - Resource constraints


CA4PRS - Construction Analysis for Pavement Rehabilitation Strategies
File Options Tools Window Help
PCCP Probabilistic - I-5 Early Scoping and Design
Project Identifier:
I-5 Early Scoping and Design
Unit
English
Metric
Project Details
Scheduling
Resource Profile
Analysis
Demolition Hauling Truck
Rated Capacity (ton):
26.5
Trucks per Hour per Team:
10.0
Packing Efficiency:
0.50
Number of Team:
2.0
Team Efficiency:
0.90
Batch Plant
Capacity (cu. yd/hour):
167.0
Number of Plants:
1
Concrete Delivery Truck
Capacity (cu. yd):
7.5
Trucks per Hour:
15
Packing Efficiency:
1.00
Base Delivery Truck
Capacity (cu. yd):
13.1
Trucks per Hour:
10
Packing Efficiency:
0.90
Paver
Speed (ft/min):
2.7
Number of Pavers:
1

Analysis Options and Results

Construction Window:	Weekend Closure (55 Hours/Weekend)
Working Method:	Sequential Single Lane (T2)
Section Profile:	PCCP: 13.0 inches, New Base: 0.0 inches
Curing Time:	8-Hours
Objective (lane-miles):	2.22
Maximum Possible (lane-miles):	0.57
Maximum Possible (c/l-miles):	0.57
Construction Windows Needed To Meet Objective:	3.90

Resource Utilization

Resource	Allocated	Utilized
Demolition Hauling Truck (per hour per team)	6.0	6.0
Base Delivery Truck (per hour)	8.0	0.0
Batch Plant (cu-yd/hour)	200.0	77.1
Concrete Delivery Truck (per hour)	12.5	10.3

CA4PRS productivity estimates can assist:

1. Evaluating different closure scenarios
2. Selecting most appropriate closure strategy
3. Identifying equipment and material requirements
4. Identifying ranges of potential contractor productivity
5. Verifying contractor productivity estimates

CA4PRS and WSDOT

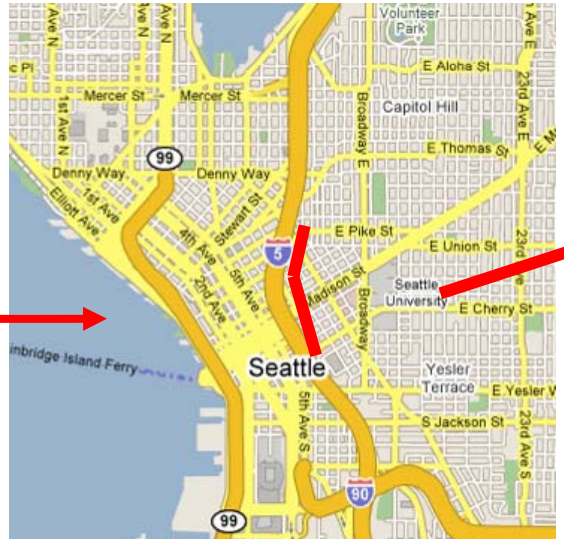
1. Is CA4PRS appropriate for projects in Washington State?

