

Georgia DOT Research Project 11-16

Final Report

EVALUATION OF DATA REQUIREMENTS FOR COMPUTERIZED
CONSTRUCTABILITY ANALYSIS OF PAVEMENT REHABILITATION PROJECTS

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16. Abstract: This research aimed to evaluate the data requirements for computer assisted construction planning and staging methods that can be implemented in pavement rehabilitation projects in the state of Georgia. Results showed that two main issues for the use of CA4PRS in the state of Georgia were (1) the need for modifications to GDOT's operating procedures and (2) lack of data required for performing the CA4PRS analysis. Several unavailable data for CA4PRS-based analysis were also identified through this research, such as efficiency for the material delivery trucks, number of batch plants, and lift cooling time for asphalt pavement. The steps involved in running the CA4PRS software for supporting decision making in rehabilitation projects are also described through this research.					
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Executive Summary

The condition of infrastructure in the United States received a poor average grade (D+) in the American Society of Civil Engineers (ASCE) 2013) report card. With the impending end of the serviceable life of the National Highway System, many transportation agencies have increased their focus on preservation, rehabilitation, and maintenance projects. However, these processes may interrupt the flow of traffic in the road networks, in particular urban networks with high average daily traffic, and may require partial or full closures; thus resulting in increased project duration and cost, wasted time, and decreased safety. To overcome this issue, this research aimed to evaluate the data requirements for computer assisted construction planning and staging methods that can be implemented in future pavement rehabilitation projects in the state of Georgia. The Construction Analysis for Pavement Rehabilitation Strategies (CA4PRS) software, a schedule and traffic analysis tool that can help planners and designers select effective and economical rehabilitation strategies, was evaluated in this study. The work plan for the research consisted of six phases: data needs analysis, data collection, data calibration and software trial runs, software performance evaluation, guidelines development, and development of CA4PRS rehabilitation alternative analysis manual for GDOT (Chapter IV of this report). Two case study projects were used for assessing the applicability of the tool. Data was collected on the background of the project, general pavement design information, contractual information, field operations and staging, resources, and constructability and safety issues. A demonstrative run of the CA4PRS program was planned with the data collected but due to lack of complete data from the case study projects, a run using data from a project on I-75 was performed instead. Results showed that two main issues for the use of CA4PRS in the state of Georgia were (1) the need for modifications to GDOT's operating procedures and (2) lack of data required for performing the CA4PRS analysis. Several unavailable data for CA4PRS-based analysis were also identified through this research, such as efficiency for the material delivery trucks, number of batch plants, and lift cooling time for asphalt pavement. The steps involved in running the CA4PRS software for supporting decision making in rehabilitation projects is also described through this research.

Keywords: Constructability, Asphalt Pavements, Staging, CA4PRS, Data Collection

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CHAPTER I

1. Introduction

1.1. Overview

The current condition of infrastructure in the United States received a poor average grade (D+) in a recent American Society of Civil Engineers (ASCE) report card for America's infrastructure (ASCE,2013). Congestion on the nation's roads is increasing and the cost to improve is ever rising, causing the roads grade to drop from a D to a nearly failing D-. For instance, the city of Atlanta ranked 2nd among the most congested cities in the United States. Current spending of \$70.3 billion per year for highway capital improvements is well below the estimated \$186 billion needed annually to substantially improve conditions. Deterioration due to age and use is the main threat to the level of service observed in transportation networks. Many of the pavements on US highways, constructed during the infrastructure construction boom in the 1960s and 1970s, have exceeded their design lives in less than 20 years due to continuously increasing traffic demand. This is evidenced by the fact that over the last 20 years, highway traffic has increased by 75% while highway facilities have expanded by only 4% during the same period (Herbsman and Glagola, 1998). Thus, highway agencies throughout the United States have been quite interested in the overall quality of their highways and bridges (Miller, 2007).

Many of the state transportation agencies (including GDOT) have already responded to the challenges of growing traffic volume and severe budget shortfalls. At many agencies, this practice started with a pavement preventive treatment, which requires the correction of all minor defects, delays future deterioration, and maintains or improves the functional performance of a highway pavement (O'Brien, 1989). These treatments range from relatively benign actions such as pothole patching, joint and bump grinding, etc., to shoulder-to-shoulder applications using thin bituminous coating (chip sealing, fog sealing, slurry sealing, etc.) or thick coats (such as thin hot mix asphalt (HMA) overlays, micro-surfacing, etc.) (Lamprey et al., 2008). The ultimate goal is based on the premise that highway assets should not be left to deteriorate up to the point where major rehabilitation is needed. For instance, there are common forms of rehabilitation

(e.g. resurfacing) that alleviate the need for major rehabilitation. However, at a certain point in the life of a flexible pavement, rehabilitation is required to improve pavement condition and to defer reconstruction (Irfan et al., 2009).

Pavement rehabilitation is defined as a structural or functional enhancement of a pavement which produces a substantial extension in service life, by substantially improving pavement condition and ride quality (Hall et al., 2001). It may include “Recycling” and/or “Reconstructing”; in recycling, the pavement materials are removed for reuse in resurfacing or reconstructing a pavement (or constructing some other pavement). Reconstruction is the removal and replacement of all asphalt and concrete layers, and often the base and sub-base layers, in combination with remediation of the subgrade and drainage, and possible geometric changes.

As most of the national highway system has reached the maximum service life, most transportation departments have turned away their focal activities from the expansion of the highway system to maintaining, preserving, and rehabilitating the existing road network. More than 90 percent of the total transportation volume in the United States relies on various highway systems (Herbsman et al., 1995). The state of Georgia has 17,985 miles (28,945 km) of state highways with additional 1248 miles (2008 km) of Interstate highways. Around 4.5% of the Georgia State highway system is built of Portland Cement Concrete (PCC) and the remaining 95.5% is Asphalt concrete composite (asphalt mixed with mineral aggregates).

Considering the above-mentioned facts, it is inevitable and critical to improve management strategies that optimize the maintenance, preservation and rehabilitation activities by minimizing costs and maximizing production rates.

1.2. Problem Statement

Although investment in new highway construction projects has declined in the last few decades, rehabilitation work and preventive maintenance projects started to have priority in fiscal programs of highway agencies (de la Garza et al., 2011). Unlike new road construction, rehabilitation projects interrupt the flow of existing traffic in the road networks. Depending on the type of interruption, the road may be closed fully or partially

which in both cases causes delays and extra fuel consumption. This problem is maximized when the project is inside an urban network with high average daily traffic (ADT). Because of this unique feature of rehabilitation activities, design and implementation of these projects are more complicated since increase in project duration may cost road users time and safety. These practices were first recorded in the 1998 FHWA report “Meeting the Customer’s Needs for Mobility and Safety During Construction and Maintenance Operations” (FHWA, 1998). According to the report, transportation departments need to recognize the impacts of rehabilitation activities in the planning stage before construction activities. This allows for appropriate cost-effective mitigation strategies to be developed and implemented prior to delays occurring.

With limited resources, decision makers must select and implement the most cost-effective rehabilitation alternatives to provide and maintain the pavements in a serviceable condition. The road transportation system is a large and complex system and the allocation of resources to different rehabilitation tasks requires an effective maintenance strategy based on a long-term perspective (Yadollahi and Zin, 2011). The rehabilitation process of road infrastructure needs a comprehensive study as well as sufficient funding for being completed. Due to constrained resources, it is necessary to make cost-effective decisions with respect to which facilities, which strategy, when to apply it, and to what extent (Bjornsson et al., 2000).

Designing a rehabilitation project is a critical process for which different conflicting objectives should be fulfilled. There should be an effective process that assesses all the possible scenarios and solutions for specific situations in order to find the best fitted answer to the question of improving the efficiency of projects. This cannot happen without a robust planning and staging system in the departments of transportation. The system should provide a solution for the problem of rehabilitation scheduling in a system of pavement facilities (Ouyang and Madanat, 2004). In a recent report from the Transportation Research Board, potential research in the application of information technology to the design and construction of highways has been identified as a key opportunity for administrators, engineers, and practitioners in their quest for improving construction delivery (Hannon, 2007).

In order to address the planning issues of rehabilitation projects, the Federal Highway Administration (FHWA) updated federal regulations governing safety and mobility in work zones: Rule 23 Part 630 Subpart J on September 9, 2004 (Ullman et al., 2009). The Rule requires the implementation of project-level procedures to assess and manage the impacts of highway construction projects. For each project, the regulation calls for a Plans Specifications and Estimate (PS&E) and Traffic Management Plan that considers tools for reducing traffic delay caused by construction.

In addition to the cost and safety issues, there are a number of variables such as design features, traffic impact, constructability, resource availability, staging, and environmental impact that further add to the complexity of the decision process (Lee et al., 2001, Dunston et al., 2000, Roesler et al., 1999). Considering this complexity, public agencies face a challenge in finding economical ways to rehabilitate deteriorating roadways in metropolitan areas while also keeping the traveling public as safe as possible and minimizing disruptions for local communities and surrounding businesses. Therefore, there is a need to study successful planning and staging methods to develop a rehabilitation scenario that has the least negative impact to the traveling public. In recent years, researchers have developed computerized tools that support this decision-making process. One of these tools is the Construction Analysis for Pavement Rehabilitation Strategies (CA4PRS) software. The results of a CA4PRS-based study are useful for transportation agencies for calculating pavement construction productivities for various construction strategies and traffic management scenarios (Gheisari et al., 2012).

1.3. Research Objectives

This study aims at proposing computer assisted construction planning and staging methods that can be implemented in future pavement rehabilitation projects in the state of Georgia. This study seeks to recommend pre-construction level processes for optimizing resources and time for pavement rehabilitation projects by investigating the applicability of the CA4PRS computer model for planning pavement reconstruction projects.

The research will benefit GDOT Engineering and Construction Divisions' personnel by providing guidelines for the collection of data required for an adequate CA4PRS-based rehabilitation alternatives analysis. GDOT personnel will then be able to perform a wide

range of analysis, such as evaluation of alternative contracting methods on critical projects where incentives and disincentives are considered, evaluation of contractors' work plans on major projects, evaluation of the impact of rapid construction strategies, and the effect of alternative construction windows among others. In addition, with requirements from the Federal Highway Administration (FHWA) for Traffic Management Plans (TMPs), the use of CA4PRS will allow GDOT to be proactive and prepared to develop and evaluate adequate TMPs that will meet all FHWA requirements.

It is envisioned that with these improved analysis capabilities, GDOT will be able to select the optimum alternative for pavement rehabilitation in the state of Georgia, making it possible to achieve a manageable and balanced schedule (construction production), reduced inconvenience (traffic delay), and thus reducing agency costs as well as user costs.

This study will review data collection practices at GDOT and determine needed changes to satisfy CA4PRS software data needs, and propose these changes to current operating procedures. The goals of the study include:

1. To identify detailed data requirements for a CA4PRS-based analysis and the challenges for acquiring the needed data.
2. To propose a CA4PRS Rehabilitation Alternative Analysis Manual for GDOT, including detailed data collection guidelines.
3. To perform comprehensive and statistically sound data collection on one ongoing GDOT pavement rehabilitation project.
4. To evaluate the performance of CA4PRS for analysis of GDOT projects using data collected from an ongoing project.

The objectives of this study are pursued through a comprehensive data collection effort on the GDOT asphalt pavement rehabilitation project CSNHS-M002-00(970) (I-285 from Paces Ferry Rd. to Ashford Dunwoody Rd.) .To aid with the successful accomplishment of these objectives, a calibration/observation study was performed on GDOT asphalt pavement rehabilitation project CSNHS-M002-00(970). In addition to this project, the research team conducted a pilot data collection effort on project CSNHS-M002-00(967) (I-285 from Ashford Dunwoody Rd. to Henderson Mill Rd.).

1.4. Research Methodology

The work plan for the research consists of six (6) tasks, which are described in the next section. The six tasks and their related subtasks are shown in Figure 1.1.

Task 1: Data Needs Analysis:

Three subtasks were performed in this stage. The first subtask consisted in performing a detailed analysis of GDOT's field management process to determine what data that are relevant to a CA4PRS analysis were currently being collected. Then, the research team determined what needed data were not available and how they can be collected as part of field management practices. The second subtask involved a review of CA4PRS data requirements. The final subtask included a mapping of the data needed by CA4PRS and GDOT's field management practices in order to develop appropriate data collection forms to be included in the Data Collection Practices section of the CA4PRS Rehabilitation Alternative Analysis Manual as can be seen in the Guidelines Development Stage in Figure 1.1. The outcome of Task 1 is a CA4PRS Data Map and Data Collection Forms specific to GDOT.

Task 2: Data Collection:

Data were collected in two GDOT projects. A project observation and data collection plan was developed and implemented for project CSNHS-M002-00(967) in DeKalb County. The plan was evaluated and adjustments were made and implemented on project CSNHS-M002-00(970) in Cobb, Fulton, and DeKalb counties. Data collection was carried out in the field to achieve statistical significance based on sample size and validity of model parameters per descriptive statistics. This task was coordinated with and subject to contractors' schedule of work. A Data Collection form based on the CA4PRS Data Map specific to GDOT was used to collect the data. In addition, video recordings of the process were made on each visit for additional data extraction or verification. Still photographs were also collected at each visit to document the construction process and the data collection process.

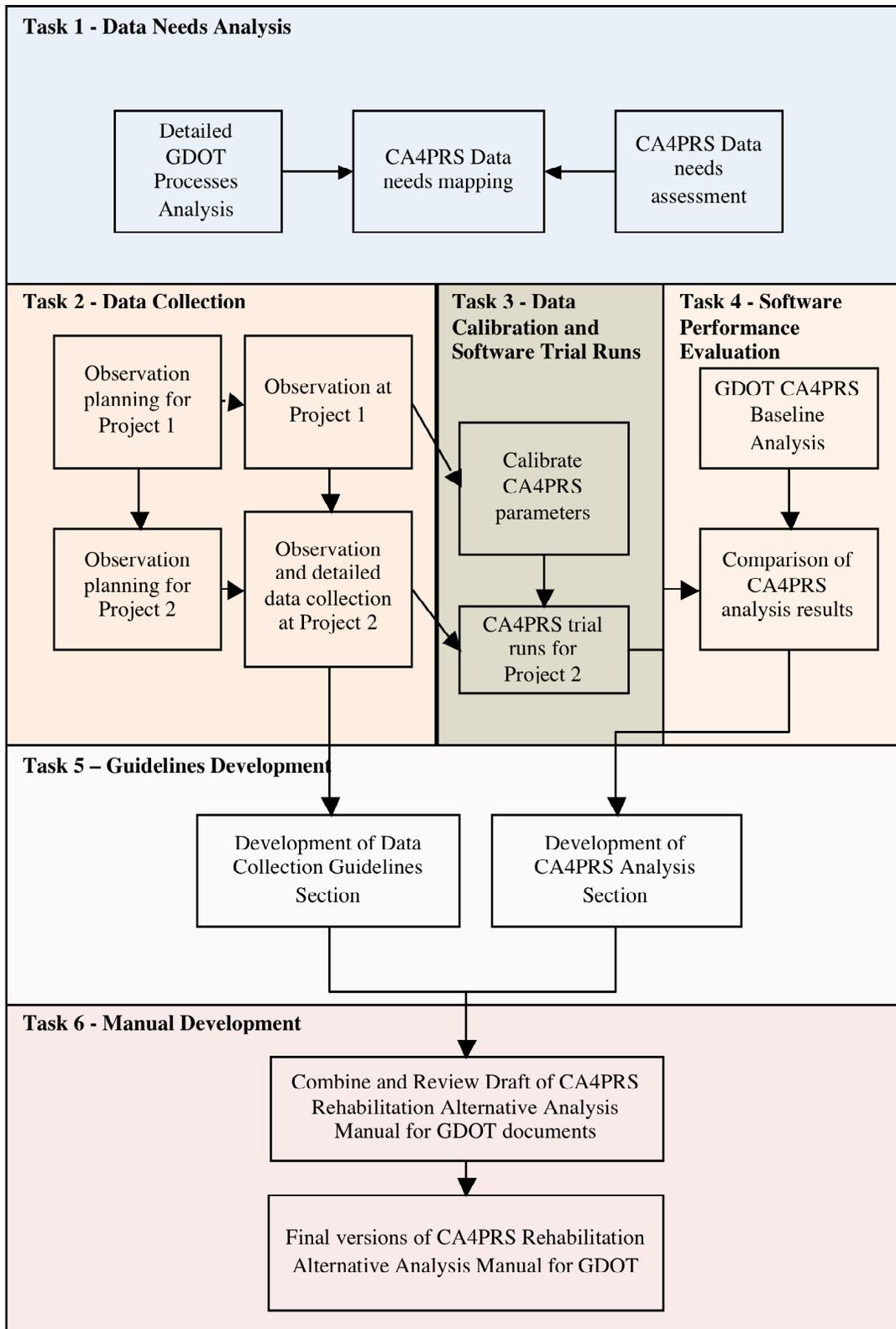


Figure 1.1 Work Plan Flowchart

On project CSNHS-M002-00(967), the research team primarily observed and collected data outside the workzone, unless the contractor permitted access inside the workzone. On project CSNHS-M002-00(970), the contractor's cooperation was required to perform observation and data collection inside the workzone. All safety measures were taken and a pre-site visit safety briefing was done before every site visit. The research team ensured that research team members were given an in-depth safety overview before the first site visit. All research team members were provided with the required safety equipment (included in the budget), which included a hardhat, reflective safety vest and safety glasses. In addition, the research team used safety cones to mark the observation locations.

Task 3: Data Calibration and Software Trial Runs:

In this task, the research team used observations from the first project to calibrate the data needed for CA4PRS input. This calibration entails an analysis of the items needed for input, number of observations for each item, etc. This shaped the plans for observation on the second project. Once observations were made and data collected on the second construction project, the research team entered the data in the CA4PRS program and performed trial runs with the collected data.

Task 4: Software Performance Evaluation:

In this task, the research team worked closely and in collaboration with designated GDOT Design personnel that will be running the CA4PRS program using baseline data and their own assumptions for non-baseline values. The research team discussed with GDOT Design personnel about their experience in using the program for the provided example analysis and the performance of the application.

Task 5: Guidelines Development:

In this task, the research team developed the Data Collection Guidelines Section based on the results of the Data Collection Task and the Software Performance Evaluation Task.

Task 6: Development of CA4PRS Rehabilitation Alternative Analysis Manual for GDOT:

In this task, a CA4PRS Analysis Manual was developed which included the guidelines sections developed in the previous task. This material is included as Chapter IV of this report.

CHAPTER II

2. CA4PRS

In this chapter, the details of CA4PRS procedures and calculations are discussed. CA4PRS, as a schedule and traffic analysis tool, allows planners and designers to select effective and economical rehabilitation strategies to reduce highway construction time and its impact on traffic. Using a simulation approach, the CA4PRS program estimates the maximum probable length of highway pavement that can be rehabilitated given the various project constraints and evaluates “what-if” scenarios with respect to rehabilitation by comparing input variables (Lee and Ibbs, 2005). Since 1999, the capabilities of CA4PRS have been evaluated by various Departments of Transportation and confirmed on several major highway rehabilitation projects in states including California, Minnesota, Oklahoma, Utah, and Washington (Jeong et al., 2010, Collura et al., 2010, Edara, 2009, Lee and Thomas, 2007, Lee et al., 2006). Some of the issues that these states were able to analyze using the program included work zone traffic impact, life-cycle cost analysis, construction productivity, optimal staging configuration, and total cost.

