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AN EXPERT SYSTEMS APPROACH TO HIGHWAY CONSTRUCTION SCHEDULING

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A report of the findings of
ICT-R27-86
An Expert Systems Approach to Highway Construction Scheduling

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16. Abstract

The goal of this project was to assist design engineers in developing more realistic construction schedules for a wide variety of IDOT projects. The research involved conducting in-depth interviews with subject matter experts in highway construction firms; reviewing the scholarly literature and published research on expert systems in highway construction scheduling and productivity rates for highway construction activities; analyzing historical weather records published by the National Oceanic and Atmospheric Administration (NOAA) to determine the probable periods during which temperature-sensitive construction operations could be conducted; and synthesizing the expert knowledge developed from all sources in a software tool to assist designers in developing schedules for a variety of typical highway construction activities. The report includes the user manual and documentation for a computer program, the Illinois Construction Scheduling Expert System (ICSES), developed using Visual Studio 2008. ICSES provides 12 road and bridge project templates, each containing typical controlling items and their sequential relationships, links controlling items to the schedule using historical temperature trends at the project location, and provides expert guidance on how to select appropriate production rates for controlling items. The output provides a bar chart schedule with completion date, number of calendar days and working days and tabulates the Estimate of Time Required.

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Michael Ripka, Office of Quality Compliance, Chair
Jerry Cameron, Bureau of Design and Environment
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Al Mlancik, Division of Aeronautics
John Negangard, District 6
Ted Nemsky, District 8
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IDOT District 8 resident engineers (RE) participated in a half-day session in January 2011 during which they provided information regarding RE reporting procedures and the controlling items of work on a variety of projects. The researchers thank Manouchr Bagheri, Scott Bateman, Brad Floerke, Paul Grabowski, Dan Hartwig, John Jilg, Dave Parker, Rich Robben, and Steve Sebena for their contributions.

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DISCLAIMER

EXECUTIVE SUMMARY

OBJECTIVES

The goal of this project was to assist design engineers in developing more realistic construction schedules for a wide variety of Illinois Department of Transportation (IDOT) projects. This goal was met by achieving three objectives. First, the research team captured the essential questions asked by veteran construction schedulers when evaluating a potential project by conducting in-depth interviews with key personnel in highway construction firms, and by reviewing the scholarly literature and published research on expert systems in highway construction scheduling and productivity rates for highway construction activities. Second, the team analyzed historical weather records published by the Illinois State Water Survey (ISWS) and the National Oceanographic and Atmospheric Administration (NOAA) and used the resulting annual trends to determine the probable number of rain days per month and probable periods during which temperature-sensitive construction operations could be conducted. Finally, the research synthesized the expert knowledge developed from all sources in a software tool to assist designers in developing schedules for a variety of typical highway construction activities.

METHODOLOGY

Data collection consisted of reviewing the relevant literature on expert systems in highway scheduling and published research reports related to highway scheduling and productivity rates; reviewing the Standard Specifications for Road and Bridge Construction in Illinois (SSRBCI), adopted January 1, 2007, the Supplemental Specifications and Recurring Special Provisions (SSRSP), adopted January 1, 2010, the Bureau of Design and Environment (BDE) Manual, and project documentation for IDOT projects; interviewing subject matter experts in highway construction scheduling; and gathering available state-wide data on temperature and precipitation in order to evaluate the winter exclusion and other state-wide weather-related restrictions on construction operations.

The data was analyzed by the researchers in consultation with the project Technical Review Panel (TRP). It was determined that a relatively small number of construction activities frequently occur as the controlling items on the construction schedule. These activities were used to develop templates for a variety of commonly occurring IDOT projects. Activities that are restricted by temperature or rainfall per the SSRBCI were identified.

Software synthesizing the knowledge gained from this data analysis was developed to assist design engineers in developing construction schedules and the Estimate of Time Required for a variety of typical highway construction projects. The software tool gives designers guidance in making decisions on how to order the controlling items in the project schedule, the likely duration of various activities, and the likely impact of temperature and rainfall at the project location based on historical records. The software was demonstrated to and tested by a group of IDOT engineers and technicians, and revised in consultation with the TRP to produce the version delivered.

RESULTS

The final report documents the results of the research and includes chapters on the following key topics: 1) interviews of subject matter experts and review of literature, 2) analysis of weather data, and 3) development of highway construction scheduling software, named the Illinois Construction Scheduling Expert System (ICSES). The report also includes the user manual and documentation for ICSES, a Windows-based program developed using Visual Studio 2008. The software provides 12 road and bridge project templates, each containing typical controlling items and their sequential relationships, that

were selected in consultation with the TRP. IDOT is given unrestricted license to use the ICSES software.

CONCLUSION

The research has combined highway construction scheduling expertise from a wide variety of sources, and used that expert input to provide guidance to designers as they estimate the time required to perform various types of construction projects. The resulting ICSES software tool is customized to Illinois, referencing the SSRBCI for temperature constraints on controlling items, using NOAA and ISWS temperature and rainfall records for the state, and incorporating the standard IDOT letting dates for calculating project start dates. ICSES allows users to select the project location within the state and links historical temperature records from that part of the state to specific controlling items in the scheduling template for the selected project type.

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CHAPTER 1 INTRODUCTION

Construction scheduling is a complex process that requires an intimate knowledge of construction methods, materials, equipment, and historical production rates for a wide range of individual activities. More than that, good scheduling takes into account the economies that can be realized by conducting multiple activities concurrently. Further, the scheduler must be able to account for the impact of weather, labor relations, subcontractor qualifications and productivity, material availability, and a host of other factors. The veteran construction scheduler combines science with art to estimate the length of time a project will take to complete. Engineers preparing the engineer's estimate of time required typically rely on historical production rates for coded pay items but lack specific knowledge of the manner in which the contractor will approach the project. The recent success of the I-64 design-build project in St. Louis, Missouri, completed ahead of its aggressive 2-year schedule, is an example of the potential benefits to be gained by learning from innovative construction professionals working in partnership with the DOT to develop the most efficient plan.

The ICT research team conducted a study to determine ways to improve the accuracy of the engineer's estimate of time required on IDOT projects. The aim of the research was to merge the knowledge of the engineer and the contractor in a software tool that will provide highway designers with expert guidance on construction scheduling and productivity. During the initial project meeting, the project TRP emphasized the need for updating the productivity rates found in BDE Manual, Figure 66-2B and used to compute the Estimate of Time Required (BDE Form 220A), and this research task was added.

The goal of the project was to assist design engineers in developing more realistic construction schedules for a wide variety of IDOT projects. The primary objective was to obtain expert input from a variety of sources, including highway contractors, resident engineers (RE), consultants, and the records of completed projects as captured in the RE's diaries and other project documentation, and to capture the essential questions asked by veteran construction schedulers when evaluating a potential project and selecting a strategy to build the project. The insights into contractors' strategies were obtained via semi-structured in-depth interviews with key personnel in highway construction firms. Additional input was obtained through interviews with engineering consultants and IDOT resident engineers, and analysis of the project documentation filed by resident engineers on completed projects. Production rates for various key activities were obtained through contractor interviews, from project records provided by members of the TRP, and from examination of published academic research and projects sponsored by other state DOTs. These sources were compared to the range of production rates published in the BDE Manual, Figure 66-2C, along with commentary on what factors impact productivity.

A second objective was to evaluate the state-wide winter exclusion period by analyzing publicly available historical temperature records published by the National Oceanic and Atmospheric Administration (NOAA) and determining trends that indicate which operations might be carried on during the winter months in all or portions of the state. The probable number of rain days per month was estimated using data from the Illinois State Water Survey (ISWS).

Finally, the researchers synthesized the knowledge developed from all sources in a software tool for design engineers, the Illinois Construction Scheduling Expert System (ICSES). The software provides 12 road and bridge project templates, each containing typical controlling items and their sequential relationships, selected in consultation with the TRP. The software tool will allow user revision of the templates or addition of new templates as new scheduling knowledge is developed over time.

CHAPTER 2 INTERVIEW OF SUBJECT MATTER EXPERTS

The heart of the expert systems approach is the elicitation of knowledge from experts in construction scheduling. This aspect of expert systems (ES) development is acknowledged by other researchers in the field to be challenging, time-consuming and difficult. The research team obtained expert knowledge by interviewing construction professionals, including those associated with cutting-edge, innovative project approaches, to determine best practices in planning the sequence and estimating the duration of a wide variety of typical highway construction operations. IDOT engineers and engineering consultants who routinely prepare plans, specifications and estimates (PS&E), and resident engineers who have experience administering IDOT contracts were also interviewed to illuminate designers' strategies in project planning and scheduling. Using PS&E from typical Illinois road construction projects, the research team documented the method of approaching the initial project planning from both the engineers' and the contractors' perspectives in preparing a computer model of planning and scheduling activities that leads to a probable schedule duration.

The researchers used a semi-structured interview process to capture the key decision-making variables in project planning, namely, breaking the project into phases and determining appropriate equipment and crews for the work. Interviews were conducted by telephone and in person. The results of these interviews were used to assist in the creation of scheduling templates containing input from the collective experts to assist in decision-making.

2.1 OVERVIEW

The researchers interviewed personnel at highway construction firms in Illinois and Missouri, consultants, and IDOT design engineers and resident engineers. Personnel from seven highway construction firms were interviewed regarding the procedures used in developing construction estimates and schedules, productivity rates on key items of work such as earthwork, concrete paving and asphalt paving, and factors that affect productivity either positively or negatively.

The engineer's perspective on construction scheduling was obtained by interviewing one consulting firm that performs work for IDOT and drawing upon the research team's professional experience. In addition, the members of the TRP were also instrumental in providing information to the researchers, including plans, specifications and estimates of time required for a number of projects of varying complexity, initial schedules and resident engineer's daily reports for a variety of completed projects.

Eight IDOT District 8 resident engineers were interviewed during a half-day group working session to determine the potential for using project documentation as an additional source of information regarding controlling items of work, measurement of quantities of work put into place, typical sequencing of work, and the type and amount of equipment and manpower on the job each day.

A significant source of information was the project documentation found in the Illinois Construction Record System (ICORS) database. The researchers were able to use the ICORS data on a limited number of projects to develop information on typical construction sequencing and productivity for common controlling items. The potential for using the ICORS database as a source for updating productivity rates on all coded pay items was also examined.

2.2 CONTRACTOR'S PERSPECTIVE

The premise of this research was that one could determine how contractors plan and schedule construction projects and share that knowledge with engineers who create the plans, specifications and estimates, including the estimate of time required. The objective was to improve the Estimate of Time Required (BDE Form 220A), which is reflected in the contract documents as the number of working days or calendar days allotted to complete a given project.

The research revealed that contractors do not create construction schedules as a separate exercise in the bidding process. Instead, the amount of time a bidder calculates is required to do the project is a function of several key variables that are addressed while bidding. These include, but not limited to, the following:

- Quantity of major items of work to be self-performed by the bidder
- Availability of subcontractors to perform designated items of work
- Proximity of project to home office or other ongoing projects
- Availability of equipment and labor needed to perform the work
- Likely competitors for the work
- Backlog of work by the bidder
- Amount of time allowed in the contract documents

The bidding process is typically conducted in a short time frame in comparison to the time devoted to developing the plans, specifications and engineer's estimate. When projects are put out for bid, the contractor has a relatively short time (typically on the order of one month) in which to examine the projects on the upcoming letting, determine which are a good fit for the firm, and make the decision to bid. For those projects selected, the contractor may have less than one week to perform the bid calculations and assemble the bid documents and schedule.

A primary estimator works with a group of key personnel to outline the parameters of the project and begin working on the estimate. Because each project is unique, team members rely on experience and good communication to help identify important items that will affect the estimate.

The primary estimator reads the bid documents, paying particular attention to the special provisions to identify unique requirements or restrictions. Environmental requirements and the soils report or soil boring information provided in the plans are considered key pieces of information. The estimator must have complete familiarity with the specifications, how each bid item is measured for payment, and what is included as incidental to each bid item.

Likely weather conditions are considered key in development of the project estimate. The estimator typically visits the NOAA website to determine the likely number of rain days per month during the project period.

Other team members verify the plan quantities, with particular attention to the items that involve the largest quantities, such as earthwork or paving. Verifying plan quantities is not the same as estimating. For example, to determine the price per foot to install a pipe culvert, the estimator must consider and price such things as the size of pipe and its depth; survey layout of the pipe; the need for trench shields, trench bracing or trench dewatering; granular backfill; and protection of adjacent utilities, among other factors. Plan quantities for this example would only include the linear feet of pipe and not provide for additional items and logic.

Depending on the size of the project, an experienced person typically visits the site and confirms key physical constraints such as stream crossings, access roads with weight or height restrictions, location of overhead utility lines or other obstructions that may impact crane or other equipment operations, traffic conditions, type and size of trees to be removed, soil, groundwater and potential flooding conditions, location of potential borrow or waste sites, equipment staging areas, and other conditions. Resources such as Google Earth or other mapping utilities may be used to supplement or substitute for a site visit depending on the complexity of the project.

Additional constraints are identified, such as requirements for night work; air and water quality permits; relative location, prices, billing terms and production capabilities of key material suppliers; noise, dust, or other daily or seasonal restrictions on construction operations; protection of endangered species or other environmental restrictions on construction operations, and others. While some firms indicated use of a checklist of general items, most acknowledged that an understanding of the extent and potential impact of various constraints is developed through experience.

Depending on the firm's capabilities, the major items of work to be self-performed versus subcontracted are identified and estimators begin to work on obtaining subcontractor bids and material quotes.

One of the most time-consuming functions is examining each pay item and identifying all the work activities required to execute that item. Each work activity requires equipment, labor and material. As each work activity is identified, the estimator begins to "build" the crews required to complete the work. Crews are typically built around major functions such as earthwork (long haul), earthwork (short haul), pipe installation, and paving. The equipment needed to perform each work activity is determined, and production rates are computed based on fundamentals such as creating a mass diagram, determining haul distance, estimating loading time for trucks and scrapers, and finding total cycle time for travel. Resources such as the Caterpillar Handbook are used to determine the capability of equipment, but historical records and "rule of thumb" production rates are also used to get quick estimates of time required.

Every firm interviewed has a different level of technological sophistication in the estimating process. Some rely heavily on the knowledge of key office and field personnel to know the firm's equipment, field procedures and likely productivity rates. Some visualize the productivity in terms of the crews (equipment and personnel) they have available to use and how much work the crews can perform daily. Others have begun to capture historical project records to estimate productivity rates in electronic form. Most use some level of computer software to aid the estimating process, although spreadsheets are adequate and are heavily used.

Contracting firms typically do not have a person whose primary job title is "scheduler." The project schedule is developed as an outgrowth of the estimating process as the office personnel (project manager, senior estimator) and field personnel (key superintendents and foremen) reach consensus on how the project will be built (methods), how the project will be executed (order of operations, application of available resources, concurrent and sequential activities), and how long the project will take (schedule). This consensus is typically developed in a pre-bid meeting in which the key personnel validate the estimate and make the final decision to commit to the numbers.

Most estimators keep track of concurrent activities mentally unless a project is complex. Creation of a bar chart schedule helps visualize the possible concurrent activities and identify the critical path and the early finish date or number of days likely to be required for the project, but formal schedules are not widely used unless required for submittal. However, the single most important factor in determining the construction schedule is how much time is allowed in the contract documents, and whether there are incentives for finishing sooner. This insight returns the burden for realistic construction scheduling to the engineers who create the contract documents and establish the contract time.

2.3 ENGINEER'S PERSPECTIVE

The engineer is charged with determining a reasonable time to complete the project. Contract time can be stated in terms of working days, calendar days, a completion date, or some combination of these. Calendar days and working days are defined in the Standard Specifications. Calendar days are every day shown on the calendar; working days are calendar days with the exception of Saturdays, Sundays, and holidays that are recognized by the contractor's entire workforce statewide, from May 1 through November 30. The period December 1 through April 30 is the winter exclusion period, during which time the contractor may perform work as long as specified restrictions regarding temperature or weather conditions are not violated, without working days being charged against the contract time. This practice of the winter exclusion is typical of northern states. A study of 13 other states' winter exclusion policies is summarized in Figures 3 and 4 in Chapter 3.

As described in the BDE Manual Chapter 66-2.03, "the number of days required for each item is obtained by dividing each quantity by its respective production rate." The production rates are published in BDE Manual Figure 66-2B for some major work activities. The production rates do not align exactly with coded pay items, and most offer engineers a range of rates that can span an order of magnitude and therefore require judgment in selection. For example, from BDE Manual Figure 66-2B, the production rates for "Earth Excavation" can vary from a low of 750 cubic yards to a high of 10,000 cubic yards per 8 hour day, with little guidance on how to select the most reasonable productivity. By contrast, the contractors interviewed think in terms of the capability of equipment they own, and the historic averages per piece of equipment for short haul (e.g., 2,000 CY per day for roadway excavation) and long haul (e.g., 1,000 CY per day for roadway excavation).

Engineers are encouraged in BDE 66-2.03 to determine a logical order of work activities, and to consider which activities can be performed concurrently. However, the engineer has no knowledge of which contractor will be awarded the project, and the size of the contractor and amount of equipment and size of workforce can have a direct impact on the contractor's daily production rates. Clearly, the "high" production rates for Earth Excavation cited in BDE Figure 66-2B above can likely be achieved only by running multiple crews.

The designer determines the "total days required" and "days not affecting time limit" on BDE Form 220A. Using a bar or arrow diagram can help determine the critical path and activities that will be controlling versus those that will not affect the early completion date.

Completion date contracts are used when there is a compelling interest in opening the road to traffic by a particular date (e.g., complete by August 15 when the road impacts a school). Where the major contract items require a tight completion date and it is not necessary for the minor items (e.g., seeding, clean-up) to be included in that date, the designer may use a completion date plus working days. The number of working days allowed after the completion date is typically kept to a minimum and is reserved for minor, off-road work. The number of working days required must also be calculated for completion date contracts. This will ensure that the completion date is realistic and allow the contractor to make allowances in the unit costs for anticipated overtime and extra crews needed to meet the completion date. The designer must clearly state in the project-specific Special Provisions which items must be completed by the completion date and which items are involved in the working days.

The use of incentive/disincentive contract provisions is intended to compensate contractors for completing critical work items ahead of schedule and penalize them for overrunning the contract time limit. The use of incentives requires the engineer to determine an accelerated schedule, based on longer work days, longer work weeks, multiple shifts, multiple crews working on several items at one time, or some combination. This level of effort is justified only on projects where it is considered critical to minimize delay or inconvenience to the travelling public.

2.4 SUMMARY

The interviews yielded new insights into contractors' views of highway construction scheduling and productivity. Specific insights into the production rates for major controlling items have been included in the scheduling software, but some representative items are summarized here.

Earthwork

- Productivity has increased due to improvements in equipment, capacity of scrapers, excavators and trucks, and use of GPS-controlled grading
- Range of productivity depends on soil type, wetness, length of haul, grade
- Develop a mass diagram to examine length of haul when feasible
- 1,000 – 2,000 CY/day/scraper depending on length of haul
- A typical scraper crew should be designed with enough scrapers to provide a steady supply of fill for the compactor and dozers grading the cut and fill areas. Longer hauls require more scrapers. Productivity 3,000 CY/day/crew.
- Off-site borrow will be performed with an excavator or front-end loader filling dump trucks. A productivity of 1,600 CY/day for a crew is assumed.

Pipe Culverts

- Rarely a controlling item, done concurrently with earthwork
- Pipe work generally can be done in winter
- Precast culverts have increased productivity over cast-in-place concrete

Pavement Sub-base and Base Course

- Complete each component of a paving system before starting next one
- On large projects with definable break points (e.g., stream crossing, intersection), may start base on one section while still working on sub-base of another, and pave sections as they are completed. Minimum size 10,000 – 15,000 SY per section, or about 1 mile of 24' wide pavement.

Portland Cement Concrete Pavement

- Plant production typically ~200-250 CY/hour
- Production, not placement, is limiting factor in productivity
- Order from multiple plants to increase productivity; material uniformity an issue

Hot Mix Asphalt

- Plant capacity typically ~200 T/hour
- Haul from multiple plants to increase productivity; material uniformity an issue
- Specifications setting feet/minute of placement tend to limit productivity
- Plants typically shut down after Thanksgiving, but can remain open
- Takes one week to re-open a plant after shutdown

Bridges

- Precast bridge decks have been a major advance in productivity

- Typically few opportunities for concurrent activities
- Traffic control/maintenance of traffic limits productivity
- Prefer to work around the clock in good weather

CHAPTER 3 WEATHER ANALYSIS

One of the key variables in highway construction is the impact of weather delays, including the frequency and duration of rainfall events, and the frequency and duration of cold and freezing temperatures that prevent key construction activities such as soil compaction and placement of asphalt or concrete pavement materials. The research therefore undertook an analysis of Illinois weather data available from public sources such as the ISWS and NOAA to determine the probable rain days per month.

In addition, the researchers used NOAA data to analyze historical trends of the number of days of below-critical temperatures for road-building activities across the state to determine whether the dates of the winter exclusion period are reasonably applied statewide, could be shortened or eliminated by District, or might be shortened or eliminated by project location. Twenty years' (1990-2010) daily precipitation records from WARM and thirty years' (1971–2000) average temperatures data from NOAA were obtained from stations across Illinois. The probable number of days that fall below various temperature thresholds as specified in SSRBCI, the probable number of days of rainfall in excess of 0.10 inch (a threshold selected by the researchers), and other construction constraints were integrated into the ICSES software tool to allow project-specific assessment of the impact of weather on various controlling items and the overall project duration.

3.1 INVESTIGATION OF WEATHER RESTRICTIONS

The researchers reviewed the SSRBCI, the Supplemental Specifications and Recurring Special Provisions (SSRSP), and the Bureau of Construction's (BC) Construction Inspection Checklists for references to rainfall and temperature restrictions on construction operations.

Seventy-four references to weather were found in the SSRBCI, of which 68 referenced temperature restrictions and 6 referenced both temperature and rain. No additional weather references were found in the SSRSP or BC checklists. A summary of the relevant articles is given in Appendix 1.

A list of 49 typical controlling items was developed through examination of baseline schedules and project documentation for completed projects, verified by examination of highway construction scheduling research, and are discussed in Chapter 4. The 16 controlling items affected by temperature as specified in the SSRBCI are listed in Table 1.

Table 1. Controlling Items Affected by Temperature

Limiting Temperature, °F	Controlling Items Affected
32	Embankment (no placement on frozen ground) Stabilized Sub-base
35	Class A Patching
40	PC Concrete HMA Leveling Binder and Binder Course Reflective Crack Control PC Concrete and HMA Joint and Crack Sealing
45	Soil Modification Lime Modification of Soil Soil Cement HMA Surface Course Concrete for Structures (limits strength gain)
50	Paint Pavement Marking Raised Reflective Pavement Markers RRPM Prismatic Reflectors
55	Thermoplastic Pavement Markings

3.2 INVESTIGATION OF WEATHER DATA

Weather records from NOAA were investigated to find the average daily rainfall, monthly average minimum, maximum and mean temperatures for all counties in the state. There are 17 NOAA Automated Surface Observation Stations in Illinois that collect data continuously. In addition, there are data collection sites across the state operated by volunteers in a cooperative program that has been in existence since 1890. Data from the period 1971-2000 are published on the NOAA website that gives the average daily minimum, maximum and mean temperatures and other data. Temperature data from 78 stations across the state were averaged and smoothed to visualize annual monthly temperatures.

Monthly Average Minimum Temperatures

The average minimum temperatures by month were obtained from 78 recording stations across Illinois over the 30 year period (1971-2000). Results were plotted using ArcView GIS software to show variations IDOT district by month (Fig. 1). The results show that December, January, and February have average minimum temperatures below freezing across the entire state. However, by March, only Districts 1-3 still have minimum temperatures in the freezing range, while average minimum temperatures in Districts 4-6 were generally above freezing, and Districts 7 through 9 are well above freezing. By April, all 9 districts have average minimum temperatures above freezing. The average date on which there is a 50% probability of frost (32°F) in spring is April 30 in Rockford, April 13 in Springfield, and March 26 in Cairo.