2. At what level of project planning is CA4PRS applicable?

3. How should WSDOT use CA4PRS?

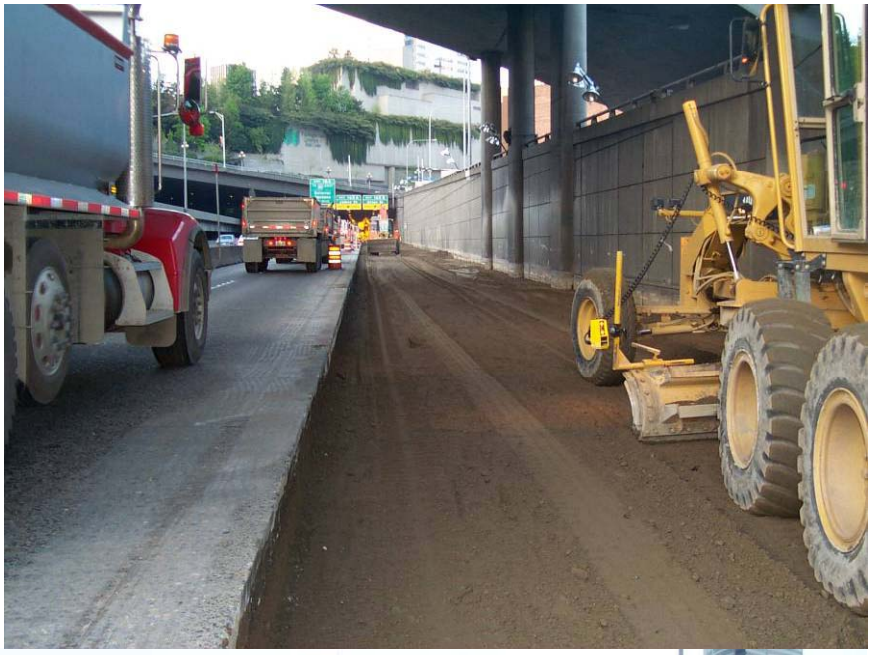
I-5 Olive to James Rehabilitation

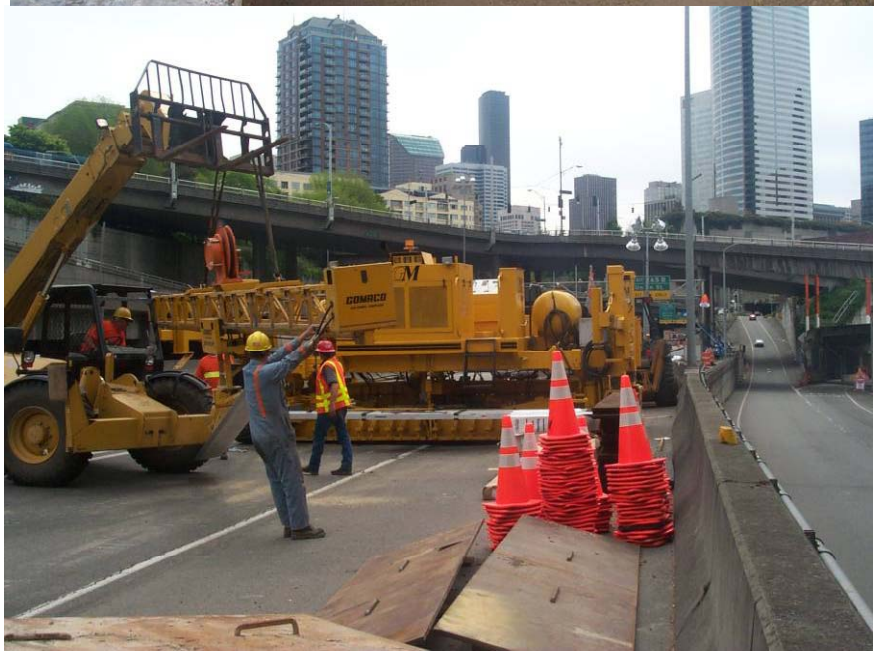
- Reconstructed outside lanes, drop lanes and ramp segments
- Removed of 6,500 yd^3 of material
- Placed of 2,500 tons of HMA base and 5,640 yd^3 concrete pavement
- Four 55-hour weekend closures



Project Location


EXIT 165 B
Union St.
EXIT ONLY





Paving Quantities and Stage Paving Lengths (lane-miles)

Stage	Fixed Form Paving	Slipform Paving	Total Paving Quantity	Stage Psuedo Length
Stage 1	776 yd^3	1100 yd^3	1876 yd^3	0.74 lane-miles
Stage 2	572 yd^3	995 yd^3	1567 yd^3	0.62 lane-miles
Stage 3	488 yd^3	808 yd^3	1296 yd^3	0.51 lane-miles
Stage 4	364 yd^3	540 yd^3	904 yd^3	0.36 lane-miles
		Total	5643 yd^3	2.22 lane-miles
		Average Paving Length Per Stage		0.56 lane-miles

Construction Sequence

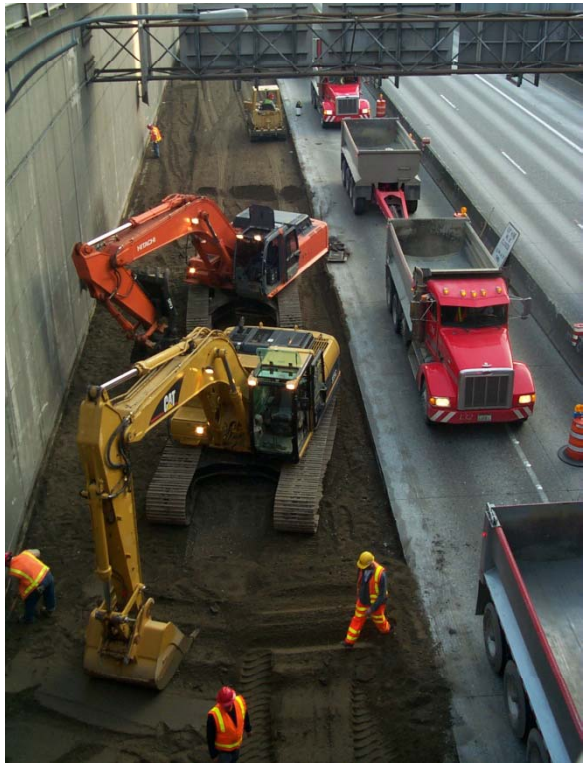
- Establish traffic control and installation of construction barrier
- Demolish and remove existing pavement
- Subgrade repair

Construction Sequence

- HMA base paving
- PCC paving
- PCC curing, sawcutting and pavement marking
- Removal of equipment and traffic control

Job Specific Constraints

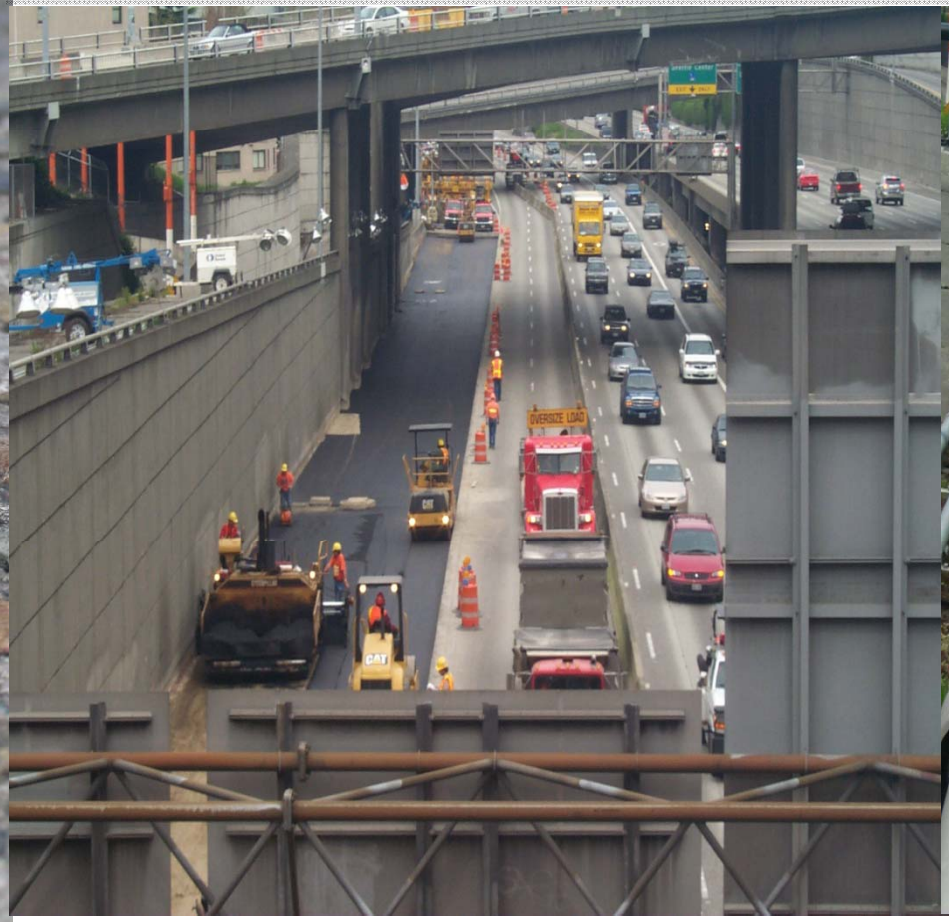
- Narrow work zone
- Slipform paving machine constraints