The Georgia Department of Transportation (GDOT) has investigated the applicability of CA4PRS for its concrete pavement rehabilitation projects since 2007, and, in 2010, GDOT completed a second analysis of the application of CA4PRS in collaboration with the Oklahoma Department of Transportation (Irizarry et al., 2008). One of the main findings of these efforts was the need for modifications to the Department’s operating procedures, in order to collect the data necessary for performing a CA4PRS-based analysis of rehabilitation alternatives. The data that would be collected will allow GDOT to adapt the CA4PRS analysis to the specific pavement rehabilitation environment in the state of Georgia. The CA4PRS program continues to be developed and, in the future, will also allow other analyses, such as widening, interchange rehabilitation, and bridge structure replacement, which will be of great benefit to all DOTs, including GDOT.

In September 2009, several GDOT design and construction personnel were trained on the basic navigation features of CA4PRS. During the training session, it was determined by the participants that although the use of the software will bring benefits to pavement

rehabilitation practices by GDOT, many of the required parameters are not available due to the lack of specific field data collection during construction, or due to the use of different staging practices, contracting methods, contractor work plans, or cost determination strategies in the state of Georgia. In addition to the basic features, this chapter explains the logic behind the numbers calculated by the software and also helps in getting a better sense of the input data needed to run the program. Also, it helps departments of transportation, contractors, and individuals to use more precise input data and increase the accuracy of calculations when using CA4PRS.

2.1. Overall Procedure of CA4PRS

A schematic of the procedure used in CA4PRS to calculate the production rate of a closure can be seen in Figure 2.1. To estimate how much pavement can be rehabilitated or reconstructed under different strategies, the following three questions need to be addressed:

- 1- Do we have a schedule that results in a constructible project?
- 2- Do we have tolerable traffic?
- 3- Do we have affordable costs?

Considering the above questions, the program contains two major modules: The scheduling module estimates highway project duration (total number of closures), incorporating alternative strategies for pavement designs, lane-closure tactics, and contractor logistics. In this regard, the program determines the typical processes of pavement rehabilitation from a constructability point of view by identifying the major constraints limiting the production capability of the rehabilitation effort. CA4PRS's traffic module (using the Highway Capacity Manual demand capacity model) quantifies the impact of construction work zone closures on the traveling public in terms of road user cost and time spent in queue.

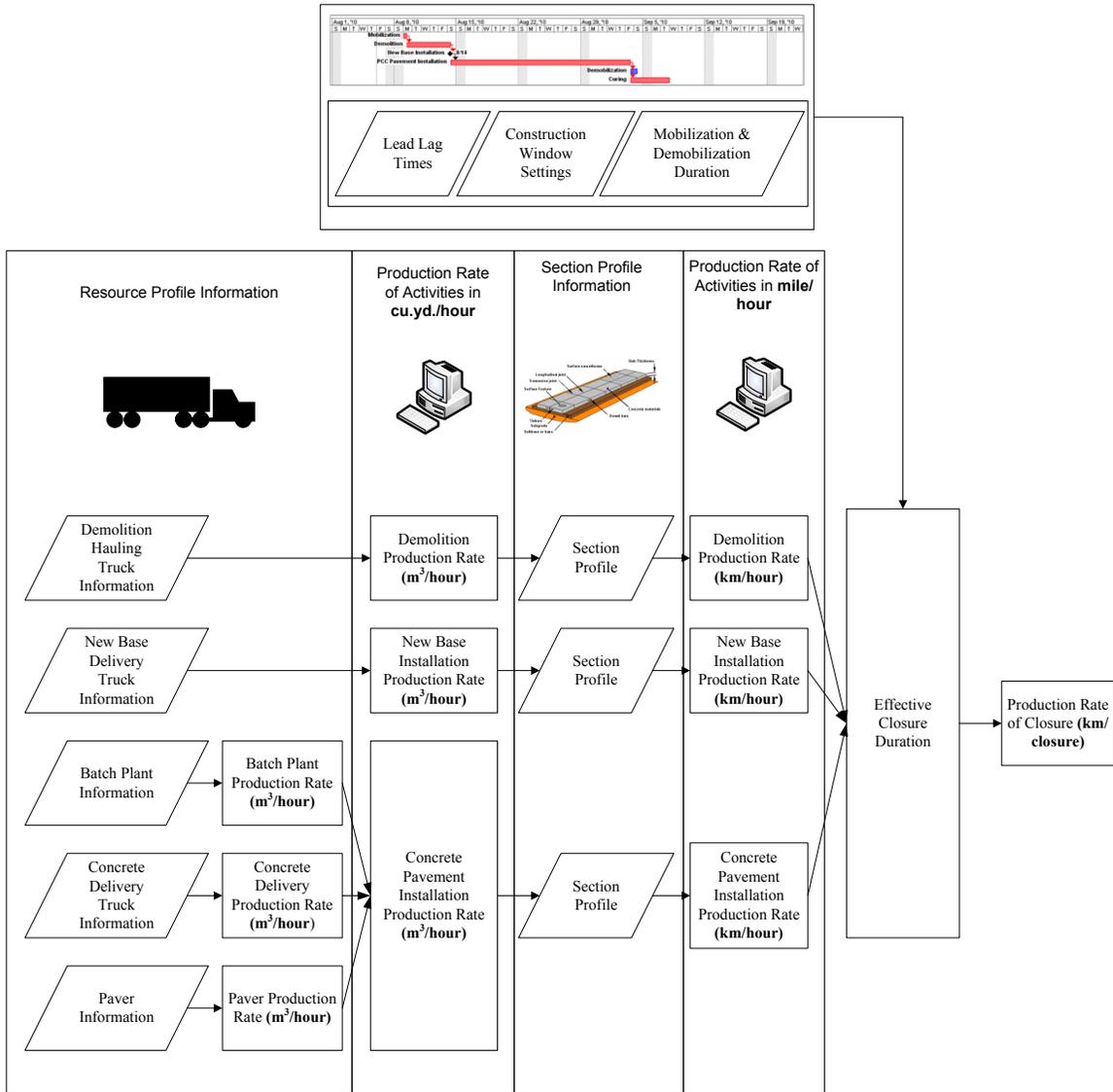


Figure 2.1 Overall Procedures of CA4PRS

CA4PRS receives the production rate of activities in the unit of cubic meter per hour as resource information. Then by combining it with the section profile information, the production rates for each activity are converted to km/hour. Finally by using the lead/lag times, construction window settings, and mobilization and demobilization information, it calculates the effective closure duration and production rate of the rehabilitation in km/closure. In other words, the production rate of each activity, section profile information, lead lag times, mobilization/demobilization durations, and construction windows directly affect the production rate of the closure. Unlike the section profile information and construction window settings which can be clearly determined and input

into the program, the production rate of each activity, lead lag times, and mobilization/demobilization information are not available and need to be estimated. Considering the fact that this input information directly affects the output results, these types of information are the most critical input information in CA4PRS.

2.2. CA4PRS Data Requirements

In this section, the data requirements of CA4PRS for asphalt pavement rehabilitation projects are discussed. The data inputs are specified in the software and in the manual provided by the software developers, but in this section the requirements will be discussed in more detail. This will clarify the logic behind the numbers calculated by the software and will also help to get a better idea of the input data needed to run the program. Furthermore, it will guide the data collection process by helping GDOT personnel identify potential sources from where to get the information needed and who is responsible for collecting the data. This will facilitate the implementation of CA4PRS and will indicate to GDOT personnel which data is the most sensitive input information that has the most influence on the output results of the software. By identifying relevant and necessary information, the accuracy of the results can be increased and more precise information can be used to support decision making for GDOT operations.

2.2.1. CA4PRS Data Need Analysis

The data requirements vary for each rehabilitation strategy since the methods and processes are different as well as the resources needed. In this section, the input data is detailed step by step as well as the location in the software for each rehabilitation strategy.

Milling and Asphalt Concrete Overlay strategy (MACO)

Tab: Project Details

1. Objective/Scope

This input is the total scope of rehabilitation in terms of lane-km or lane-miles. It is calculated as: miles x number of lanes x number of directions

All of the other information is supplementary information that will help identify the project. It is not required for the other windows to be filled in, but it will help keep a record of projects. This information describes the project (i.e. project description, route name, and project notes) and its location (i.e. location, begin MP, end MP). Figure 2.2 shows the project details window of CA4PRS, in which the scope information is entered as well as the project description and location.

Mill And Fill Deterministic - 1. Milling AC Overlay (Weekend Closure): I-15 Mountain Pass Project (Your name)

Project Identifier: 1. Milling AC Overlay (Weekend Closure): I-15 Mountain Pass Project (Your name) Unit: English Metric

Project Details | Activity Constraints | Resource Profile | Schedule Analysis | Work-Zone Analysis | Agency Cost

Project Description: I-15 Mountain Pass Milling AC Overlay

Analyst Name: Your Name Analysis Date: 3 / 1 / 2007

Route Name: I-15 Bailey to Yetz Well Road

Begin MP: 100.00 End MP: 120.00

1 Objective/Scope (lane-miles) 43.50

Location: Mountain Pass, San Bernardino County, CA

Project Notes: Scope = 70 lane-km = 2 lanes x (12.5 mile NB + 9.3mile SB)
6" Milling + 6" HMA Paving

Save Close

Figure 2.2 Project Details

Tab: Activity Constraints

2. Mobilization

The mobilization time in hours is entered in this part. Mobilization is the duration it takes until the major rehabilitation operations start. The traffic closure is the main activity during the mobilization.

3. Demobilization

The demobilization time in hours is also entered in this part. Demobilization is the duration from the time the rehabilitation operations end until the end of the closure. Traffic opening and time allocated for concrete curing are the main activities during the demobilization.

4. Lag Times between Milling and Paving (Finish to Start)

In this section, the lag time between milling and paving is entered in hours. Since Base Paving is not included in this project, only the lag time from milling to paving needs to be specified.

5. Half Closure Traffic Switch

This input is time (hour) minimally required to switch traffic with half-closure from one side of construction to the other side during the AC overlay operation when lifts are placed lane by lane.

Figure 2.3 shows the activity constraints window of CA4PRS. In this window, all the time constraints of the project are entered.

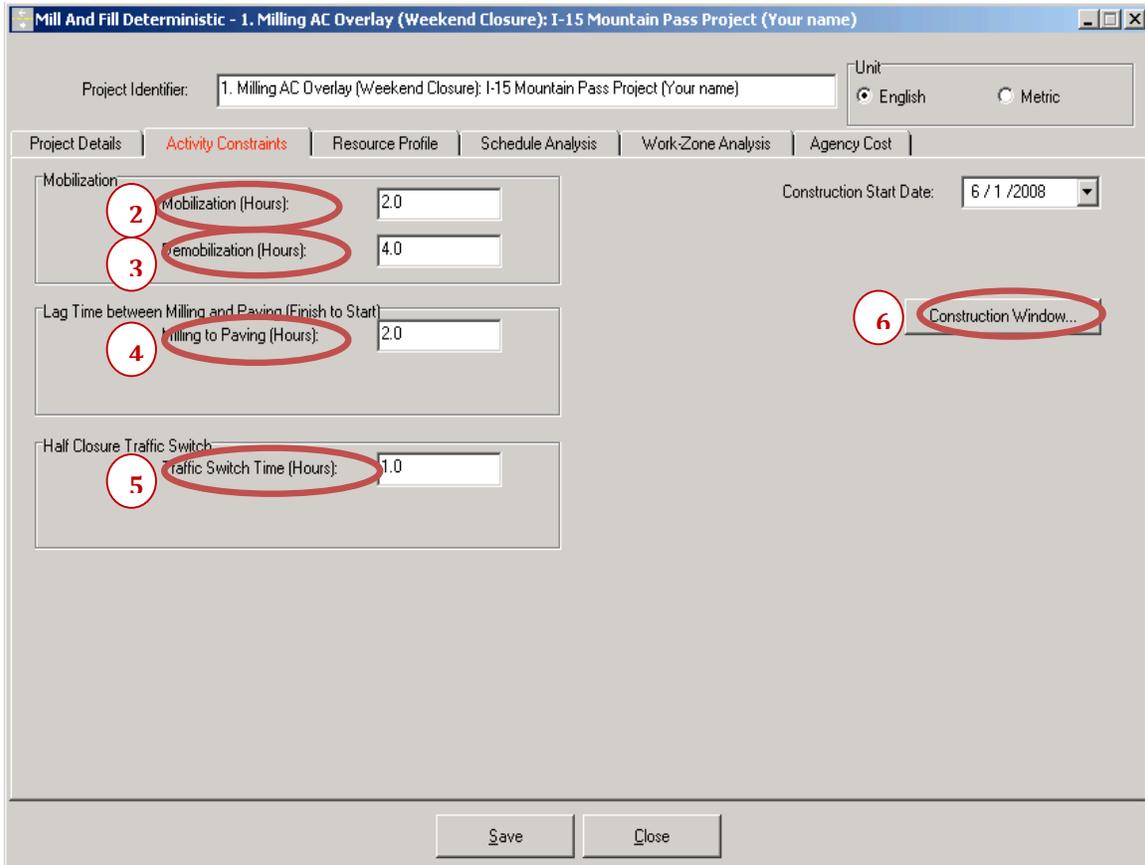


Figure 2.3 Activity Constraints

6. Construction Window Settings

Four construction windows or closure timings have been designed in the program, which are as follow:

- (I) Weekend Closure: In weekend closure construction window, one direction of the road is closed to traffic from Friday night to Monday morning. CA4PRS developer sets the weekend closure time of 56 hours (Friday 9:00 p.m. to the following Monday 5:00 a.m.). The traffic on the other direction of road is counter-flow traffic. The main advantage of this scenario is minimal traffic interruption during the weekdays. The disadvantages of this construction window are repeated mobilization and demobilization, curing time requirements, and higher labor costs on weekends.
- (II) Nighttime Closure: Nighttime closure is the traditional closure scenario. The main advantage of this construction window is less interruption to traffic.

The disadvantages of this closure are limited construction time, higher labor costs, and lower production rates.

- (III & IV) Continuous Closure with Continuous (24-hour) Operation & Continuous Closure with Daytime Shift Operation: This construction window keeps traffic off the newly constructed lanes until the contractor has finished paving. Continuous closures could serve as an alternative strategy because it will reduce the total time required to finish the rehabilitation project. The major advantages of continuous closures are the ability to maximize working hours by minimizing repeated mobilization/demobilization. Based on the number of operation shifts, continuous closure has two options: a) Continuous closure, continuous operation (3 shifts), and b) Continuous closure, daytime operation (1 or 2 shifts). The disadvantages of continuous closure, continuous operation includes the disadvantages of nighttime operations and high labor and equipment costs. These disadvantages can be reduced by using continuous closure, daytime operation which eliminates the disadvantages of construction operations at night.

The durations can be adjusted by the user and reflect the times available to conduct operations. This information is relevant to comparing multiple closure scenarios. Figure 2.3 shows the activity constraints window and Figure 2.4 shows pop-up window for the user to input the detailed information of the construction windows. Note that the information of up to four closures can be entered for a multi-comparison.

The screenshot shows a software window titled "Construction Window Settings". It contains four main sections for configuring work schedules:

- Weekend Closure:** Start Time is Friday 10:00 PM, End Time is Monday 05:00 AM, and Available Hours is 55.0.
- Nighttime Closure:** Start Time on First Day is 08:00 PM, End Time on Next Day is 08:00 AM, and Available Hours per Day is 12.0.
- Continuous Closure/Continuous Operation:** Start Time on First Day is 12:00 AM, No. of Continuous Work Days is 3.0, and Available Hours per Day is 24.0.
- Continuous Closure/Shift Operation:** Daily Start Time is 08:00 AM, No. of Continuous Work Days is 6.0, and Available Hours per Day is 9.0.

At the bottom of the window are two buttons: "Save" and "Close".

Figure 2.4 Construction Window

Tab: Resource Profile

7. Milling and Hauling

This input is the number of teams used for the milling operation and the efficiency of each team in percentage.

8. Milling Machine

In this part, information about the milling machine is entered. It includes machine class, material type, and efficiency factor for downtimes.

9. Hauling Truck

In this part, information about the hauling trucks is entered. It includes rated capacity in tons, trucks per hour per team, and packing efficiency. Packing efficiency is the efficiency of loose hauling volume compared to the solid volume of demolished pavement, depending on the type of demolition methods. Team efficiency decreases by any chance of interference loss. All the information in this part is utilized to

calculate the productivity rate of the demolition activity in unit of volume per unit of time.

10. Batch Plant

In this section, the productivity rate of concrete production is entered. This input includes the number of batch plants used and the capacity in ton/hr.

11. Hot Mix Asphalt (HMA) Delivery Truck

In this part, information about the HMA delivery trucks is entered. It includes rated capacity in tons, trucks per hour per team, and packing efficiency. Packing efficiency is the efficiency of loose asphalt volume compared to the solid volume of asphalt, depending on the type of asphalt. Team efficiency decreases by any chance of interference loss. All the information in this part is utilized to calculate the productivity rate of the paving activity in unit of volume per unit of time.

12. Paver

This input is the non-paving speed of the paver in miles/hr. This information is needed for calculating the distance the paving machine can travel.

Figure 2.5 shows the resource profile window and the space where each data are entered.

Project Identifier: 1. Milling AC Overlay (Weekend Closure): I-15 Mountain Pass Project (Your name) Unit: English Metric

Project Details Activity Constraints **Resource Profile** Schedule Analysis Work-Zone Analysis Agency Cost

7 Land Hauling
 Number of Team: 1.0
 Team Efficiency: 1.00

8 Milling Machine
 Machine Class: Large
 Material Type: AC - Medium
 Efficiency Factor for Downtimes: 0.70

9 Hauling Truck
 Rated Capacity (ton): 26.5
 Trucks per Hour per Team: 12.0
 Packing Efficiency: 0.75

Batch Plant
10 Capacity (ton/hour): 30.7
 Number of Plants: 1

HMA Delivery Truck
11 Capacity (ton): 26.5
 Trucks per Hour: 12
 Packing Efficiency: 0.90

Paver
12 Travel Speed (mph): 15.0

Save Close

Figure 2.5 Resource Profile

Tab: Schedule Analysis

13. Construction Window

In this section, the potential construction windows that can be used are selected. By selecting these windows, the program compares multiple closure scenarios for the same section. The detailed timing of the four main construction windows has already been set in the construction windows settings (see input 6). A user is able to check one or as many construction windows available to make the comparison.