Monthly Average Mean Temperatures

Examination of the monthly mean temperatures (Fig. 2) gives a clearer indication that the southern districts have warmer days throughout the winter months. Only in January is the mean monthly temperature below freezing throughout most of the state, with the exception of the southern portions of District 9. In both December and February, Districts 7 through 9 have mean temperatures above freezing. By March, the mean temperature is above freezing throughout the state, and is in the 40s in Districts 5 through 9. By April, the mean temperatures are mid 40s in Districts 1 through 3, low to mid-50s in Districts 4 through 7 and high 50s to 60 degrees in Districts 8 and 9.

Figure 1. Monthly Average Minimum Temperatures During Winter Exclusion Period

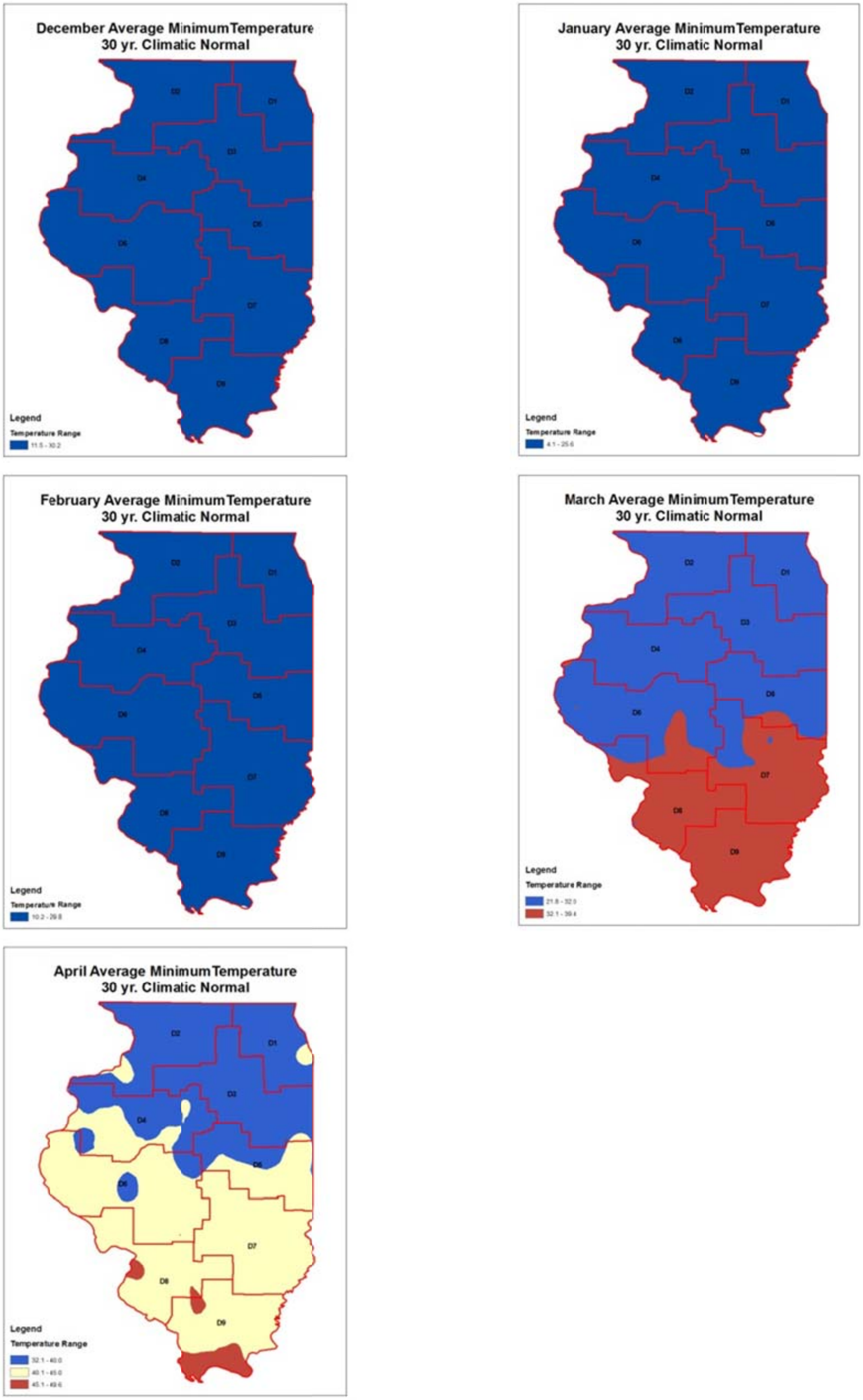
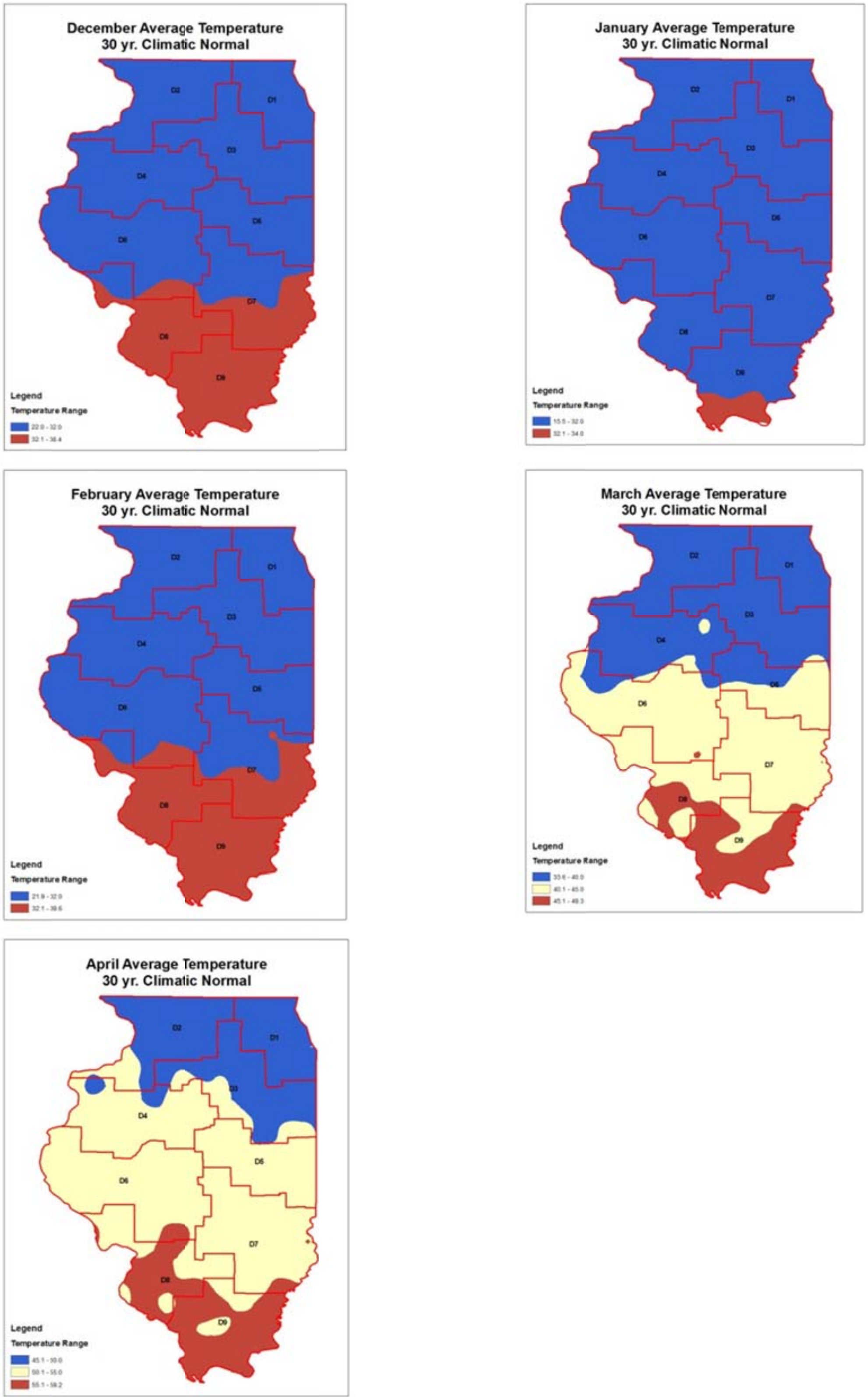


Figure 2. Monthly Average Mean Temperatures During Winter Exclusion Period



3.3 ANALYSIS OF WINTER EXCLUSION PERIOD

Thirteen adjacent states' policies on winter exclusion period were examined: Arkansas, Indiana, Iowa, Kentucky, Ohio, Oklahoma, Michigan, Minnesota, Nebraska, New York, Pennsylvania, Tennessee and Wisconsin. Most of these states lie in similar latitudes, but some were selected that lie entirely north or south of Illinois for comparison. A summary of these states' policies on winter exclusion dates is given in Figures 3 and 4.

Five states (Illinois, Nebraska, Indiana, Ohio and Kentucky) start their winter exclusion on December 1 (Fig. 3). Six northern states start earlier, but all of those end their winter exclusion earlier than Illinois. Only Ohio and Illinois end the winter exclusion on April 30 (Fig. 4). Kansas and Tennessee do not have specific dates for a winter exclusion period.

Figure 3. Start Dates of Winter Exclusion in 14 States

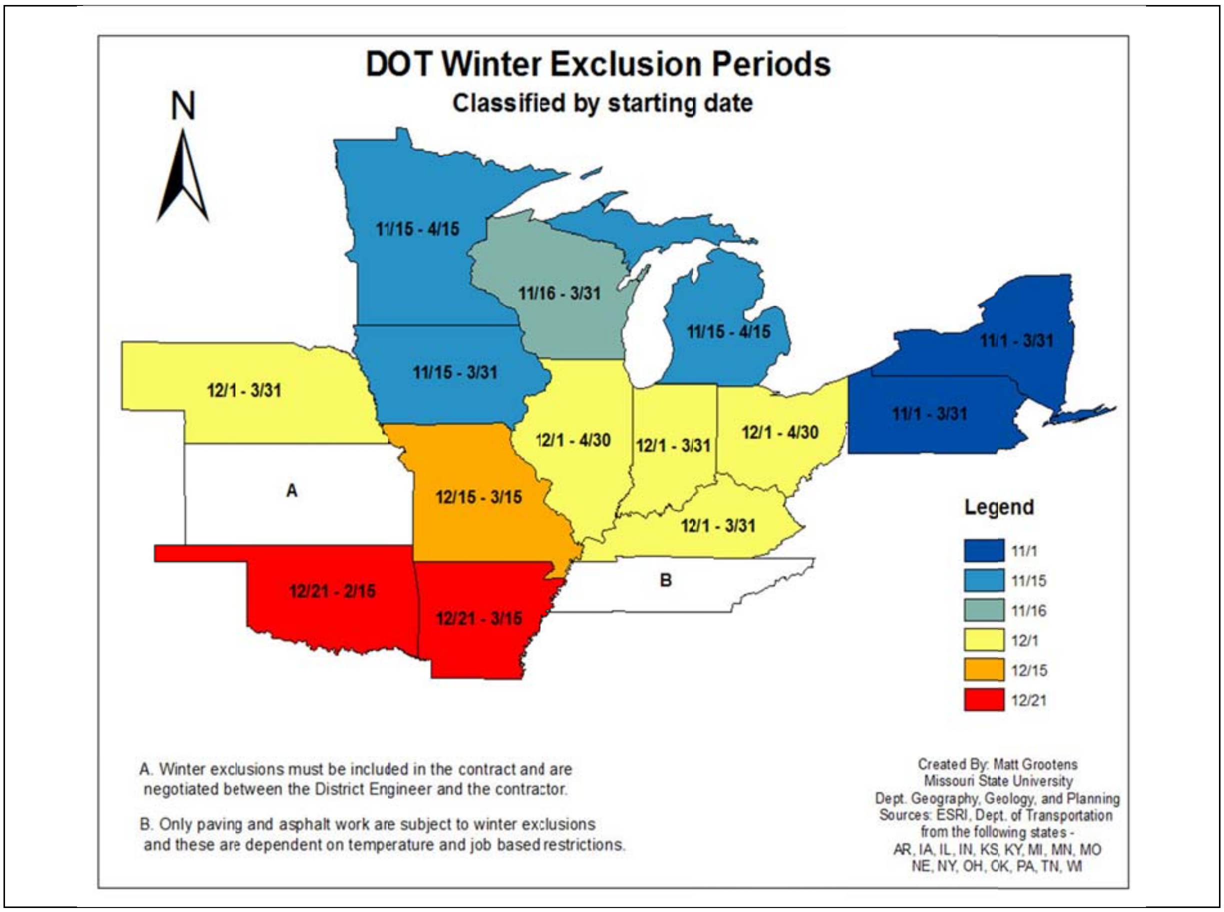
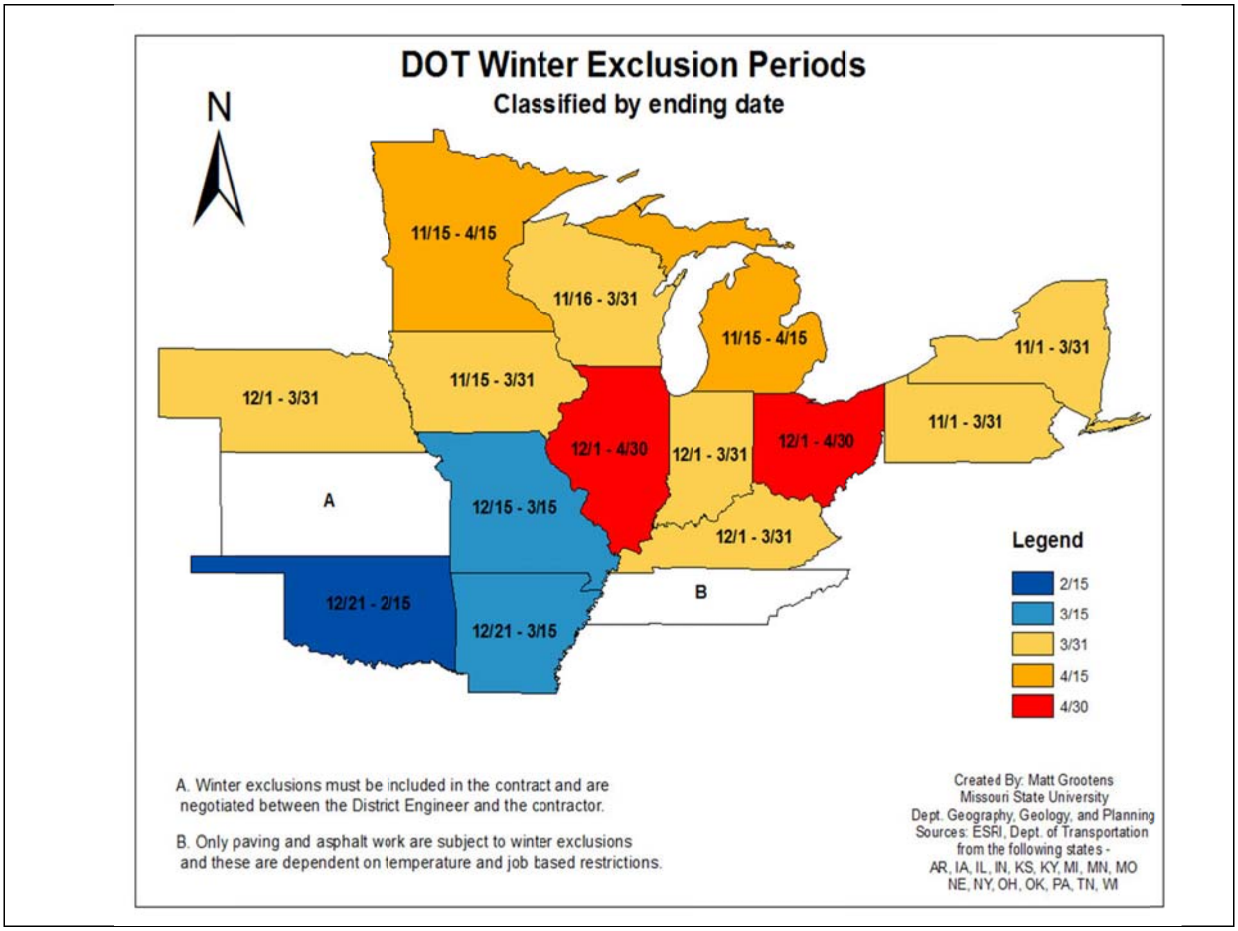


Figure 4. End Dates of Winter Exclusion in 14 States



CHAPTER 4 DEVELOPMENT OF HIGHWAY SCHEDULING SOFTWARE

A key aspect of the research was the development of customized highway scheduling software that synthesized the knowledge gained from the diverse expert sources and packaged them into a tool to assist engineers. The Illinois Construction Scheduling Expert System (ICSES) is the result of this effort. The development and functions of ICSES are briefly described here. The instructions for use of the software and example projects are given in the ICSES User Manual.

The results of the research indicated that many highway projects share the same controlling items, and that many common construction activities do not affect the overall project duration. A decision was made in consultation with the project TRP to develop project templates using only controlling items. In order to standardize the terminology used to describe these controlling items, the terms used for the production rates given in BDE Manual, Figure 66-22B were selected. Terms describing the construction of “bituminous” pavement were updated to “HMA” pavement to reflect current terminology used in the SSRBCI and the list of coded pay items. Terms describing sub-tasks in bridge construction were added. A final list of 49 controlling items was selected to form templates covering the construction of the most common types of highway projects in Illinois (Table 2).

Table 2. Controlling Items for Development of ICSES Scheduling Templates

Borrow Excavation	PC Concrete Pavement
Bridge Approach Pavement	Pipe Underdrains
Checkout / Acceptance	Place Abutment
Class A Patching	Place Bridge Deck
Class B Patching	Place Pier Cap
Class C / D Patching	Place Pile Cap
Concrete Curing	Place Columns
Concrete Structures	Precast Box Culverts
Concrete Superstructure	Precast Concrete Beam Erection
Curb / Gutter – Drainage	Precast Concrete Bridge Deck
Deck Slab Repair (Partial Depth)	Process Lime Stabilized Soil
Driving Piles	Raised Reflective Pavement Markers
Earth Excavation	Removal of Existing Concrete Deck
Earth Excavation (Shoulders / Widening)	Removal of Existing Substructure
Fabricate Bridge Deck Formwork	Removal of Existing Superstructure
Fabricate Bridge Deck Reinforcing	Seeding
Gravel or Crushed Stone Base Course	Stabilized Subbase
Gravel or Crushed Stone Shoulders	Steel Plate Beam Guardrail
HMA Pavement	Storm Sewers (Dependent on size, depth)
HMA Shoulders	Strip Reflective Crack Control
HMA Surface Removal	Thermoplastic Pavement Marking (Hand)
HMA Pavement Removal	Thermoplastic Pavement Marking Symbol
Mobilization	Traffic Control
Paint Pavement Marking (Hand)	Tree Removal
Paint Pavement Marking (Truck)	

In consultation with the TRP, the researchers developed scheduling templates for the following 12 project types:

1. Roadway Rehabilitation
2. Roadway Reconstruction
3. Roadway New Alignment
4. Intersection Reconstruction
5. Interchange with Bridge Replacement
6. Grading
7. Bridge Repair and Deck Overlay
8. Bridge Rehabilitation
9. Bridge Reconstruction
10. Bridge New Construction
11. Patching and Resurfacing—PCC
12. Patching and Resurfacing—HMA

Suggested templates for each of the 12 project types are provided for the user, but may be modified by deleting unnecessary controlling items, or by adding controlling items from the list in Table 2. Because the templates are constructed using only controlling items, the user can quickly generate a project schedule and estimate the project completion date, number of working days and number of calendar days. Assumptions can be easily changed to study the impact on the completion date.

The user will open a new project, select the project type from this list and an estimated start date. A drop-down box will allow the user to base the start date on any one of the 7 annual IDOT letting dates, or to enter a proposed starting date.

The schedule template will open with suggested controlling items shown and an initial minimal duration assigned for each item. Controlling items can be added or deleted by the user. The user will then edit the project calendar. The default calendar accounts for two-day weekends and recognized holidays and the winter exclusion period of December 1 through April 30. These can be removed or modified. The expected number of working days per month can be entered based on tabulated values of Projected Working Days per Month (BDE Manual Table 66-2C), or calculated based on the expected number of rain days developed from 20-year ISWS rainfall records. These rain days are evenly dispersed throughout the month.

Location and temperature-based exclusion dates can be used instead of the standard winter exclusion period. The user selects the Map function which displays a state map with county boundaries. Activities in the scheduling template with temperature restrictions per the SSRBCI are listed. The user clicks the approximate project location on the map and the software determines the date in the fall at which the average minimum, mean, or maximum temperature falls below the critical value for each activity and the date in the spring when that temperature is exceeded. The minimum temperature value is used by default, but the user may select the less conservative mean value, if appropriate. The user can edit the constraints, accepting the dates provided, overriding them to insert other dates, or ignoring them.

Other constraints that could impact the project schedule can be selected from a drop-down menu, including such items as utility relocations, permits, long lead-time procurement items, public events affecting traffic (e.g., major sporting event, State Fair), farm to market routes, critical land uses (e.g., hospitals or schools), seasonal load limits, critical habitats (e.g., nesting dates for Indiana bat), or other user-specified constraints. The user can link these constraints to the activities that they affect.

After saving and closing the calendar, the user is presented with a preliminary project schedule, with default durations for each controlling item in the template. The user will select each controlling item in turn, which will open a dialogue box that prompts the user to enter the plan quantity and production rate. Comments in the dialogue box developed from contractor interviews and other sources provide the user with expert guidance in the selection of an appropriate production rate for a standard crew. Calculators are also provided for some activities to assist in setting the production rate. The user may indicate the use of multiple crews for large projects or projects with critical completion dates. The number of days required to complete the activity is calculated and the schedule updated based on this input. The user may enter notes detailing the assumptions made in calculating the duration of each activity.

The project schedule is updated after every change. When the duration of all controlling items have been calculated, the output displays the critical path, expected completion date and the number of working days and calendar days. The bar chart schedule also identifies the non-working days. A text file can be printed to document the project information and any notes made during the exercise, and an Excel file provides the Estimate of Time Required in the familiar format of BDE Form 220A. The project can be saved, re-opened and rerun with new assumptions to test the impact of changing the start date and other variables on the expected completion date.

The software was demonstrated to the members of the TRP during a project meeting on June 2, 2011 for beta testing. In addition, the software was tested during a half-day group working session of IDOT District 8 Plans and Studies engineers and technicians on June 3, 2011. Eight engineers participated in the beta-testing of the software, completing exercises to create schedules for typical projects, critiquing the schedule templates provided, and commenting on the software usability and functionality. Changes to the software were made in response to comments from these two user groups and continued testing and use of the software by the research team.

The user manual for ICSES and the computer code for the software are provided as deliverables together with this report.

CHAPTER 5 SUMMARY AND CONCLUSIONS

The goal of the project was to develop a software tool to assist IDOT design engineers in developing more realistic construction schedules for a wide variety of IDOT projects. The knowledge input for the tool included contractors, design engineers, resident engineers, consultants, historical project records, and published research on highway construction scheduling. The research approach was to focus on controlling items for a set of typical highway construction projects. Scheduling templates for 12 types of road and bridge construction projects were developed from a list of 49 controlling items that were selected in consultation with the project TRP based on an examination of historical project records and published research. The resulting software tool, the Illinois Construction Scheduling Expert System (ICSES) is customized to Illinois, referencing the SSRBCI for temperature constraints on controlling items, using NOAA and ISWS temperature and rainfall records for the state, and incorporating the standard IDOT letting dates for calculating project start dates. ICSES allows users to select the project location within the state and links historical temperature records from that part of the state to specific controlling items in the scheduling template for the selected project type.

Temperature variations from north to south across the state are significant enough to warrant a shortened exclusion period in the southern districts. The tools available in ICSES will make it easier for engineers to study the possibility that the contractor can make progress on controlling items during the winter months in establishing the contract time.

The research proposal did not include a complete update of all production rates contained in BDE 66-2B. However, the researchers did examine and make recommendations on the selection of productivity rates for typical controlling items for roadway construction, including earthwork and paving activities, based on an examination of historical project documentation on actual production rates, input from project TRP members on their research on production rates, and published research from other state DOTs. The data contained in the ICORS database was examined for possible use in updating production rates for a wide variety of activities. The daily quantity reports could be paired with the diaries to provide a verifiable source of productivity data if a system were established to use standard terminology for pay items and controlling activities. It is recommended that a standard terminology be developed across the Standard Specifications, Coded Pay Items, and production rates published in the BDE Manual.