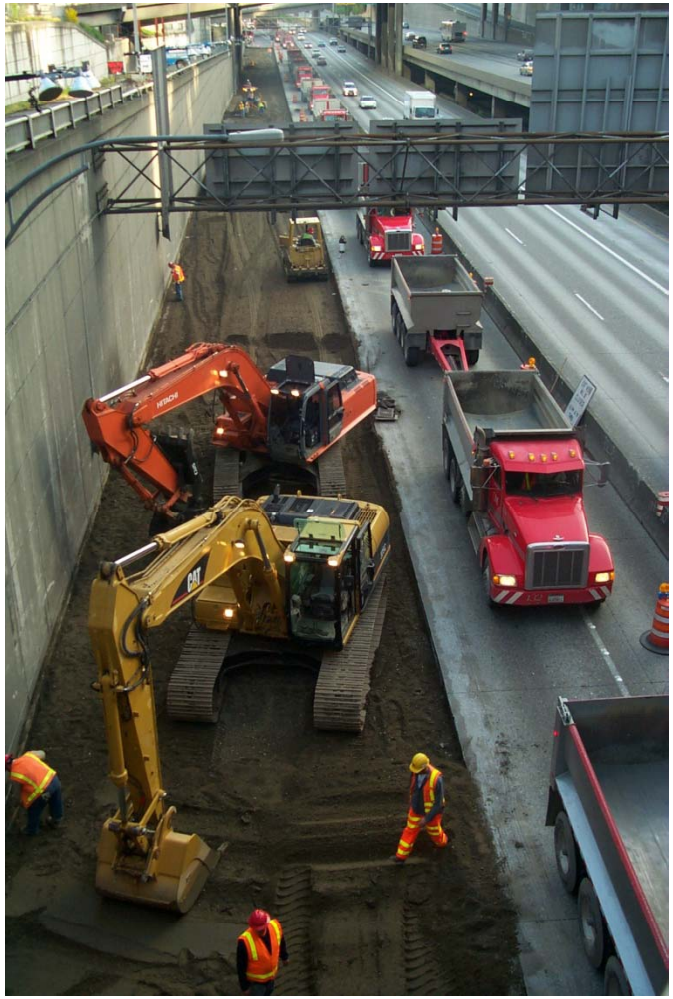
Job Specific Constraints

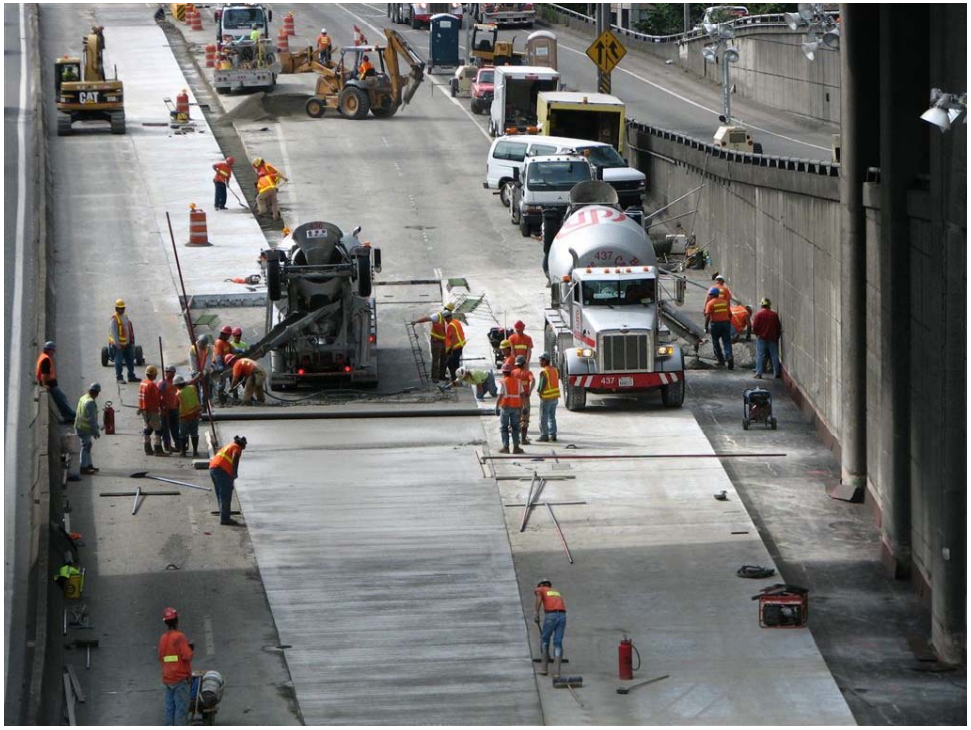
- Paving lane access
- Adjacent commercial development
- Site access