14. Section Profile

The section of rehabilitation is defined in this input. The user may either check the standard section profiles available or define a new section by inputting thicknesses. Also, it should be specified whether the rehabilitation involves a change in roadway elevation or not. By utilizing this information, the program is able to calculate the demolition volume needed for the rehabilitation activity. Like the construction window, section more

than one section profile can be entered for analysis and the program generates the results for all the options.

15. Shoulder Overlay

This input determines if the AC overlay of the outside and median shoulders is done prior to the main lanes within the closure. Pre-paving, where shoulder overlay is excluded from the main closure, should be performed either separately before or after the main line overlay or at the same time as main lane paving. Pre paving is usually done in exceptional projects. Additionally, the outside and inside shoulder widths are entered in ft.

Figure 2.6 shows the schedule analysis window and the space where each data are entered.

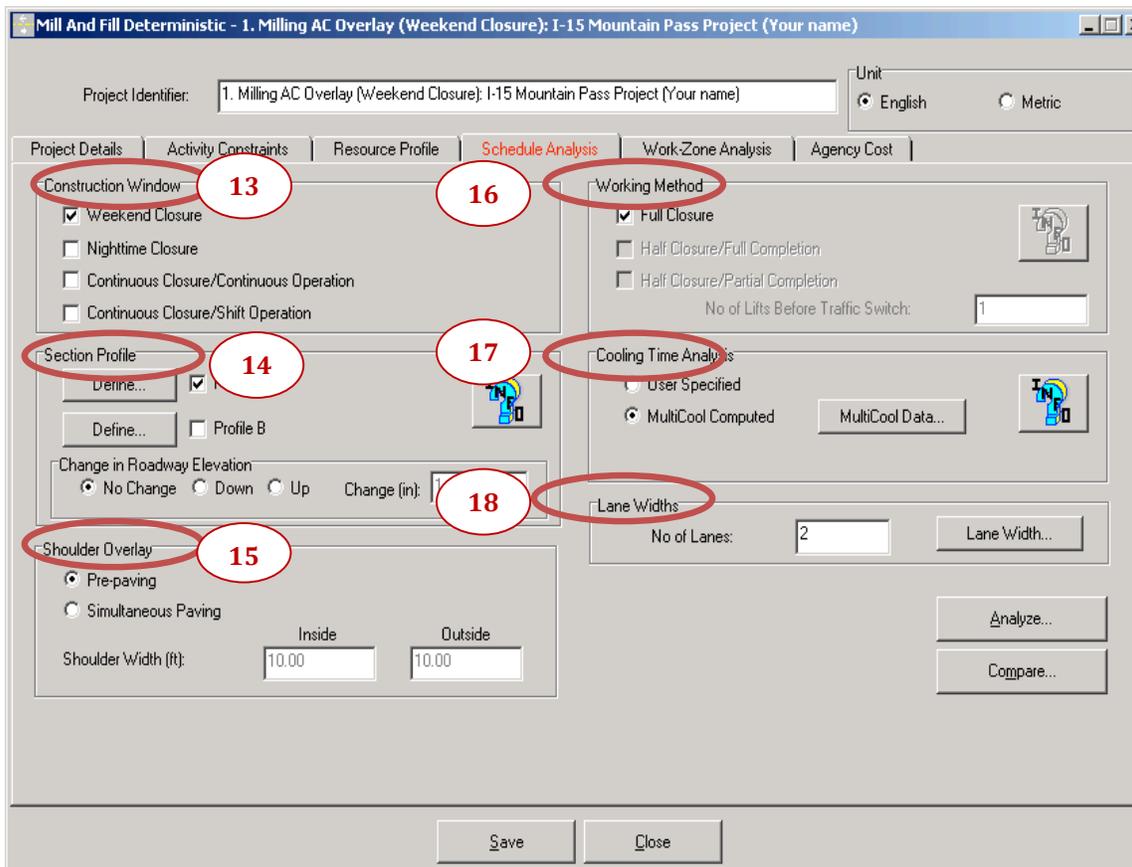
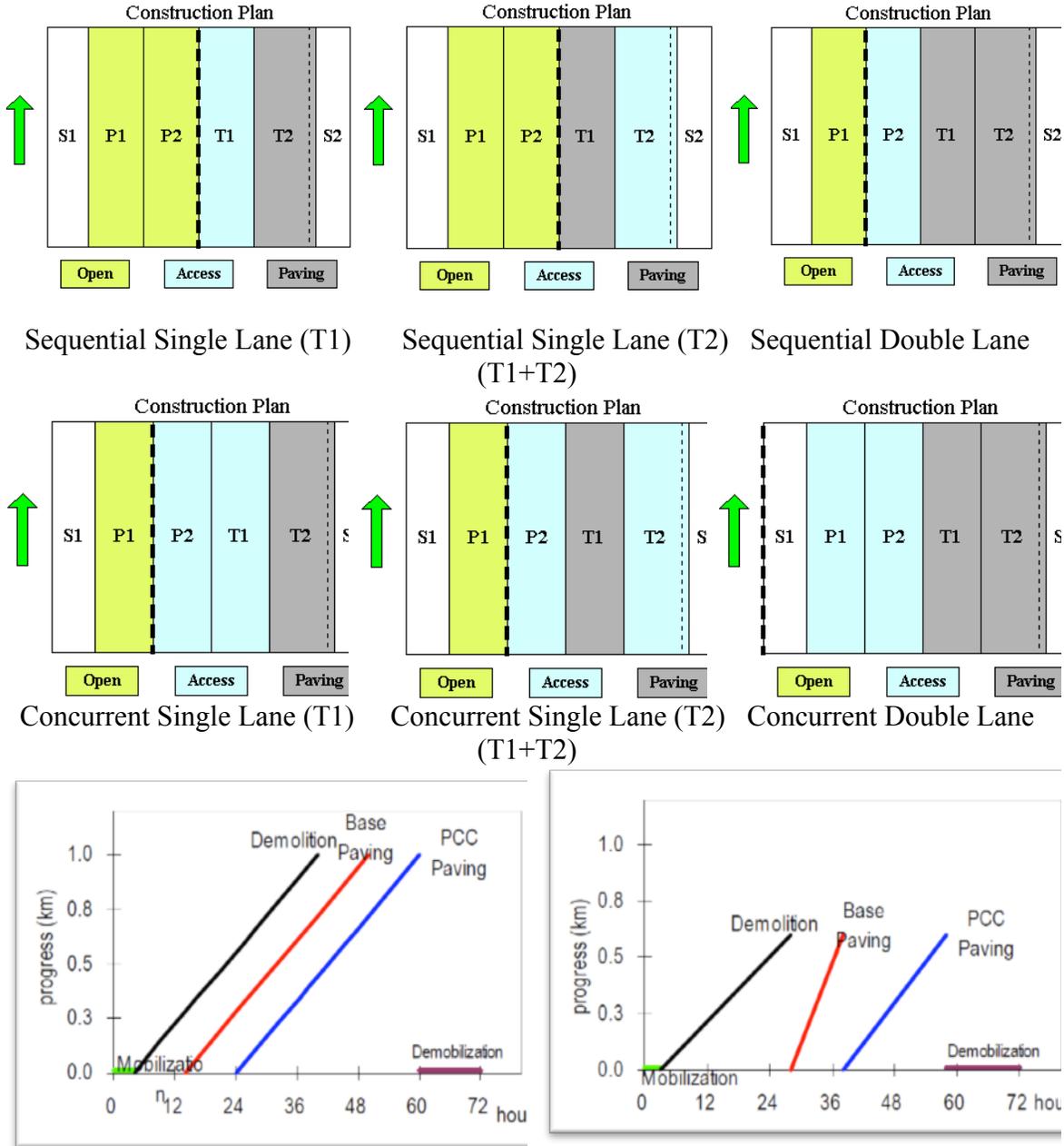


Figure 2.6 Schedule Analysis

16. Working Method

Any of the six working methods as a combination of Sequential or Concurrent and Single or Double lane rehabilitation can be included in the comparison analysis. Figure 2.7 shows different lane closure tactics provided by the program.



Linear Scheduling: Concurrent-Method

Linear Scheduling Sequential Method

Figure 2.7 Lane Closure Schemes and Progress of Linear Scheduling

17. Cooling Time Analysis

This input is the AC cooling time that should be checked to see if there is any interference with the paving suspension. The user specified option allows the user to directly input Lift cooling time. If the user does not have cooling time information and needs a more realistic analysis, it can select the MultiCool computed option. If the MultiCool option is selected, a sub-window is opened so the user can input entries. These entries include existing surface, mix specifications, and environmental conditions for different scenarios. Figure 2.8 shows the MultiCool Data.

MultiCool Data

Construction Start Date: 6/1/2008 Latitude (Deg North): 35

Existing Surface

Material Type: AC

Moisture Content: Dry

Moisture State: Unfrozen

Surface Temperature (F): 80.0

Mix Specifications

Mix Type: Dense Graded

Delivery Temperature (F): 300

Stop Temperature (F): 165

Open to Traffic Temperature (F): 140

Environmental Condition				
Period	Time	Ambient Temperature (F)	Average Wind Speed (mph)	Sky Conditions
1	12:00 AM	65.0	5.0	Clear & Dry
2	06:00 AM	70.0	1.0	Clear & Dry
3	12:00 PM	90.0	1.0	Clear & Dry
4	06:00 PM	80.0	1.0	Clear & Dry

Ok Cancel

Figure 2.8 MultiCool Data

Figure 2.9 shows the HMA Layer Definition.

Lift Number	Lift Thickness (in)	Lift Name	Lift Cooling Time (hour)	Paver Speed (mph)
3	1.00	OGAC	0.50	4.65
2	3.00	HMA (C)	2.00	2.75
1	2.00	HMA (C)	1.00	3.70
Total: 6.00		Average: 1.17		Average: 3.70

Buttons: Insert, Delete, Ok, Cancel

Figure 2.9 HMA Layer Definition

18. Lane Width

Provide the length of the rehabilitation activity, which is utilized to calculate milling, and paving quantities.

Once all the input information is entered, the program will be able to analyze the data and calculate the productivity rate of the closure. The productivity rate of the closure would be the length of the road (in lane-miles) that can be rehabilitated during a construction window. Table 2.1 shows all the data required for running the analysis for the MACO version within CA4PRS software.

Table 2.1 CA4PRS MACO

	Variables	ID	Description	Units	Input
Project details	Objective scope	1A	Total miles per lane* number of lanes	Lane-mile	
	Begin	1B	Begin MP	MP	
	End	1C	End MP	MP	
Activity constraints	Mobilization	2A	Until major rehabilitation operations start	Hr	
	Demobilization	2B	When rehabilitation operations end	Hr	
	Lag time between Milling and Paving (finis h to start)	2C	Milling to paving	Gr	
	Half closure traffic switch	2D	Traffic switch time	Hr	
Construction window	Weekend closure	3A	Start time	Time	
		3B	End time	Time (hr.min)	
	Continuous closure / continuous operation	4A	Start time on first da y	Time (hr.min)	
		4B	No. continuous work days	No.	
		4C	Available hours per day	Hr	
	Nighttime closure	5A	Start time on first da y	Time (hr.min)	
		5B	End time on next day	Time (hr.min)	
		5C	Available hours per day	Hr	
	Continuous closure / shift operation	6A	Start time on first da y	Time (hr.min)	
6B		No. continuous work days	No.		
6C		Available hours per day	Hr		
Resources	Milling and hauling	7A	Number of teams	No.	
		7B	Team efficiency	%	
	Milling machine	8A	Machine class	Large/medium/small	
		8B	AC material type	Hard/medium/soft	
		8C	Efficiency factor	%	
	Batch plant	9A	Capacity	Ton/hr	
		9B	Number of plants	No.	
	Hauling truck	10A	Rated capacity	Ton	
		10B	Trucks per hour per tea m	No.	
		10C	Packing efficiency	%	
	HMA delivery truck	11A	Rated capacity	Ton	
		11B	Trucks per hour	No.	
11C		Packing efficiency	%		
Paver	12	Non-paving travels peed	Mile/hr		
Schedule analysis	Section profile	13A	Lift thickness	in	
		13B	Lift name	No.	
		13C	Lift cooling time	Hr	
		13D	Pavers peed	Mile/hr	
	Change in roadway elevation	14A	Change	No/up/down	
		14B	Change	mm	
	Shoulder overlay	15A	Pre-paving	Yes/no	
		15B	Simultaneous paving	Yes/no	
	Simultaneous paving	16A	Shoulder width inside	m	
		16B	Shoulder width outside	m	
	Cooling time user-specified	17	User-specified	Yes/no	
	Multi Cool computed data	18A	Material type	PCCP/granular base/Subgrade	
		18B	Moisture content	Dry/wet	
		18C	Moisture state	Frozen/unfrozen	
		18D	Surface temperature	°C	
		18E	Latitude	°	
		18F	Delivery temperature	°C	
		18G	Stop temperature	°C	
18H		Open to traffic temperature	°C		
Lane widths	19A	No. of lanes	no.		
	19B	Lane width	m		
Working method	20	Full closure	Select/no		

According to the CA4PRS user manual, the major steps in the solution process for PCC reconstruction analysis are described below:

Using the resource profile, construction method, and pavement cross-section, CA4PRS determines the production rate of each of the main rehabilitation activities (unit length/time). CA4PRS determines the effective duration available for major rehabilitation operations after the mobilization and demobilization durations are accounted for within the construction window. Certain activities, such as concrete curing, can continue during demobilization, are taken into account in determining the effective duration.

Based on the selected construction method (concurrent or sequential), CA4PRS identifies the groups of concurrent activities and, using the rates determined above, the critical production activity within each group. Using the linear scheduling technique for critical activities identified in step 3, CA4PRS determines the maximum rehabilitation length that can be achieved within the construction window.

2.2.2. CA4PRS, Exits and Ramps

CA4PRS is not capable of assessing the data associated to the bridges as well as the ramps/exits. The implications of bridges and ramps/exits for the use of the program may be discussed in two different strategies:

1. Concurrent execution;
2. Sequential execution.

In the first strategy, work on bridges and ramps will be carried out parallel to main line work. As previously discussed for mainline work, CA4PRS's traffic module (using the Highway Capacity Manual demand capacity model) quantifies the impact of construction work zone closures on the traveling public in terms of road user cost and time spent in queue. In addition, same as main line work, in bridges and ramps work execution, CA4PRS uses the production rate of activities in cubic meters per hour as resource information. Then by combining it with the section profile information, the production rates for each activity are converted to km/hour. Finally, by using the lead/lag times, construction window settings, and mobilization and demobilization information, it calculates the effective closure duration and production rate of the rehabilitation in km/closure. In other words, the production rate of each activity, section profile information, lead lag times, mobilization/demobilization durations, and construction

windows directly affect the production rate of the closure. Unlike the section profile information and construction window settings which can be clearly determined and input into the program, the production rate of each activity, lead lag times, and mobilization/demobilization information are not available and need to be estimated. Thus, the total duration of the project in this strategy would be the one predicted by the program.

In the second strategy, work on bridges and ramps will be conducted sequentially with main line work. The description would be same as the previously described strategy, but the total duration of the project would be summation of the duration predicted by the program and the duration of work on bridges and ramps.

2.2.3. CA4PRS, Incentives and Disincentives

The Federal Highway Administration has encouraged state transportation agencies to implement Incentive/Disincentive (I/D) contracting provisions to complete projects before their contract completion dates and also to minimize the disruption to traffic flow in road construction projects. Most of the State Highway Agencies use a fixed amount or fixed percent of construction cost as the maximum incentive. Some of them restrict the maximum amount of I/D fees (e.g. 5% of the total construction cost), but others vary their limit amounts depending on the project or do not have any restrictions on amounts (Shr and Chen 2004). In GDOT's case, the disincentive or liquidated damages (LD) amount is specified in Standard Specifications Section 108.08 (updated amounts are included in Supplemental Specifications Section 108.08 and is used for projects let after January 25, 2009). See Figure 2.10 for the updated Schedule of Deductions for Each Day of Overrun in Contract Time from Section 108.08. The LD value for each range of contract amount was determined after a process that considered project duration and costs. The project duration or completion date is estimated based on the selected staging plan and probable activity durations based on historical production rates. GDOT determines the LD daily charges considering the value of the project's scope, the cost of inspection by the department, and road user costs (Flournoy, 2013).

Schedule of Deductions for Each Day of Overrun in Contract Time		
Original Contract Amount		Daily Charges
From More Than	To and Including	Calendar Day, Completion Date or Available Day
\$0	\$500,000	\$84
\$500,000	\$1,000,000	\$151
\$1,000,000	\$2,000,000	\$247
\$2,000,000	\$5,000,000	\$391
\$5,000,000	\$10,000,000	\$713
\$10,000,000	\$20,000,000	\$1191
\$20,000,000	\$40,000,000	\$1869
\$40,000,000	—	\$5089

Figure 2.10 Schedule of Deductions for Each Day of Overrun in Contract Time (GDOT Supplemental Specifications Section 108.08)

For projects that require an earlier completion than what is estimated, which are very rare for GDOT (one or two projects per year), the amounts of early completion incentives are determined by the Division Director of Construction, the State Construction Engineer, and various designers who together determine the incentive rate to be applied to the project (Flournoy, 2013)

The CA4PRS-based rehabilitation alternatives analysis can assist GDOT Engineering and Construction Divisions' personnel in evaluating alternative contracting methods on critical projects where incentives and disincentives could be considered. The Work-Zone Analysis module provides an analytical traffic analysis that can be used for calculating the amount of Incentive/Disincentive. This analysis can also be used to determine if achieving an incentive is feasibility or not and determine the probability of the project incurring in disincentives (LDs). Using average annual daily traffic (AADT) and the closure hours, CA4PRS calculates the hourly traffic demand of the road and, by comparing traffic demand and capacity, it calculates the costs of delays to the public. As mentioned earlier, CA4PRS's traffic module quantifies the impact of construction work zone closures on the traveling public in terms of road user cost and time spent in queue. Using the user costs and delays to the public, incentive/disincentive and lane rental fees can be calculated. Since CA4PRS allows evaluation of the four rehabilitation strategy

alternatives the program contains, GDOT’s personnel could compare different incentive/disincentive clauses in the possible rehabilitation contracts.

2.2.4. Sources to Gather Information

Figure 2.11 illustrates the steps in the methodology for this research. The first task involves a review of CA4PRS data requirements. All the data needs of the CA4PRS were assessed in detail. The output from the CA4PRS data needs assessment was used to develop a data collection form to be used for jobsite observations. The observation study was performed on two GDOT asphalt pavement rehabilitation projects in Fulton County, Cobb County, and DeKalb County, Georgia. The first project was observed from July to September 2011 and the second from September to October 2012.

