Construction Analysis for Pavement Rehabilitation Strategies (CA4PRS)

Design, construction, and traffic engineers now have a decision-making software tool to help select the best construction schedules and minimize traffic delay and agency costs for high-volume highway rehabilitation and reconstruction projects.

Many state highway pavements, constructed during the infrastructure construction boom in the 1960's and 1970's, exceeded their design lives in less than 20 years of service. In 1998, the California Department of Transportation (Caltrans) launched the Long-Life Pavement Rehabilitation Strategies (LLPRS) program to rebuild approximately 2,800 lane-kilometers (lane-km) of high volume urban freeways in the 78,000 lane-km state highway network over a 10-year period. CA4PRS (Construction Analysis for Pavement Rehabilitation Strategies) software was developed as a scheduling and production analysis tool for LLPRS projects. The development of the software represents a cooperative effort with funding from the Federal Highway Administration pooled fund SPR-3(098) sponsored by the Five-State Pavement Technology Consortium (California, Florida, Minnesota, Texas, and Washington).

CA4PRS estimates the optimal distance and duration of highway rehabilitation projects, taking into account the constraints of scheduling interfaces, pavement design, lane closure tactics, and contractor logistics. The software is designed to help high-

A collaboration of the following agencies:

U. S. Department of Transportation
Federal Highway Administration

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way agencies and paving contractors make construction schedule decisions that balance rehabilitation productivity, traffic inconvenience, and agency cost. Application of the CA4PRS model to urban freeway rehabilitation projects in California, including Interstate 10 in Pomona, Interstate 710 in Long Beach, and Interstate 15 in Devore, has demonstrated its value in saving millions of dollars for both Caltrans and road users.

Need for Highway Rehabilitation

The deterioration of pavements caused by continually increasing traffic demand and heavier vehicles adversely affects road user safety, ride quality, vehicle operation, and highway maintenance costs, and causes delays. As a result, state and federal transportation agencies have turned their attention from new construction to 4-R projects (Restoration, Resurfacing, Rehabilitation, and Reconstruction).

Caltrans selected LLPRS candidate projects based on their poor pavement condition and ride quality, and minimum 150,000 Average Daily Traffic (ADT) or 15,000 Average Daily Truck Traffic. Most of the candidate projects were Portland cement concrete (PCC) freeways in Southern California and the San Francisco Bay Area and were 25 to 45 years old and had not yet had any major rehabilitation or reconstruction.

CA4PRS: A Decision-making Tool

CA4PRS is a software program that estimates the optimal distance and duration of highway rehabilitation and reconstruction projects under a given set of constraints, such as scheduling interfaces, pavement materials and design, contractor logistics and resources, and traffic operations. The software is a knowledge-based computer model utilizing Monte Carlo simulation to evaluate various alternatives for highway pave-ment rehabilitation from the perspective of schedule and production.

The main parameters are pavement rehabilitation type, schedule interfaces between major activities, contractor resource constraints, pavement design and materials properties, and lane closure tactics. The three most common LLPRS methods – concrete reconstruction; Crack, Seat and AC Overlay rehabilitation (CSOL); and Full-Depth AC replacement (FDAC) - are incorporated as analysis modules in CA4PRS.