The software tool ICSES will allow a more standardized approach to highway construction scheduling, providing design engineers across the state with standard project templates that link project-specific controlling items to dates when temperatures will affect completion of those items. The tool provides flexibility for designers to modify templates and to create and share new templates developed over time. A mechanism for sharing, commenting on and accepting project templates department-wide is recommended.

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APPENDIX 1 SUMMARY TABLES

Table A.1. Weather-related Restrictions from Standard Specifications

Article #	Item	Temperature Restriction	Reference Link
205.05	Embankment	Unspecified: no placement on frozen soil	http://www.dot.state.il.us/desenv/spec2007/div200.pdf
252.04	Sodding	0 ºF < T < 80 ºF (26 ºC) Sod shall not be placed during July and August.	http://www.dot.state.il.us/desenv/spec2007/div200.pdf
252.09	Sodding	> 80 ºF (26 ºC)	http://www.dot.state.il.us/desenv/spec2007/div200.pdf
253.03	Planting Woody Plants	> 35 ºF (2 ºC)	http://www.dot.state.il.us/desenv/spec2007/div200.pdf
253.04	Planting Woody Plants	> 35 ºF (2 ºC).	http://www.dot.state.il.us/desenv/spec2007/div200.pdf
282.03	Filter Fabric	> 140 ºF (60 ºC)	http://www.dot.state.il.us/desenv/spec2007/div200.pdf
285.05	Concrete Revetment Mat	< 70 °F (21 °C)	http://www.dot.state.il.us/desenv/spec2007/div200.pdf
302.04	Soil Modification	Soil temperature, measured 6 in. (150 mm) below the surface > 50 °F (10 °C) Ambient air temperature in shade > 45 °F (7 °C).	http://www.dot.state.il.us/desenv/spec2007/div300.pdf
302.1	Soil Modification	> 45 °F (7 °C)	http://www.dot.state.il.us/desenv/spec2007/div300.pdf
310.04	Lime Stabilized Soil Mixture	Soil temperature measured 6 in. (150 mm) below the surface > 50 °F (10 °C) Ambient air temperature in shade > 45 °F (7 °C).	http://www.dot.state.il.us/desenv/spec2007/div300.pdf
312.09	Stabilized Subbase	Air temperature in shade > 40 °F (4 °C).	http://www.dot.state.il.us/desenv/spec2007/div300.pdf
312.14	Stabilized Subbase	< 32 °F (0 °C)	http://www.dot.state.il.us/desenv/spec2007/div300.pdf
312.18	Stabilized Subbase	Air temperature in the shade is above 40 ºF (4 ºC).	http://www.dot.state.il.us/desenv/spec2007/div300.pdf
312.27	Cement Aggregate Mixture II	Air temperature in the shade > 40 °F (4 °C).	http://www.dot.state.il.us/desenv/spec2007/div300.pdf
352.04	Soil Cement Base Course	Subgrade temperature, measured 6 in. (150 mm) below the surface, > 50 °F (10 °C) Ambient air temperature in the shade > 45 °F (7 °C).	http://www.dot.state.il.us/desenv/spec2007/div300.pdf

403.02	Bituminous Surface Treatment	Warm 68 to 85°F (15 - 30 °C) Hot > 85°F (30 °C)	http://www.dot.state.il.us/desenv/spec2007/div400.pdf
403.04	Bituminous Surface Treatment	Air temperature in the shade > 60 ºF (15 ºC). No work shall be started if local conditions indicate that rain is imminent.	http://www.dot.state.il.us/desenv/spec2007/div400.pdf
406.05.b.	HMA Prime Coat	When emulsified asphalt is used, the temperature in the shade > 60 ºF (15 ºC)	http://www.dot.state.il.us/desenv/spec2007/div400.pdf
406.06.b.	HMA Leveling Binder and Binder	> 40 ºF (5 ºC) and rising	http://www.dot.state.il.us/desenv/spec2007/div400.pdf
406.06.b.	HMA Surface Course	> 45 ºF (8 ºC) and rising	http://www.dot.state.il.us/desenv/spec2007/div400.pdf
420.12	PCC Pavement Joints	Air temperature in the shade > 50 ºF (10 ºC)	http://www.dot.state.il.us/desenv/spec2007/div400.pdf
420.18	PCC Pavement Protective Coat	Concrete and air > 40 ºF (4 ºC)	http://www.dot.state.il.us/desenv/spec2007/div400.pdf
422.09	PCC Railroad Crossing	> 40 ºF (5 ºC)	http://www.dot.state.il.us/desenv/spec2007/div400.pdf
442.06.g.	Pavement Patching	< 55 ºF (13 ºC), insulation 55 – 96 ºF (13 – 35 ºC), insulation optional > 96 ºF (35 ºC), no insulation	http://www.dot.state.il.us/desenv/spec2007/div400.pdf
442.08.a.	Class D Pavement Patching	> 40 ºF (5 ºC) and rising and subgrade not frozen	http://www.dot.state.il.us/desenv/spec2007/div400.pdf
443.07	Reflective Crack Control System B	> 40 ºF (5 ºC)	http://www.dot.state.il.us/desenv/spec2007/div400.pdf
443.08.c.1.	Reflective Crack Control System C	>60 °F (15 °C) and rain not imminent	http://www.dot.state.il.us/desenv/spec2007/div400.pdf
444.04	Fiberglass Fabric Repair System	Ambient and pavement temperatures > 50 °F (10 °C) and rising	http://www.dot.state.il.us/desenv/spec2007/div400.pdf
451.04	HMA Crack Sealing	Air temperature in the shade > 40 ºF (5 ºC)	http://www.dot.state.il.us/desenv/spec2007/div400.pdf
452.04	PCC Crack and Joint Sealing	Air temperature in the shade > 40 ºF (5 ºC)	http://www.dot.state.il.us/desenv/spec2007/div400.pdf

502.11	Excavation for Structures	In the absence of tests to determine the flexural strength, the additional material on the higher side shall not be placed until at least 14 days have elapsed after the placing of the concrete, exclusive of days on which the temperature of the air surrounding the concrete falls below 45 ºF (7 ºC).	http://www.dot.state.il .us/desenv/spec2007 /div400.pdf
503.05	Concrete Structures	Falsework shall remain in place until at least 14 days have elapsed after the placing of the concrete, exclusive of days in which the temperature falls below 45 ºF (7 ºC).	http://www.dot.state.il .us/desenv/spec2007 /div400.pdf
503.06	Concrete Structures	Forms shall remain in place until at least 14 days have elapsed after placing the concrete, exclusive of days the temperature falls below 45 ºF (7 ºC).	http://www.dot.state.il .us/desenv/spec2007 /div400.pdf
503.06.a.	Concrete Structures	The temperature differential between the form liner and concrete shall not be greater than 9 ºF (5 ºC) for normal ambient conditions. In ambient conditions above 90 ºF (32 ºC), form liner attachment shall allow for thermal expansion.	http://www.dot.state.il .us/desenv/spec2007 /div400.pdf
503.18	Concrete Structures	No waterproofing shall be done in wet weather, or if local conditions indicate that rain is imminent, or when the temperature of the air in the shade < 50 ºF (10 ºC)	http://www.dot.state.il .us/desenv/spec2007 /div400.pdf
503.18	Concrete Structures: Waterproofing	Temperature of air in the shade is below 45 ºF (7 ºC), and the requirements of Article 1020.13(d) have been complied with, asphalt emulsion waterproofing may be applied down to a temperature of 32 ºF (0 ºC).	http://www.dot.state.il .us/desenv/spec2007 /div400.pdf
503.19	Concrete Structures: Protective Coat	Temperature of the concrete and air > 40 ºF (4 ºC)	http://www.dot.state.il .us/desenv/spec2007 /div400.pdf
504.06.e.	Precast Concrete Structures	50 ºF (10 ºC) < temperature of grout < 90 ºF (32 ºC)	http://www.dot.state.il .us/desenv/spec2007 /div400.pdf
505.08.m. 2.	Steel Structures: Welding	Welding shall not be done when the base metal temperature < 0 ºF (-17 ºC), or when the surface is wet.	http://www.dot.state.il .us/desenv/spec2007 /div400.pdf
506.04.c.	Cleaning and Painting Metal Structures	Primer shall be applied when the temperature of the metal and the air > 32 ºF (0 ºC)	http://www.dot.state.il .us/desenv/spec2007 /div400.pdf
580.04	Membrane Waterproofing for Railway Structures	Bituminous membrane waterproofing > 50 ºF (10 ºC) Butyl rubber membrane > 10 ºF (-12 ºC)	http://www.dot.state.il .us/desenv/spec2007 /div400.pdf
581.05	Waterproofing Membrane System for Bridge Deck	> 45 ºF (7 ºC)	http://www.dot.state.il .us/desenv/spec2007 /div400.pdf

581.07	Waterproofing Membrane System: Asphalt Sand Seal	> 50 ºF (10 ºC)	http://www.dot.state.il.us/desenv/spec2007/div400.pdf
583.03	PC Mortar Fairing Course	> 45 ºF (7 ºC)	http://www.dot.state.il.us/desenv/spec2007/div400.pdf
586.03	Sand Backfill for Vaulted Abutments	Sand backfill shall not be placed until at least 14 days have elapsed after the placing of the concrete, exclusive of days on which the temperature of the air surrounding the concrete falls below 45 ºF (7 ºC).	http://www.dot.state.il.us/desenv/spec2007/div400.pdf
588.03	Concrete Sealer	> 68 ºF (20 ºC) and rising	http://www.dot.state.il.us/desenv/spec2007/div400.pdf
589.03	Elastic Joint Sealer	> 40 ºF (4 ºC)	http://www.dot.state.il.us/desenv/spec2007/div400.pdf
593.03	Controlled Low-Strength Material, Backfill	>35 ºF (2 ºC) and rising. Mixing and placing shall stop when the air temperature is 40 ºF (5 ºC) and falling.	http://www.dot.state.il.us/desenv/spec2007/div400.pdf
661.03	HMA Shoulder Curb	Base on which the curb is placed > 40 ºF (4 ºC)	http://www.dot.state.il.us/desenv/spec2007/div600.pdf
780.05	Pavement Marking: Thermoplastic	> 55 ºF (13 ºC) and no later than November 1 or earlier than April 15.	http://www.dot.state.il.us/desenv/spec2007/div700.pdf
780.06	Pavement Marking: Paint	> 50 ºF (10 ºC)	http://www.dot.state.il.us/desenv/spec2007/div700.pdf
780.07.b.	Pavement Marking: Preformed Plastic	> 60 ºF (15 ºC) and rising and the pavement temperature > 70 ºF (21 ºC). Not allowed after October 15.	http://www.dot.state.il.us/desenv/spec2007/div700.pdf
780.08	Pavement Marking: Preformed Thermoplastic	>32 ºF (0 ºC)	http://www.dot.state.il.us/desenv/spec2007/div700.pdf
780.09	Pavement Marking: Epoxy	> 35 ºF (2 ºC) and rising	http://www.dot.state.il.us/desenv/spec2007/div700.pdf
781.03.a.	Raised Reflective Pavement Markers	> 50 ºF (10 ºC)	http://www.dot.state.il.us/desenv/spec2007/div700.pdf

781.03	Raised Reflective Pavement Markers: Prismatic Reflectors	> 50 ºF (10 ºC)	http://www.dot.state.il.us/desenv/spec2007/div700.pdf
1008.03.d.5.	Structural Steel Coatings: Aluminum Epoxy Mastic	>75 ºF (24 ºC) cure temperature	http://www.dot.state.il.us/desenv/spec2007/div1000.pdf
1020.05.b.1	Portland Cement Concrete	> 65 ºF (18 ºC), a retarding admixture shall be used	http://www.dot.state.il.us/desenv/spec2007/div1000.pdf
1020.05.b.3	Portland Cement Concrete: Class PP-1 or RR	< 55 ºF (13 ºC), the non-chloride accelerator shall be calcium nitrite	http://www.dot.state.il.us/desenv/spec2007/div1000.pdf
1020.05.b.5.	Portland Cement Concrete: Class PP-2	< 55 ºF (13 ºC), the non-chloride accelerator shall be calcium nitrite	http://www.dot.state.il.us/desenv/spec2007/div1000.pdf
1020.05.c.1.h.	Portland Cement Concrete: Fly Ash	< 40 ºF (4 ºC) shall not be used	http://www.dot.state.il.us/desenv/spec2007/div1000.pdf
1020.05.c.2.g	Portland Cement Concrete: GGBF Slag	< 40 ºF (4 ºC), shall not be used	http://www.dot.state.il.us/desenv/spec2007/div1000.pdf
1020.13.c.	Portland Cement Concrete: Other than Structures	< 32 °F (0 °C), concrete less than 72 hours old shall be provided specified protection.	http://www.dot.state.il.us/desenv/spec2007/div1000.pdf
1020.13.d.	Portland Cement Concrete: Structures	< 45 °F (7 °C), than 72 hours old shall be provided specified protection. Concrete shall also be provided protection when placed during the winter period of December 1 - March 15.	http://www.dot.state.il.us/desenv/spec2007/div1000.pdf
1020.13.d.1.	Portland Cement Concrete: Forms	> 35 °F (2 °C) and rising for form removal.	http://www.dot.state.il.us/desenv/spec2007/div1000.pdf
1020.13.d.2.	Portland Cement Concrete: Protection Method II	The concrete shall be enclosed in adequate housing and the air surrounding the concrete kept at a temperature of not less than 50 °F (10 °C) nor more than 80 °F (27 °C) for a period of seven days after the concrete is placed.	http://www.dot.state.il.us/desenv/spec2007/div1000.pdf
1020.14.a.	Portland Cement Concrete: Other than Structures	> 35 ºF (2 ºC) and rising <40 ºF (4 ºC) and falling, placement stops	http://www.dot.state.il.us/desenv/spec2007/div1000.pdf

1020.14.b.	Portland Cement Concrete: Structures	> 40 ºF (4 ºC) and rising < 45 ºF (7 ºC) and falling, placement stops	http://www.dot.state.il.us/desenv/spec2007/div1000.pdf
1030.08	HMA	< 60 ºF (15 ºC), insulated beds to transport HMA	http://www.dot.state.il.us/desenv/spec2007/div1000.pdf
1055.01	Mastic Joint Sealer for Pipe	20 - 100 ºF (–7 and 38 °C)	http://www.dot.state.il.us/desenv/spec2007/div1000.pdf

Table A.2 Production Rates from Bureau of Design and Environment Manual

MAJOR WORKTYPE	SUB WORKTYPE	DESCRIPTION	UNIT	LOW	HIGH
Bridge	Bridge	Bearing Assembly	each	5	10
Bridge	Bridge	Bridge Deck Concrete Overlay	square yard	200	500
Bridge	Bridge	Bridge Deck Grooving	square yard	500	800
Bridge	Bridge	Bridge Deck Scarification (Cold Milling)	square yard	350	1000
Bridge	Bridge	Bridge Deck Scarification (Hydroblasting)	square yard	175	500
Bridge	Bridge	Concrete Structures	cubic yard	10	25
Bridge	Bridge	Concrete Superstructure	cubic yard	10	30
Bridge	Bridge	Clean & Paint Steel Bridge - SP 10	square foot	1000	2100
Bridge	Bridge	Clean & Paint Steel Bridge - SP 6	square foot	800	1600
Bridge	Bridge	Clean & Paint Steel Bridge - SP 3	square foot	250	550
Bridge	Bridge	Cofferdam (Doesn’t apply for major river bridges)	each	0.20	0.50
Bridge	Bridge	Concrete Removal	cubic yard	5	20
Bridge	Bridge	Deck Slab Repair (Full Depth)	square yard	10	25
Bridge	Bridge	Deck Slab Repair (Partial Depth)	square yard	25	50
Bridge	Bridge	Driving Piles	foot	250	500
Bridge	Bridge	Cofferdam Excavation	cubic yard	75	150
Bridge	Bridge	Formed Concrete Repair	square foot	50	100
Bridge	Bridge	Jacking & Cribbing (per beam)	each	5	10
Bridge	Bridge	Precast Concrete Beam Erection	foot	150	325
Bridge	Bridge	Precast Concrete Beams (Fabricate & Furnish)	calendar day	30	120
Bridge	Bridge	Precast Concrete Bridge Deck	square foot	500	800
Bridge	Bridge	Precast Deck Beams	square foot	1000	3000
Bridge	Bridge	Protective Shield	square yard	160	250
Bridge	Bridge	Reinforcement Bars (Substructure)	pounds	4000	6000
Bridge	Bridge	Reinforcement Bars (Superstructure)	pounds	10000	15000
Bridge	Bridge	Removal of Existing Concrete Deck	square yard	150	300
Bridge	Bridge	Removal of Existing Substructure	cubic yard	20	40
Bridge	Bridge	Removal of Existing Superstructure	square yard	100	250
Bridge	Bridge	Slope Wall	square yard	25	75
Bridge	Bridge	Structural Steel Erection	foot	150	250
Bridge	Bridge	Structural Steel (Fabricate & Furnish)	calendar day	60	270
Bridge	Bridge	Stud Shear Connectors	each	1000	2500
Bridge	Bridge	Temporary Sheet Piling	square foot	300	1000
Bridge	Bridge	Test Pile	Each	0.5	1
Bridge	Bridge	Waterproofing Membrane System	square yard	100	250
Electrical	Electrical	Conduit in Trench	foot	75	325
Electrical	Electrical	Conduit (Pushed)	foot	30	75
Electrical	Electrical	Controller	each	0.5	1
Electrical	Electrical	Detector Loop	foot	150	300
Electrical	Electrical	Electric Cable	foot	1500	3000
Electrical	Electrical	Electrical Conductors in Conduit	foot	750	1300
Electrical	Electrical	Foundations – Controller, Signal	foot	2	5
Electrical	Electrical	Foundations – Light Poles	foot	10	20
Electrical	Electrical	Foundations – Light Towers	foot	20	25
Electrical	Electrical	Handholes	each	2	4
Electrical	Electrical	Junction Box	each	2	5
Electrical	Electrical	Light Pole	each	4	6
Electrical	Electrical	Light Tower	each	1	2
Electrical	Electrical	Luminaire	each	5	10
Electrical	Electrical	Mast Arm Assembly & Pole	each	2	4
Electrical	Electrical	Raceway for Magnetic Detectors	foot	100	200
Electrical	Electrical	Relocate Existing Traffic Signal Posts	each	2	4
Electrical	Electrical	Service Installation	each	0.5	1

Electrical	Electrical	Signal Head	each	5	10
Electrical	Electrical	Signal Post (wood or metal)	each	4	8
Electrical	Electrical	Trench & Backfill	foot	75	350
Electrical	Electrical	Unit Duct	foot	550	700
Electrical	Electrical	Unit Duct/without Cable	foot	150	350
Landscape	Landscape	Evergreens	each	20	40
Landscape	Landscape	Excelsior Blanket	square yard	1000	4000
Landscape	Landscape	Intermediate Trees	each	20	40
Landscape	Landscape	Seeding	acre	5	10
Landscape	Landscape	Seedling Trees	each	2000	3000
Landscape	Landscape	Shade Trees	each	20	40
Landscape	Landscape	Shrubs	each	200	400
Landscape	Landscape	Sodding	square yard	1000	1500
Landscape	Landscape	Straw Mulch	ton	10	20
Landscape	Landscape	Vines	each	1000	2000
Landscape	Landscape	Weed Control Spraying	acre	50	100
Roadway	Aggregate	Granular Backfill	cubic yard	300	600
Roadway	Aggregate	Granular Embankment Special	ton	800	1500
Roadway	Aggregate	Gravel or Crushed Stone Base Course	ton	700	1200
Roadway	Aggregate	Gravel or Crushed Stone Shoulders	ton	500	1200
Roadway	Aggregate	Gravel or Crushed Stone Surface Course	ton	700	1200
Roadway	Aggregate	Porous Granular Embankment	cubic yard	400	1000
Roadway	Aggregate	Subbase Granular Materials	ton	700	2000
Roadway	Drainage	Adjust Frames & Grates	each	5	10
Roadway	Drainage	Catch Basins	each	2	5
Roadway	Drainage	Concrete Box Culverts	cubic yard	8	15
Roadway	Drainage	Concrete Headwalls	cubic yard	3	8
Roadway	Drainage	Concrete Gutter	foot	400	1400
Roadway	Drainage	Curb & Gutter	foot	300	1200
Roadway	Drainage	End Sections (Pipe Culvert & Storm Sewer)	each	5	10
Roadway	Drainage	Inlets	each	2	5
Roadway	Drainage	Manholes	each	2	4
Roadway	Drainage	Paved Ditch	foot	200	400
Roadway	Drainage	Pipe Culverts (Depending on size and depth)	foot	100	300
Roadway	Drainage	Pipe Underdrains	foot	1500	7500
Roadway	Drainage	Precast Box Culverts	foot	75	250
Roadway	Drainage	Reinforcement Bars (Culverts)	pound	3000	5000
Roadway	Drainage	Riprap	square yard	100	200
Roadway	Drainage	Storm Sewers (Dependent on size and depth)	foot	75	300
Roadway	Drainage	Trench Backfill	cubic yard	100	200
Roadway	Drainage	Exploration Trench	foot	250	1000
Roadway	Excavation	Embankment	cubic yard	500	10000
Roadway	Excavation	Borrow Excavation	cubic yard	1000	10000
Roadway	Excavation	Channel Excavation	cubic yard	200	500
Roadway	Excavation	Earth Excavation (Shoulders & Widening)	cubic yard	500	1000
Roadway	Excavation	Earth Excavation	cubic yard	750	10000
Roadway	Excavation	Rock Excavation (Ripping or Blasting)	cubic yard	500	2000
Roadway	Excavation	Excavation (Special)	cubic yard	500	1000
Roadway	Excavation	Excavation (Topsoil)	cubic yard	500	1000
Roadway	Excavation	Process Lime Modified Soil	square yard	2000	6500
Roadway	Excavation	Process Lime Stabilized Soil	square yard	2000	6500
Roadway	Excavation	Topsoil Placement	square yard	5000	25000
Roadway	Miscellaneous	Chain Link Fence	foot	300	500
Roadway	Miscellaneous	Concrete Barrier	foot	200	400
Roadway	Miscellaneous	Delineators	each	75	150
Roadway	Miscellaneous	Furnishing and Erecting Row Markers	each	10	30

Roadway	Miscellaneous	Noise Abatement Wall	square foot	800	1000
Roadway	Miscellaneous	Steel Plate Beam Guardrail	foot	300	600
Roadway	Miscellaneous	Steel Plate Beam Guardrail Removal	foot	500	800
Roadway	Miscellaneous	Temporary Concrete Barrier Wall	foot	500	1500
Roadway	Miscellaneous	Woven Wire Fence	foot	500	1000
Roadway	Patching	Class A	square yard	50	100
Roadway	Patching	Class B	square yard	50	100
Roadway	Patching	Class C & D	square yard	100	150
Roadway	Paving	Bituminous Concrete Base Course Widening	square yard	500	2000
Roadway	Paving	Bituminous Concrete Binder & Surface Course SuperPave	ton	500	1600
Roadway	Paving	Bituminous Materials	gallon	3000	10000
Roadway	Paving	Bituminous Pavement Removal & Replacement	square yard	50	100
Roadway	Paving	Bituminous Shoulders	square yard	1500	4500
Roadway	Paving	Bridge Approach Pavement	square yard	50	100
Roadway	Paving	Continuously Reinforced Concrete Pavement	square yard	2000	7000
Roadway	Paving	Bituminous Concrete Pavement (Full depth)	square yard	1000	3500
Roadway	Paving	Level Binder	ton	50	1600
Roadway	Paving	Median Surface (Concrete)	square foot	750	2000
Roadway	Paving	Pavement Fabric	square yard	1200	6000
Roadway	Paving	Pavement Reinforcement	square yard	1500	5000
Roadway	Paving	PC Concrete Base Course	square yard	1500	6000
Roadway	Paving	PC Concrete Base Course Widening	square yard	750	2500
Roadway	Paving	PC Concrete Driveways	square yard	100	150
Roadway	Paving	PC Concrete Pavement	square yard	1500	6000
Roadway	Paving	PC Concrete Pavement (Hinge Joint)	square foot	1500	6000
Roadway	Paving	PC Concrete Sidewalks	square yard	1000	1500
Roadway	Paving	PCC Shoulders	square yard	1200	6000
Roadway	Paving	Protective Coat	square yard	3000	7000
Roadway	Paving	Stabilized Subbase 4″	square yard	3000	10000
Roadway	Paving	Strip Reflective Crack Control	foot	10000	20000
Roadway	Pvt Mk	Paint Pavement Marking (Hand)	foot	500	1000
Roadway	Pvt Mk	Paint Pavement Marking (Truck)	foot	10000	20000
Roadway	Pvt Mk	Raised Reflective Pavement Markers	each	100	200
Roadway	Pvt Mk	Thermoplastic Pavement Marking Symbol	square foot	450	900
Roadway	Pvt Mk	Thermoplastic Pavement Marking (Hand)	foot	500	1000
Roadway	Pvt Mk	Thermoplastic Pavement Marking (Truck)	foot	10000	20000
Roadway	Removal	Bituminous Surface Removal	square yard	2000	10000
Roadway	Removal	Curb & Gutter Removal	foot	600	1400
Roadway	Removal	Pavement Grinding	square yard	1000	2000
Roadway	Removal	Pavement Removal	square yard	1000	2000
Roadway	Removal	Sidewalk Removal	square foot	1500	2500
Roadway	Removal	Tree Removal	acre	2	4
Roadway	Removal	Tree Removal (6 to 15 Units Diameter)	units	150	400
Roadway	Removal	Tree Removal (Over 15 Units Diameter)	units	100	300
Signing	Signing	Metal Post	foot	250	400
Signing	Signing	Overhead Sign Foundation	cubic yard	5	16
Signing	Signing	Overhead Sign Structure	foot	25	50
Signing	Signing	Sign Panel	square foot	500	2000
Signing	Signing	Structural Steel Sign Support Non-Breakaway	pound	1000	15000

APPENDIX 2 ILLINOIS CONSTRUCTION SCHEDULING EXPERT SYSTEM
VERSION 1.0, JUNE 2011

Illinois Construction Scheduling Expert System

User's Manual
Version 1.0 – June 2011

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Illinois Center for Transportation
Illinois Department of Transportation

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PREFACE

Illinois Construction Scheduling Expert System (ICSES) is a Windows-based software program used for planning and scheduling road construction projects. The program is designed to allow users to develop an engineer's estimate of time required to complete road and bridge construction projects.