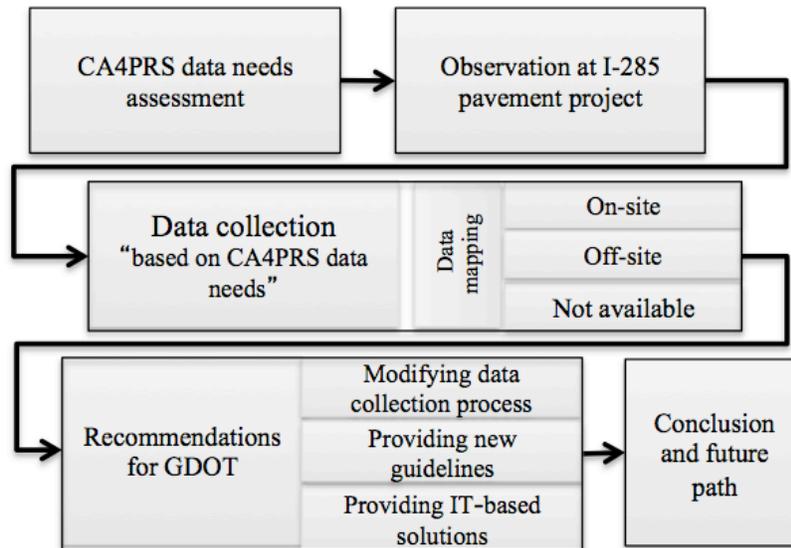


Figure 2.11 Methodology

A detailed analysis of GDOT’s field management process was performed and a data map was developed based on the on-site, off-site, and not available data. The final task included development of recommendations based on the data needed by CA4PRS and GDOT’s field management practices. Finally, conclusions for this stage of the research were provided and next steps were discussed.

2.2.5. Addressing Limited Number of Activities

As can be seen in the Linear Scheduling Diagram shown in Figure 2.12, CA4PRS only considers three major activities and three minor activities for the analysis. The major

activities are Demolition, New Base Installation, and Pavement Installation. The minor activities are Mobilization, Demobilization, and Curing. While minor activities are always assumed to be sequential related to other activities, major activities can be assumed to be either sequential or concurrent related to each other. Also the lead and lag times for finish-to-start (sequential) and start-to-start (concurrent) relationships can be entered by the user. The scheduling of the project is performed by a combination of Critical Path Method (CPM) and Linear Scheduling techniques. In this section, inclusion of other activities and their effects on the scheduling of the project will be elaborated.

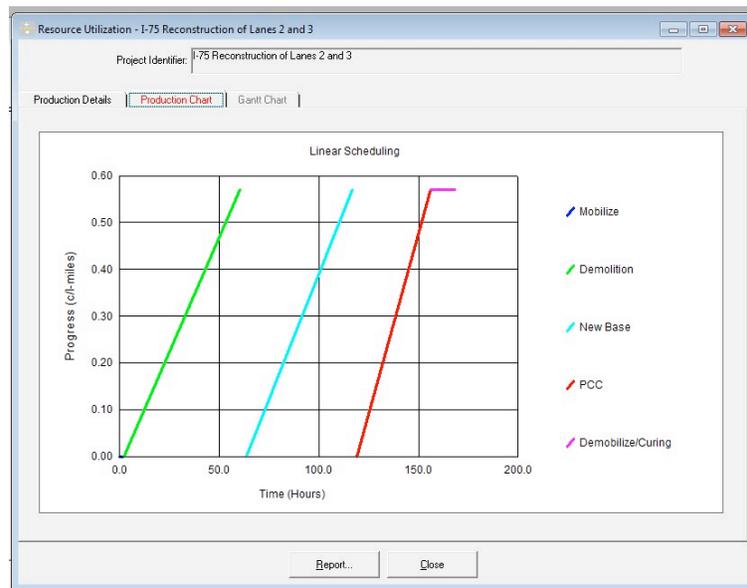


Figure 2.12 Linear Schedule

The number of activities in a rehabilitation project is usually more than these six activities. Activities such as construct crossovers, set temporary barrier, grade shoulders, saw and seal joints, install guardrail, install temporary pavement marking, among others are usually included in a rehabilitation project. In addition, the relationships between such activities may vary based on the situation of project or characteristics of the activity itself. These activities are not analyzed by CA4PRS; therefore, they are not considered in productivity rate calculations.

2.2.6. Resource Profile Information

In using the CA4PRS, the output information is highly dependent on the resource profile information. Although there are guidelines in the software manual that help in choosing

the right resource profile information, standard input information needs to be developed for rehabilitation projects in different states. This is due to the fact that this data is highly dependent on contractors' capabilities and characteristics of projects that are different in each state. For instance, the capabilities of roadway contractors working in California may be higher than the contractors working in Oklahoma in terms of equipment efficiency, resource allocation, and production rates. Consequently, the production rates assumed in California may not be achievable in other states. A standard input data was developed based on analyzing the actual activity durations on the I-285 project, visiting the job sites, and measuring the production rates and the number of pieces of equipment for each activity.

Table 2.2 shows the suggested resource profile information. This study indicates that even in a single job and for a single contractor, the rates are not close to each other. For example, the number of base delivery trucks per hour changed from 14.66 to 32.64 with an average of about 22 trucks per hour (on site) while the CARPRS manual suggests 10-20 delivery trucks per hour. Furthermore, the number of hauling trucks per hour changed from 15.89 to 19.22 with an average of about 17 (on site) while the CA4PRS manual suggests 8-12 hauling trucks per hour. Also Table 2.2 shows the minimum and maximum number of resources together with the average of these numbers and suggested amounts by the CA4PRS manual. This table can be used by GDOT as a starting point and needs to be frequently updated with collected project information from different site conditions and different contractors.

Table 2.2 Suggested Resource Profile Information

Resource Description	Suggested Input Data	Minimum Observed	Maximum Observed	Mean	CA4PRS Manual
Milling and Hauling	Number of teams	1	2	1.5	1 to 2
	Team efficiency	-	-	-	0.75 to 1
Milling Machine	Class	Medium	Large	-	Per Case
	Type	AC-Medium	AC-Medium	-	Per Case
	Efficiency	-	-	-	-
Hauling Truck	Truck Capacity:	-	-	24	15 to 22
	Trucks per Hour per Team:	15.89	19.22	17.26	8 to 12
	Packing Efficiency:	-	-	-	0.70-0.80
HMA Delivery Truck	Truck Capacity: (Specify)	-	-	24	12.4-19.8
	Trucks per Hour:	14.66	32.64	22.13	10-20
	Efficiency:	-	-	-	-
Batch Plant	Capacity: 200 ton	-	-	-	246-411
	Number of Plants:	1	2	1.5	1
Paver	Non-paving speed: km/hr	-	-	-	30
	Number of Pavers:	1	2	1.5	1

CHAPTER III

3. Case Studies

After assessing the applicability of the tool, two case studies were run using the information gathered from two ongoing GDOT projects. Information that was collected included background of the project, general pavement design information, contractual information, field operations and staging, resources, and constructability and safety issues. The main source of data for the case studies was based on the site visits and monitoring construction activities. Moreover, regular meetings with GDOT and contractor engineers helped the research team to gather the input data for CA4PRS more accurately.

3.1. Case Study I: I-285 Resurfacing from Ashford Dunwoody Road to Henderson Mill Rd. Bridge (CSNHS-M002-00(967))

3.1.1. Project Overview

The objective of Project CSNHS-M002-00(967) was to rehabilitate a 6.43-mile (39 lane-miles) asphaltic concrete pavement segment of Interstate 285 (I-285) located between Ashford Dunwoody Road (milepost 0.59) and Henderson Mill Road Bridge (milepost 7.02) in DeKalb County, GA (Figure 3.1). The highway segment is a heavily congested route carrying about 371,500 vehicles per day (VPD) and its travel way varies from 3 to 6, 12 feet wide lanes. For the entire segment, the rehabilitation strategy was a micro-mill and inlay of travel lanes and shoulder overlap to remove surface irregularities and restore proper grade and transverse slope. The micro-milled surface had to provide a texture suitable for use as temporary riding surface or an immediate overlay with no further treatment or overlays.

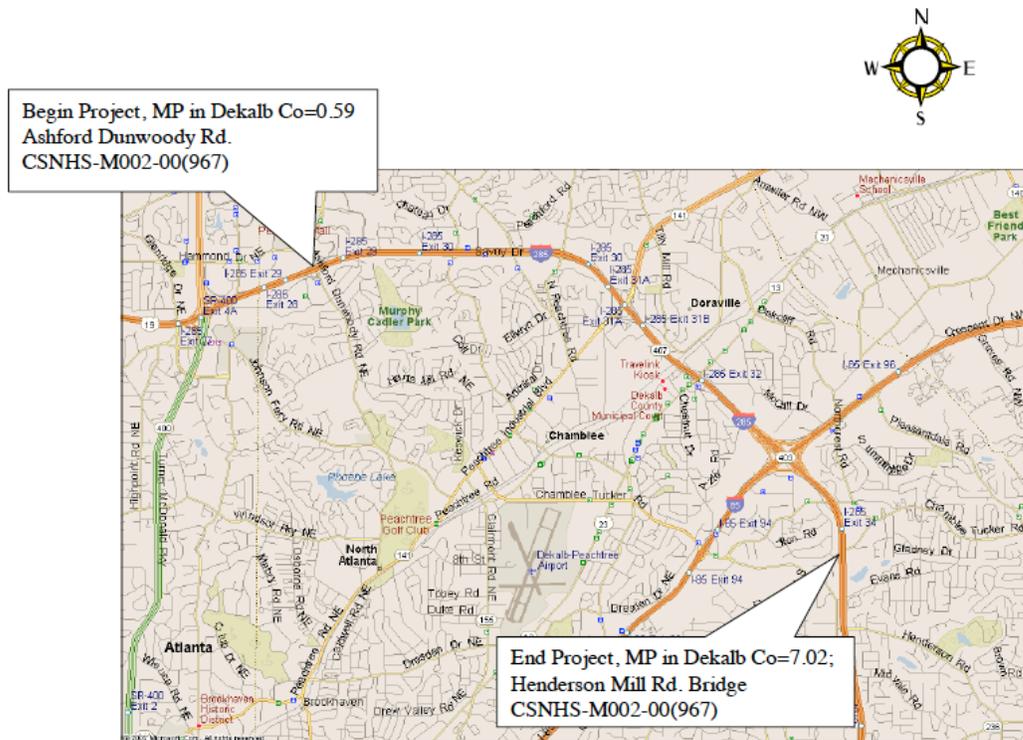


Figure 3.1 Project Location Map in DeKalb County, Atlanta, GA (GDOT, 2012a)

3.1.2. Contractual Features

As per contract requirements, the staging used in the project required the contractor to always maintain two lanes in each direction open for traffic. In addition, the contractor couldn't simultaneously perform work on both inside and outside shoulders in either direction of traffic flow when the work was within 12 ft. of the travel-way, unless such areas were separated by at least one-half mile of distance. Due to reconstruction, ramps had to be completely closed to traffic requiring work to be finished during the allowed 56-hour weekend construction window. The contractor couldn't close lanes or move equipment or materials on the travel way between 5:00AM and 9:00PM Monday morning through Friday evening. Single and double lane closures were allowed on weekdays from 9:00PM to 5:00AM and weekends starting Friday at 9:00PM and ending Monday at 5:00AM. Triple lane closures were allowed on weekdays from 10:00PM to 5:00AM and weekends starting Friday at 10:00PM and ending Monday at 5:00AM. Quadruple closures were only allowed on weekends starting Friday at 10:00PM and ending Monday at 5:00AM. Work that interfered with traffic was not allowed during Memorial Day, Independence Day, and Labor Day.

The project contract included monetary clauses to penalize late project completion and reopening of the highway segment. A late lane-opening penalty of \$2,500 per 1 hr. period without limitation was established if the traffic lanes were not reopened at the times specified. Additionally, a penalty of \$1,000 per calendar day was established if a milled area wasn't covered on same day milled and prior to opening lanes to traffic. Finally, if the contractor failed to complete the work within the time stipulated in the contract, a charge of \$1,191 per day was assessed against any money payable to the contractor. The project was let in April 2011 at a cost of about \$11 million. The Notice to Proceed was given on May 2011 and the first lane and ramp closure occurred in June 2011.

3.1.3. Data Collection Methodology

Data collection was carried out in the field to achieve descriptive statistics based on sample size and validity of model parameters. The contractor would work on the project only during weekends so all the observations happened during this time frame. The research team conducted 10 site visits between July and September 2011. It was agreed with the project contractor that the research team would make weekly site visits to the project and would coordinate with the contractor for access to the work zone. The contractor usually provided information about the segment of the project that would be closed for rehabilitation and the start and end times of construction operations. Since no standard format construction schedule was available, this was the only source of activity performance times. Figure 3.3 shows a sample of the planning information provided to GDOT by the contractor. In addition to the data collection, which was based on the CA4PRS data needs, video recordings of the process were made on each visit for additional data extraction or verification. Still photographs were also collected at each visit to document the construction process and the data collection process. A schematic map of the project was prepared for each week to visualize project completeness. Figure 3.2-a is an example of this visualization and shows the completeness of project at week 5; red color represents scheduled lanes to be paved in week 5 while the gray color represents the lanes that had been paved during the previous weeks. Figure 3.2-b illustrates section b in the Figure 3.2-a and shows project completeness between Ashford Dunwoody Rd and Chamblee Dunwoody Rd in I-285. The research team used the

Atlanta Traffic Cameras (version 1.5) iPhone application (Irizarry, 2011) as well as real-time traffic cameras from the Georgia Navigator website (Georgia Navigator 2011) to confirm locations and status of project activities. Figure 3.2-c shows a screenshot of the Atlanta Traffic Camera application for the I-285 east of Buford Highway. Figure 3.2-d is a still photograph showing the workers doing the pavement activities on one of the lanes on jobsite. Figure 3.3 discusses the schedule bar chart for projects from contractor.

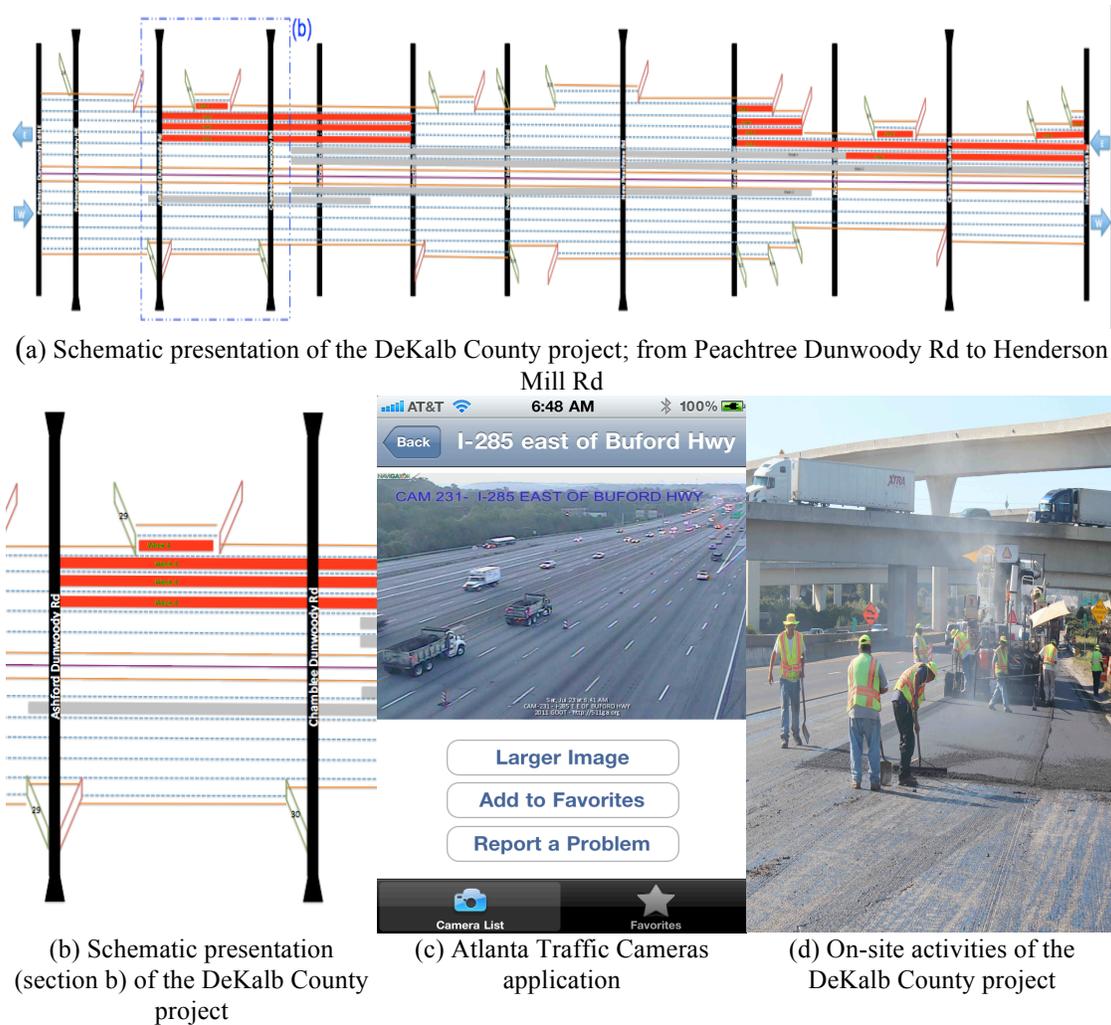


Figure 3.2 Tools Used During the Data Collection Phase



Figure 3.4 Milling & Paving Operations

3.1.4. Data Requirements

Table 3.1 shows the data required to run the CA4PRS software and the source of the data. The “on-site” data was collected on the weekend of August 26, 2011 at CSNHS-M002-00 (967) rehabilitation project in DeKalb County, Georgia. The CA4PRS program uses data for calculation in metric and English units simultaneously; thus, the different units are included in Table 3.1.

Table 3.1 Data requirements of CA4PRS

Variables		Units	Source
Activity Constraints	Mobilization Time	1.5 hr	On-site
	Demobilization Time	1 hr	On-site
	Lag Time between Milling and Paving	24 hr	On-site
	Half Closure Traffic Switch	1 hr	On-site
Construction Window	Weekend Closure	Start time	9:00 PM
		End time	5:00 AM
Resource Profile	Milling and Hauling	Number of teams	2
		Team efficiency	0.875
	Milling Machine	Machine class	Large
		AC material type	AC-medium
		Efficiency factor	0.875
	Batch Plant	Capacity	400 ton/hr
		Number of plants	-
	Hauling Truck	Rated capacity	19 ton
		Trucks per hour per team	10.71
		Packing efficiency	0.75
	HMA Delivery Truck	Rated capacity	20 ton
		Trucks per hour	15.46
		Packing efficiency	-
	Paver	Non-paving travel speed	30 km/hr
Schedule Analysis	Section Profile	Lift thickness	1.5 in.
		Lift name	OGFC
		Lift cooling time	-
		Paver speed	27 ft/min
	Change in Roadway Elevation	Change	No
	Shoulder Overlay	Pre-paving	No
		Simultaneous paving	Yes
	Simultaneous Paving	Shoulder width in	2 m
		Shoulder width out	1.5 m
	Cooling Time User-specified	User-specified	No
	MultiCool Computed Data (non-user specified)	Material type	Granular base
		Moisture content	-
		Moisture state	-
		Surface temperature	-
		Latitude (degree North)	33 degree
		Delivery temperature	320°F
		Stop temperature	275°F
Open to traffic temperature		-	
Ambient temperature		88.5°F	
Average wind speed		12 mph	
Sky conditions	Partly cloudy		

3.2. Case Study II: I-285 Resurfacing from Paces Ferry Road to Ashford Dunwoody Road (CSNHS-M002-00 (970))

3.2.1. Project Overview

The objective of Project CSNHS-M002-00 (970) was to rehabilitate a 10.250-mile (39 lane-miles) asphaltic concrete pavement segment of Interstate 285 (I-285) located between Ashford Dunwoody Road (milepost 0.59) and Paces Ferry Road Bridge (milepost 3.83) in Fulton County, Cobb County, and DeKalb County, GA (Figure 3.5). The highway segment is a heavily congested route carrying about 371,500 vehicles per day (VPD) and its travel way varies from 3 to 6, 12 feet wide lanes. For the entire segment, the rehabilitation strategy was a micro-mill and inlay of travel lanes and shoulder overlap to remove surface irregularities and restore proper grade and transverse slope. The micro-milled surface had to provide a texture suitable for use as temporary riding surface or an immediate overlay with no further treatment or overlays (Figure 3.6).