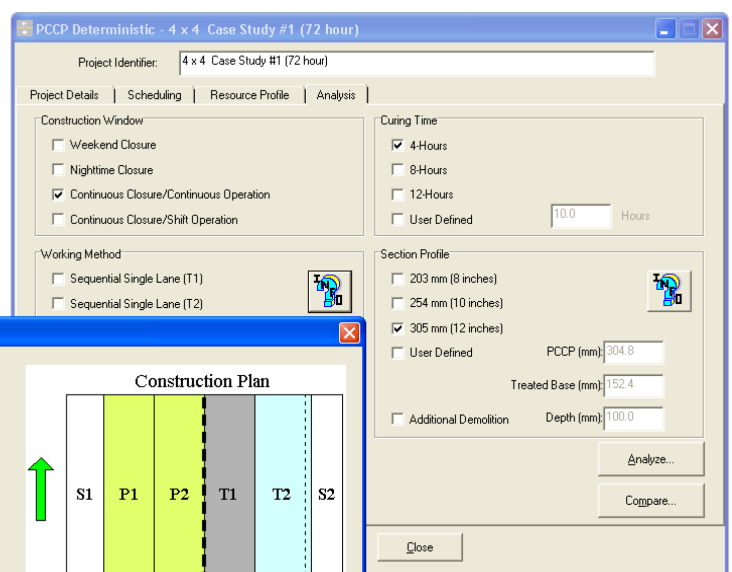
Input Interfaces

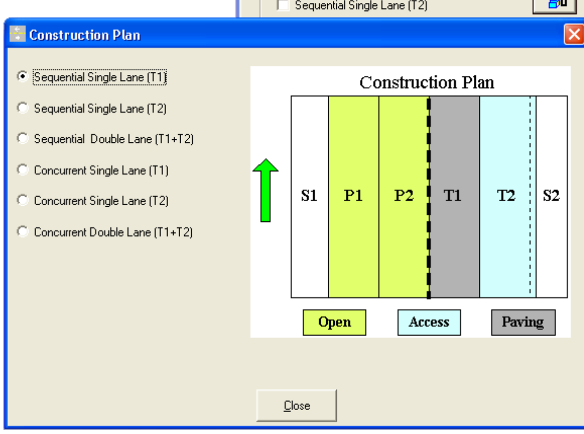
CA4PRS runs on Microsoft Windows 95/NT/98/2000/XP or higher operating systems. The software was developed with Microsoft Visual Basic 6.0 and utilizes a Microsoft Access 2000 database. The database interface helps recall input parameters from previous analyses and transmit project information to other users. A single computer can run CA4PRS as a stand-alone application or it can run on a network server to allow multi-user access and database sharing.

CA4PRS starts with a prompt for user input with the following four tab windows:

- Project Details: The user enters basic project information, including project descriptions, route names, post (station) miles, location, etc. The user enters the total lane-km to be rehabilitated, which acts as the baseline for computing the total number of closures required. CA4PRS then computes this total based on predicted production rates.

- Scheduling: The user enters the minimum times required for mobilization and demobilization activities, such as site preparation, cleanup, and most importantly, deployment and removal of traffic control. The user specifies lead-lag relationships and minimum time interfaces among major operations. Three alternative closure time frames are available: nighttime, weekend, and continuous.





Planning construction and closure scheme in CA4PRS.

- Resource Profile: The user specifies contractor logistics and resource constraints. Resource inputs such as the number of demolition hauling trucks per hour rely on the user's knowledge, experience, and personal judgment for accuracy.

- Analysis: The user can select from the multiple input categories, including construction windows, rehabilitation sequence with respect to lane closure tactics, mix design in terms of concrete curing and AC cooling time, pavement cross-section changes, and truck lane width (PCC only).