Construction Process



Job Specific Constraints



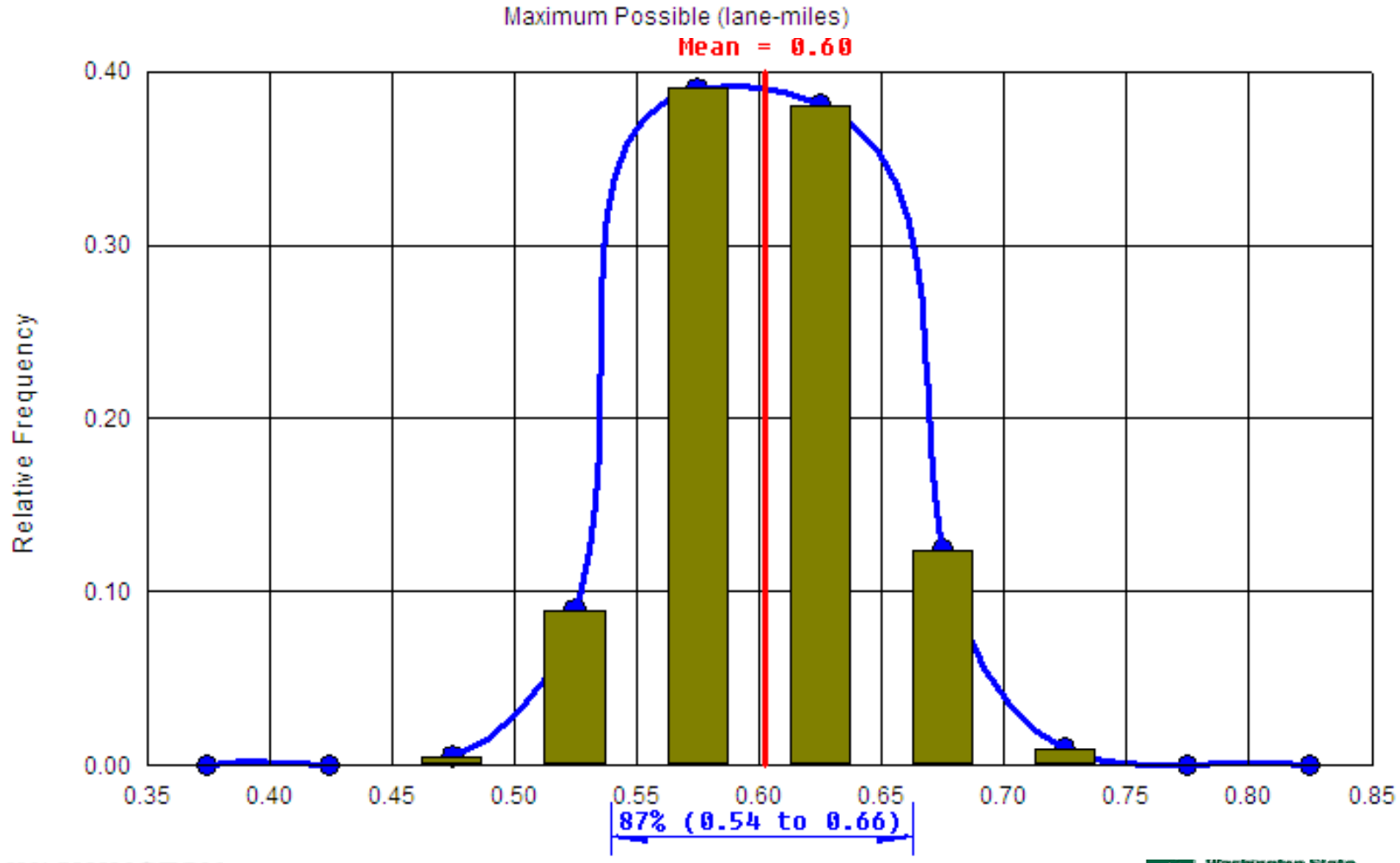


1st Analysis: CA4PRS Applicability For Early Scoping and Design Evaluation

- Sufficient project information available for CA4PRS estimate development
- Input parameters established from similar and previously completed projects
- Slipform and fixed form operations combined into a pseudo paving speed of 2.67 ft/min

1st Analysis: CA4PRS Applicability For Early Scoping and Design Evaluation

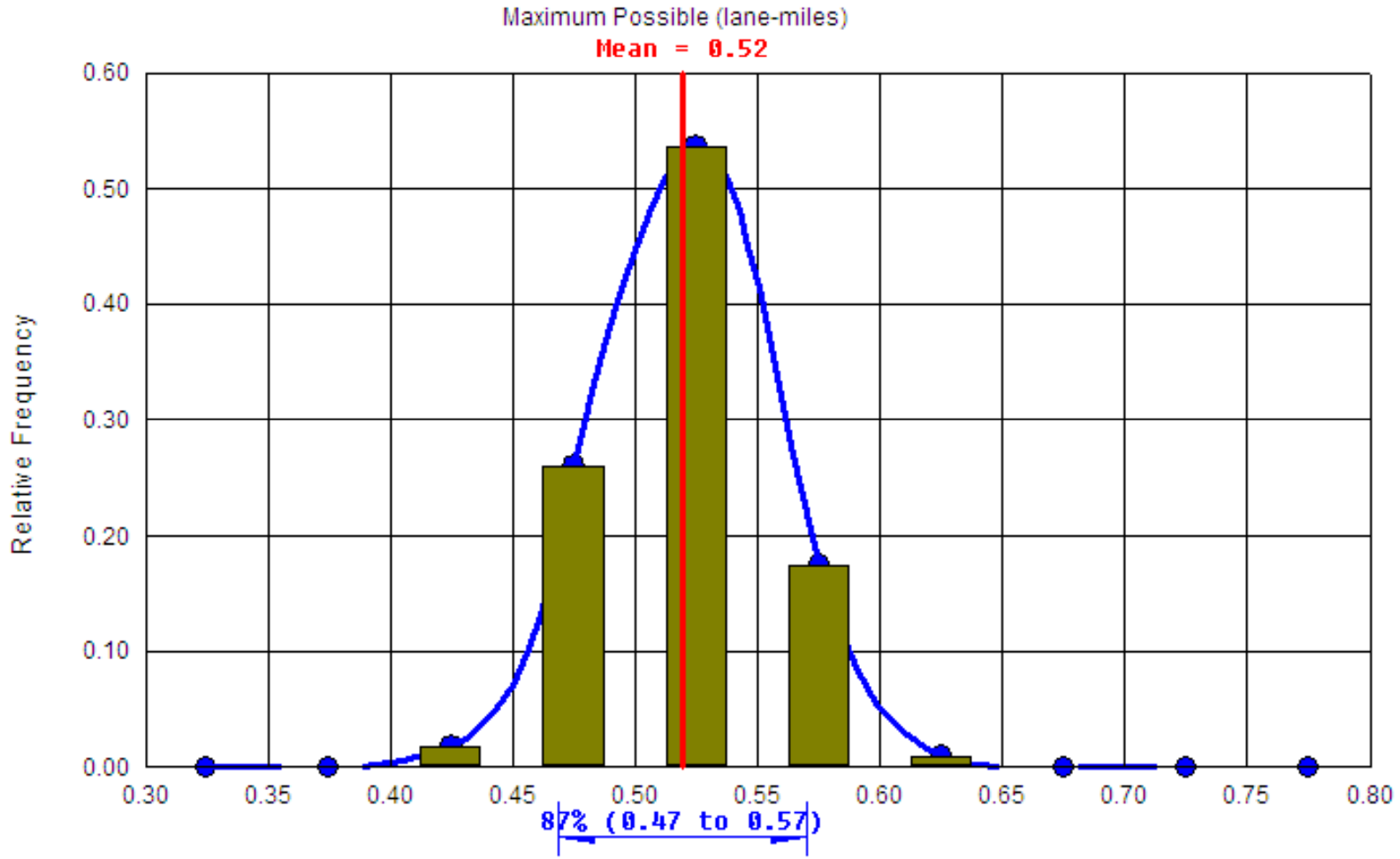
	Estimated		
	Minimum	Mean	Maximum
Lane-Miles Paved Per Weekend Closure	0.54	0.6	0.67
Number of Required Weekend Closures	4.11	3.69	3.31