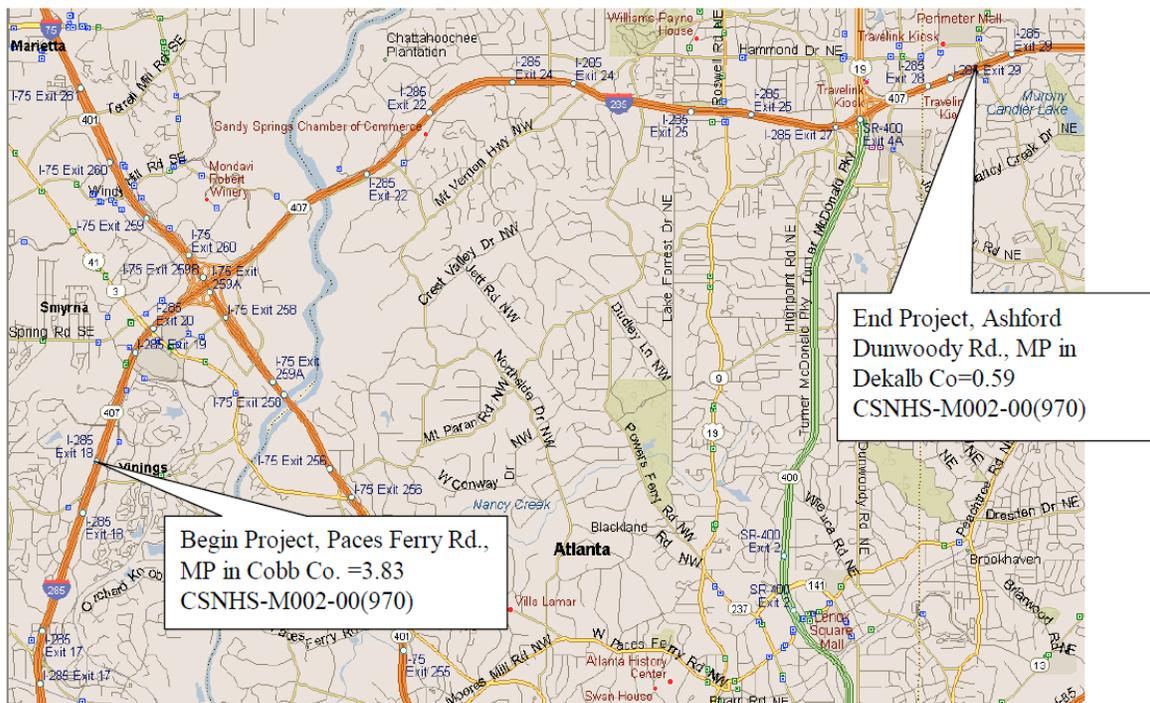


Figure 3.5 Project Location Map in Atlanta GA (GDOT, 2012b)

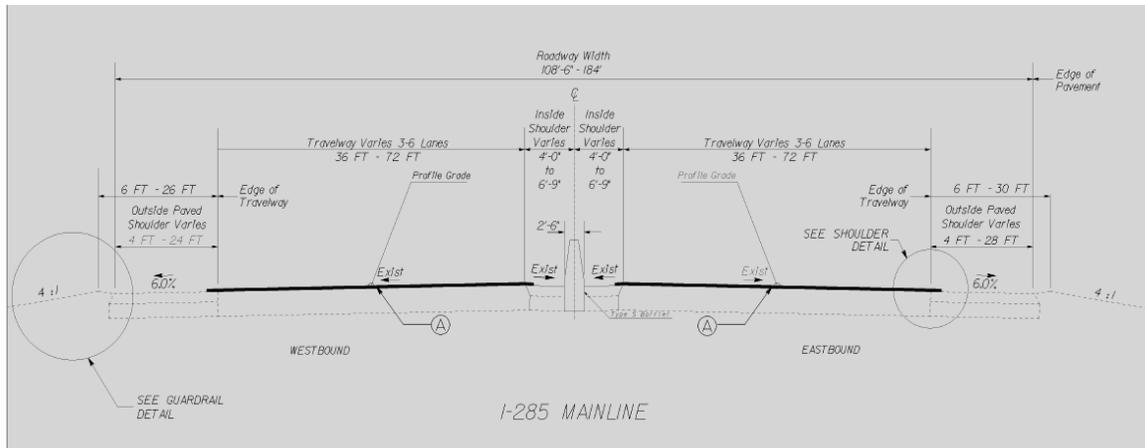


Figure 3.6 Pavement Cross Section

3.2.2. Contractual Features

As per contract requirements, the staging used in the project required the contractor to always maintain two lanes in each direction open for traffic. In addition, the contractor couldn't simultaneously perform work on both inside and outside shoulders on either direction of traffic flow when the work was within 12 ft. of the travel-way, unless such areas were separated by at least one-half mile of distance. Due to reconstruction, ramps had to be completely closed to traffic requiring work to be finished during the allowed 56-hour weekend construction window. The contractor couldn't close lanes or move equipment or materials on the travel way between 5:00AM and 9:00PM Monday morning through Friday evening. Single and double lane closures were allowed on weekdays from 9:00PM to 5:00AM and weekends starting Friday at 9:00PM and ending Monday 5:00AM. Triple lane closures were allowed on weekdays from 10:00PM to 5:00AM and weekends starting Friday at 9:00PM and ending Monday at 5:00AM. Quadruple closures were only allowed on weekends starting Friday at 10:00PM and ending Monday at 5:00AM. Work that interfered with traffic was not allowed during Memorial Day, Independence Day, Labor Day, and Thanksgiving Day through New Year's Day.

The project contract included monetary clauses to penalize late project completion and reopening of the highway segment. A late lane-opening penalty of \$2,500 per 1 hr. period without limitation was established if the traffic lanes were not reopened at the times specified. Additionally, a penalty of \$1,000 per calendar day was established if a milled area wasn't covered on same day milled and, prior to opening lanes to traffic.

Finally, if the contractor failed to complete the work within the time stipulated in the contract, a charge of \$500 per day was assessed against any money payable to the contractor. The project was let in April 2011 at a cost of about \$38,800,370. The Notice to Proceed was given on May 2011 and the first lane and ramp closure occurred in June 2011.

3.2.3. Data Collection Methodology

Data collection was carried out in the field to achieve descriptive statistics based on sample size and validity of model parameters. The contractor would work on the project only during weekends so all the observations happened during this time frame. The research team conducted 6 site visits between September – October 2012. It was agreed with the project contractor that the research team would make weekly site visits to the project. Since no standard format construction schedule was available, this was the only source of activity performance times. In addition to the data collection, which was based on the CA4PRS data needs, video recordings of the process were made on each visit for additional data extraction or verification. Still photographs were also collected at each visit to document the construction process and the data collection process. The research team used the Atlanta Traffic Cameras (version 1.5) iPhone application (Irizarry, 2011) as well as real-time traffic cameras from the Georgia Navigator website (Georgia Navigator 2011) to confirm locations and status of project activities.

A detailed analysis of GDOT's field management process was performed to identify the currently collected data (on-site or off-site) required to perform a CA4PRS analysis. Then, the research team determined what data requirements are not met and how field management practices might be modified to allow collection of the needed data. Figure 3.7 shows some photographs of the project. As previously discussed, all the photographs and videos taken by research team have been enclosed in a Compact Disc.



Figure 3.7 Milling & Paving Operations

3.2.4. Data Requirements

Table 3.2 shows the data required to run the CA4PRS software and the source of the data. The data labeled “on-site” was collected on the weekends of September-October 2012 at CSNHS-M002-00 (970) rehabilitation project in DeKalb County, Georgia.

Table 3.2 Data requirements of CA4PRS

Variables		Units	Source	
Activity Constraints	Mobilization Time	1 hr	On-site	
	Demobilization Time	1 hr	On-site	
	Lag Time between Milling and Paving	1 hr	On-site	
	Half Closure Traffic Switch	1 hr	On-site	
Construction Window	Weekend Closure	Start time	9:00 PM	On-site
		End time	5:30 AM	On-site
Resource Profile	Milling and Hauling	Number of teams	2	On-site
		Team efficiency	0.875	CA4PRS manual
	Milling Machine	Machine class	Medium	On-site
		AC material type	AC-medium	Off-site
		Efficiency factor	0.875	CA4PRS manual
	Batch Plant	Capacity	400 ton/hr	CA4PRS manual
		Number of plants	2	On-site
	Hauling Truck	Rated capacity	20 ton	Off-site
		Trucks per hour per team	10.71	On-site
		Packing efficiency	0.75	CA4PRS manual
	HMA Delivery Truck	Rated capacity	20 ton	Off-site
		Trucks per hour	15.46	On-site
		Packing efficiency	-	Unavailable
	Paver	Non-paving travel speed	30 km/hr	CA4PRS manual
Schedule Analysis	Section Profile	Lift thickness	1.5 in.	Off-site
		Lift name	OGFC	Off-site
		Lift cooling time	-	Unavailable
		Paver speed	27 ft/min	On-site
	Change in Roadway Elevation	Change	No	On-site
	Shoulder Overlay	Pre-paving	No	On-site
		Simultaneous paving	Yes	On-site
	Simultaneous Paving	Shoulder width in	3 m	On-site
		Shoulder width out	3 m	On-site
	Cooling Time User-specified	User-specified	No	Off-site
	MultiCool Computed Data (non-user specified)	Material type	Granular base	Off-site
		Moisture content	-	Unavailable
		Moisture state	-	Unavailable
		Surface temperature	-	Off-site
		Latitude (degree North)	33 degree	Off-site
		Delivery temperature	307.5°F	Off-site
Stop temperature		275°F	Off-site	
Open to traffic temperature		-	Unavailable	
Ambient temperature		74.14°F	On-site	
Average wind speed		5.90 mph	On-site	
Sky conditions	Partly cloudy	On-site		

CHAPTER IV

4. Data Mapping & Implementation

4.1. On-site Data

Information that was collected on-site included activity constraints such as closure schedules, mobilization time, demobilization time, and lag time between milling and paving. Resource profile data such as number of teams, milling machine type, and number of hauling and delivery trucks per hour were also collected on-site. Finally, elevation changes and operations in shoulders as well as weather conditions were also part of the site visit information that was observed, calculated or obtained from personnel at the jobsite. For instance, to calculate the number of hauling trucks per hour, the team timed the trucks' cycle. The cycle started when the milling machine started loading material on the truck and ended when it was completely loaded. A total of 12 measurements were taken, resulting in an average cycle time of 6.53 min and a total of 9.21 trucks per hour.

Table 4.1 CA4PRS On-Site Data Requirements

Variables		Units	
Activity Constraints	Mobilization Time	Hour	
	Demobilization Time	Hour	
	Lag Time between Milling and Paving	Hour	
	Half Closure Traffic Switch	Hour	
Construction Window	Weekend Closure	Start time	AM/PM
		End time	AM/PM
Resource Profile	Milling and Hauling	Number of teams	#
	Milling Machine	Machine class	
	HMA Delivery Truck	Trucks per hour per team	#
Schedule Analysis	Section Profile	Paver speed	Feet per minute
	Change in Roadway Elevation	Change	Yes or No
	Shoulder Overlay	Pre-paving	Yes or No
		Simultaneous paving	Yes or No
	Simultaneous Paving	Shoulder width in	Meter
		Shoulder width out	Meter
	MultiCool Computed Data (non-user specified)	Ambient temperature	Fahrenheit
Average wind speed		Mile per hour	
Sky conditions		Partly cloudy?	

4.2. Off-site Data

Information that was collected off-site included AC material type, capacity of the hauling and delivery trucks, lift characteristics, and cooling requirements and timing. For instance, to determine the lift name, the team met with the contractor and looked at the information on the “request for approval of asphaltic concrete job mix formula” document. All of the data gathered off-site were gathered from the contractor’s documents and their knowledge of the project.

Table 4.2 CA4PRS Off-Site Data Requirements

Variables		Units
Resource Profile	Milling Machine	AC material type
	Hauling Truck	Rated capacity
	HMA Delivery Truck	Rated capacity
Schedule Analysis	Section Profile	Lift thickness
		Lift name
	Cooling Time User-specified	User-specified
	MultiCool Computed Data (non- user specified)	Material type
		Surface temperature
		Latitude (degree North)
		Delivery temperature
Stop temperature		

4.3. CA4PRS Manual

Efficiency factors (milling and hauling team, milling machine, and the hauling truck) as well as the capacity of the batch plant were obtained from the typical values recommended in the CA4PRS manual (CA4PRS User manual 2007).

Table 4.3 CA4PRS Manual Data Requirements

Variables		Units
Resource Profile	Milling and Hauling	Team efficiency
	Milling Machine	Efficiency factor
	Batch Plant	Capacity
		Packing efficiency
	Paver	Non-paving travel speed

4.4. Unavailable Data

Unavailable data include efficiency for the delivery truck, number of batch plants, lift cooling time, moisture content and state, and the open to traffic temperature.

Table 4.4 CA4PRS Unavailable Data Requirements

Variables		Units	
Resource Profile	Batch Plant	Number of plants	-
	HMA Delivery Truck	Packing efficiency	-
Schedule Analysis	Section Profile	Lift cooling time	-
	MultiCool Computed Data (non-user specified)	Moisture content	-
		Moisture state	-
		Open to traffic temperature	-

4.5 Implementation, An Example Project with CA4PRS Software

This section describes the steps that are followed to run the CA4PRS software and support decision-making in rehabilitation projects. As an example of a Portland cement concrete (PCC) project, which is commonly known as jointed plain concrete (JPCP) rehabilitation project, specifically the I-75 project is discussed. This was the example that was provided to GDOT Design Engineers to allow them to experience working with the application. The analysis process would be similar for rehabilitation strategies using other materials such as asphalt so the experience of using the application would be the same. First, all the data variables that need to be entered and the typical values for each of the variables (according to the CA4PRS manual) are described. Second, a brief discussion to aid the user in interpreting the outputs and reports of the software is presented. Any user can start the analysis by inputting data from a project or using an existing project from the CA4PRS database. The data required is divided in four tab windows:

1. Project details
2. Activity constraints
3. Resource profile
4. Schedule analysis

No discussion for the last two tabs, that is, work-zone analysis and agency cost is provided in this report since they are beyond the scope of this research. However, the user is encouraged to look at the CA4PRS manual for a detailed explanation of these two

windows. To run this example the user goes to: File > New > JPCP Rehabilitation > Deterministic. A quick start demonstration with the I-75 rehabilitation project is provided.

Project details: In the project details window (see Figure 4.1), general information about the project is provided including cells such as the project identifier (the file will be saved under this name), a brief description, the analyst name, and route name. In the begin mile post and end mile post cells, the user can specify the mile posts if known, but it is not required.

Construction start date: The date of construction is input for information purposes only.

Objective/scope: In the objective/scope cell, the user must specify the project scope by entering the total lane-miles or lane-km that must be rehabilitated. This value can be calculated as (see equation 1):

$$\text{lane - mile} = \text{miles} \times \# \text{lanes} \times \# \text{directions} \quad (1)$$

This objective is the total length to be rehabilitated, which is the value that serves to determine the number of closures required to complete the project. Finally, in this window, the user can specify the location and add any pertinent notes.

The screenshot shows a software window titled "JPCP Deterministic - 1. PCC Tutorial: I-15 Devore Continuous Closures / 12-h RSC Mix (Your Name)". The window has a tabbed interface with "Project Details" selected. The form contains the following fields and values:

- Project Identifier:** I-75 Reconstruction of lanes 2 and 3 with JPCP
- Unit:** English (selected), Metric
- Project Description:** I-75 Reconstruction of lanes 2 and 3 with JPCP
- Analyst Name:** GDOT
- Analysis Date:** 9/6/2012
- Route Name:** I75
- Begin MP:** 0
- End MP:** 11.5
- Objective/Scope (lane-miles):** 46
- Location:** Dooly County GA
- Project Notes:** Scope=46 lane mile=11.5 mile x 2 lanes x 2 directions

At the bottom of the window, there are "Save" and "Close" buttons.

Figure 4.1 Project Details

Note that the software supports either English or metric units. The input and output values are automatically converted between the unit systems. Once all the data is input for this window, the user should click the save button. It is encouraged to click this button after each input change.

Activity constraints: In the activity constraints window (see Figure 4.2), information about the estimated times for some activities is provided.

Mobilization time: Traffic closure is the main activity during the mobilization. The CA4PRS manual suggests a value of 1 hour for a nighttime closure and about 2 to 3 hours for a continuous weekend closure (55 hour closure).

Demobilization time: On the other side, traffic opening and curing time for concrete or AC cooling are the main activities during demobilization. No typical values are provided in the manual.

Construction start date: The date of construction is input for information purposes only. However, if the user specifies data for the *Multicool* option (for milling

rehabilitation), then this date is considered to calculate curing time considering the intensity of sun radiation.