ICSES was developed by researchers at Missouri State University (MSU) in Springfield, Missouri. The program is the product of research sponsored by the Illinois Center for Transportation (ICT) and MSU. Principal researchers on the project were Dianne K. Slattery, Ph.D., P.E, Kerry T. Slattery, Ph.D., P.E., and Richard D. Bruce, Ph.D. ICSES was designed and written by Kerry Slattery. Program documentation and a user manual were written by Kerry Slattery and Dianne Slattery. Project guidance was given by a Technical Review Panel (TRP) consisting of members from the Illinois Department of Transportation and the Federal Highway Adminstration. Special thanks is due to TRP chairman Michael Ripka and members Jerry Cameron, Kensil Garnett, Michael Hine, Al Mlancik, John Negangard, Ted Nemsky and Dan Wilcox. Personnel from IDOT District 8, Karen Challandes, Pattie Connor, Jon Dintelman, Herve Gegin, Aaron Karlas, Gwen Lagemann, Art Muehlfeld, and Tim Padgett participated in a half-day review of the program and provided many valuable suggestions that were incorporated in the final version.

DEFINITIONS AND ACRONYMS

BDE – Bureau of Design and Environment

HMA – Hot Mix Asphalt

ICSES – Illinois Construction Scheduling Expert System

ICORS – Illinois Construction Record System

ICT – Illinois Center for Transportation

IDOT – Illinois Department of Transportation

SSRBCI – Standard Specifications for Road and Bridge Construction in Illinois, adopted January 1, 2007

BACKGROUND INFORMATION

The Illinois Department of Transportation (IDOT) identified a need to improve engineers' estimates of time required to construct typical IDOT projects. A research team from Missouri State University (MSU) was selected to perform the work outlined in a Request for Proposal from the Illinois Center for Transportation (ICT) project "An Expert Systems Approach to Highway Construction Scheduling" ICT project R27-86. The project began on July 1, 2010 and was completed on June 30, 2011.

The primary objective of this research was to develop a software tool to assist highway designers in developing more accurate estimates of the time required to complete highway construction projects in Illinois, and to examine the statewide winter exclusion period and evaluate which construction operations might be carried out in parts of the state during this time based on historical weather records.

Interviews with highway construction contractors, input from IDOT design and construction personnel, records from the Illinois Construction Record System (ICORS), and published reports from the other state DOTs and reference sources provided expert knowledge on how planning and scheduling of highway projects is carried out, the work activities that typically affect project duration (controlling items), and the production rates of those work activities.

Using these sources, the researchers developed project templates for 12 project types and guidance to assist designers in selecting the production rates for controlling items. Each template will present a bar chart project schedule showing only the controlling items. Concurrent activities that may be required to complete the project but are not likely to impact project completion date are not shown.

Constraints on the project can be selected, including the current Projected Number of Working Days per month as specified in Bureau of Design and Environment (BDE) Manual Figure 66-2C, and the winter exclusion period of December 1 through April 30. Historical temperature and rainfall records can be selected to allow users to study the impact of various start dates, the likely project-specific weather throughout the calendar year, and other project specific constraints such as protection of bat habitat or restrictions on road closure dates.

Weather-related constraints on controlling items were referenced to the Standard Specifications for Road and Bridge Construction in Illinois (SSRBCI) adopted January 1, 2007. The researchers used the production rates for activities listed in the BDE Manual Figure 66-2B as the standard for naming controlling items, but updated the term "bituminous" to "HMA" for consistency with the SSRBCI.

After finding the duration of each of the controlling activities for a project, the user is given the projected number of working days, the projected number of calendar days, and a completion date for the project.

GETTING STARTED

System Requirements

ICSES will run on computers running the Windows XP or Windows 7 operating systems. Display resolution should be at least 1280 X 800 pixels. The program uses default font sizes that are not adjustable. Contact your systems administrator for questions regarding your computer's display properties.

Installing ICSES

ICSES Version 1.0 is distributed by the IDOT Bureau of Information Processing (BIP)

Uses for ICSES

ICSES was designed to develop the estimate of time required for typical highway construction project types for the Illinois Department of Transportation. The tool references the SSRBCI and Illinois climate data. The scheduling tool uses production rates from the IDOT BDE Manual Chapter 66, supplemented with guidance derived from a variety of reference sources.

Exiting ICSES

To close ICSES, use the File function on the Menu bar and Select Exit. You will be prompted to save the project before closing.

USER INTERFACE

The **Illinois Construction Scheduling Expert System (ICSES)** user interface provides a menu bar to access program functions. Figure 1 shows the **ICSES** form. The File tab allows the user to manage project files with the New Project, Open Project, Save Project and Save Project As options shown.

Figure 1. Illinois Construction Scheduling Expert System form.

The Calendar option is selected under the Edit tab to edit the project calendar. The Refresh and Generate Report options under the Schedule tab refresh the schedule display and generate reports of the results.

File Options

Projects are stored in a text file with a ".esp" file extension.

New Project

Selecting New Project opens the New Project form shown in Figure 2. The user may enter appropriate identifying designations in the Project, Route, Section, County and Description text boxes. The Project entry is the default name for project files.

Expanding the Letting Date drop-down box displays standard IDOT letting dates for a three year period from the current date The expected Start Date for the project is determined based on the values for Days to Award and Days to Start on the form. Default values of 30 days between letting and contract award and 15 days between award and project start are provided, but these may be changed by the user. The calculated Start Date can be modified by typing in a start date or by clicking the C (Calendar) button to display a monthly calendar to select the expected start date.

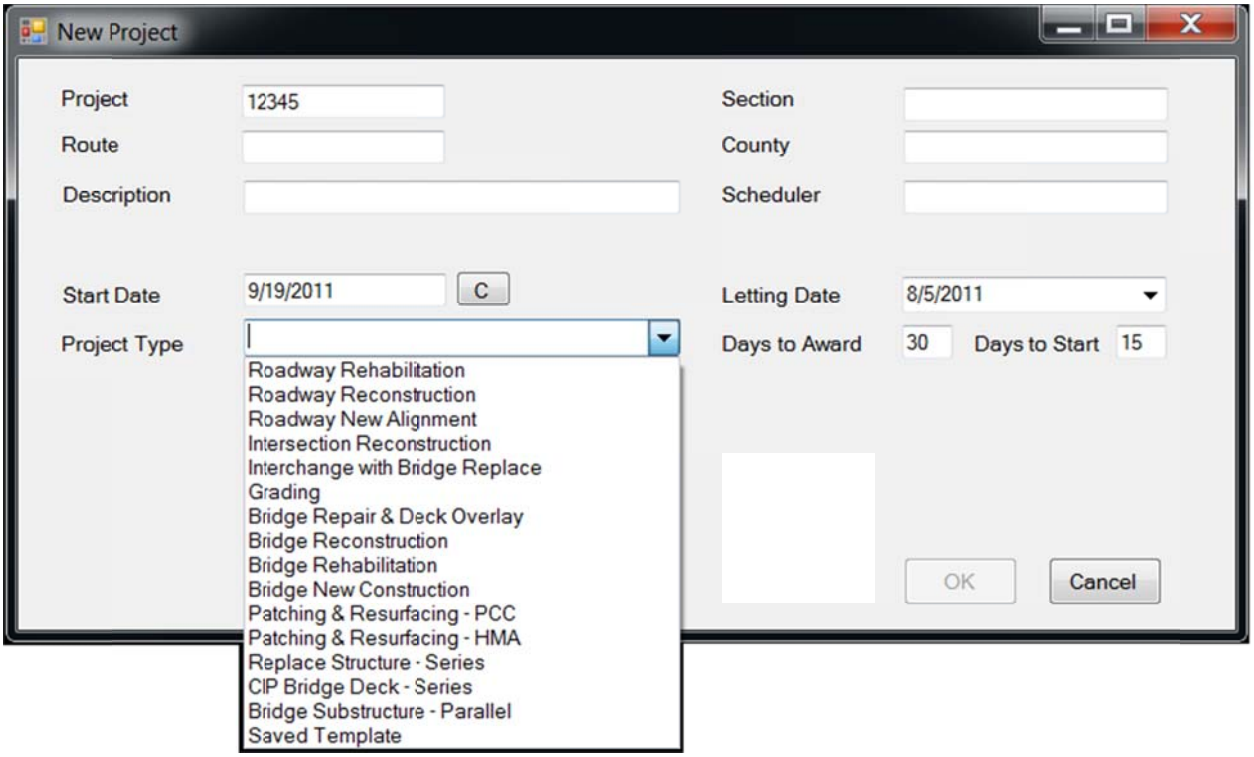

Figure 2. New Project form.

Using Project Templates

Expanding the Project Type drop-down box, as shown in Figure 2, displays available templates of typical project types with which to build the project schedule. Templates list the construction activities that usually control the schedule on each project type in the typical order. Non-controlling activities are not considered. Most templates assume that these activities are performed sequentially with no overlap.

Templates with names ending in "- Series" or "- Parallel" may be selected but are intended to be used as Master activities for more complex schedules. These are described in detail under *Multi-layer Schedules*.

Selecting the *Saved Template* option prompts the user to choose a template created previously by modifying a standard template. These are stored in *.est files. These templates may be shared among users.

After the Type is selected, a Review button is displayed as shown in Figure 3. Clicking the Review button displays the Template Review form that lists the Activities in the template and their Predecessors. Figure 4 shows this form for the Roadway New Alignment template.

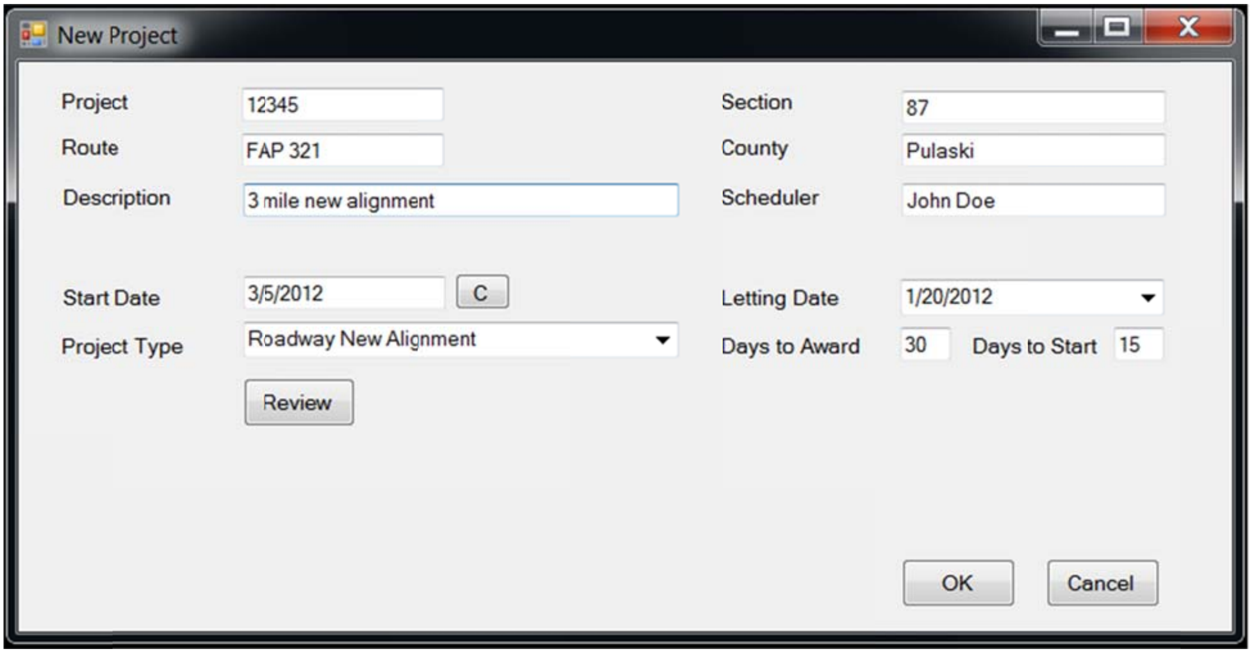

Figure 3. New Project form – Review button displayed.

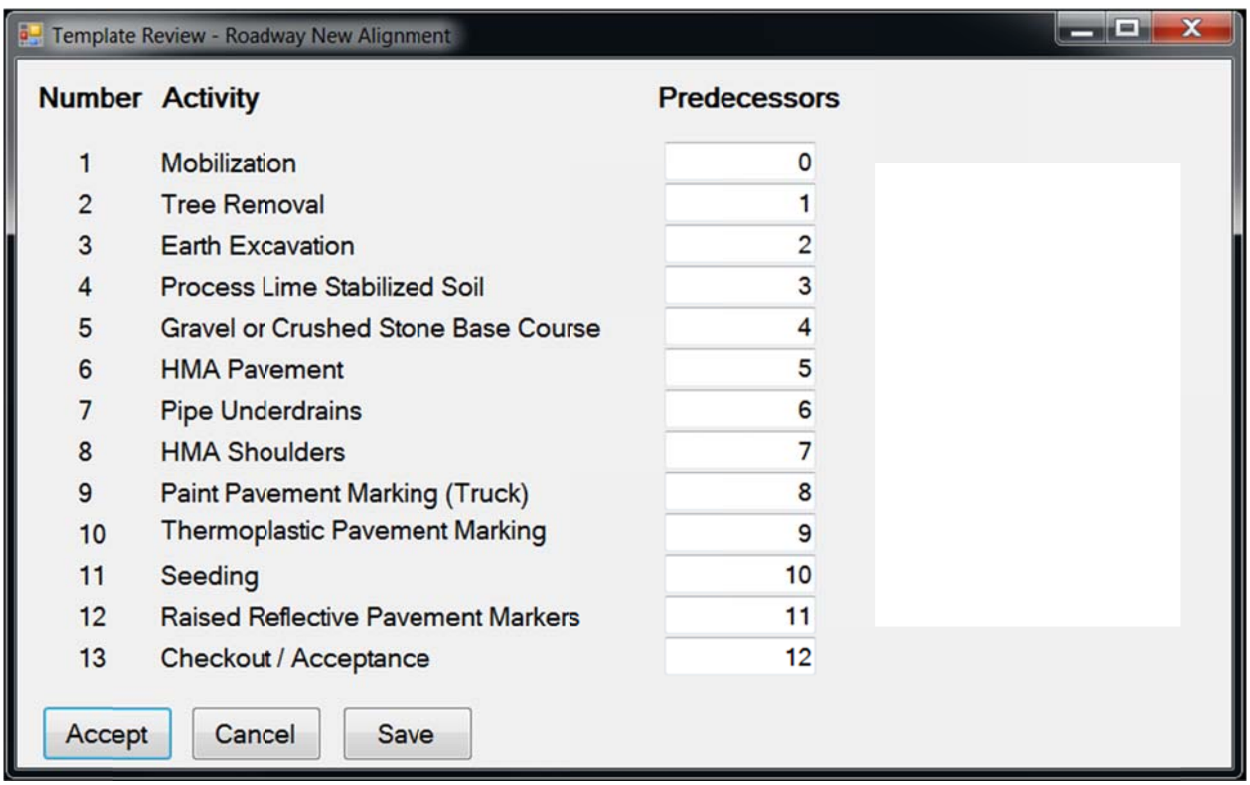

Figure 4. Template Review form

Modifying Project Templates

The template can be accepted as presented, or can be modified by the user. Predecessors can be changed by modifying the numbers. Multiple predecessors can be assigned to one activity by separating the preceding activity numbers with commas in the text box, e.g. 3,4,7. The assumed precedence is Finish-To-Start; that is, if the predecessor for Activity 3 is Activity 2, Activity 2 must be completed before Activity 3 is started. A Start-To-Start precedence can be specified by adding SS+n after the preceding activity number, where n is the lag time between the start of the two activities. For example, if the predecessor for Activity 3 is 2SS+4, Activity 3 may begin 4 days after Activity 2 begins. The lag time can be modified as the schedule is developed. Figure 5 shows examples of these predecessor options.

Clicking an Activity name displays two buttons: Add Above and Delete, as shown in Figure 6. Clicking the name again removes these buttons. Selecting Add Above inserts a drop-down box of allowable activities above the selected activity (Figure 7). The user selects the desired activity and modifies the predecessors, if required. The Delete button removes the selected activity from the template. Predecessors for other tasks are automatically updated but should be reviewed. The user can click the Save button to save the modified template to a *.est file for use on other projects.

The user clicks Accept to use the modified template. Cancel reverts to the original, default template. Either choice closes the form and returns to the New Project form. The user selects OK to create the project. The user is then prompted to select a file name. The default name is the Project designation followed by the .esp extension.

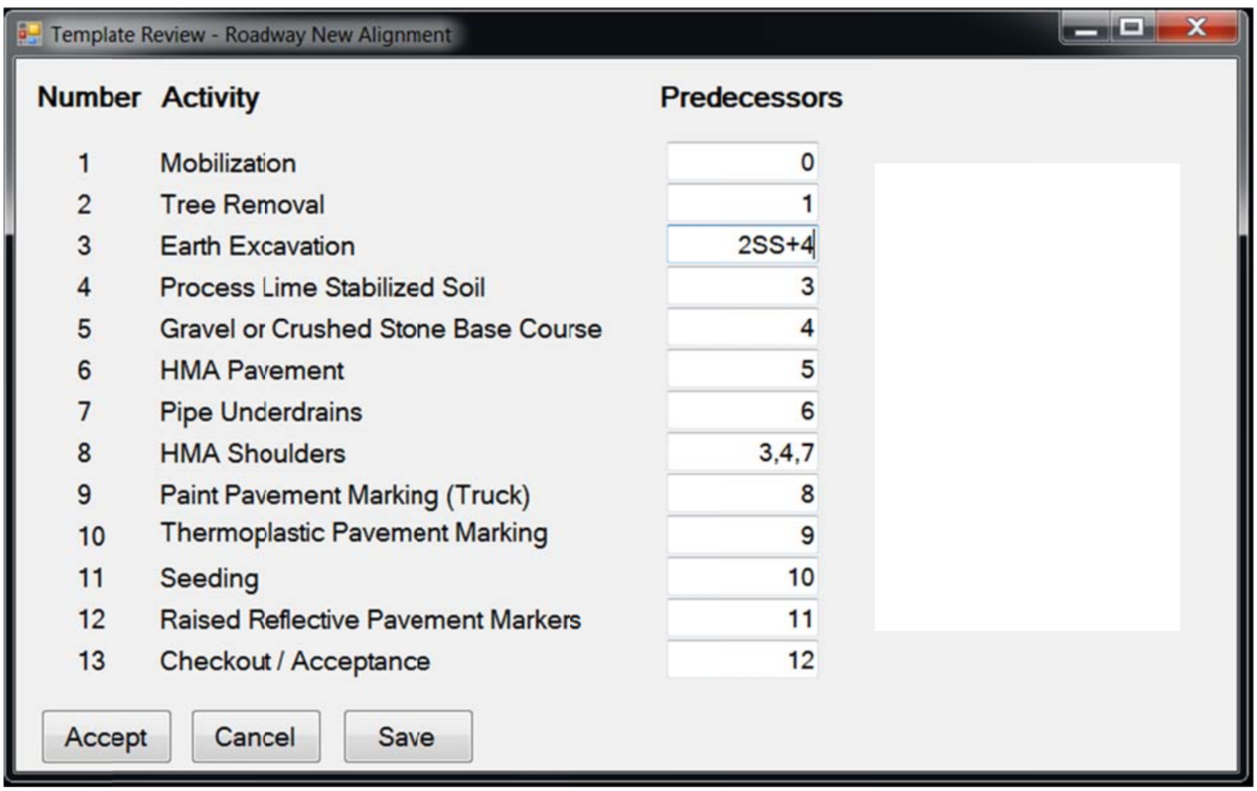

Figure 5. Enter multiple or Start-To-Start predecessors.

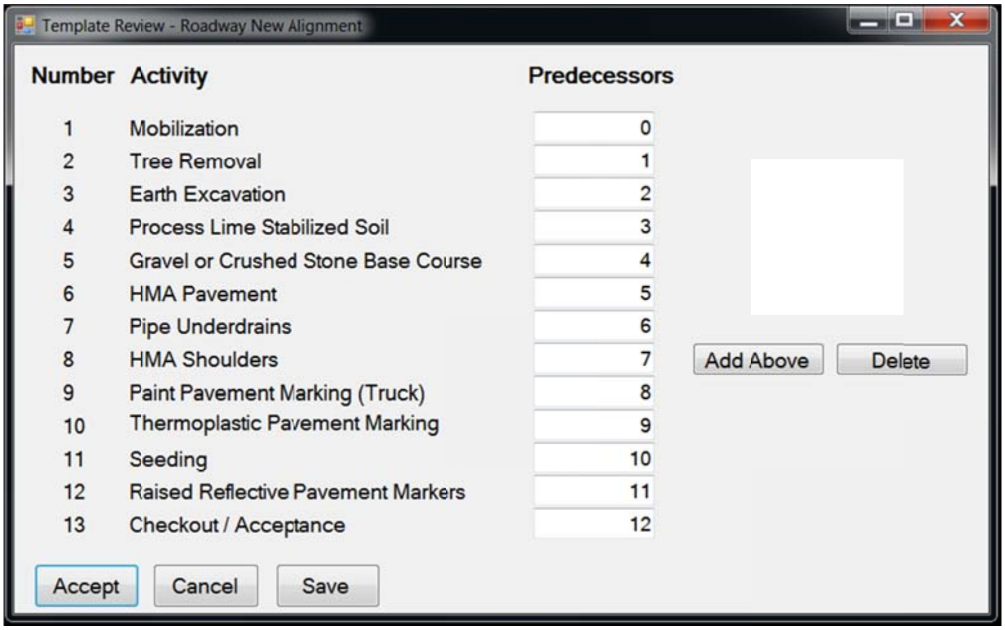

Figure 6. Add Above and Delete options for HMA Shoulders activity.