2nd Analysis: CA4PRS Applicability For Post-Award Pre-Construction Evaluation

- Contractor schedules used to refine:
  - Construction sequencing
  - Activity lag times
  - Mobilization and demobilization times

	Estimated		
	Minimum	Mean	Maximum
Lane-miles Paved Per Weekend Closure	0.47	0.52	0.57
Number of Required Weekend Closures	4.72	4.28	3.89



CA4PRS Guidelines

- Base decisions on probabilistic outputs
- Maintain a database of construction productivity
- Assign triangular distributions to probabilistic inputs if distribution data is unavailable
- Round estimated construction windows up to nearest whole number

Evaluation Conclusions

1. CA4PRS can be used during early scoping and design as well as post-award pre-construction verification
2. Produce estimates from probabilistic analysis
3. CA4PRS estimates are reasonably accurate with generic input parameters

Evaluation Conclusions

4. Input parameter selection determines estimate accuracy
5. Input parameter variation may not encompass productivity for constrained projects
6. CA4PRS requires further refinement to make it more generic and flexible

CA4PRS at UW

- The University of Washington graduates 120 civil engineers each year to meet regional demand
- CEE 404 Infrastructure Construction
  - Transportation project development and construction
  - CA4PRS combines real-world information with project planning

From Loyd C. Heath Photography

CA4PRS Analysis
I-5 Bow Hill,
Crack and Seat Overlay

UNIVERSITY OF WASHINGTON

Washington State Department of Transportation

Project Parameters

- Crack and Seat and Overlay two NB lanes of I-5 between MP 231.8 to MP 243.33 (south of Bellingham, WA)
- 20 lane-miles
- Classified as a rural freeway with a 23,000 ADT and 9% trucks
- Two 12-ft lanes with a 4 feet inside and a 10 feet outside shoulders
- Constructed in 1966 using 9 inches of JPCP
- Rehabilitated in 1993 with a 4 inch HMA overlay and sub-sealing due to considerable faulting

Construction Process

- Expose PCCP pavement by milling the 4 inch overlay
  Shoulders remain as is, no milling
- Divert traffic on SB I-5 lanes using counter-flow traffic operations
- Overlay the crack and seat slabs with 8 inches of HMA pavement in three lifts: 4 inch initial lift followed by two additional 2 inch lifts

Construction Scenarios

- **Baseline**. All operations (milling, crack and seat and the full 8 inch overlay paving) are accomplished during each closure.
- **Baseline but with 2 Milling teams and 2 paving teams**. It is likely that 2 milling and paving teams (e.g., 2 milling machines and 2 paving machines) can operate in the project area.
- **Just milling 4.2 inches of mainline pavement with 2 milling teams**. An obvious breakpoint in the work would be after milling off all the HMA in the mainline.
- **Just milling 4.2 inches of mainline pavement with 4 milling teams 50% efficiency**. The lower efficiency is an attempt to account for the added complexity of operations with 4 milling teams.
- **Crack and seat plus a 4.2 inch overlay to bring the mainline pavement height up to the existing shoulder height**. This operation would follow the "just milling" one.

Overlay the final 4.0 inches for the mainline and shoulders. This operation would follow the "crack and seat plus 4.2 inches overlay" one.

Baseline Inputs:		
Activity Constraints		
Input	**Value**	**Distribution / Comments**
Mobilization	1.0 hour	None – Deterministic. Set traffic control, mobilize equipment.
Demobilization	2.0 hours	None – Deterministic. Remove traffic control and equipment.
Half Closure Traffic Switch	0.5 hours	Triangular (min = 0.25 hrs, max = 0.75 hrs). Time to switch traffic if only closing 1 lane in NB direction.

Resource Profile		
Input	**Value**	**Distribution / Comments**
Milling and Hauling		
Number of Team	1 team	None – Deterministic.
Team Efficiency	0.80	Triangular (min = 0.7, max = 0.9)
Milling Machine		
Machine Class	Large	Choices are large, medium, small
Material Type	AC – Hard	Good choice for hard rock in western WA
Efficiency Factor	0.70	Triangular (min = 0.6, max = 0.8) Tooth replacement may affect downtime.
Hauling Truck		
Rated Capacity	18.0 tons	None – Deterministic.
Trucks/hr/team	13/hr	Triangular (min = 11/hr, max = 15/hr)
Packing Efficiency	1	None – Deterministic.