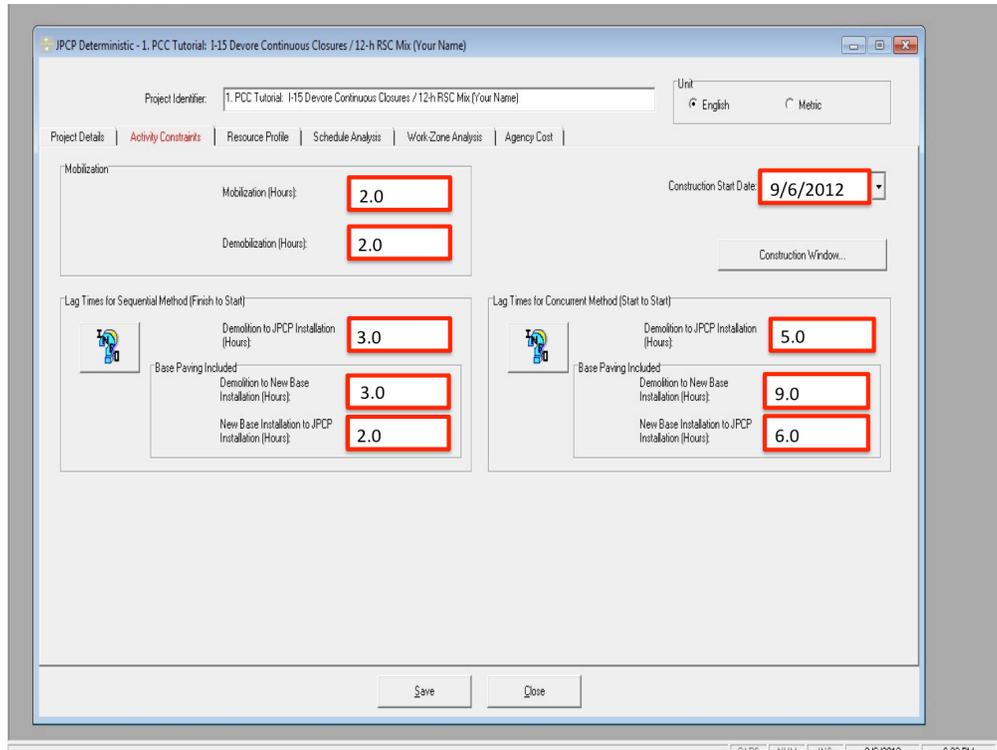


Figure 4.2 Activity Constraints Window

Lag times: The user can specify lag times for sequential method and/or for concurrent method. The lag times that can be specified are (in hours):

- Demolition to JPCP installation
- Demolition to new base installation
- New base installation to JPCP installation

Sequential method: In this rehabilitation strategy, paving can only start after the demolition and base activities are finished. This sequence is required when the activities share the construction access space. Typically, projects use the sequential lag time finish-to-start. A negative number means the following operation can start before (early as the corresponding negative number) the precedent operation is fully completed. An example of a lead-lag time relationship of a sequential method will be illustrated with Figure 4.11 and discussed on the text that precedes the figure. Note that activities start once the precedent activity has finished.

Concurrent method: This sequence is required when there is enough space for construction that activities can occur in parallel. The input gaps or lead times between operations determine the start-to-start relationships. Typically, projects use the sequential lag time finish-to-start. A negative number means the following operation can start before (early as the corresponding negative number) the precedent operation is fully completed.

Construction window settings: In the construction window settings (see Figure 4.3), information about the available construction windows for the project is inputted. The user can specify closure times for:

- Weekend closure
- Nighttime closure
- Continuous closure/Continuous operation
- Continuous closure/Shift operation

The user can adjust the start and end times for both the weekend closure and nighttime closure and the software automatically totals the number of hours available. For both cases of continuous closure, the user just specifies the start time and the number of continuous work-days and the software automatically adjusts the available hours per day. Note that the continuous operation implies a 24-hour operation whether the shift operation implies a daytime shift operation.

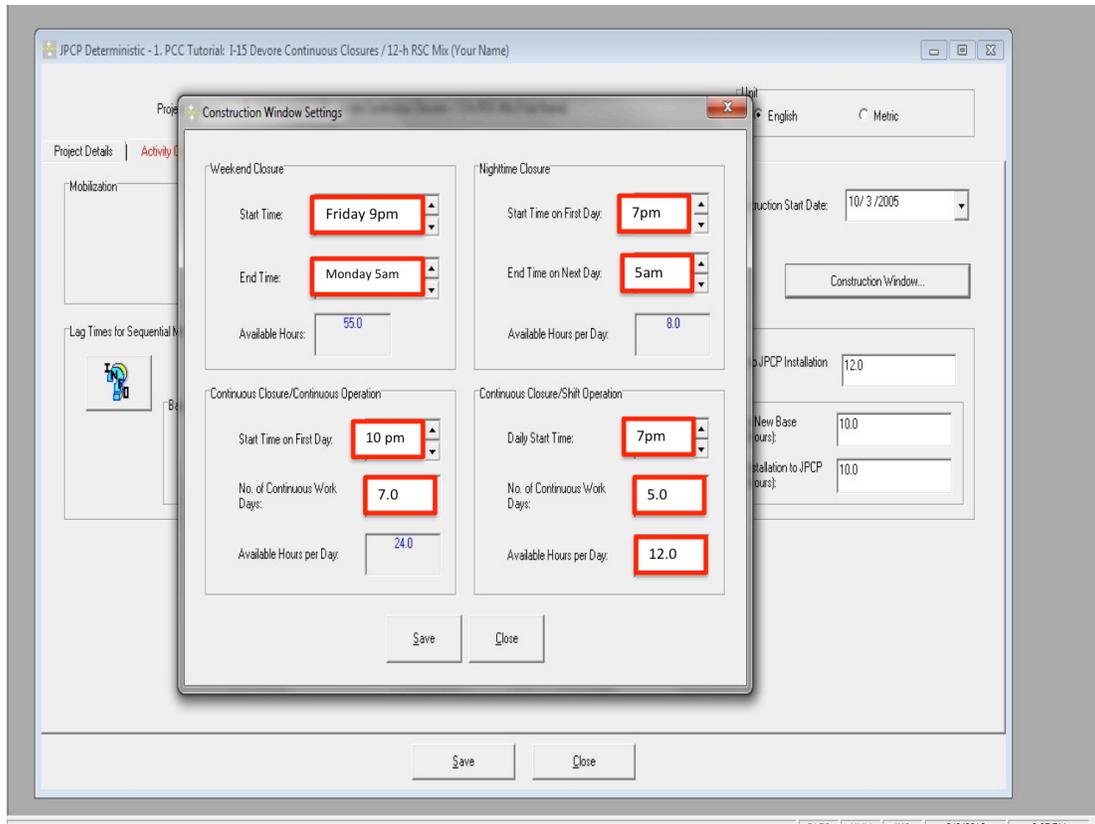


Figure 4.3 Construction Window

Resource profile: In the resource profile window (see Figure 4.4), information about the resources is provided.

Demolition hauling truck: Input information for this resource includes: (based on the CA4PRS manual)

- Rated capacity: usually about 15-22 tons
- Trucks per hour per team: usually 8-12 trucks turned around per hour
- Packing efficiency: usually 0.5 to 0.7 as the efficiency. Typical values are 0.5 for non-impact demolition of concrete pavement, 0.6 for impact demolition of concrete pavement, and 0.7 for milling of AC pavement.
- Number of team: crew number usually 1 or 2.
- Team efficiency: usually 0.75 to 1 (considering interference loss).

Base delivery truck: Input information for this resource includes: (based on the CA4PRS manual)

- Rated capacity: usually about 6-10 m³

- Trucks per hour per team: usually 6-10 trucks turned around per hour
- Packing efficiency: no typical values specified in CA4PRS manual.

Batch plant: Input information for this resource includes: (based on the CA4PRS manual)

- Capacity: usually about 100-200 m³
- Number of plants: no typical values specified in CA4PRS manual.

Concrete delivery truck: Input information for this resource includes: (based on the CA4PRS manual)

- Capacity: usually about 6-9 m³
- Number of trucks: 10-15 trucks turned around per hour

Paver: Input information for this resource includes: (based on the CA4PRS manual)

- Speed: 2-3 meter per minute
- Number of paving machines: 1 in most cases

The screenshot shows the 'Resource Profile' window in the CA4PRS software. The window title is 'JPCP Deterministic - 1. PCC Tutorial: I-15 Devore Continuous Closures / 12-h RSC Mix (Your Name)'. The 'Project Identifier' field contains the same text. The 'Unit' is set to 'English'. The 'Resource Profile' tab is selected, showing the following resource configurations:

Resource	Property	Value
Demolition Hauling Truck	Rated Capacity (ton)	18.5
	Trucks per Hour per Team	10.0
	Packing Efficiency	0.60
	Number of Team	2.0
	Team Efficiency	0.875
Batch Plant	Capacity (cu. yd./hour)	196.2
	Number of Plants	1
Concrete Delivery Truck	Capacity (cu. yd)	9.8
	Trucks per Hour	13
	Packing Efficiency	0.6
Base Delivery Truck	Capacity (cu. yd)	10.46
	Trucks per Hour	8
	Packing Efficiency	0.6
Paver	Speed (ft/min)	7.5
	Number of Pavers	1

At the bottom of the window, there are 'Save' and 'Close' buttons. The status bar at the very bottom shows 'CADDS' and 'MILL'.

Figure 4.4 Resource Profile

Schedule analysis: In the schedule analysis window (see Figure 4.5), the user specifies information to run the analysis.

Construction window: In the construction window category, the analyst determines the windows that are available and the ones he/she wants to consider for the analysis. Note that any one closure and up to four closures can be chosen for comparison purposes.

Section profile: In the section profile category, the user specifies the changes of concrete pavement cross section. The INFO button has a more detailed and graphical explanation of typical sections. In the 8 in. alternative, only the existing slab is replaced with a slab of equal thickness. In the 10 in. and 12 in. alternatives, new sections replace the existing base of 6 in. as well. If none of these sections is used, then the user can specify the particular section for the project.

Change road elevation: In the change in road elevation category, the user specifies a situation where the new pavement surface is not the same as the existing surface level. If “no change” is selected, it means the new pavement surface remains the same as the existing pavement surface. If “down” is selected, it means the new surface level after rehabilitation is lower as much as it is specified in the “change” window. Likewise, if “up” is selected, it means the new surface level after rehabilitation is higher as much as it is specified in the “change” window.

Lane width: The width of the new rehabilitated lanes is defined in this input. Typical values are for newly rehabilitated truck lanes, which are 14 ft. wide.

Curing time: In the curing time category, the user specifies the concrete curing time. Note that one curing time can be chosen for analysis, and this time usually depends on the mix design. The time is measured from after concrete placement to opening to traffic. Typical curing times include 4 hr., 8 hr., and 12 hr. The user can also specify a curing time and it can be changed after the initial analysis for a multi-comparison.

Working method: In the working method category, information about the working method for the project is inputted. The user can specify one out of six working methods:

- Sequential single lane (T1)
- Sequential single lane (T2)
- Sequential double lane (T1+T2)
- Concurrent single lane (T1)

- Concurrent single lane (T2)
- Concurrent double lane (T1+T2)

The INFO button has a more detailed and graphical explanation of typical working methods. This information aids the user in determining the type of method which depends on the number of lanes closed for construction and lanes open for traffic.

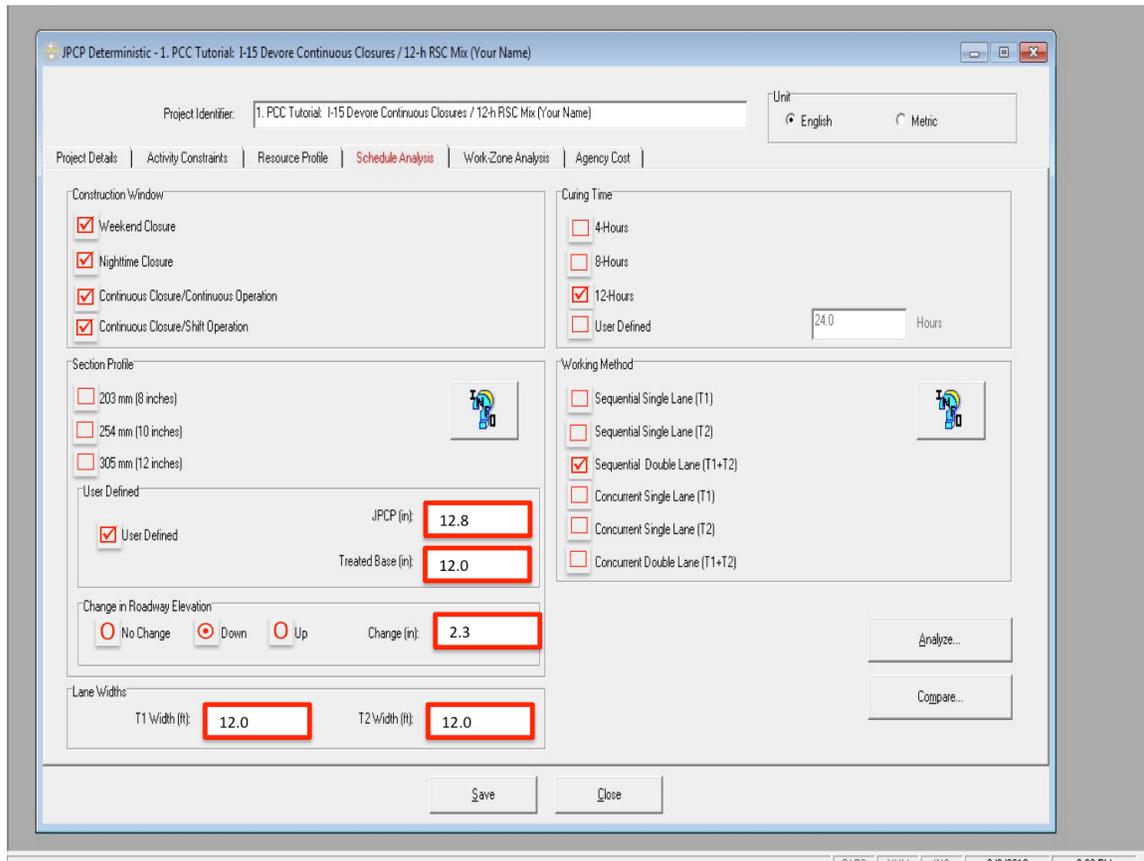


Figure 4.5 Schedule Analysis

Output and results: Once the user has finished entering the values for the variables in the four tab windows, he/she can proceed to analyze and compare different options.

Analyze: When the user clicks the analyze button, the output of the software is a detailed summary and complimentary chart for each of the construction windows selected in the analysis.

Production details: In the production details tab, a table is produced with information about the production and schedule estimates. The “closure production” (highlighted in yellow) provides the estimate of the maximum production in terms of the centerline-miles. In this case, 0.16 miles can be rehabilitated in each closure. The

“construction windows needed to meet objective/scope” determines the number of windows required to complete the rehabilitation project. Around 147 construction windows are required to complete this rehabilitation project. The “constraint resource” identifies the resource that is constraining the production based on the linear scheduling technique. That is, for a higher production, the team needs to increase this resource. Three resources are constraining the production: demolition hauling truck, base delivery truck, and concrete. In other words, all these allocated resources will be utilized during the rehabilitation process.

The table also provides other values that help characterize the rehabilitation production such as the demolition quantity, new base quantity, concrete quantity, and demolition hours among others.

To the right of the general information table, a more detailed table with the allocated and utilized resource quantities is provided. That is, values for trucks, batch plants, and paver quantities are provided, which help the user identify the resources that are scarce and the ones that are exceeding their use. By changing the quantities of resources, a better allocation of costs can be achieved. The costs of excess resources can be allocated to resources that will help increase the overall production.

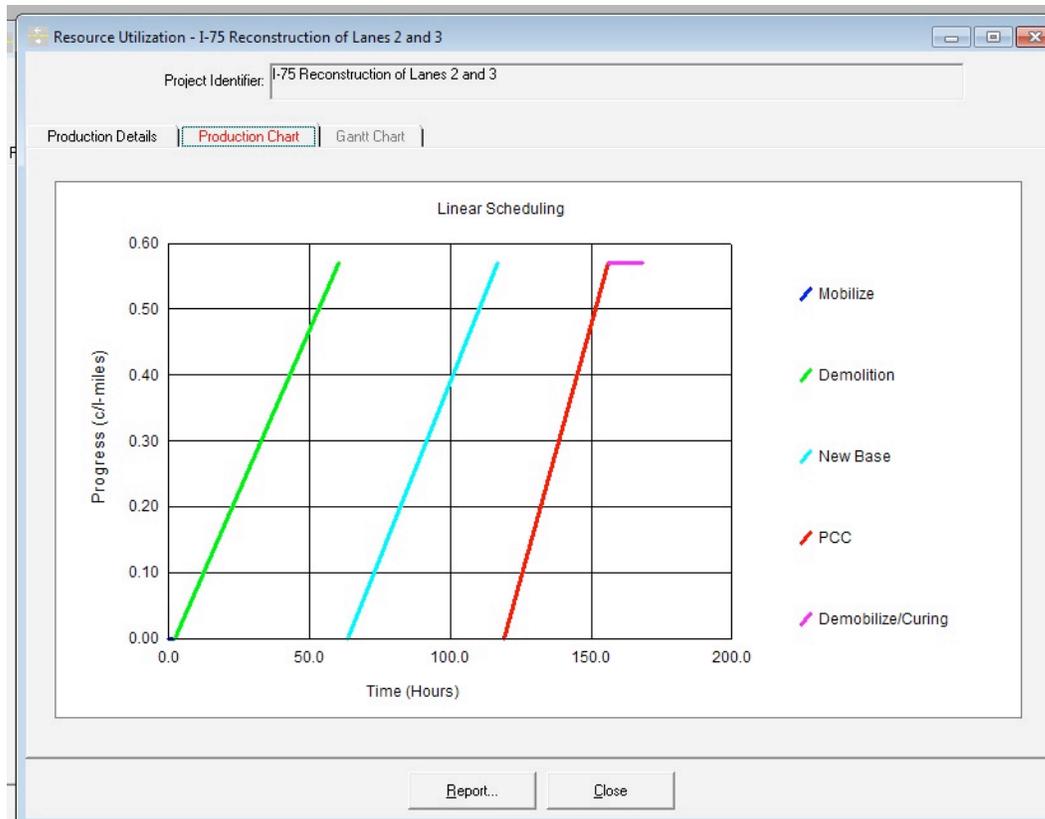


Figure 4.7 Output – Production Chart for “Closure Production = .16”

Figure 4.8 shows the output for the weekend closure construction window. Note that 0.14 centerline-miles are produced requiring a total of about 163 closures for the project completion.