Outputs and Reports

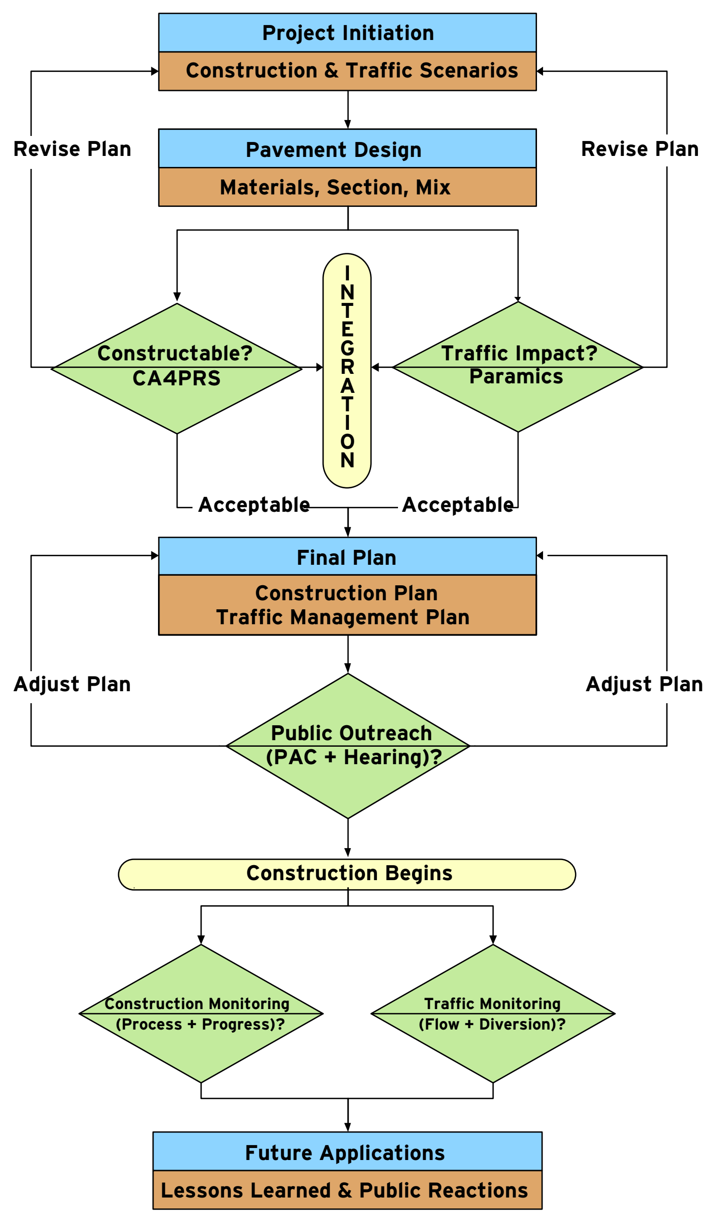
CA4PRS provides extensive graphical and tabular outputs, and incorporates a report feature that allows input and output information to be printed in PDF or RTF format. In deterministic mode, the output comes in two parts: Production Details and Production Chart. Production Details include a user input summary and the principal analysis results (maximum production of each rehabilitation scenario and the number of closures required to finish the project). The Production Chart shows a line of balance schedule illustrating the linear progress of the main rehabilitation operations over time. The user can also generate a comparison table, summarizing the main inputs and outputs relative to combinations of various production variables; e.g., construction window, section profile, rehabilitation sequence, etc.

The probabilistic mode generates a distribution plot showing the range of rehabilitation production. It uses Monte Carlo simulation and produces a sensitivity analysis chart, permitting the user to see the relative sensitivity of production to each input variable.

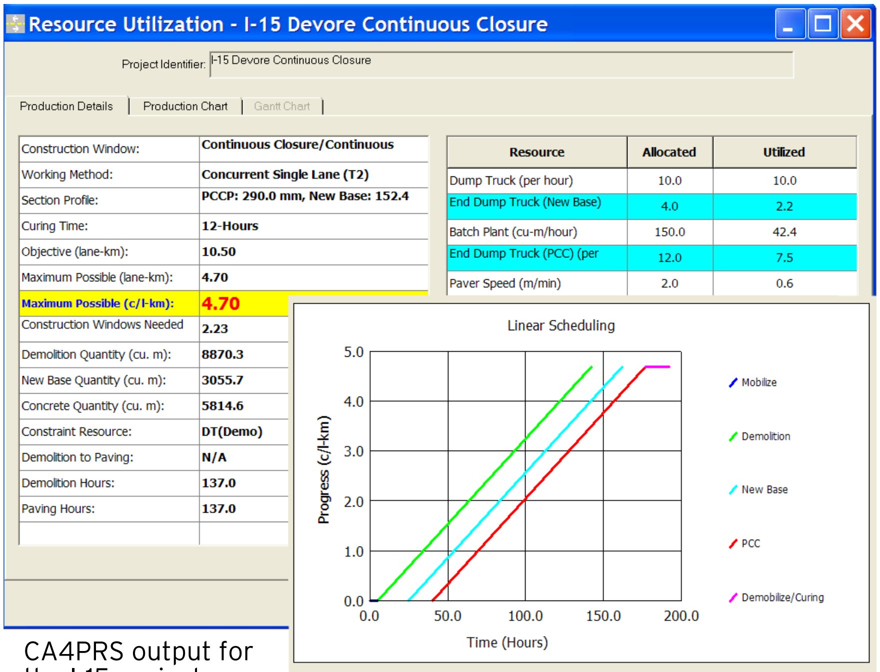
Validation and Deployment

The CA4PRS model has been applied to urban freeway rehabilitation projects, including Interstate 10 in Pomona, Interstate 710 in Long Beach, and Interstate 15 in Devore. The first CA4PRS validation project was the LLPRS concrete pilot project on I-10 in Pomona. At that site, a 2.8 lane-km section of deteriorated truck lane was rebuilt during one 55-hour weekend closure (Friday 10 p.m. to Monday 5 a.m.). The CA4PRS analysis precisely predicted the contractor's actual production rate.