Resource Profile (cont.)		
Input	**Value**	**Distribution / Comments**
Batch Plant		
Capacity	350 t/hr	Triangular (min = 300 t/hr, max = 400 t/hr)
Number of Plants	1	None - Deterministic
HMA Delivery Truck		
Capacity	16 tons	None – Deterministic. Anticipate trucks with pups with total capacity of truck and pup at about 32 tons. This means, on average each dump will be filled with 16 tons of mix.
Trucks per Hour	12/hr	Triangular (min = 11/hr, max = 15/hr)
Packing Efficiency	1.0	None - Deterministic
Paver	None	N/A (no base material)
Non-Paving Speed	15 mph	

Baseline Schedule Analysis

Input	Value	Distribution/Comments
Construction Window	weekend nighttime continuous	55-hour weekend closures 10-hour nighttime closures 168-hour continuous week-long closures
Section Profile	2-2-4	Bottom lift: 4 inches (0.33 mph for paver) Middle lift: 2 inches (0.66 mph for paver) Top lift: 2 inches (0.66 mph for paver)
Change in Roadway Elevation	+4 inches	The new roadway will be 4 inches higher than the old after milling and overlaying.

Baseline Schedule Analysis (cont.)

Input	Value	Distribution/Comments
Shoulder Overlay	Simultaneous	Shoulders already contain 4.2 inches of HMA. They will be overlayed with an additional 4 inches of HMA.
Working Method	Full closure	Only allowed option in CA4PRS.
Cooling Time Analysis	User Spec.	Time calculated in MultiCool and manually entered
Lane Widths		
No. of Lanes	2	Travelled lanes only
Lane Widths	12 ft each	

MultiCool Input Parameters:

Constant Inputs for All Scenarios	
Input	**Value**
Start Time	1000, 7/15/2011
Environmental Conditions	
Ambient Air Temp.	60°F
Average Wind Speed	5 mph
Sky Conditions	Clear&Dry
Latitude	44° North
Existing Surface	
Material Type	PCC
Moisture Content	N/A
State of Moisture	N/A
Surface Temp.	55°F

MultiCool Inputs in All Scenarios (cont.)	
Input	**Value**
Mix Specifications	
Mix Type	Dense Graded
PG Grade	70-22
Delivery Temp.	300°F
Stop Temp.	130°F
Lift Thicknesses	
1st 4 inches of HMA	Paved as one 4-inch lift
2nd 4 inches of HMA	Paved as two 2-inch lifts

Baseline Results

Scenario	Closure Production	Construction Windows	Total Working Hours
14-hour nighttime closures	Not possible	N/A	N/A
55-hour weekend closures	1.01 lane-miles	19.71	1084.3 hrs
Continuous closure	38 days to pave 20 lane-miles		905.4 hrs
Constraints: Milling Machines, HMA trucks			

Milling Teams and 2 Paving Teams

Scenario	Closure Production	Construction Windows	Total Working Hours
14-hour nighttime closures	Not possible	N/A	N/A
55-hour weekend closures	1.92 lane-miles	10.43	573.7 hrs
Continuous closure	21 days to pave 20 lane-miles		498.3 hrs
Constraints: HMA batch plant, Milling machine			

Just Milling with 2 Milling Teams

Scenario	Closure Production	Construction Windows	Total Working Hours
14-hour nighttime closures	1.47 lane-miles	13.60	190.4 hrs
55-hour weekend closures	7.01 lane-miles	2.85	156.9 hrs
Continuous closure	7 days to mill 20 lane-miles		498.3 hrs
Constraints: Milling machine			

Just Milling with 4 Milling Teams at 50% efficiency due to congestion			
Scenario	**Closure Production**	**Construction Windows**	**Total Working Hours**
14-hour nighttime closures	1.84 lane-miles	10.89	52.5 hrs
55-hour weekend closures	8.75 lane-miles	2.29	125.7 hrs
Continuous closure	6 days to mill 20 lane-miles		498.3 hrs
Constraints: Milling machine			