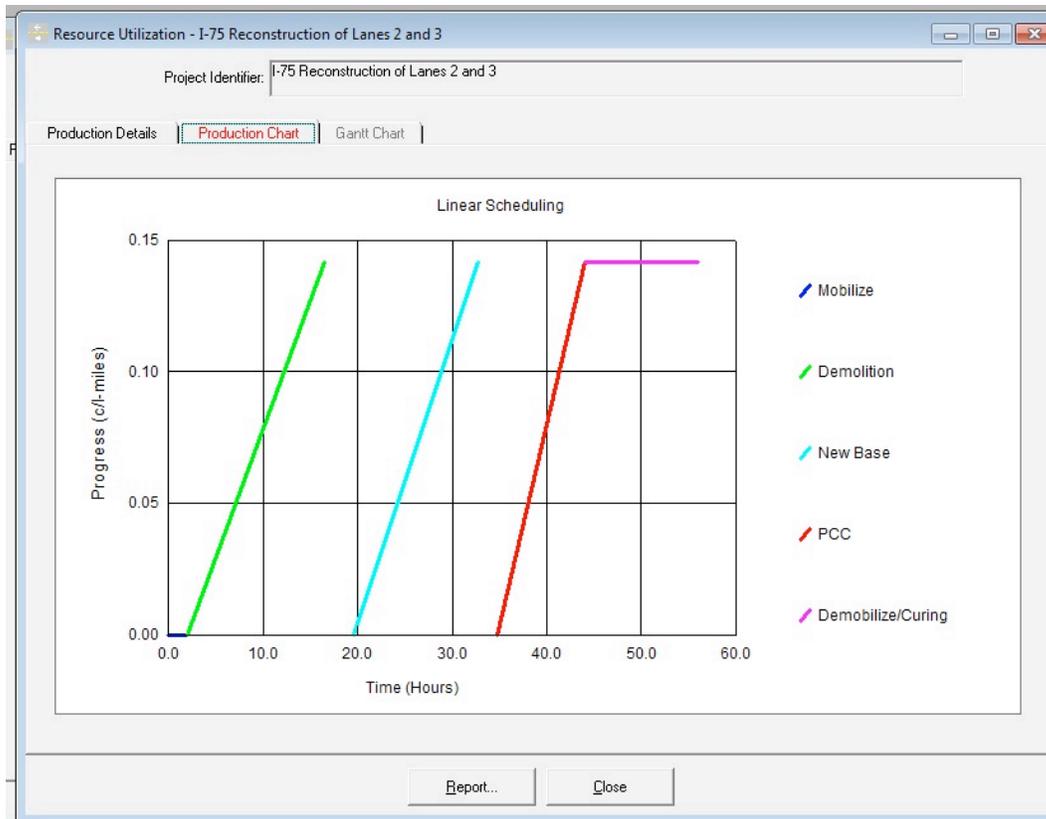


Figure 4.9 Production Chart for “Closure Production = .14”

Figure 4.10 shows the output for the continuous closure continuous operation option. Note that 0.57 centerline-miles are produced requiring a total of about 41 closures for the project completion.

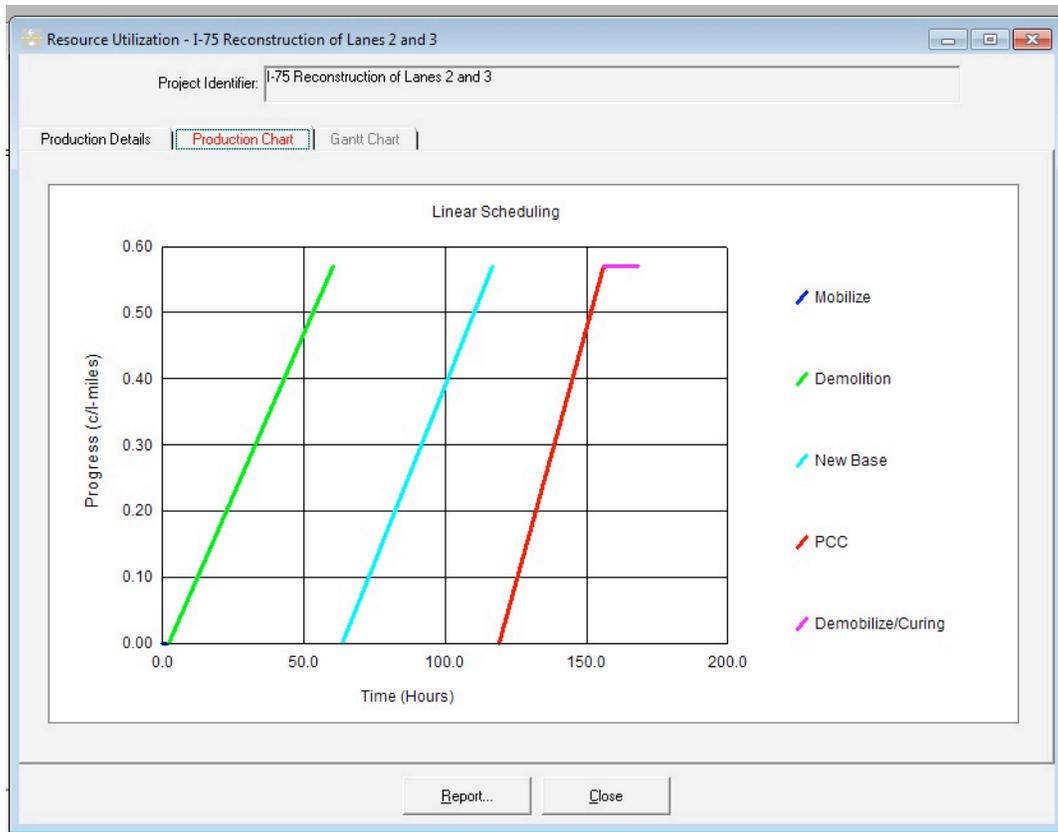


Figure 4.11 - Production Chart for “Closure Production = .57”

Compare: When the user clicks the compare button, a comparison between all the options is determined facilitating the output for a multi-comparison.

Figure 4.12 shows a table for multi-window comparison. As shown in the table, 4 construction window options are evaluated. Note that three windows can be used to complete the objective/scope; but, they do require more than one construction window to complete it. Also note that the nighttime closure option is not feasible since the activities involved cannot be completed during that short period of time.

CHAPTER V

5.1. Conclusion

This study evaluated the data needs for computer-assisted analysis of construction planning and staging methods to optimize resources and to minimize costs (including user costs) and time for pavement rehabilitation projects in the state of Georgia. CA4PRS was used as a computerized tool for calculating pavement construction productivities for various construction strategies and traffic management scenarios. Two rehabilitation projects in the Atlanta metropolitan area were used as case studies to assess the applicability of the tool, and needed changes to satisfy the CA4PRS software data requirements were determined. Examples of these data include, but not limited to the background of the project, general pavement design information, contractual information, field operations and staging, resources, and constructability and safety issues.

The application of the CA4PRS program for the analysis of GDOT projects highlights the need for considering the effect of pavement rehabilitation design on production rate as well as modifications to the Department's operating procedures, in order to collect the data necessary for analysis of different rehabilitation alternatives. Also, the current planning procedures do not evaluate all the possible closure scenarios in selecting the most optimum one for the project. Different closure scenarios (nighttime, weekend, and continuous closures) have different impacts on the traveling public and produce different production rates in the rehabilitation project. All the possible closure scenarios must be evaluated and the one that minimizes the user cost and maximizes the production rate should be selected.

According to FHWA, traffic management plans (TMP) should be established to identify the potential impacts of rehabilitation projects on the public and then mitigate them on the day-of-event. The study showed how the CA4PRS program could help GDOT to develop and evaluate adequate TMPs that meet all FHWA requirements. For example, the CA4PRS's program traffic module quantifies the impact of construction work zone closures on the traveling public, which would enable GDOT's personnel to compare different TMPs in the possible rehabilitation contracts.

This project has also identified some practical shortcomings of the CA4PRS software. The program is not capable of analyzing the impact of exit ramps and bridges on productivity of the rehabilitation project. Two different strategies (i.e. analysis of concurrent and sequential work) for bridges and ramps using the program were discussed in Section 2.2.2 (CA4PRS, Exits, and Ramps). Also, the effect of queuing of resources is not considered in the input information, so the CA4PRS program does not calculate the optimum number of resources. The output of the CA4PRS program is highly dependent upon the input information, which includes resource profile information, mobilization/demobilization durations, lead/lag times and construction windows. Considering the distribution of the data requirements by source, almost half of the information was collected on-site, and other portions were gathered from the CA4PRS program's documentation provided by the software developer, contract documents and meetings with personnel off-site. However, there were several unavailable data for the CA4PRS program through this research (e.g. efficiency for the delivery truck, number of batch plants, and lift cooling time), which posed significant challenges for GDOT Engineers who participated in the study by performing test runs of the software.

For the on-site information, the main challenge was the fact that the contractor had no schedule of the activities that were conducted during each closure. The start and end times of the weekend closure were known in advance, but the specific times of when the activities were programmed were not known. For that reason, the research team scheduled the visits based on the contractor's approximate work times that were e-mailed a few days before the closure as well as by constantly observing road cameras. In addition to the schedule issue, there were also some challenges acquiring the off-site information. The project journals kept by GDOT personnel were not an appropriate source for obtaining the required data. Information regarding material type wasn't available in the construction documents, making it necessary to rely on the information provided by contractor's personnel.

These challenges and the resulting data mapping lead to a set of recommendations that would facilitate the CA4PRS program-based data collection and analysis by GDOT personnel. As shown in the case studies of this research, the CA4PRS program requires

accurate input parameters to produce productivity estimates. To be able to use the program, GDOT has to collect or generate accurate input parameters that reflect realistic construction constraints. In order to produce accurate outputs, GDOT could collect and catalogue input parameter data from construction projects that have different requirements and construction conditions. Also, efforts should be made to collect and develop a database of input data for reliable CA4PRS program-based analysis.

Program users developing project duration estimates for future projects can use these catalogued input parameters for CA4PRS program-based estimates. Additionally, the CA4PRS program has the ability to reduce the amount of construction knowledge necessary for these estimates, but is not a replacement for experience in the design and construction fields. Therefore, experienced personnel in these fields should always review the estimates that result from using the software. Also, GDOT personnel could benefit from the use of IT tools that would facilitate their data collection and analysis process. In addition, simulation programs such as the Cyclone program can be used in determining the optimal number of resources of major activities. The input data for the resource profile tab in the CA4PRS program could be generated using such simulation programs.

The CA4PRS program continues to be developed and, in the future, will also allow other analyses, such as widening, interchange rehabilitation, and bridge structure replacement, which could be beneficial to all DOTs, including GDOT.

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Appendix

Case Study I Site Reports
CSNHS-M002-00(967)

Case Study I: CSNHS-M002-00(967)

Site visit #1

July 15th, 2011

Milling Contractor is Miller Group (subcontract with ER Snell).

The research team arrived to the site around 10:00 p.m. The purpose of the visit was to observe the closure being started and later the actual micro milling operation. No access to the work zone was possible, so the operations were observed from a distance of work on EB (East Bound) Lane 1 from two bridges.

This is Terry Hollis's email on work to be done during the weekend:

...

On Jul 6, 2011, at 12:51 PM, Terry Hollis wrote:

Hello Javier, We will not be doing any micro milling this weekend. Patching and approach slab replacement only. Right now we are scheduled to micro mill and pave back lanes 1&2 the weekend of July 15.

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...

As observed from this first visit:

1. Closure starts at 9 p.m. Friday.
2. It takes the contractor approximately one hour to move the milling equipment and crew into position. During this time, the closure is also done and all the cones and safety information signs are displayed.
3. Milling shifts are typically 12 hours.
4. First milling shift starts on Friday night.
5. Second milling shift starts on Saturday morning and ends on Saturday night.
6. Paving starts on Saturday night.
7. Paving ends around Sunday morning.

As discussed in the meeting of July 19th, Javier Irizarry reported:

...

The GDOT engineers went over the work done during the weekend of July 15. They indicated that work started at the beginning of the project alignment with the micromilling operation on the inside lane until 2 a.m. and then the paving operation started after that going until Saturday night. The contractor also worked on one lane on the east direction that was a change in schedule as notified to GDOT engineers on Friday 15 July around noon. Then work proceeded in the east direction and ended Monday around 4 a.m.

...

Also, in the meeting, it was stated that:

- Velocity of milling machine is around 30ft/min.
- Lead time between milling and paving is 12 hours.
- Total length of 1 bound is around 6 miles.

Case Study I: CSNHS-M002-00(967)

Site visit #2

July 22nd, 2011

Milling Contractor is Miller Group (subcontract with ER Snell).

The milling operations had started at 7:30 am. The research team got there at 9 p.m. and successfully got the data that were needed. Around 11:15 p.m., they left.

As discussed in the meeting of July 19th:

Javier Irizarry reported:

...

GDOT engineers talked about work for the weekend on July 22 which will include micromilling of the remainder of lane one on the east direction starting around 9 p.m. on Friday in the vicinity of Peachtree Industrial Blvd. and paving on that same lane on Saturday night. They indicated that lag time was approximately 24 hours between milling and paving activities This should somehow be verified. It was also mentioned that the long lag time was justified by the slow speed of the paver cited as 30 ft per minute by DOT personnel.

...

Case Study I: CSNHS-M002-00(967)

Site visit #3

July 23rd, 2011

Milling Contractor is Miller Group (subcontract with ER Snell).

The research team arrived to the site around 10:00 p.m. The purpose of the visit was to observe the actual paving operation. Observation of work on EB Lane 1 was done.

As observed from this visit:

1. Closure starts at 9 p.m. Friday.
2. It takes them approximately one hour to move the milling equipment and crew into position. During this time, the closure is also done and all the cones and safety information signs are displayed.
3. Milling shifts are typically 12 hours.
4. First milling shift starts on Friday night.
5. Second milling shift starts on Saturday morning and ends on Saturday night.
6. Paving starts on Saturday night.
7. Paving ends around Sunday morning.

Resources observed and production notes:

- 5 hauling trucks observed
- 1 water truck
- Labor observed in the milling crew was 1 machine operator, 2 workers verifying machine operation and 1 truck flagger (total 4 crew members).
- From marker 498 to 499, 2 min 25 sec.
- There was a 20-minute delay when water ran out and truck had to get more.

Case Study I: CSNHS-M002-00(967)

Site visit #4

August 5, 2011

Time of Observation: determine from images

Location of Observation: determine from images

Milling Contractor is Miller Group (subcontract with ER Snell).

As discussed with Terry Hollis on the phone, Masoud Gheisari reported on the work scheduled for the weekend:

...

Hello Team,

I just contacted Terry Hollis. He said that they will start the micro milling of lane2 EB at 9 p.m. on Friday and the paving on Saturday night at 7p.m.

Regards,

Masoud

...

Milling Machine in Use: CMI1050



The machine has 968 teeth, with approximately 500 needing to be changed typically at approximately 10,000 ft of milling. A CAT 3116 and 3412 engines power the machine. Approximately 400 gallons of water are required for operation of the machine.

As discussed with the foreman “Nino”, the schedule of work is typically as follows:

1. Closure starts at 9 p.m. Friday.
2. It takes the contractor approximately one hour to move the milling equipment and crew into position.
3. Milling proceeds in shifts. First milling shift ends at 7a.m. Saturday. Shifts are typically 12 hours.

4. Road test is performed at 6 a.m. on Saturday (we need to plan to observe this, coordination with DOT will be needed).
5. Second milling shift ends at 7p.m. Saturday.
6. Paving starts at 7p.m. on Saturday.
7. Paving ends around 2 a.m. Sunday.

Foreman indicated that the lag between milling and paving was approximately 24 hours.

Resources observed and production notes:

- 5 hauling trucks observed
- 1 water truck was sufficient for milling and filling 5 truckloads.
- Contractor personnel indicated that approximately 700 ft could be served by one water truck (double check this).
- Labor observed in the milling crew was 1 machine operator, 2 workers verifying machine operation and 1 truck flagger (total 4 crew members).
- From marker 491 to 497, 13 minutes of milling (distance between markers is 1000ft)
- From marker 498 to 499, 2 min 25 sec.
- There was a 20-minute delay when water ran out and truck had to get more.

Case Study I: CSNHS-M002-00(967)

Site visit #5

August 12, 2011

Milling Contractor is Miller Group (subcontract with ER Snell).

The research team arrived to the site around 10:00 p.m. The purpose of the visit was to observe the closure being started and later the actual micro milling operation.

Observations of milling operations of work on EB Lane 3, 4, 5 & 6 were performed. The work covered milling from Ashford-Dunwoody to N Peachtree.

As stated by Terry Hollis in an email sent on August 10th on the work to be done on the weekend:

...

From: Terry Hollis <thollis@ersnell.com>

Date: Wed, Aug 10, 2011 at 5:23 PM

Subject: Re: Site visit for this weekend

To: Masoud Gheisari <masoud.gheisari@gmail.com>

We will be micro milling lanes 3,4,5 & 6 from the beginning of the project to N Peachtree east bound beginning at approximately 10:15 p.m. Friday night. Ashford Dunwoody on ramps will be closed; Chamblee Dunwoody off ramp will be closed. In addition, all of Chamblee Tucker ramps will be closed and repaved. Milling on ramps at Chamblee Tucker will start at approximately 9 p.m. Friday night, and then the Chamblee Dunwoody off ramp will be milled. Paving these ramps will start at approximately 7 a.m. Saturday morning. Mainline paving will start at approximately 7 p.m. Saturday night and continue until complete mid afternoon Sunday. Chamblee Dunwoody off ramp will then be paved to complete this weekend's paving operations. No milling or paving on Ashford Dunwoody on ramps.

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...

As stated by another email from Tim Evans included on an email on August 12th:

The contractor will be working on the EB side this weekend, micro-milling lanes 3, 4, 5, & 6 from Ashford-Dunwoody to N Peachtree. You may want to contact Terry Hollis about the specific location.

Tim Evans

Resources observed and production notes:

- 14 hauling trucks were observed.

Case Study I: CSNHS-M002-00(967)

Site visit #6

August 13, 2011

Time of Observation (road test): 11:00 a.m.-12:00 p.m.
Time of Observation (operations): 8:00 p.m.-10:00 p.m.
Location of Observation: determine from images
Milling Contractor is Miller Group (subcontract with ER Snell).

The research team arrived to the site around 11:00 a.m. The purpose of the visit was to observe the road test that is done right after the milling operations end. We took pictures of the car that is used to do the test, talked to the GDOT engineers that are in charge of the test and observed the reports that are produced after the test.

As observed from the road test visit:

1. Road test is done usually on Saturday morning at different times.
2. It takes them approximately one hour to do the test.
3. The purpose is to check if the width of the road after the milling complies with the requirements.
4. The depth of the milling is typically one inch.

As emailed by Terry Hollis on the road test:

...

GDOT engineers have been doing the road test between 1 a.m. - 2:30 a.m. Saturday morning and between 6 p.m. & 8p.m.

Tim Evans

Construction Project Engineer

Area One Construction

Office#: 404-299-4386

Fax#: 404-299-4387

Cell#: 404-XXX-XXXX

e-mail: XXXXXXXXX@dot.ga.gov

...

Javier Irizarry's comments on the road test:

Ok. Given Tim's response, Masoud, please contact Terry and verify location and time for the 6-8 a.m. road test so you and Laura can be present for it. You will be collecting data in the form of pictures, crew and resource information, and a description of the process with technical details from talking to appropriate personnel if possible.

The research team arrived to the site around 8:00 p.m. The purpose of the visit was to observe the actual paving operation. The operations were observed from the work zone EB Lane 2. The work covered paving from Ashford-Dunwoody to N Peachtree. The

research team left around 10:00 p.m.

Resources observed and production notes:

- 12 HMA delivery trucks were observed.
- For the first time, we were able to see the “paving tickets”. Nathan, a contractor worker, showed us the tickets that are used to charge the paving operations and verify compliance. He said there are 2 copies of the tickets. One is given to the contractor and one is given to GDOT. It has information about:
 - Trucks
 - Driver
 - Pounds of material received
 - Pounds ordered
 - Pounds remaining
 - Address to be delivered
 - Contract number

Case Study I: CSNHS-M002-00(967)

Site visit #7

August 26, 2011

Time of Observation: 11:10 p.m. – 12:50 a.m.