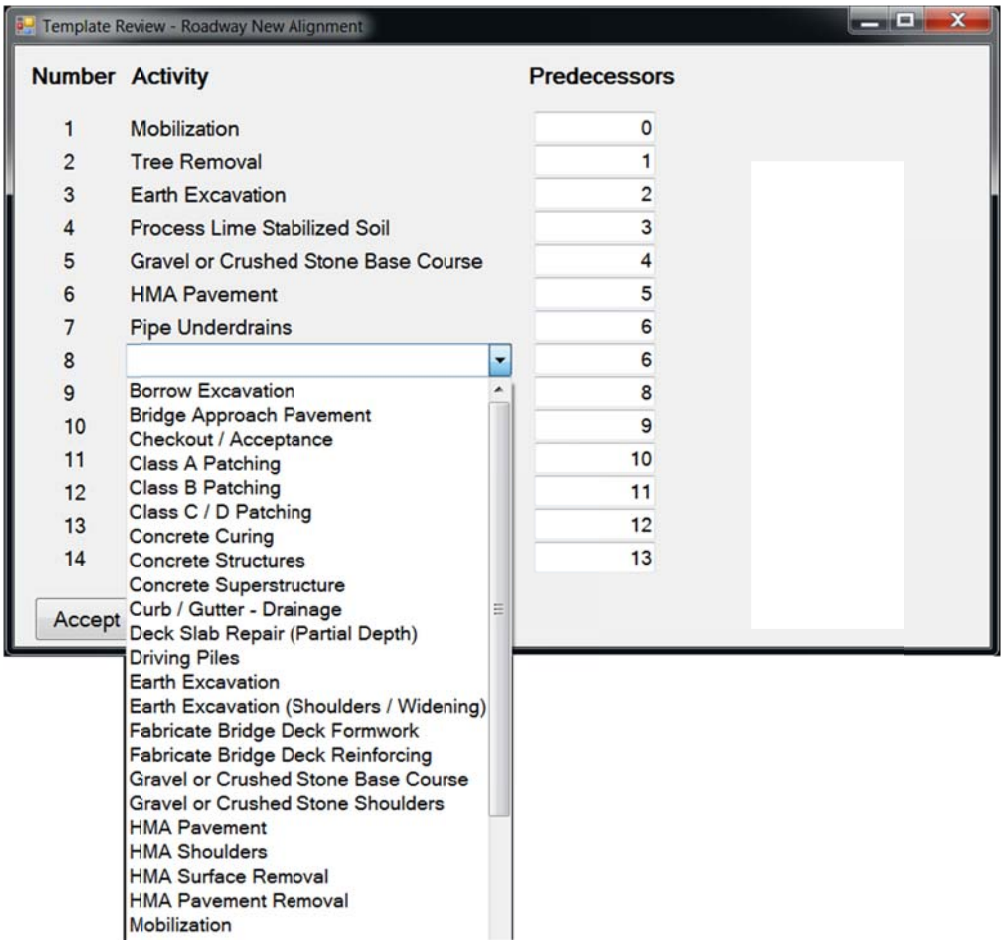

Figure 7. Select an available activity to add to the template.

Open Project

Form|Open Project is selected to open an existing project. A standard dialog box appears to select the desired project file. The Open Project form appears displaying the data entered in the New Project form identifying the project. All entries other than Project Type can be changed.

Save Project/Save Project As

The project can be saved at any time. The Save Project As option allows the user to save under a new name. The previously saved version will be retained under the old name.

Exit

Select Exit to exit the program.

Edit Options

The user Edits the Calendar for the project to characterize work restrictions due to weather and other constraints. Weekends, holidays, expected rain days and days that are too cold to perform controlling items are identified. The user can also enter other types of constraints related to local and job conditions that will restrict when work is allowed.

Calendar

The Edit|Calendar menu option is automatically selected when a new project is created. It can be selected at any other time to make additional updates. The default Calendar includes a 5-day work week, the winter exclusion period of December 1 – April 30, the Projected Working Days per month from BDE Manual Figure 66-2C (Table 1) and 7 standard holidays per the SSRBCI, Article 107.09. Figure 8 shows the Calendar with the four default constraints defined. The Holidays constraint is selected. Days on which holiday restrictions are imposed are not bold. Those not affected by holidays are bold.

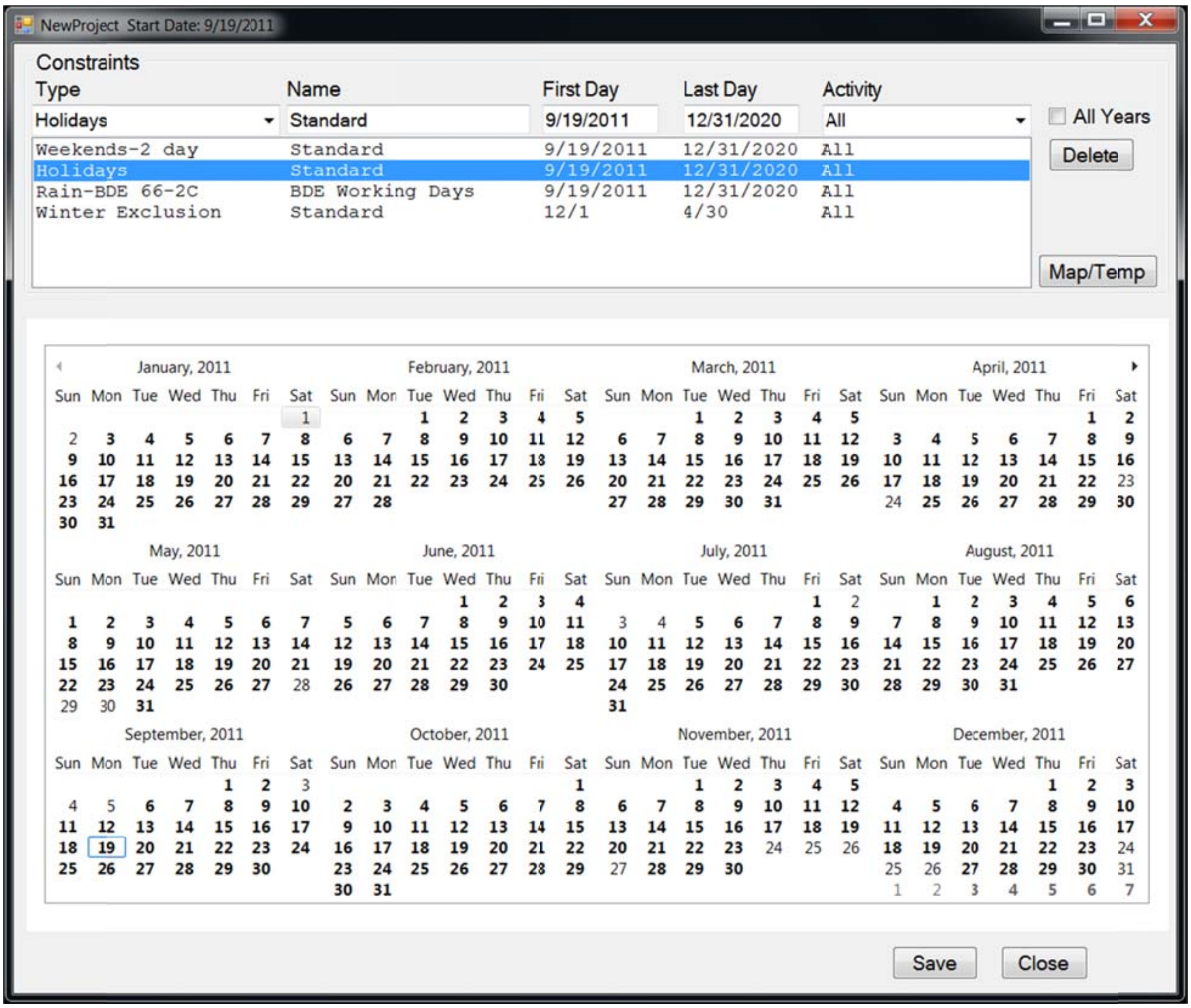

Figure 8. Calendar form.

Table 1. Working Days Per Month, from BDE Manual Chapter 66, Figure 66-2C.

WORKING DAYS PER MONTH												
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
WORKING												
DAYS	0	0	0	0	15	17	17	17	16	16	14	0
CALENDAR												
DAYS	31	28	31	30	31	30	31	31	30	31	30	31

The default constraints can be modified to study the impact of:

- Allowing work during the winter exclusion period (Delete Winter Exclusion)
- Working 6-day weeks (Add Weekends-1 day, Delete Weekends-2 day)
- Expected rain days based on historical records

Note that the Rain-BDE 66-2C constraint adds enough rain days throughout the month to ensure the number of working days specified in Table 1. Historical rain days are scattered throughout the month and may fall on non-working days such as weekends or holidays.

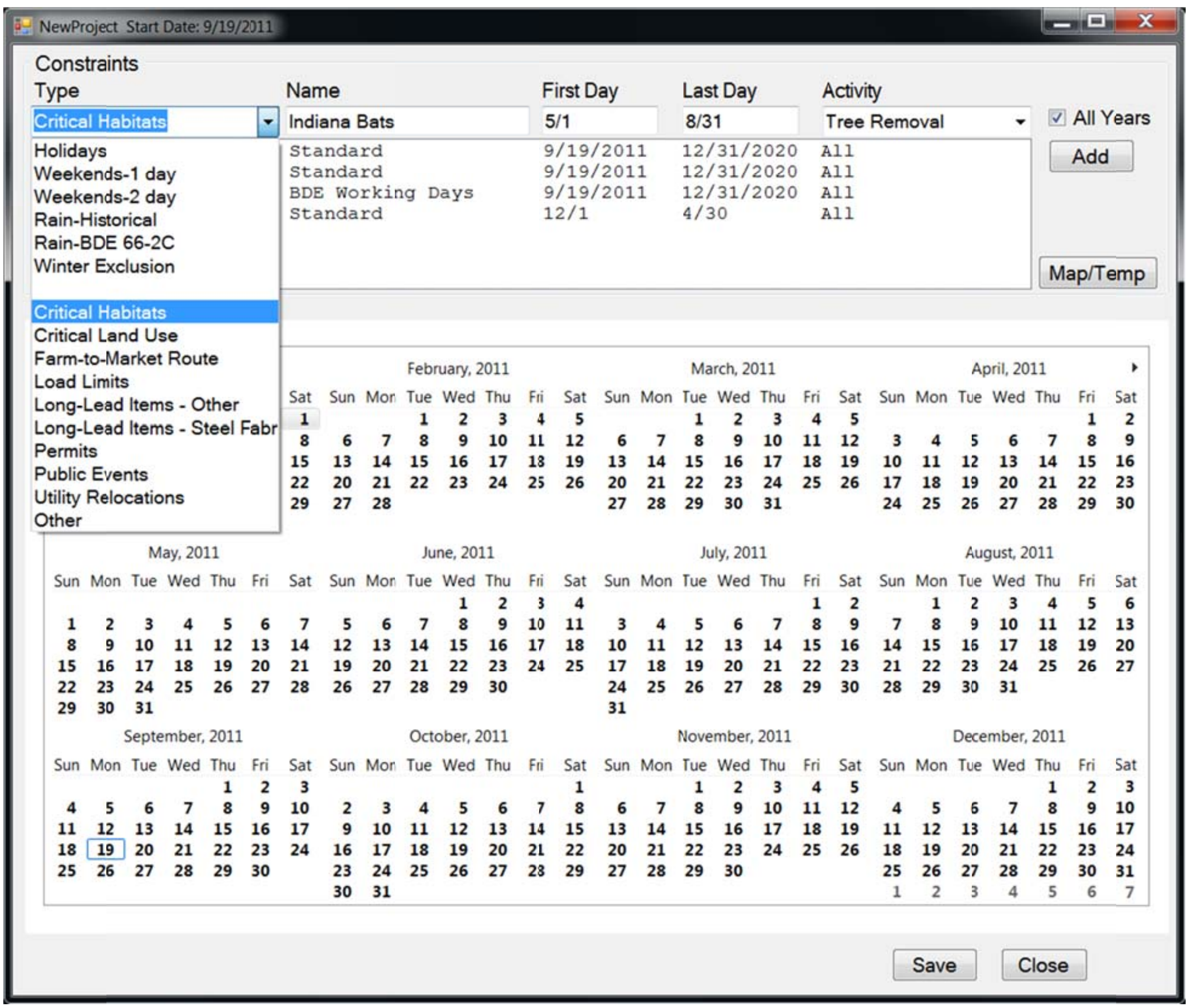

Figure 9. Select constraint type.

Adding constraints

Figure 9 shows the list of available constraint types. The job-specific constraint types below the break are other items that may restrict work on the project. The user selects the Type, enters a Name and selects the First Day and Last Day that work is restricted. These dates may be selected by dragging the mouse from the first day on the calendar to the last day. The first and last days may also be clicked separately. The calendar can be advanced to the next year before clicking the last day, if necessary. The date in the text box may also be modified.

The user then designates which activity in the schedule template is restricted by the constraint. Expanding the Activity combo box displays all activities for the user to select from. There is an option to select All activities. If a constraint affects more than one activity, but not all, different constraints must be entered for each. The All Years box should be checked if the constraint is identical for every year of the project. When All Years is checked, the date in the display does not include a year. The example in Figure 9 restricts tree removal during the Indiana Bat nesting season. Click Add to add the new constraint.

When a constraint is selected, the Add button changes to Delete. Clicking the Delete button removes the selected constraint.

Instead of deleting, the user can make changes to the selected constraint. The Delete button changes to Modify when a change is made. Click Modify when changes are complete.

Temperature-based constraints

Constraints based on temperature can be tailored to the project location and the specific temperature requirements for an activity as stated in the SSRBCI. Clicking the Map/Temp button displays a map of Illinois and lists the activities in the project template that have temperature restrictions (Figure 10). The button text changes to Calendar indicating that clicking again will return to the calendar. The user first clicks the Locate button then moves the mouse over the map and selects the approximate project location. The program then accesses temperature records and determines the First Day and Last Day on which the average temperature crosses the threshold temperature for each activity. These dates are then displayed as shown in Figure 11.

Three Types of temperature data are available: average minimum, average mean or average maximum daily temperature. The default Type is the minimum temperature. The user can change the threshold temperature, the First and Last Day and the Type, if desired. The **Upd**ate must be clicked after changing the Temperature or Type to update the First and Last Days based on historical temperature records. If **Upd**ate is clicked after manually changing the First Day or Last Day, these values will revert to historically-based dates. The user clicks the Add button next to each of the temperature-based constraints to add it to the general list of constraints for the project.

The Save button is clicked to save changes to the project constraints. The user clicks Close to exit the calendar and display the preliminary project schedule.

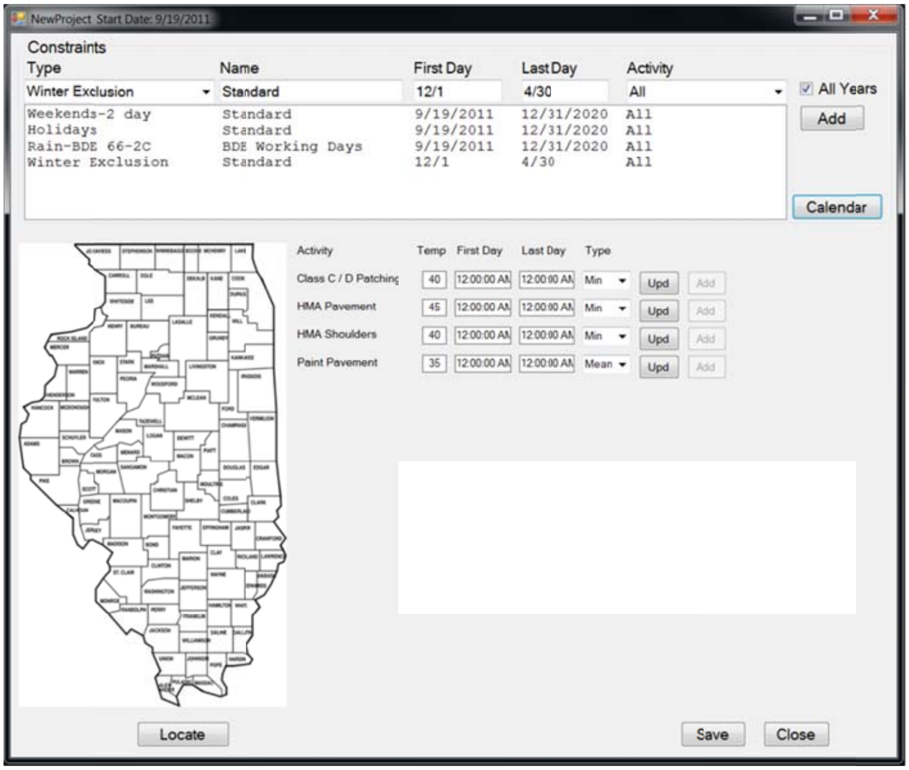

Figure 10. Temperature-based constraint utility.

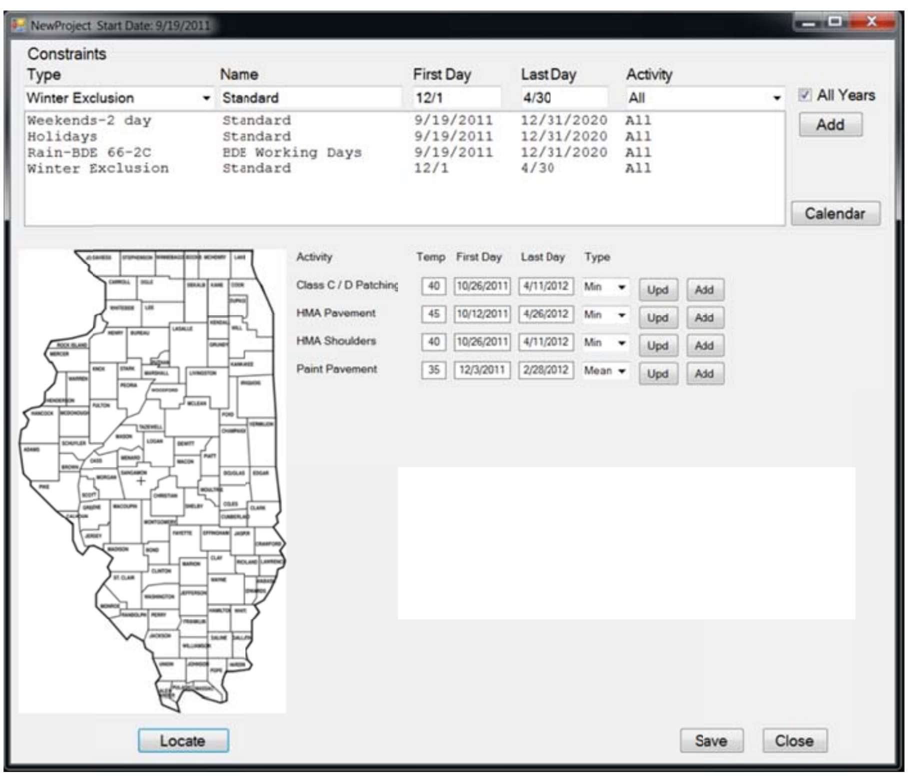

Figure 11. Location/activity-based temperature constraints defined.

Schedule Options

Preliminary Schedule

The bar chart schedule shows the order and duration of the activities in the project template. Figure 12 is the default schedule after the calendar has been defined with the default constraints. Most activities are arbitrarily assigned a duration of five working days. The red background color on the duration buttons indicates that the default values have not been changed. The top bar chart shows the beginning of the project before temperature conditions are expected to restrict paving. The bottom bar chart, accessed by scrolling to the right, shows the end of the project.

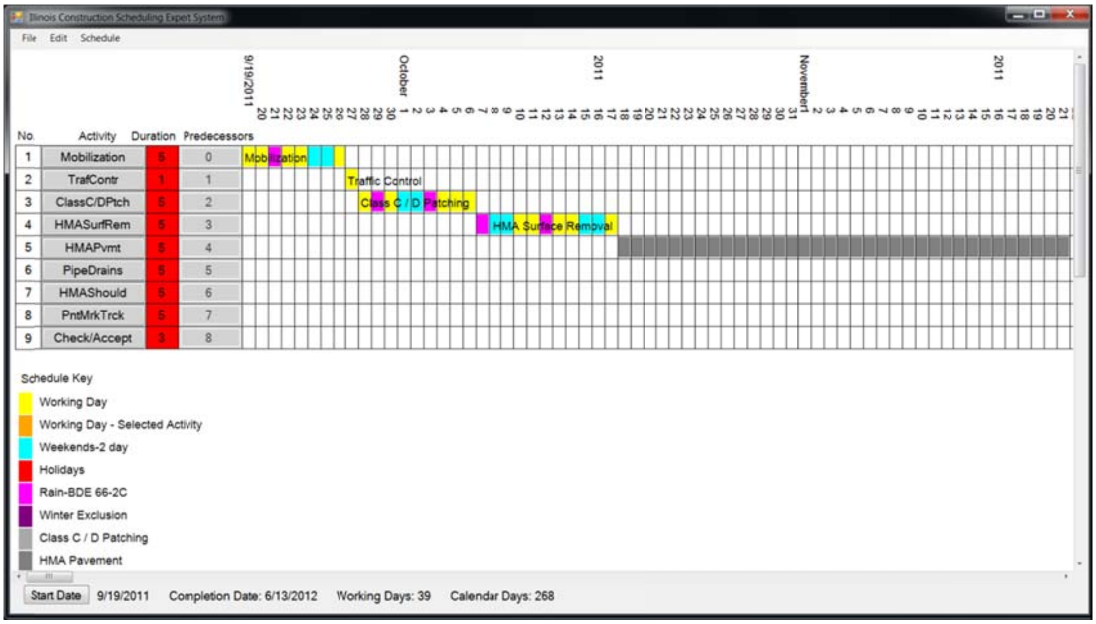

Figure 12. Default bar chart schedule.

Finalizing the Schedule

The user is expected to evaluate and update the duration of all activities based on the project quantities for the controlling items listed in the project template.

Schedule Key

The bar colors may vary daily to indicate which constraint is expected to prevent work on that day. Yellow or orange days are working days. The currently selected activity is highlighted in orange. The Key for other bar colors is provided below the chart. In Figure 12 May 26-28 are dark orange for HMA Shoulders indicating the Memorial Day weekend holiday. The magenta rain days are scattered over each month. As the Rain-BDE 66-2C constraint is used, the rain days are defined to ensure the Projected Number of Working Days each month as defined in BDE Manual Figure 66-2C.

The Start Date, Completion Date, number of Working Days and number of Calendar days are shown below the bar chart for the current schedule.

Edit Activity

Clicking on an Activity in the left column opens the Activity Duration Estimation (ADE) Form. Figure 13 shows the ADE form for the Earth Excavation activity. The user enters the activity quantity in the Quantity text box. Forms for each activity provide a discussion on estimating the production rate for that activity. Many are based on a typical production rate for one crew, and the default value is provided in the Crew Production text box.

Relevant production rate data from various references is provided on the form when available. The current Low and High productivity values from the BDE manual are shown along with the calculated average value. The three references are: Reference 1(O'Connor et al., 2004), Reference 2 (Atreya, 2007), Reference 3 (IDOT District 5 Production Rate Data)

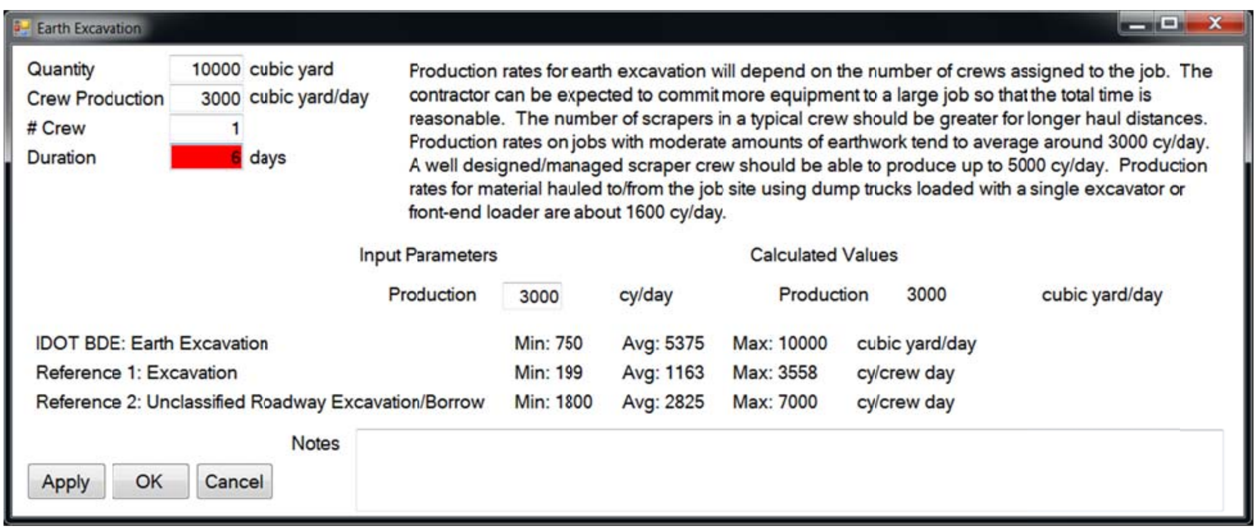

Figure 13. Activity Duration Estimation form.