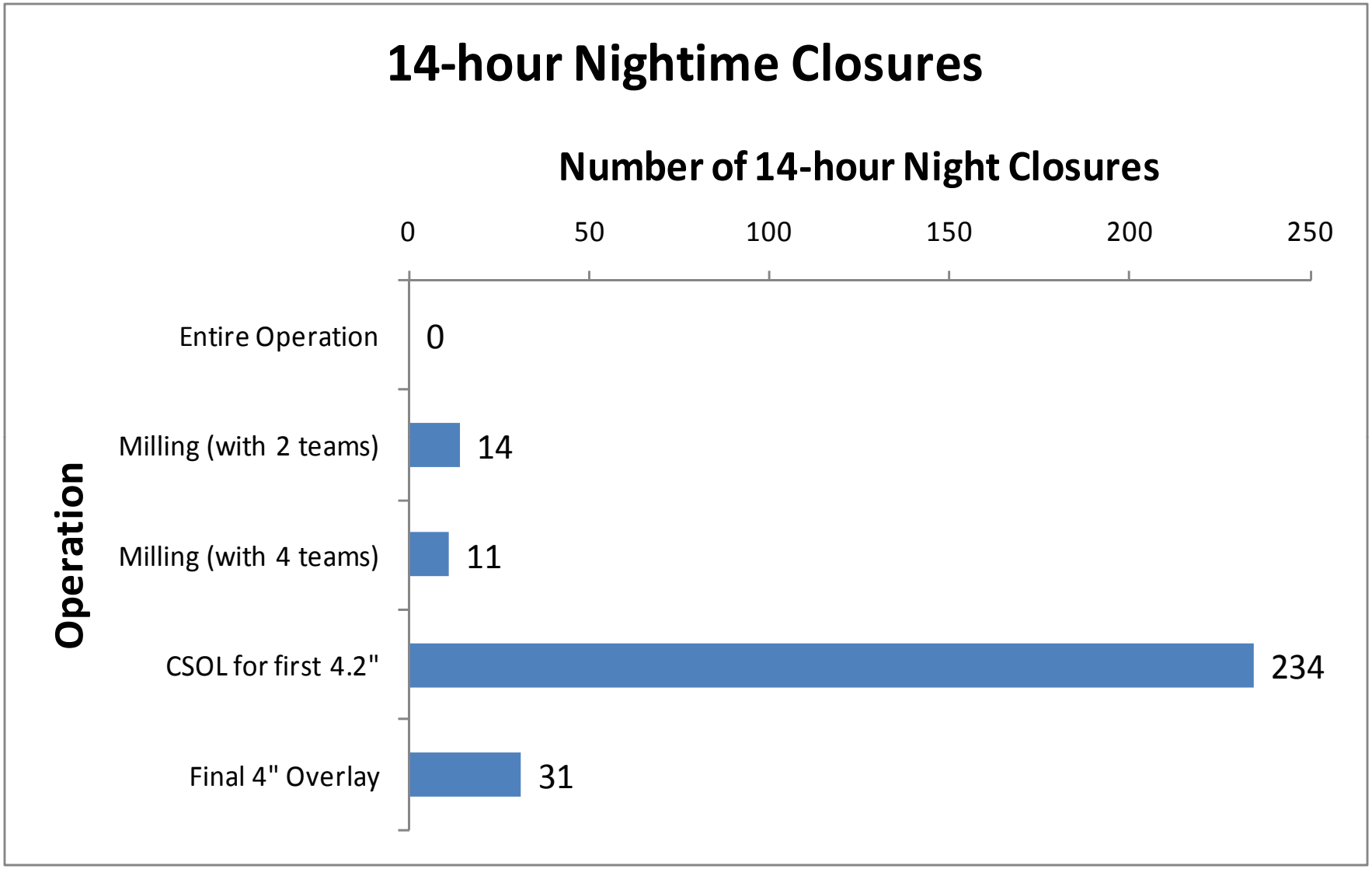
Crack and Seat + Overlay first 4.2 inches (4 inches mainline, no shoulder paving)

Scenario	Closure Production	Construction Windows	Total Working Hours
14-hour nighttime closures	0.09	233.34	3266.7 hrs
55-hour weekend closures	11.82 lane-miles	1.69	93.0 hrs
Continuous closure	4 days to pave 20 lane-miles		88.7 hrs
Constraints: Batch plant			

Just Overlay final 4.0 inches (4 inches mainline and shoulder paving)

Scenario	Closure Production	Construction Windows	Total Working Hours
14-hour nighttime closures	0.65	30.99	433.9 hrs
55-hour weekend closures	7.25 lane-miles	2.76	151.7 hrs
Continuous closure	6 days to pave 20 lane-miles		157.2 hrs
Constraints: Batch plant			