Location of Observation: determine from images

Milling Contractor is Miller Group (subcontract with ER Snell).

The research team arrived to the site around 11:00 p.m. The purpose of the visit was to observe the actual micro milling operation. Access to the work zone was possible, so the operations of work on EB Lane 3, 4, 5 &6 were observed. The team left around 12:50 a.m.

This is Terry Hollis’s email on work to be done during the weekend:

“...285 east bound from Buford Hwy to end project all remaining mainline and ramp lanes that require micro milling. START Friday night at 10 p.m. with micro milling, start repaving operations Saturday a.m. around 9 or 10 a.m. All east-bound (EB) I-285 traffic to I-85 north and south will be directed to the EB which will take them N or S on I-85. The I-85 ramps to I-285 east will be closed Saturday a.m. until repaving and stripping is completed on Sunday. Buford Hwy on-ramp to I-285/85 will be closed Friday night until late Saturday night. The Chamblee Tucker on ramp east bound will also be closed Saturday until paving and stripping is complete on Sunday. All goes well and we will probably close the right ramp lane from I-285 west to I-85 N and S early Sunday to micromill and repave getting ready for next weekend that we work....”

Resources observed and production notes:

- Between truck 3 and truck 4, there was a delay of about 6 min due to traffic. No truck was ready for the milling.
- As discussed with the foreman “Nino”, the reason behind using only 1 water truck is that the contractor estimates that a truck is enough to provide water for the milling operation. No other truck is required since the truck can load the milling machine to its full capacity while getting out of the site to be loaded again without a need to stop the operation. Additionally, the contractor estimates that having an additional truck may save them only about 10-15 minutes in the whole operation, which does not justify the increase in cost of having an additional truck.
- There was a 10:05.18 minute delay when water ran out and truck had to get more.
- 12 hauling trucks were observed.

Case Study I: CSNHS-M002-00(967)
Site visit #8
August 27, 2011
<p>Time of Observation: 5:00-6:40 p.m. Milling Contractor is Miller Group (subcontract with ER Snell).</p> <p>The research team arrived later in the afternoon around 5:00 p.m. The paving operation was observed. The team left the site at around 6:40 p.m. after gathering the necessary data for the analysis. By the time the research group left, the contractor's crew were cleaning the machine, cleaning the extra material that was in the road in the connection between the road and bridge and crews were getting ready to start the paving again in the section after the bridge.</p> <p>Resources observed and production notes:</p> <ul style="list-style-type: none"> • 1 paving machine • Labor observed in the paving operation was 2 machine operators, 2 workers verifying paving pouring in the back, 4 workers with shovels taking the extra material on the sides (the opposite side of traffic) and 2 workers removing the accumulated material in the front of the machine (total 9 crew members). • 10 HMA delivery trucks observed.

Case Study I: CSNHS-M002-00(967)

Site visit #9

September 9, 2011

Time of Observation: 11:30 p.m.-12:30 p.m.

Milling Contractor is Miller Group (subcontract with ER Snell).

The purpose of the visit was to observe the paving. Since the contractor hadn't replied to the emails about the time of site visits, the research team decided to get there based on what was observed in the cameras. Terry Hollis, the contractor, told us he had been really busy and hadn't had a chance to email us on the status of the work. One of the workers told us they started the operations on the previous Wednesday and they had been working on the road to makeup for labor day weekend. By the time we got there, we couldn't take any data. The paving machine had broken and they were waiting to bring a new one to start operations again. The paving machine that was broken was a small paver. The contractor delayed starting work on ramps and waited for another paving machine to be brought to site. The research team left around 12:30 p.m.

As observed from this visit:

- The paving machine is not smaller. All are the same size, but what changes is the "teeth" used in the operation. For a normal lane, the contractor crew uses the 12ft teeth and for the corridor, it uses 7ft teeth.

Case Study I: CSNHS-M002-00(967)

Site visit #10

September 10, 2011

Time of Observation: 4:40 p.m.-6:00 p.m.

Milling Contractor is Miller Group (subcontract with ER Snell).

The first time the research team got there on that day was around 11:45a.m. The purpose of the visit was to observe the paving. Since the contractor hadn't replied to the emails about the time of site visits, we decided to get there in the morning based on what was observed in the cameras. One of the workers told us they had finished paving the east bound at 10:30 a.m. and they were going to start the west bound about 3:30 p.m. We planned on getting there around 4:00 p.m. for a second time.

The research team arrived to the site around 4:40 p.m. Just as we got there, the paving machine that was being discharged with a HMA delivery truck broke. It was broken for about 12 minutes before the operations started again. Then we were able to time 4 trucks before the paving machine broke for a second time. It was broken for about 26 minutes. Then a new truck delivered paving material and the section was completed. After the 5th truck, the operations were stopped since the workers had to wait to start the new section after the bridge. We waited for 10 minutes and then we decided to leave. The machine was still having problems.

As observed from this visit:

1. According to Joseph, one of the contractor's workers, there were 6 crews of 15 people at the beginning of the contract. However, due to a reduction in costs, they were now operating with 4 crews of 15 people.
2. The first time the machine broke down, it was stopped for about 12 minutes.
3. The second time the machine broke down, it was stopped for 26 minutes.

Case Study II Site Reports
CSNHS-M002-00(970)

Case Study II: CSNHS-M002-00(970)

Site visit #1

Milling

Friday, September 7, 2012

- Time of Observation: 10:00 p.m.-12:00 a.m.
- Location of Observation: I-285 between Lake Forrest Dr. NW and Long Island Dr. NW on the West Bound (WB). Lanes 1, 2 and 3 were closed. Lanes 1 and 2 were being constructed and lane 3 was for access.
- The research team arrived to the site around 10:00 p.m. The purpose of the visit was to observe the milling operation. Access to the site was possible.

As observed from this first visit:

- Closure starts around 9:00 p.m Friday.
- It takes the contractor approximately 40 min -1 hour to move the milling equipment and crew into position. During this time, the closure is also done and all the cones and safety information signs are displayed.
- Milling shifts are typically 12 hours.
- First milling shift starts on Friday night.
- Second milling shift starts on Saturday morning and ends on Saturday night.
- Paving started on Saturday morning around 2:00 a.m.
- Paving ends around Sunday morning.
- This was a project with a tight schedule so milling and paving were done simultaneously because they have to be done before Thanksgiving (according to an engineer on site).
- Milling was removing 6 ½ inch of asphalt.
- Crew: one worker was driving machine and one other worker was observing.
- There were 2 milling machines per section.
- The scope of this weekend is 6-7 miles.

Case Study II: CSNHS-M002-00(970)
Site visit #2
Paving
Saturday, September 8, 2012
<ul style="list-style-type: none"> • Time of Observation: 10:30 a.m. -12:00 p.m. • Location of Observation: I-285 between Riverside Dr. NW and Northside Dr. NW on the WB. Lanes 1, 2 and 3 were closed. Lanes 1 and 2 were being constructed and lane 3 was for access. • The research team arrived to the site around 10:30 a.m. The purpose of the visit was to observe the paving operation. Access to the site was possible. • Weather conditions: T: 81°F Wind speed: 10 mph Humidity: 73% <p>Data gathered from the visit:</p> <ul style="list-style-type: none"> • Productivity of paving machine is around 0.277miles/hour. • 3 batch plants are used for the operations. Two are actively used (located in Kennesaw GA 30144) and 1 plant is a backup (located in Norcross GA). • Trucks per hour were stopped at times because of the heavy traffic at that time in the area. • Crew: 1 worker driving truck, 1 supervising asphalt, 1 driving machine, 1 driving paver, about 4-5 looking at material • Delivery temperature of asphalt 300°F (a supervisor from GDOT was measuring the delivery temperature of each truck). • Demobilization takes around 1 hour according to an engineer on-site. • Paving is done as soon as milling is finished (no lag time).

Case Study II: CSNHS-M002-00(970)

Site visit #3

Milling and paving

Sunday, September 16, 2012

For the milling operation:

- Time of Observation: Sunday 11:30 a.m.-14:00 p.m.
- The research team arrived to the site around 11:30 a.m. Access to the site was possible.

Weather conditions:

T: 82° F

Wind speed: 4.5 mph

Weather: Cloudy

As observed from this visit:

- A site engineer told the research team that the start time of the operation was on Friday, 10 p.m., and it will be finished on Monday 5 a.m.
- The mobilization time was 2 hours, and the demolition time was 2-3 hours. It was told us that a water tank will bring water each 30 minutes; however, we just saw one water tank during our observation.
- The inside/outside shoulder width was 10ft.
- The average speed of milling machines was 35 ft/min.
- There were two milling machines working together, for one milling machine 2 trucks and for the other one 8 trucks were waiting.
- The average time to fill a truck was 01:17.0 min, and the average number of trucks filling per 10 minutes was 6.

For the paving operation:

- Time of Observation: Sunday 11:30 a.m.-2:00 p.m.
- The research team arrived to the site around 11:30 a.m. The purpose of the visit was to observe the paving operation. Access to the site was possible.

Weather conditions:

T: 79° F

Wind speed: 3 mph

Weather: Partly cloudy

As observed from this visit:

- A site engineer told us that the lag between milling and pavement is 8 hours, and after a while, there will be a 1000ft lag between milling and pavement.
- The start time of the pavement was on Saturday, 6 a.m, and it will be finished on Monday 5 a.m.
- The mobilization time was 2 hours, and the demolition time was 2-3hours.
- The inside/outside shoulder width was 10ft.
- The average speed of paving machines was 40ft/min.
- There was one paving machine working during observation.
- The average time to fill a truck was 01:38.4 min, and the average number of trucks filling per 10 minutes was 5.

Case Study II: CSNHS-M002-00(970)

Site visit #4

Milling and paving

Saturday, September 22, 2012

For the milling operation:

- Time of Observation: Saturday 11:30 a.m. -12:30 p.m.
- Location of Observation: I-285 between Lake Forrest Dr. NW and Long Island Dr. NW on the EB. Lanes 1, 2, and 3 were closed. Lanes 1 and 2 for access and lane 3 was being milled.
- The research team arrived to the site around 11:30a.m. Access to the site was possible. The milling operation was on the East bound.

Weather conditions:

T: 76°F

Wind speed: 5 mph

Humidity: 64%

As observed from this visit:

1. Crew is: 1 truck driver, 2 supervising milling machine, 1 machine driver (that is a crew per milling machine).
2. There were 2 milling machines. One milled half lane and the other the other half.
3. The machines operated one behind the other with its own trucks.
4. The machines stopped to be re-filled with a water truck. This took approximately 20 min. One machine was filled and the other stopped and then the other way, the one behind resumed operations and the one in front stopped for water.
5. The capacity of the trucks varied. Some trucks were 1.5 times bigger than others. So a wide variety of trucks were being used.

For the paving operation:

- Time of Observation: Saturday 10:00 a.m. -11:30 a.m.
- Location of Observation: I-285 between Lake Forrest Dr. NW and Long Island Dr. NW on the WB. Lanes 1, 2 and 3 were closed. Lanes 1 and 2 were for access and lane 3 was being paved.
- The research team arrived to the site around 10:00 a.m. The purpose of the visit was to observe the paving operation. Access to the site was possible. The paving operation was on the West bound.

Weather conditions:

T: 65°F

Wind speed: 0 mph

Humidity: 90%

As observed from this visit:

- The crew is: 1 truck driver, 1 supervising material, 1 driver of paving machine, 1 driver for pouring machine, 2 supervising paving machine and 1 supervising temperature.
- The supervisor of temperature is a consultant for GDOT from Moreland Altobelli Associates Inc.
- The section to be paved is around 5-6 in.
- The delivery temperature is about 315°F.
- There are 3 shifts during the weekend. The one that was working during the visit started at 5:00 a.m. and went all the way to 6:00 p.m.
- There is no lag time between milling and paving. Paving is done as soon as the contractor cleans the road, but some plastic for protection has to be installed and this takes around 45minutes-1hour.
- Material comes from Norcross, GA.
- According to an engineer on site, mobilization takes 1 hour and demobilization takes around 2 hours.

Case Study II: CSNHS-M002-00(970)

Site visit #5

Milling and paving

Sunday, September 30, 2012

For the milling operation:

- Time of Observation: Saturday 12:30 p.m.-2:00 p.m.
- The research team arrived to the site around 12:30 p.m. Access to the site was possible.

Weather conditions:

T: 75° F

Wind speed: 4 mph

Weather: Partly cloudy

As observed from this visit:

- The site engineer told us that the lag between milling and pavement is 8 hours, and after a while, there will be a 1000ft lag between milling and pavement.
- The start time of the pavement was on Saturday, 6 a.m., and it will be finished on Monday 5 a.m.
- The mobilization time was 2 hours, and the demolition time was 2-3hrs.
- The inside shoulder width was 10ft and the outside shoulder width was 6ft.
- The average speed of paving machines was 45ft/min
- There was one paving machine working during observation.
- The average time to fill a truck was 01:11.8 min, and the average number of trucks filling per 10 minutes was 5.

For the paving operation:

- Time of Observation: Saturday 12:30 p.m.-2:00 p.m.
- The research team arrived to the site around 12:30 p.m. The purpose of the visit was to observe the paving operation. Access to the site was possible.

Weather conditions:

T: 75° F

Wind speed: 4 mph

Weather: Cloudy/ rainy

As observed from this visit:

- A site engineer told us that the start time of the operation was on Friday, 10:30 p.m, and it will be finished on Monday 5 a.m.

- The mobilization time was 1:30 hours, and the demolition time was 1 hours.
- It was told us that a water tank will bring water every 20 minutes; however, we didn't see any water tank during our observation lasting around one and half hour.
- The inside shoulder width was 10ft and the outside shoulder width was 6ft.
- The average speed of milling machines was 50ft/min.
- There were 3 milling machines working together; for one of the milling machine, 1 truck was waiting and 2 trucks were waiting for each of two other milling machines.
- We counted number of trucks and also recorded the filling time of each truck to calculate the average time to fill a truck per team.
- The average time to fill a truck was 02:08.8 min, and the average number of trucks filling per 10 minutes was 4.

Case Study II: CSNHS-M002-00(970)

Site visit #6

Milling

Saturday, October 6, 2012

- Time of Observation: 7:00 p.m -9:00 p.m.
- Lanes 4, 5, and 6 were closed. Lanes 4 and 5 were for access and lane 6 was being paved.
- The research team arrived to the site around 7:00 p.m. The purpose of the visit was to observe the milling operation. Access to the site was possible but very restricted. There were trucks and machines everywhere so they recommended not moving around a lot.

Weather conditions:

T: 73°F

Wind speed: 9 mph

Humidity: 79%

As observed from this visit:

- The crew is: 1 truck driver, 1 milling machine driver, 1-2 supervising the machine and looking at the depth and the water.
- 1 water tank was used and was parked next to the machine.
- All the trucks were parked there in the road waiting to be packed.
- Milling a 1.2 m segment.
- According to the milling machine driver, the speed is about 75 ft/min.
- There are 3 shifts during the weekend.
- 3 lanes open to traffic, 3 lanes closed and the contractor crew was milling lane 7.

Case Study II: CSNHS-M002-00(970)

Site visit #7

Milling and paving

Saturday, October 13, 2012

For the milling operation:

- Time of Observation: Saturday 11:00 a.m.-1:00 p.m.
- The research team arrived to the site around 11:00 a.m. Access to the site was possible.

Weather conditions:

T: 70° F

Wind speed: 6 mph

Weather: Sunny

As observed from this visit:

- A site engineer told researchers that the start time of the operation was on Friday, 9:30 p.m., and it will be finished on Monday 5 a.m.
- The mobilization time was 1 hour, and the demolition time was 1 hour.
- The site engineer told us that a water tank will bring water every 30 minutes; however, we didn't see any water tank during our observation.
- The inside/ outside shoulder width was 10ft.
- The average speed of milling machines was 30ft/min.
- There were 4 milling machines working on two lanes.
- For the four milling machines 13, 3, 4, and 2 trucks were waiting respectively.
- The average time to fill a truck was 02:43.2 min, and the average number of trucks filling per 10 minutes was 3.

For the paving operation:

- Time of Observation: Saturday 11:00 a.m.-1:00 p.m.
- The research team arrived to the site around 11:00 a.m. The purpose of the visit was to observe the paving operation. Access to the site was possible.

Weather conditions:

T: 70° F

Wind speed: 6 mph

Weather: Sunny

As observed from this visit:

- A site engineer told us that the lag between milling and pavement is 9 hours, and after a while, there will be a 1000ft lag between milling and pavement.

- The start time of the pavement was on Saturday, 6:30 a.m. and it will be finished on Monday 5 a.m.
- The mobilization time was 1 hour, and the demolition time was 1 hour.
- The inside/outside shoulder width was 10ft.
- The average speed of paving machines was 47ft/min.
- There was 1 paving machine working during observation.
- The average time to fill a truck was 01:07.2 min, and the average number of trucks filling per 10 minutes was 6.

REQUIRED JOBSITE FORMS

For CA4PRS-related Calculations



**STATE OF GEORGIA
DEPARTMENT OF TRANSPORTATION**

CA4PRS On-Site Data Requirements Form

Project No: -----

Form Completed by: -----

Date of the Report: -----

Time of the Report: -----

Temperature (°F): -----

Site Location: -----

Variables		Value	Units
Activity Constraints	Mobilization time		hrs
	Demobilization time		hrs
	Lag time between Milling and Paving		hrs
	Half closure traffic switch		hrs
Construction Window	Weekend closure	Start time	AM/PM
		End time	AM/PM
Resource Profile	Milling and hauling	Number of teams	#
	Milling machine	Machine class	
	HMA delivery truck	Trucks per hour per team	#
Schedule Analysis	Section profile	Paver speed	Ft/min
	Change in roadway elevation	Change	Yes/No
		Shoulder overlay	Pre-paving
	Simultaneous paving		Yes/No
	Simultaneous paving	Shoulder width in	m
		Shoulder width out	m
	MultiCool computed data (non user specified)	Ambient temperature	°F
		Average wind speed	mph
Sky conditions		-	

Comment:.....



**STATE OF GEORGIA
DEPARTMENT OF TRANSPORTATION**

CA4PRS Off-Site Data Requirements Form

Project No: -----

Form Completed by: -----

Date of the Report: -----

Time of the Report: -----

Temperature (°F): -----

Site Location: -----

Variables		Value	Units	
Resource Profile	Milling machine	AC material type	AC-medium?	
	Hauling truck	Rated capacity	tons	
	HMA delivery truck	Rated capacity	tons	
Schedule Analysis	Section profile	Lift thickness	in.	
		Lift name	OGFC?	
	Cooling time user-specified	User-specified	Yes/No	
	MultiCool computed data (non-user specified)	Material type		Granular base?
		Surface temperature		-
		Latitude (degree North)		33 degree?
		Delivery temperature		°F
Stop temperature		°F		

Comment:.....