If the user expects the contractor to assign multiple crews to an activity, this is indicated in the # Crew text box. The Duration is calculated from these values and rounded up to the nearest integer. The background color for the Duration text box is red to indicate that the duration was simply selected by the user and not based on a calculation related to the quantity and production rate. For the example in Figure 13, the user has opted to enter a 6-day duration. The Notes box in the lower portion of the form allows the user to document the assumptions made or reasons for selecting this duration.

Calculators are provided on the ADE form to assist with estimating. The Earth Excavation task in Figure 13 is an example of a very simple calculator. The crew production value can be entered under Input Parameters. The value is calculated under Calculated Values and the Crew Production rate is updated. Alternatively, the user could change the Crew Production value.

Figure 14 shows a more complex calculator for full depth HMA pavement. The production rate will generally be governed by the tons/hour supplied by the asphalt plant supporting the activity, while the bid quantity is given in square yards. The calculator allows the user to input additional parameters for the paving job to convert tons/hour available from the asphalt plant to square yards/day. The minimum lift thickness is also input to calculate the maximum speed of the paver in feet per minute, a factor that may be governed by the contract.

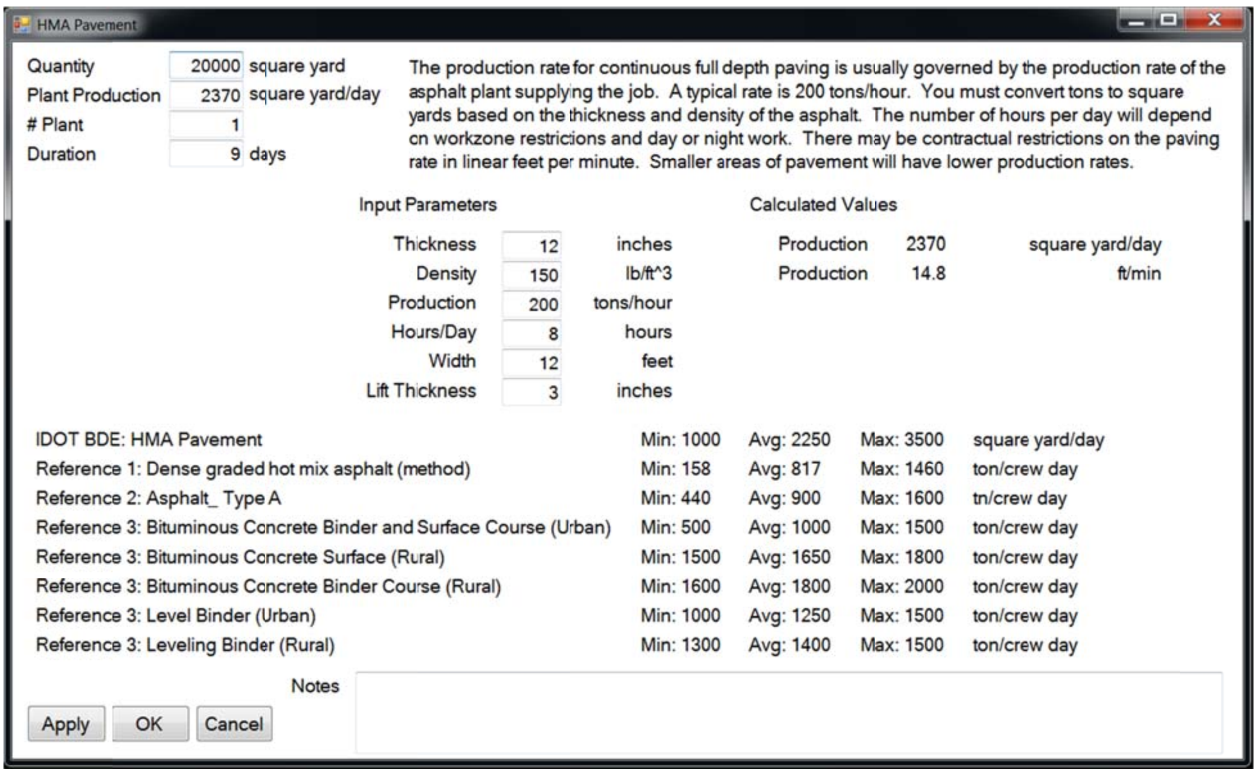

Figure 14. HMA Pavement ADE form.

Multi-layer Schedules

Templates for projects with major, complex activities that are performed multiple times may include Master activities that are themselves templates consisting of a series of individual activities. Activities in a Master template may also be Master activities so the schedule may have up to three layers. There are currently three such Master templates for bridge projects:

Replace Structure – Series, CIP Bridge Deck – Series, and Bridge Substructure – Parallel. A Series template implies that the first Master activity must be completed before the second begins; that is, the first bridge would be completed and traffic moved to it before demolition begins on the second bridge. With a Parallel template, multiple crews are working on activities in progression. For example, on the bridge substructure the pile driving crew moves to the second pier as the forming crew constructs formwork for the pile cap on the first pier.

Figure 15 shows the default schedule for a bridge reconstruction project. The fifth activity is a Master activity – Replace Structure – Series. The button for this Activity is highlighted in red with the caption Master. The activity name is superimposed on the bar schedule. The red highlight informs the user that this activity must be updated. That is, the duration on this activity is not valid unless the calendar is updated. The calendar for this Master activity is displayed the first time the Master button is clicked. Procedures for updating the calendar are identical to those for the project calendar except that the project location has already been established. After closing the calendar, the default schedule for replacing two bridge structures is shown (Figure 16). The user was prompted earlier to state how many structures were involved. The ten activities in the Replace Structure – Series template are shown twice for a total of 20 activities.

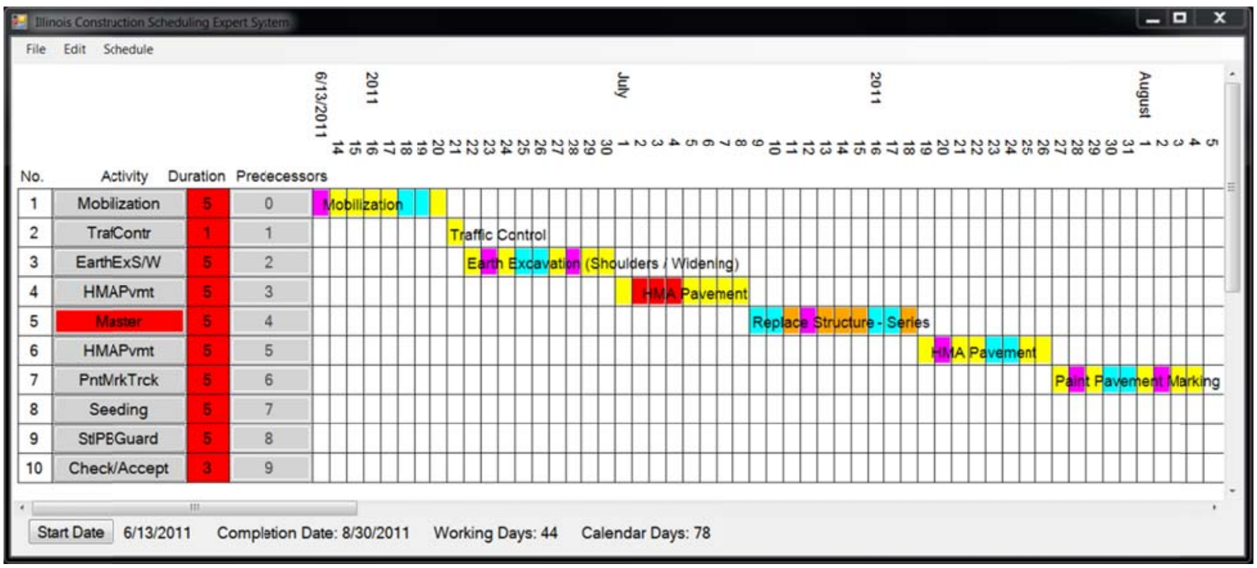

Figure 15. Project schedule with Replace Structure Master activity.

When an activity in a Master template is clicked to open the ADE form, note that a check box labeled Link Similar is displayed below the Duration (Figure 17). If this is checked (the default), the duration for the same task for other structures will be calculated based on the same values. This box should be un-checked if quantities or production rates are different. The Replace Structure schedule has a button labeled Master above the Activity label. Clicking this returns the user to the project schedule.

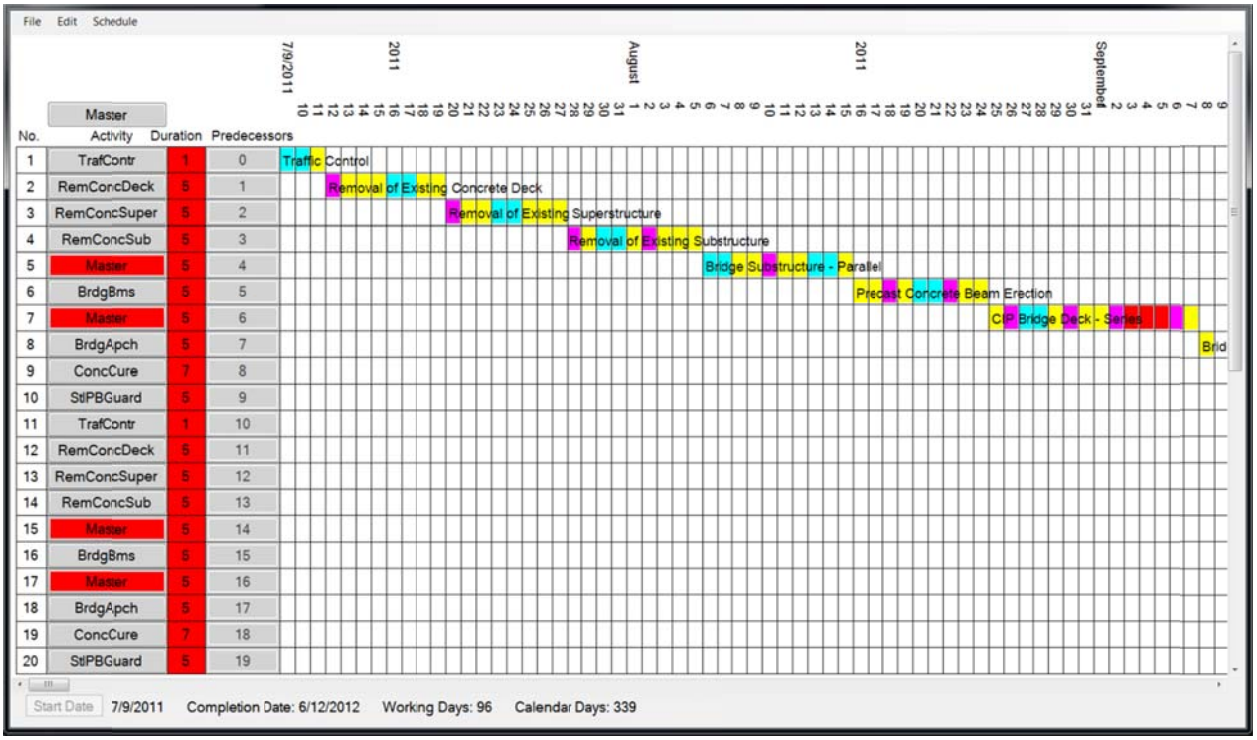

Figure 16. Replace Structure schedule.

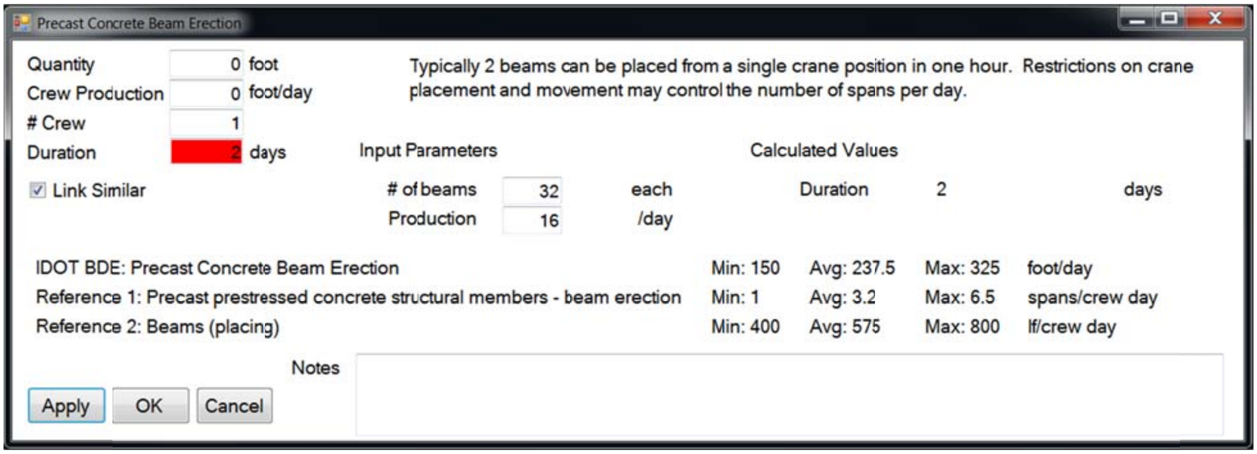

Figure 17. ADE form showing Link Similar check box.

Each bridge span in the schedule in Figure 16 has two Master tasks, Bridge Substructure – Parallel and CIP Bridge Deck – Series. Clicking the Master button for the Bridge Substructure opens the schedule for one bridge substructure. Again, the Calendar will be displayed for editing the first time this is opened and the user was prompted earlier for the number of substructure components (abutments and piers) required for each span. Figure 18 shows this parallel schedule. Note that Place Abutment and Place Pile Cap are shown as concurrent activities for each substructure. A substructure is either an abutment or a pier so the duration of one of these is set to zero along with the corresponding Place Columns and Place Pier Cap tasks for abutments. The example in the figure is a 2-span bridge with 2 abutments and one pier. When the Master button above the Activity label is clicked, the program returns to the Replace Structure schedule and the bar in the schedule for this Master activity reflects the total duration derived in the Bridge Substructure schedule as reflected in Figure 19.

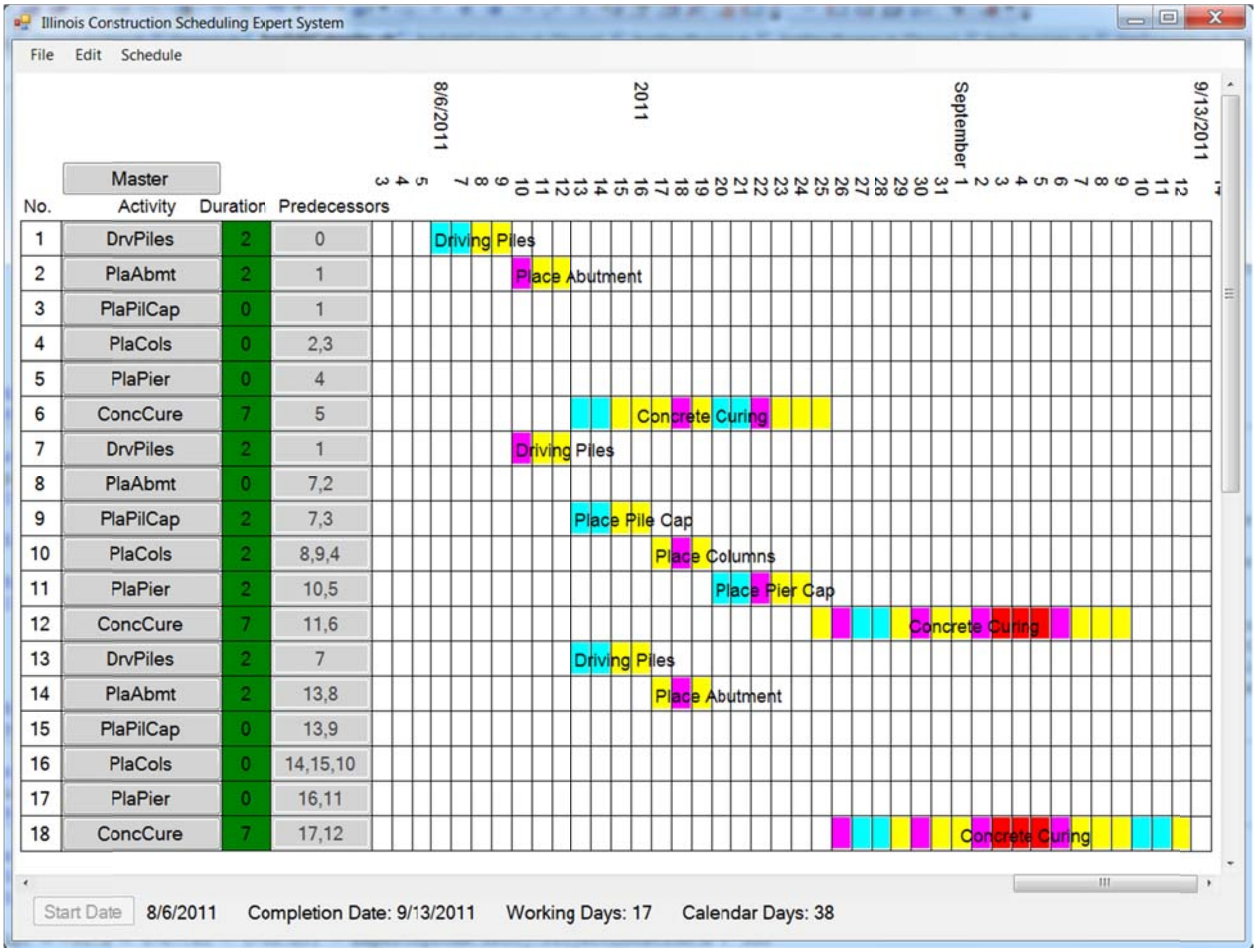

Figure 18. Bridge Substructure schedule.

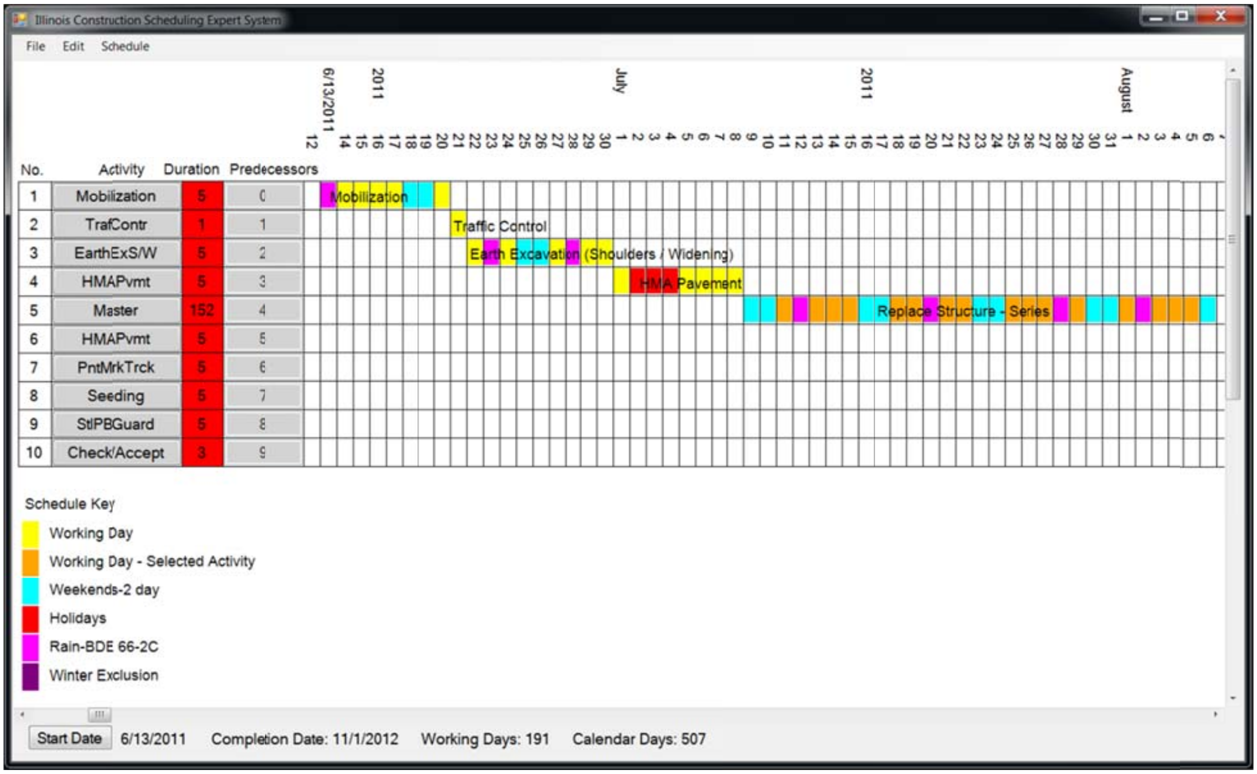

Figure 19. Project schedule after all Master activities are scheduled.

Start Date

The Start Date for the project can be modified by clicking the Start Date button at the lower, left-hand corner of the schedule form. In multi-layer schedules it is only enabled when the project schedule is displayed. The user enters the new start date when prompted and clicks OK in the input box to update the entire schedule. This may take several seconds with multi-layer schedules as each master activity must be reevaluated. The Start Date button is disabled when the update begins and will be enabled when the process is finished.

Refresh

The user can select Schedule | Refresh at any time; however, the schedule is automatically refreshed after any change so this will rarely be necessary.

Generate Report

Select Schedule | Generate Report to save the schedule documentation to text files. Two files will be generated: *ProjectName*.csv and *ProjectName*.esr. The first is intended to be opened using Microsoft Excel. The data can then be cut and pasted into the "BDE220a.xls" spreadsheet to produce a report in the standard format. "Paste Special" should be used with "Paste Values" to preserve the formatting on the worksheet. "Select All" of the *ProjectName*.csv file and paste to cell A1 of the BDE 220a sheet.

The Expert System Report (esr) file can be viewed in a text file viewer such as Notepad. It provides additional documentation about how the schedule was developed.

EXAMPLES

Example 1: Roadway Rehabilitation project

This example is based on a project from Vermillion County completed in 2009. Actual production rates from the project are used in the example. Project data is entered in the New Project form as shown in Figure 20. The actual start date was entered and the Roadway Rehabilitation project type selected.

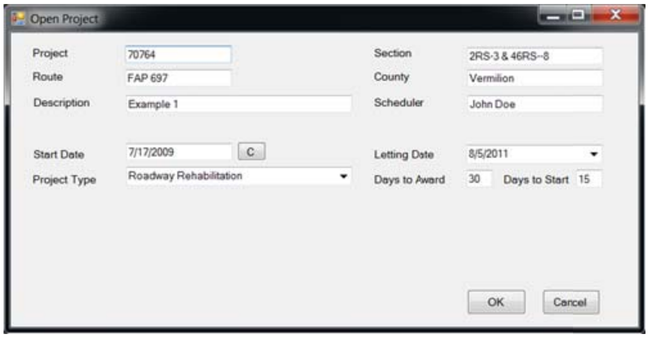

Figure 20. New project form

Clicking OK displays the Calendar form using default constraints shown in Figure 21. No job-specific constraints were input, and, since the standard Winter Exclusion period is used, no additional, temperature-based constraints were considered. The Save button is clicked then the Close button.