Next, CA4PRS was used to evaluate the LLPRS asphalt pilot project on I-710 in Long Beach. On that project, 26 lane-km of deteriorating PCC pavement was replaced with long-life asphalt concrete pavement over eight 55-hour weekend closures. CA4PRS analysis warned that the contractor's initial staging plan of rehabilitating two FDAC sections (about 0.8 km) together with one CSOL section (1.3 km) per weekend was overly optimistic. The contractor revised his production plan based on the production levels estimated by CA4PRS. Actual production performance was within 5 percent of those estimates.



Framework for the integration of construction and traffic delay analysis for urban freeway reconstruction.



CA4PRS output for the I-15 project.

This achieves the objective of integrating pavement design, construction logistics, and traffic operations for highway rehabilitation and reconstruction projects, especially in urban areas with high traffic volume.

CA4PRS can also help engineers from design, construction, and traffic operations to develop a schedule baseline during the estimating and control stages of highway rehabilitation projects to determine reasonable productivity goals. For example, paving contractors and consultants will find this tool useful for checking construction staging plans, identifying critical resources constraining production, and quantifying the probability of meeting incentives/disincentives and cost plus schedule contracts.

Finally, the software was used during the planning and design of a project rebuilding 4.2-km of deteriorated PCC truck lanes on I-15 in Devore. Caltrans decided to implement two single-roadbed continuous closures (about 200 hours for each closure) with round-the-clock operations, the most economical in terms of both agency and road user (traffic delay) costs compared to 10-hour nighttime weekday closures, 55-hour weekend closures, and 72-hour weekday closures. The scenario selection was based on production schedules predicted by CA4PRS, traffic delay analyses with several tools [i.e., the Highway Capacity Manual, macroscopic (FREQ) and microscopic (Paramics) traffic simulations], and agency cost.

Compared to traditional 10-hour nighttime closures, the single-roadbed continuous closure scenario requires 81 percent less total closure time, 39 percent less road user cost due to traffic delay, and 51 percent less agency cost for construction and traffic control.

Potential Payoffs

CA4PRS can evaluate various traffic lane closure strategies and pavement design alternatives for highway rehabilitation. Added benefit comes when CA4PRS users integrate results with macroscopic and microscopic traffic simulation tools for estimating road user delay. Various traffic lane closure strategies and pavement design alternatives can be evaluated with the goal of maximizing new pavement life expectancy and construction production and minimizing traffic delay and agency costs.

Integrated Comparison of Construction Schedule and Traffic Delay for the I-15 Devore Project

Construction Scenario	Schedule Comparison		Cost Comparison ($M)			Max. Peak Delay (min.)
	Total Closures	Closure Hours	Agency Cost	User Delay	Total Cost	
72-Hour Weekday Continuous	8	512	16.0	5.0	21.0	50
55-Hour Weekend Continuous	10	550	17.0	10.0	27.0	80
1 Roadbed Continuous	2	400	15.0	5.0	20.0	80
10-Hour Night-time Closures	220	2,200	21.0	7.0	28.0	30

For More Information

CA4PRS Website:
http://www.dot.ca.gov/research/roadway/ca4prs/ca4prs.htm

Selected References
Lee, E.B., and Ibbs, C.W. "A Computer Simulation Model: Construction Analysis for Highway Rehabilitation Strategies (CA4PRS)," *Journal of Construction Engineering and Management*, ASCE, approved for publication, June, 2004.

Lee, E.B., Ibbs, C.W., Roesler, J.R., and Harvey, J.T. "Construction Productivity and Constraints for Concrete Pavement Rehabilitation in Urban Corridors." *Transportation Research Record No. 1712*, National Research Council, Washington, D.C., 2000.

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