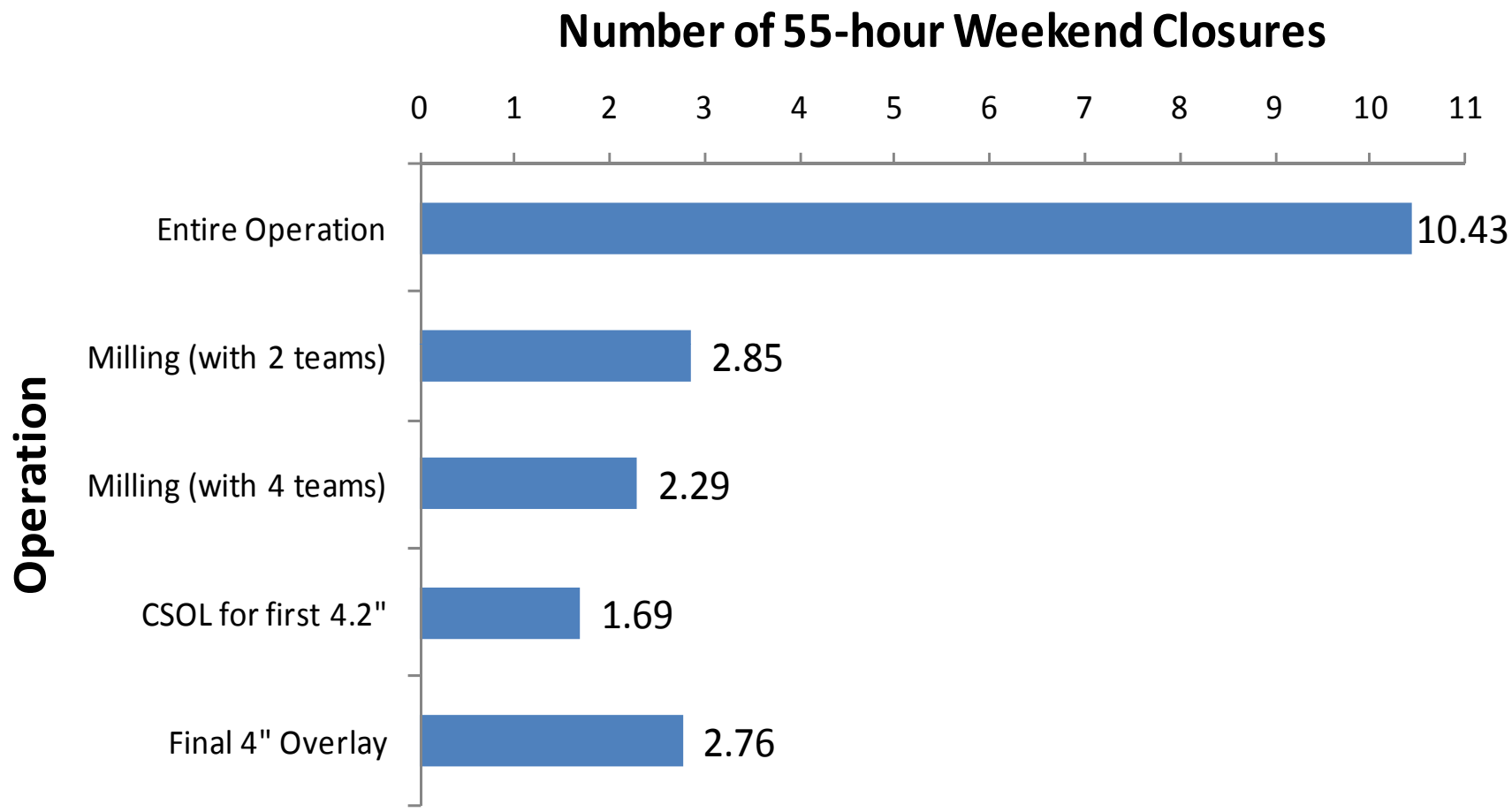
14-hour Nightime Closures



UNIVERSITY OF WASHINGTON

Washington State Department of Transportation

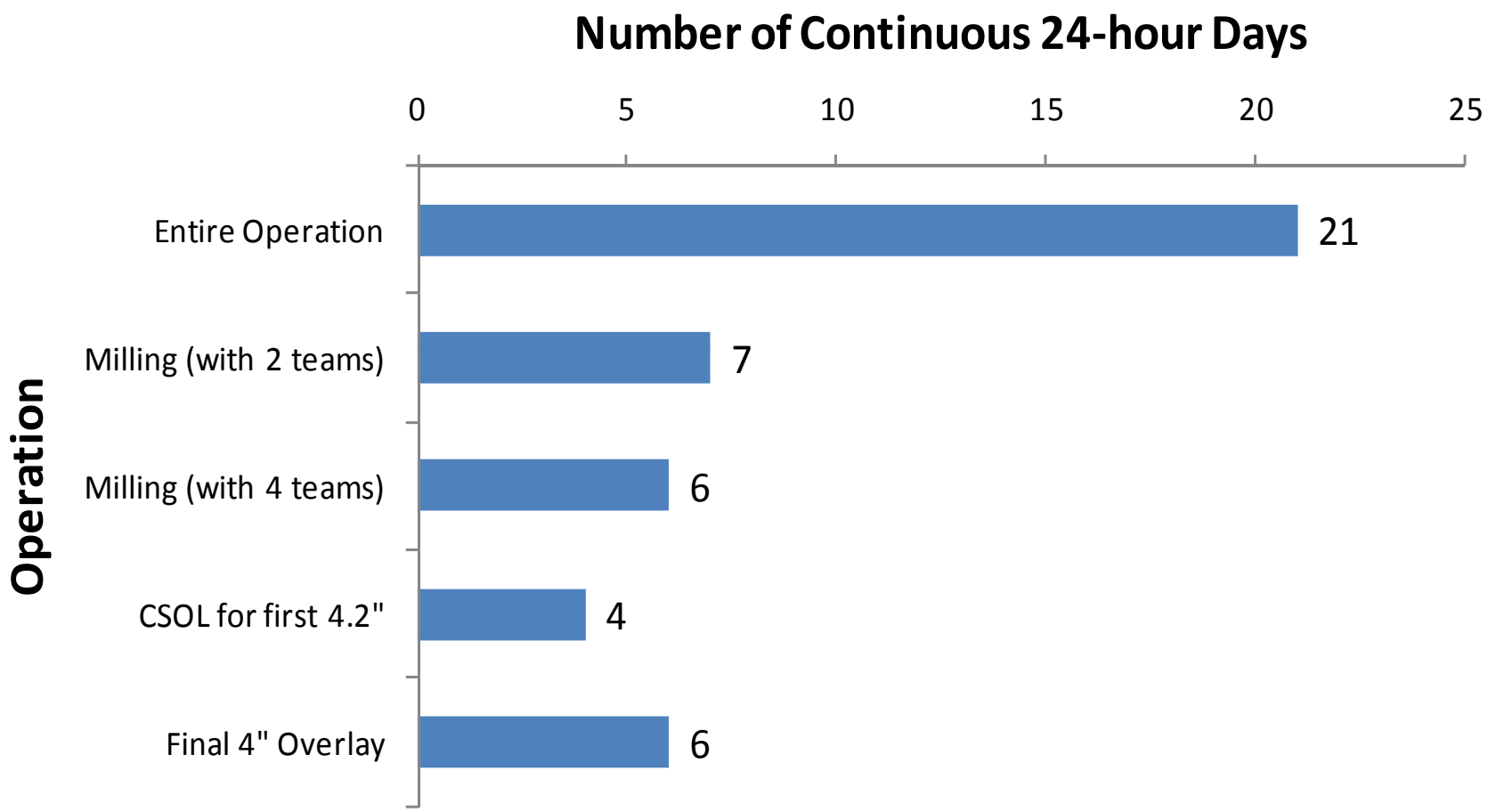
55-hour Weekend Closures



UNIVERSITY OF WASHINGTON

Washington State Department of Transportation

Continuous Closures



UNIVERSITY OF WASHINGTON

Washington State Department of Transportation

Observations

- 10-hour nighttime closures were not considered. They are less productivity than 14-hour closures
- Milling may be possible during 14-hour nighttime closures. No other modeled operation seems feasible
- No probabilistic scenarios were run but it is reasonable to add the following uncertainties to the estimates:
    - 14-hour nighttime closures: ±5 days
    - 55-hour weekend closures: ±1 weekend
    - Continuous closures: ±2 days

Observations

- The best possible solution is likely a combination of closure scenarios

  Milling – performed over 14 nighttime (14 hour closures)

  CSOL and overlays (8 inch total) performed over five 55 hour closures
- No traffic analysis was done at this point. Results may become clearer with traffic numbers

Contact Information

Jeff Uhlmeyer, State Pavement Engineer

Washington State Department of Transportation

360-709-5485

uhlmeyj@wsdot.wa.gov

UNIVERSITY OF WASHINGTON

Washington State Department of Transportation


25 1:37PM
UNIVERSITY OF WASHINGTON
Washington State Department of Transportation