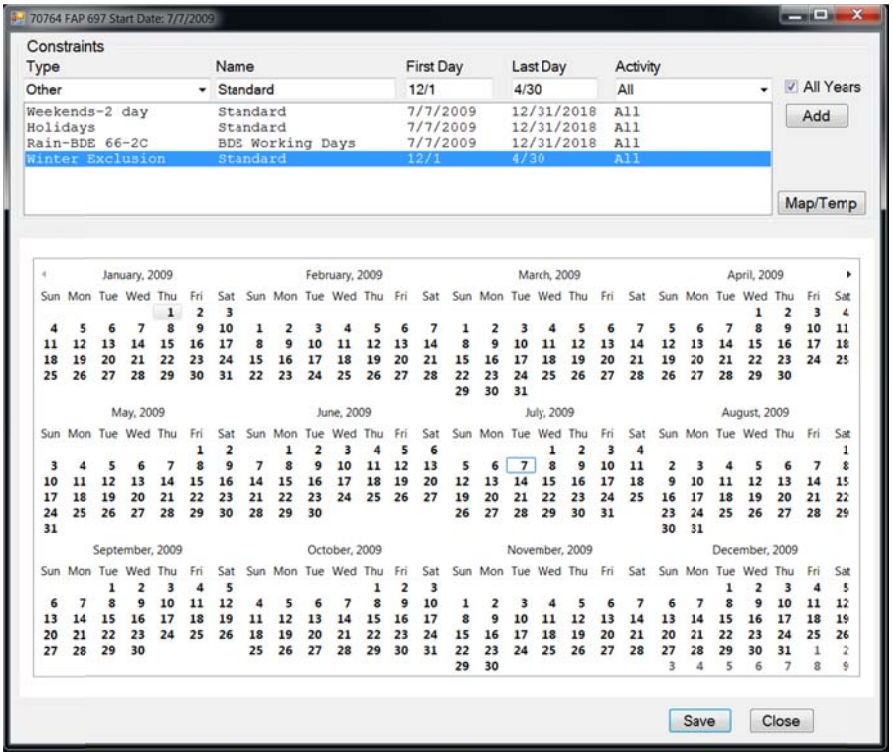

Figure 21. Project calendar

The default schedule, shown in Figure 22, is then displayed.

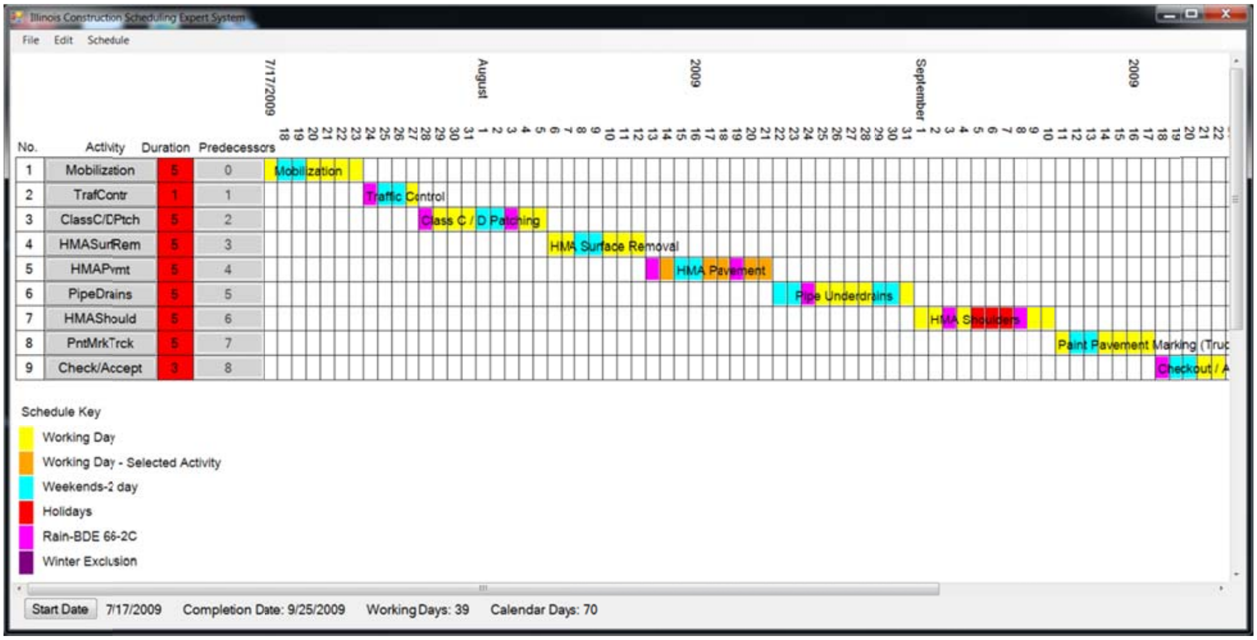

Figure 22. Default schedule

The Mobilization and TrafContr buttons were clicked and 1-day durations input for each. Clicking ClassC/DPtch displays the Activity Duration Estimation (ADE) form in Figure 23. A production rate of 144 sy/day was entered.

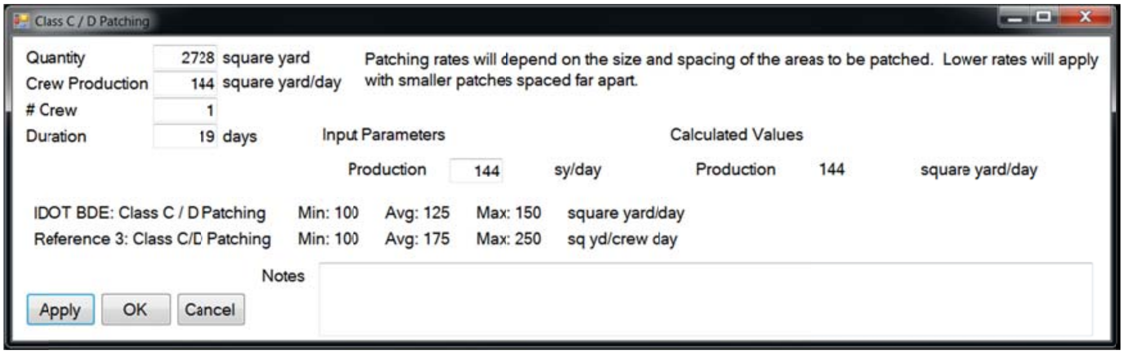

Figure 23. Class C/D Patching ADE

Clicking the HMASurfRem button displays the ADE shown in Figure 24. The Crew Production rate was entered directly in the text box under Quantity so the calculator was not used.

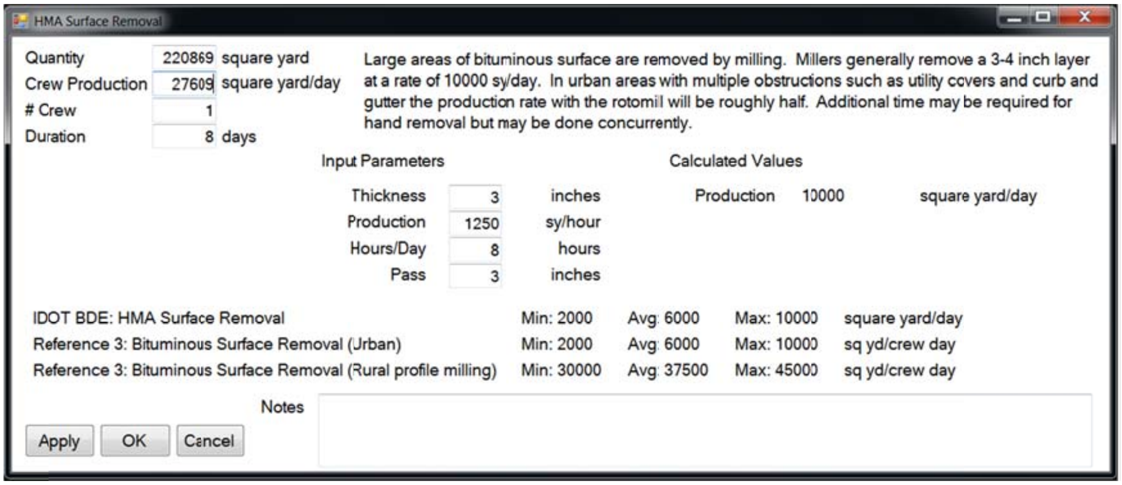

Figure 24. HMA Surface Removal ADE

The HMA Pavement activity combined three activities from the Progress Schedule: HMA Level Binder, HMA Surface and Incidentals. A composite production rate was used in the ADE in Figure 25. The average rate was 1080 tons/day, so 135 tons/hour was used in the calculator.

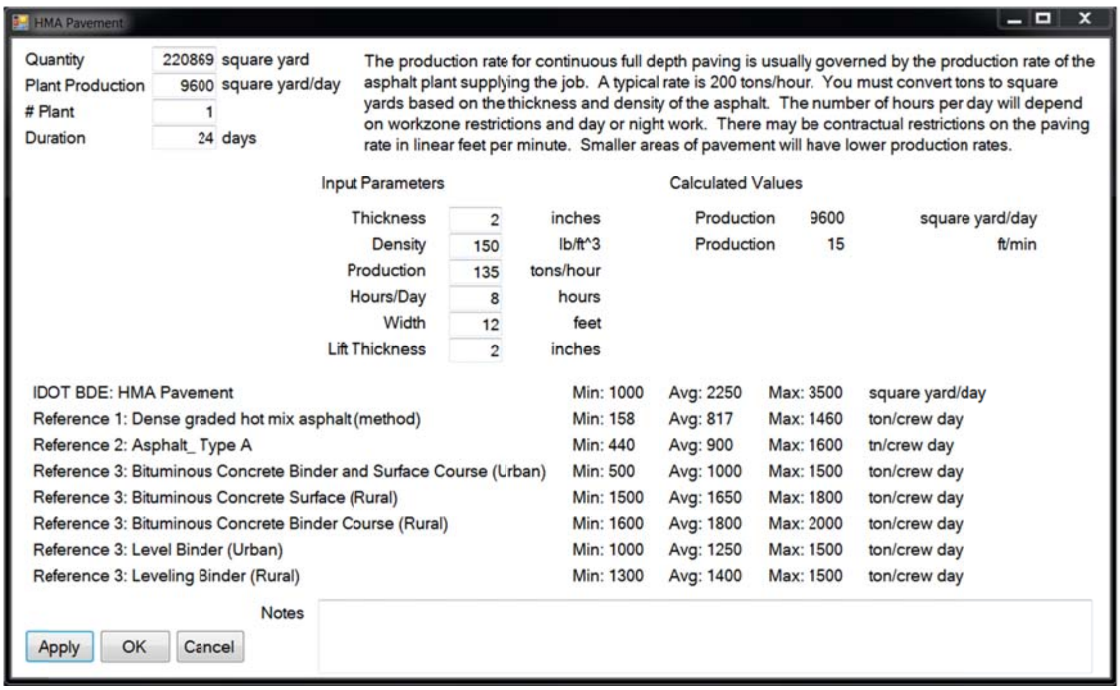

Figure 25. HMA Pavement ADE

There were no Pipe Drains on this project so 0 was entered for Duration on the ADE. This activity could also have been deleted in the Template Review process available from the New Project form. The HMA Shoulders ADE was accessed to calculate the activity duration. Figure 26 shows the Paint Pavement Marking ADE.

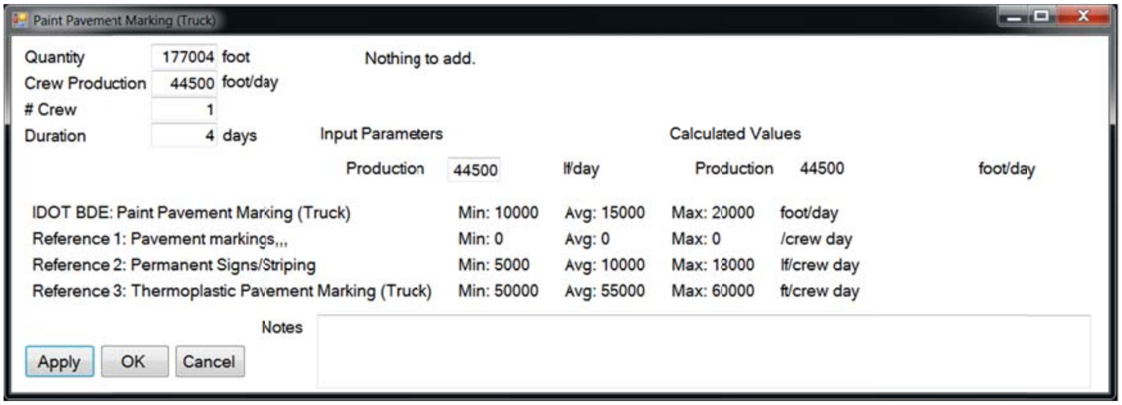

Figure 26. Paint Pavement Marking ADE

The completed schedule is shown in Figure 27.

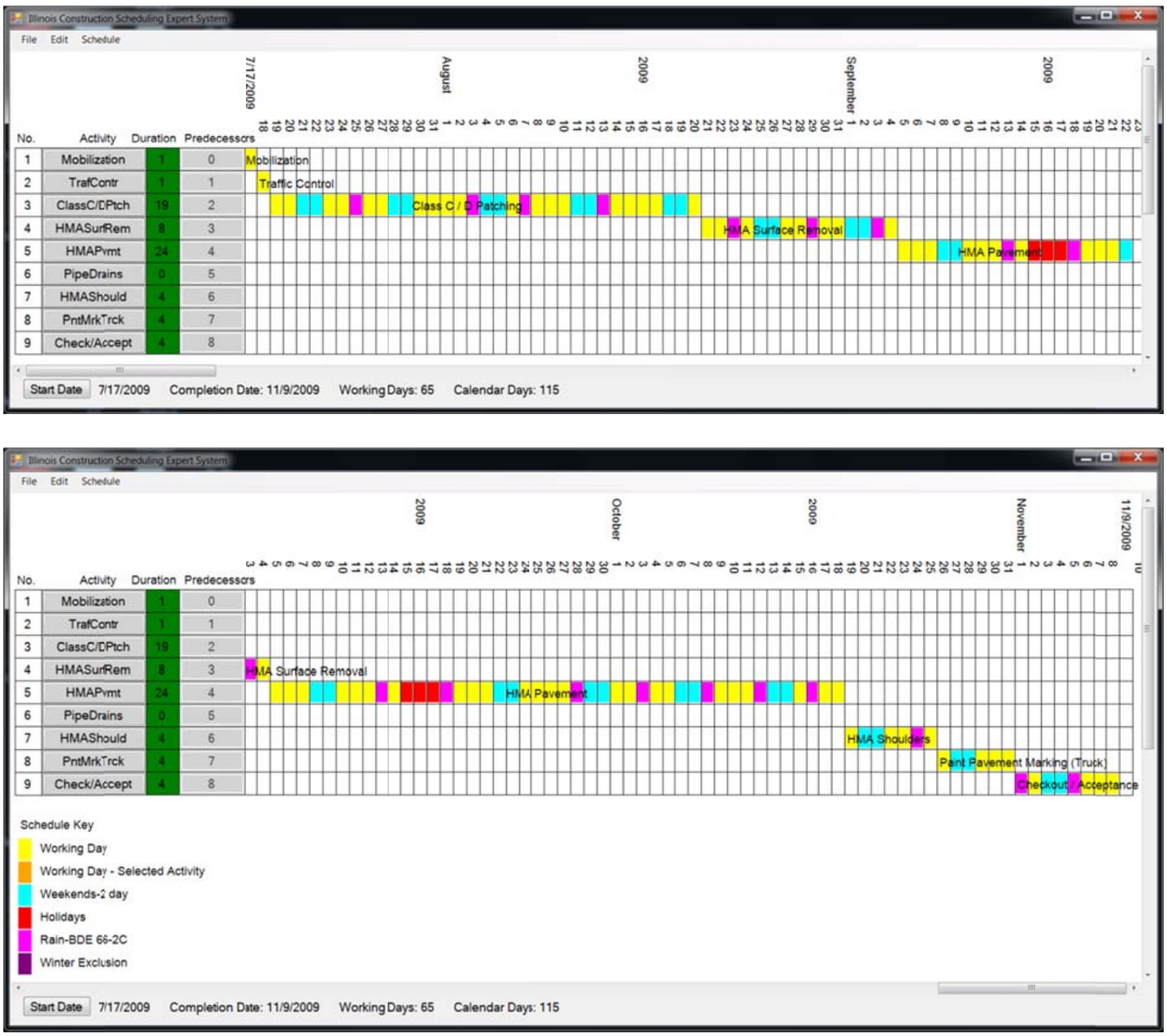

Figure 27. Completed schedule

Example 2: Interchange with Bridge Replacement

This example demonstrates the use of multi-level scheduling templates. The initial start date was determined based on a 9/23/2011 letting date. The template includes a master activity so the user is asked how many times that will repeat as shown in Figure 28. The bridge consists of two spans so the first will be completely replaced before the second is started.

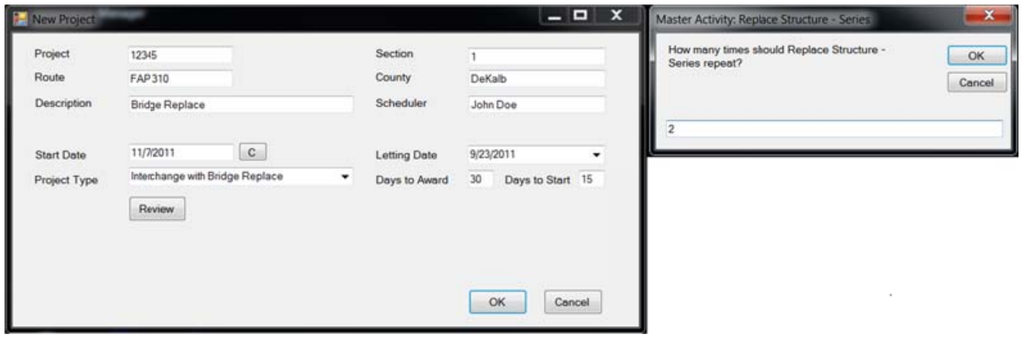

Figure 28. Replacing two bridge structures

The Replace Structure – Series template includes two master activities so the user is asked the number of times each is repeated for each structure. In Figure 29 the user inputs that there are 5 substructures on the first bridge to be replaced. Figure 30 shows the input for the number of bridge deck placements for the second structure.

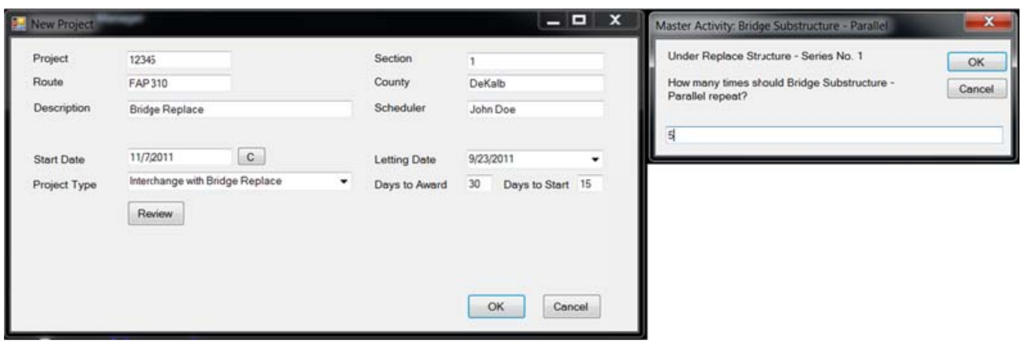

Figure 29. Bridge No. 1 has 5 substructure components – 2 abutments and 3 piers

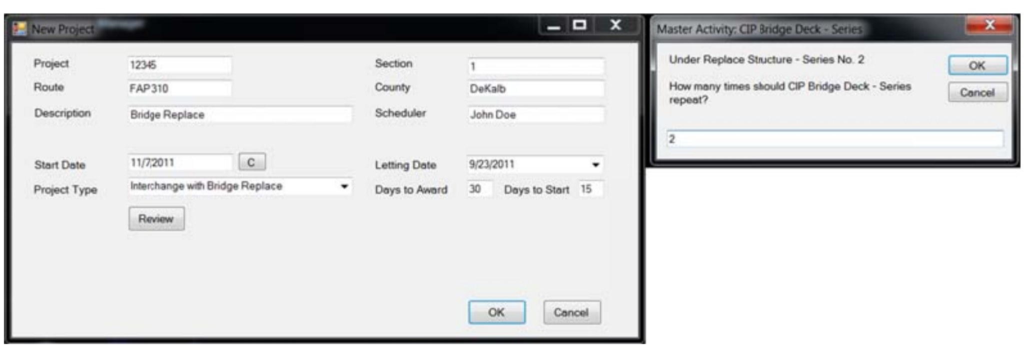

Figure 30. The cast-in-place deck on Bridge No. 2 will be constructed in two parts

The user will not use the standard winter exclusion period with the BDE 66-2C working days per month so these default constraints were deleted and the Rain-Historical constraint was added as shown in Figure 31.

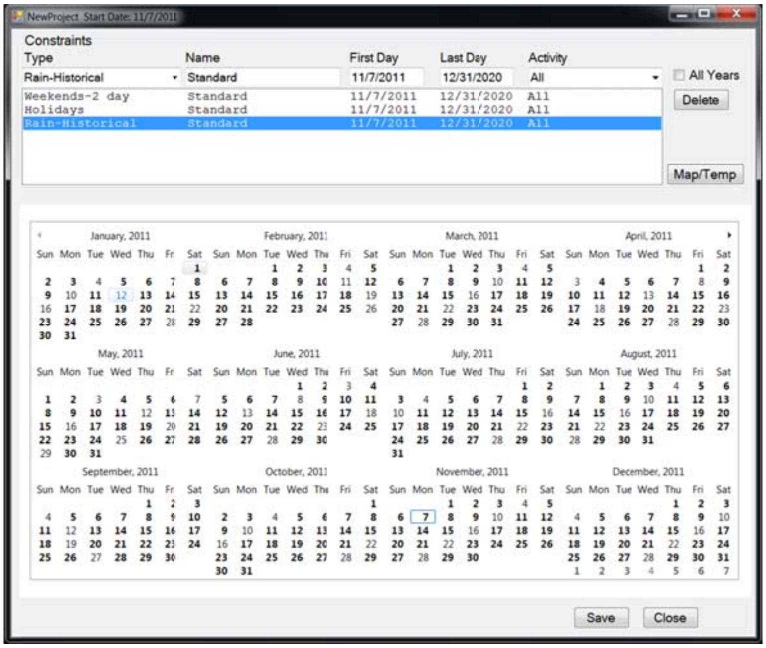

Figure 31. Modify default constraints

Clicking the Map/Temp button displays the state map and temperature-based constraints for activities in the main project template. The user clicked the Locate button and clicked a point in DeKalb county to indicate the project location. Dates at which the average minimum temperature crosses through the critical temperature for each activity are displayed.

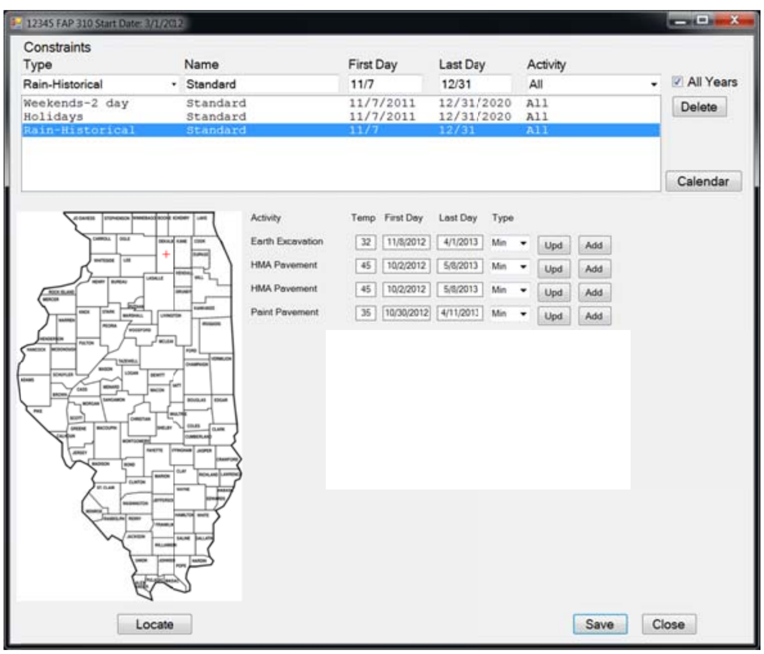

Figure 32. Select location in DeKalb county and evaluate temperature-based constraints

Clicking the Add button next to each activity adds these constraints to the calendar (Figure 33). The Add button disappears after being clicked.

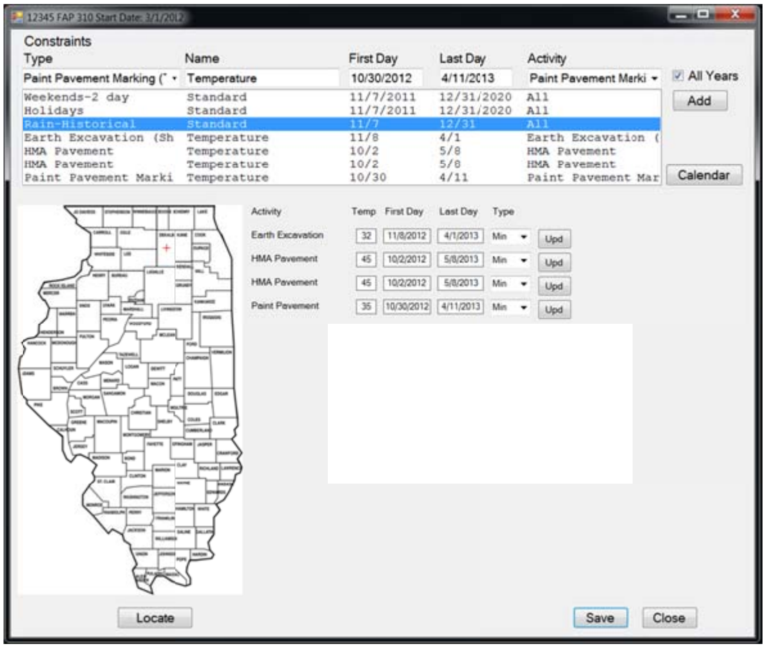

Figure 33. Add selected temperature constraints

After clicking Save and Close on the calendar shown in Figure 33, the project schedule is displayed. The user clicked the Master button for the Replace Structure-Series master activity. The calendar for this activity was displayed as shown in Figure 34. The user added a constraint for the two Precast Concrete Beam Erection activities (one for each bridge structure) to ensure that enough time is provided to procure the beams after contract award.

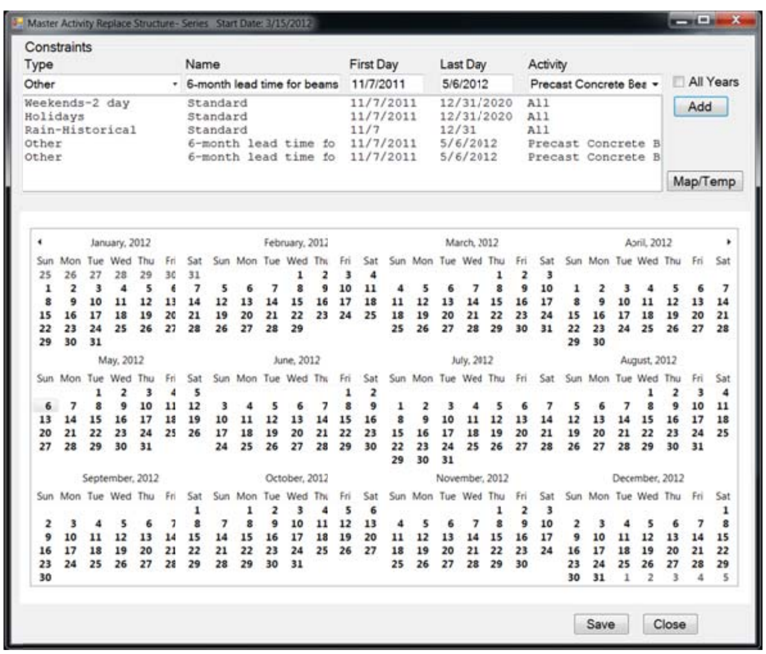

Figure 34. Add lead time constraint for precast concrete beams

Clicking Map/Temp displays the state map along with temperature-based constraints for activities in the master template. Adding these generates one constraint for each bridge structure as shown in Figure 35.

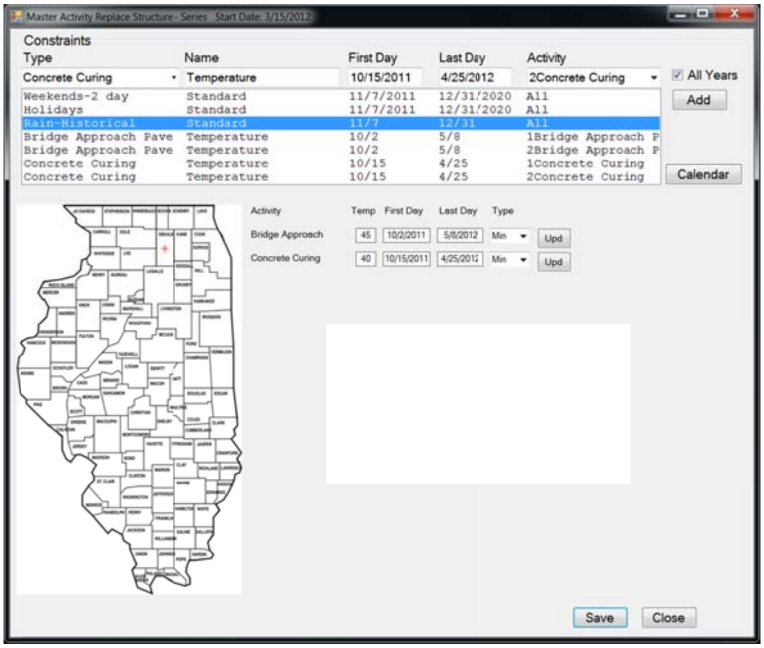

Figure 35. Add temperature constraints for concrete on bridge

After creating and saving calendars for all master activities, the user begins to determine durations for all activities in the main project schedule. Figure 36 shows the ADE for Earth Excavation (Shoulders / Widening). While this is paid in cubic yards the production rate is as much a function of area as volume of excavation. A relatively low production rate was selected.

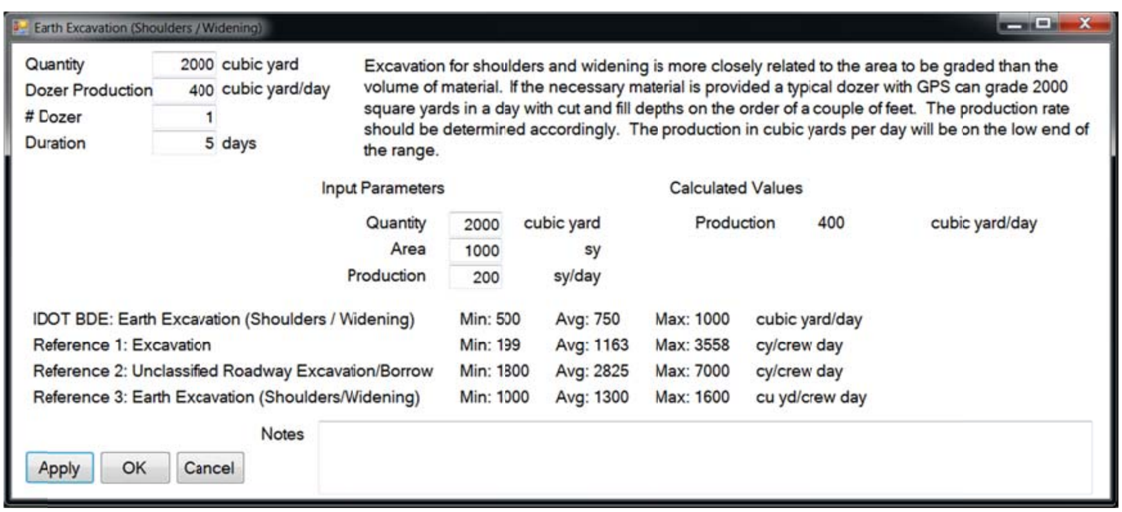

Figure 36. Use low production rate for shoulders and widening earth excavation

Figure 37 shows the project schedule after updating durations for all non-master activities. The next step is to click Master.

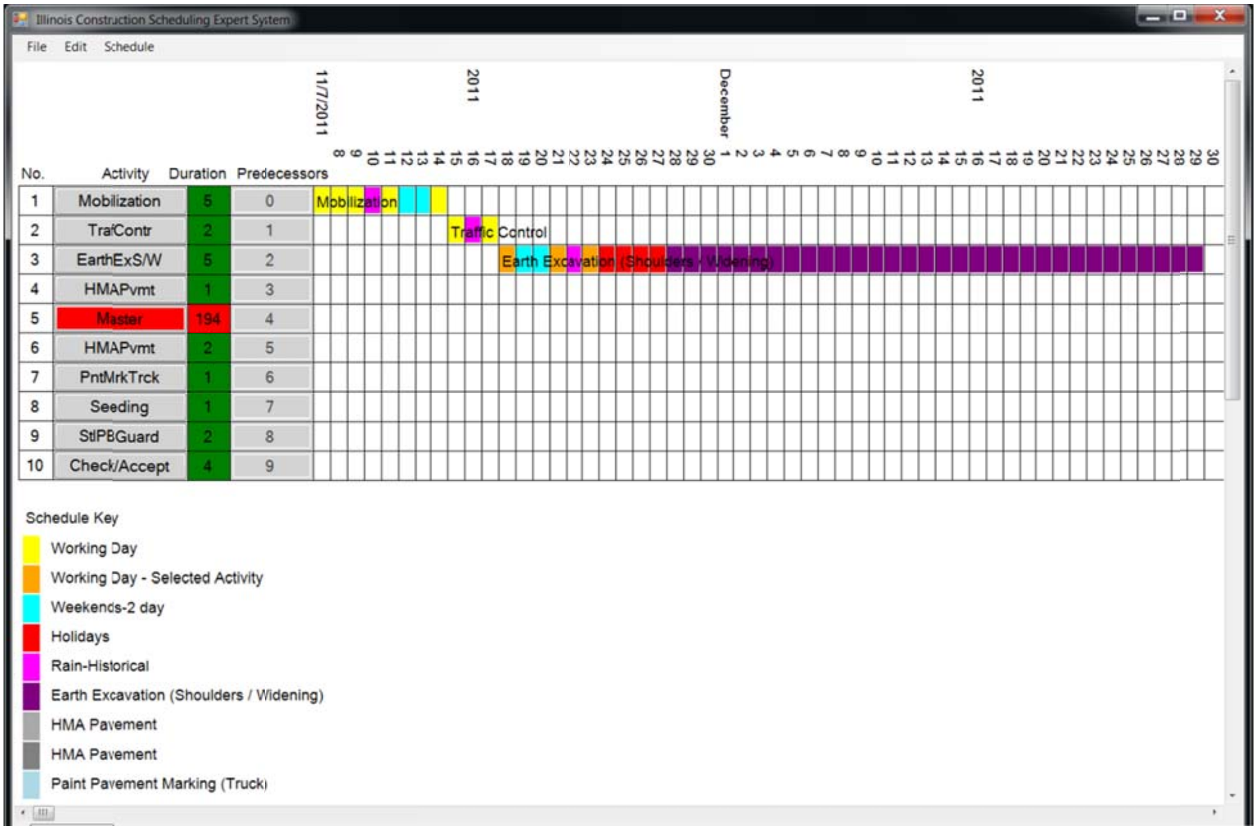

Figure 37. Project schedule activities updated

Figure 38 shows the ADE for Precast Concrete Beam Erection. The calculator for this ADE considers the number of beams to be erected. This bridge has four spans with 8 beams each. The user expects to place 2 spans per day.

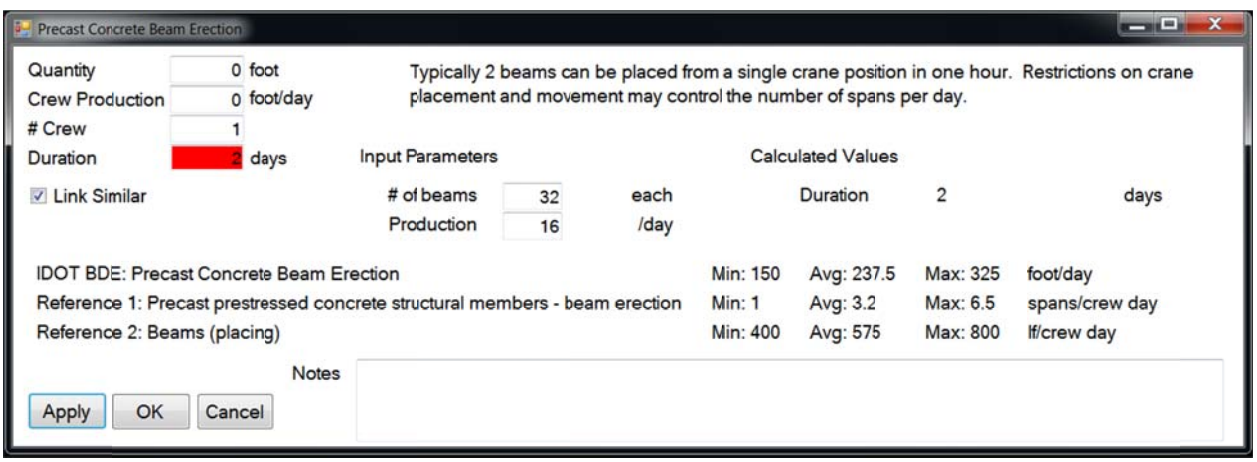

Figure 38. Precast Concrete Beam Erection ADE

Figure 39 shows the updated durations for all activities in the Replace Structure – Series template.

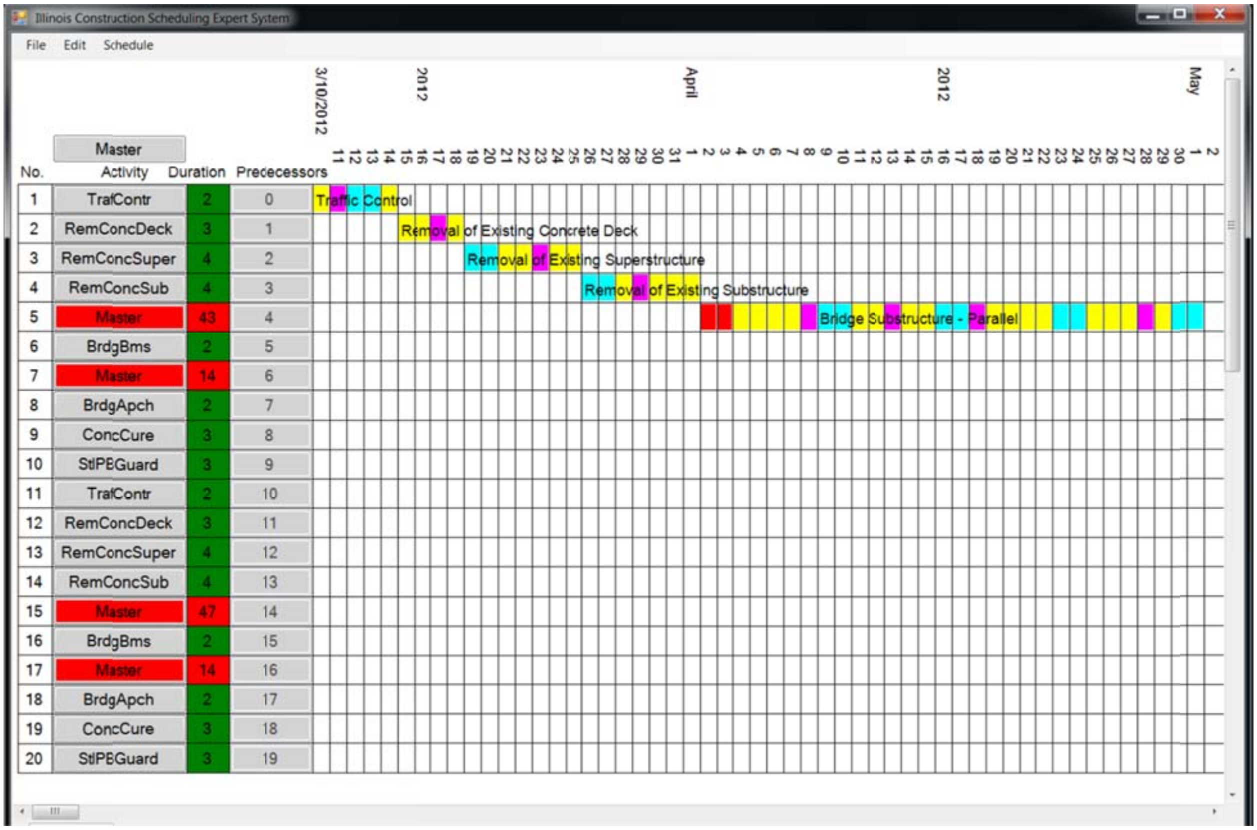

Figure 39. Replace Structure-Series template activities

Concrete curing is an activity that is repeated for each substructure component. It will only be a controlling item on the last component. Figures 40 shows that the duration is set to zero with the Link Similar box checked. The last Concrete Curing activity is selected and the duration is set to an appropriate value with the Link Similar box unchecked as shown in Figure 41.

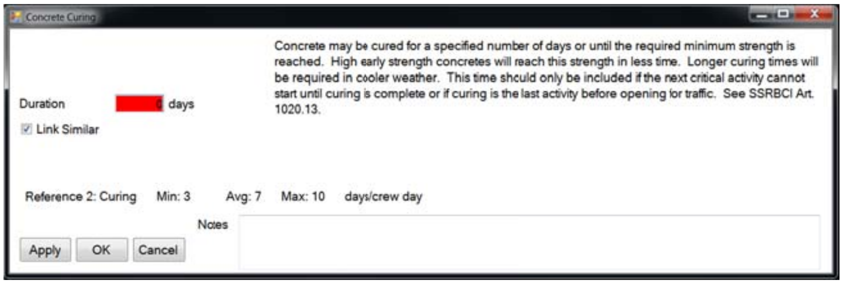

Figure 40. Zero concrete cure time for early pours

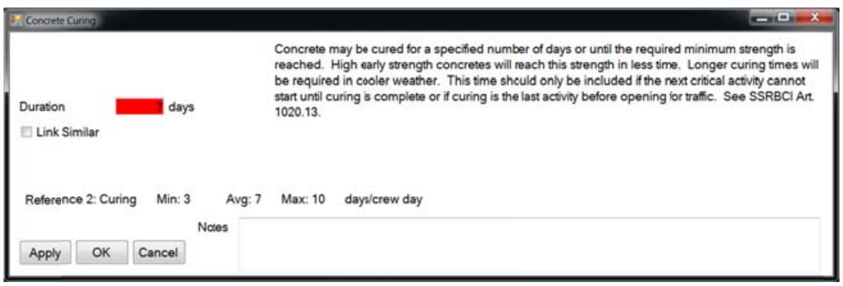

Figure 41. Last concrete cure is controlling

Figure 42 shows a partial completed schedule for the Bridge Substructure-Parallel master template. As the first substructure is an abutment, irrelevant activities have zero duration.

Figure 42. Bridge substructure master activity

Figure 43 displays part of the completed schedule. Although the contract was awarded early enough to start the project in November, temperature constraints will prevent much work on the ground in 2011. The Start Date button was clicked and the date was changed to 3/1/2012 to show a more practical schedule starting just as the weather begins to allow earthwork (Figure 44). The early contract date allows the contractor to procure the bridge beams during the winter season.

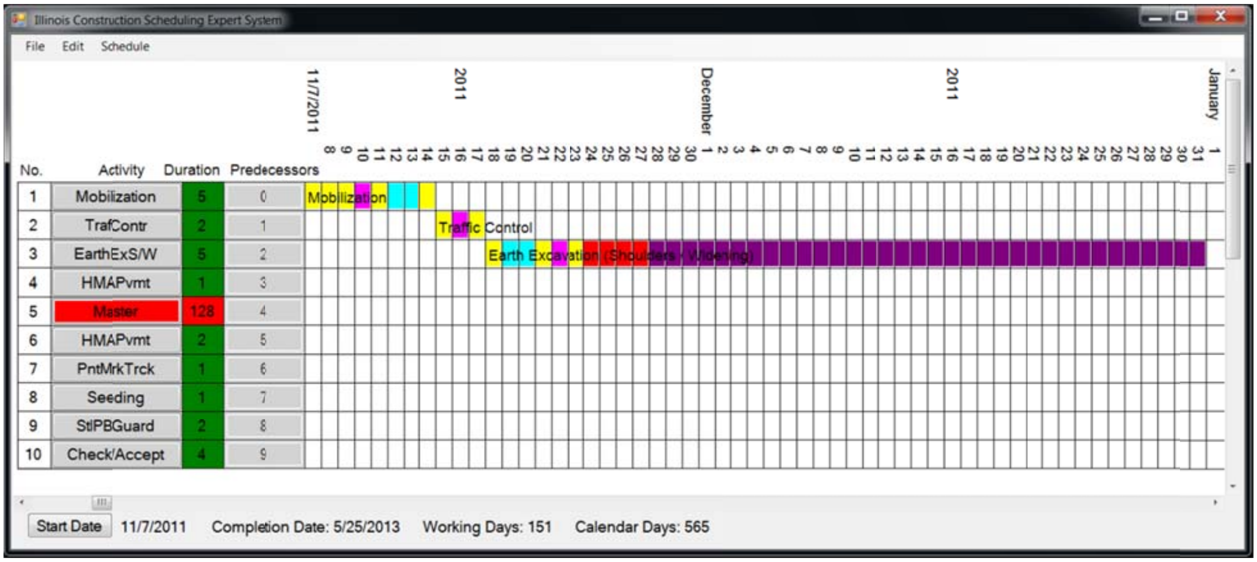

Figure 43. Completed project schedule

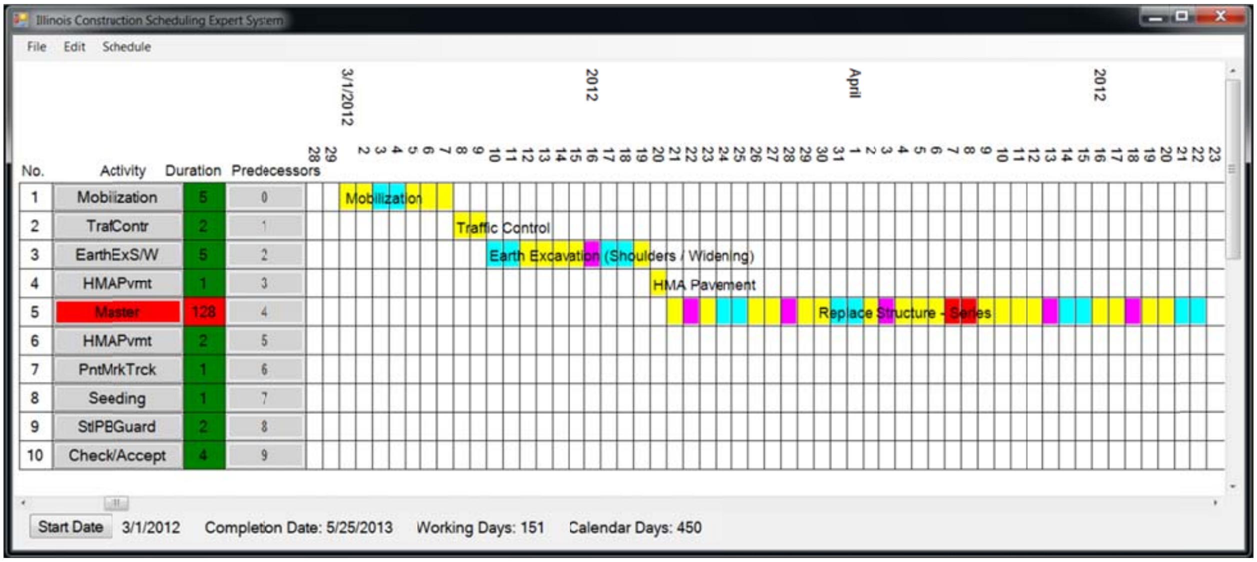

Figure 44. Change start date to 3/1/2012