An *IPRF* Research Report

Innovative Pavement Research Foundation

Airport Concrete Pavement Technology Program

Report IPRF-01-G-002-02-3

Accelerated Practices for Airfield Concrete Pavement Construction—Volume I: Planning Guide

Programs Management Office
5420 Old Orchard Road
Skokie, IL 60077

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Accelerated Practices for Airfield Concrete Pavement Construction—Volume I: Planning Guide

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EXECUTIVE SUMMARY

This research report, *Accelerated Practices for Airfield Concrete Pavement Construction*, presents information and experiences about accelerated or "fast-track" PCC paving projects from the airport pavement industry. It is based on detailed case studies that were developed from an extensive list of accelerated projects compiled from available resources in the airfield paving industry, including contractors, designers, owners, and industry representatives.

The key to applying accelerated paving techniques for rigid pavements lies in understanding the available strategies, and in knowing when and how these strategies should be applied. There is a range of materials that are available for accelerating pavement opening times; however, beyond the simple selection of appropriate materials lie many other strategies that can accelerate an airfield PCC paving or repair project, including thorough planning and coordination of work activities, efficient sequencing of construction steps, and application of appropriate criteria for early opening to traffic. While the materials and procedures are not necessarily new, there is very limited guidance on their integrated application in the aviation industry.

This report summarizes much of the experience that is known about accelerated airfield concrete pavement construction projects, based on case studies developed for some of the most important projects. Site visits, telephone and electronic mail interviews, and review of available documents were conducted to assemble as much information for each case study as possible. The information in Volume I of this report, *Planning Guide*, represents the "lessons learned" from the case studies and other reported experiences. Volume I also includes a "decision tool" that is developed based on project variables to help identify techniques that could be beneficial for other accelerated projects. The decision tool also provides information on what case studies are directly related to, or similar to, the selected project variables. The case studies themselves are presented in Volume II of this report, *Case Studies*; they offer detailed information about how the various projects were approached.

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1. INTRODUCTION

The key to applying accelerated paving techniques for rigid pavements lies in understanding the full breadth of available strategies, and knowing when and how these strategies should be applied. There are a range of materials that are available for accelerating pavement opening times, from modified Type I and II cements, to Type III cements and other cementitious materials. However, beyond the simple selection of appropriate materials lie many other strategies that can accelerate a PCC paving or repair project, including thorough planning and coordination of work activities, efficient sequencing of construction steps, and application of appropriate criteria for early opening to traffic. While the materials and procedures are not necessarily new, there is very limited guidance on their integrated application in the aviation industry.

The research summarized in this *Planning Guide* was conducted under IPRF Project 01-G-002-02-3. The project's goals include collecting and documenting useful information and experiences about accelerated or "fast-track" PCC paving projects from the airport pavement industry (identified as case studies in this report) and presenting accelerated strategies so that a potential user can easily identify projects similar in scope and size and apply the lessons learned from those projects to their anticipated needs.

> In this report, the term "accelerated" (or fast-track) does not apply solely to accelerated construction projects under short closure times. Projects can be accelerated in any phase:
>
> - Planning
> - Design
> - Construction

The projects included in the detailed case studies are selected from an extensive list of accelerated projects compiled from available resources in the airfield paving industry, including contractors, designers, owners, and industry representatives. Several key variables were considered in selecting projects for inclusion, including airport classification, facility type, climatic region, accelerated phase, and rehabilitation method. Site visits, telephone and electronic mail interviews, and review of available documents were conducted to assemble the information for each case study, and the results are used to summarize available accelerated techniques.

1.1. Overview of Document

This report is presented in two volumes. Volume I presents the lessons learned from the case studies in the form of a *Planning Guide*. It is organized into three primary phases of accelerated projects: planning, design, and construction; a set of other issues that does not fit neatly into these three phases is presented under the heading of "ancillary issues." Each topic has several subtopics where appropriate information has been obtained. Although the topics are discussed discretely, often there are interrelated elements which need to be collectively considered. For example, scheduling decisions can often be based on a review of the available design alternatives. Similarly, design alternatives may be based on scheduling decisions. Additionally, some of the topics (such as stakeholder coordination) are relevant to all phases of a project, while others (such as lighting) can be quite specific.

Volume I also includes a methodology ("decision tool") that users can apply to determine which techniques might be appropriate for a given project.

Volume II presents the project case studies, providing the reader with detailed information about the design and construction of the selected projects. In addition to detailed descriptions of what was done to accelerate construction in these projects, this volume also includes various plan sheets, specifications, and other "tools" that will be of interest to those undertaking an accelerated project. Also included in Volume II are appendices that provide additional information on data collection efforts.

1.2. Disclaimer

This document is based on data found in the published record and information collected from airports, consulting engineers, and contractors. To the extent that the provided information is correct, this document reflects the interpretation of the factual record by the research team. This document is not a specification, standard, or regulation, and should not be used as a substitute for project plans and specifications that are properly designed for any given project.

1.3. Selected Case Studies

The projects summarized in Table 1-1 were ultimately selected for study as the basis of this *Guide*. Complete case studies are contained in Volume II.

Case studies included in this report are for projects at:

- Airborne Airpark (Ohio)
- Charleston (South Carolina) International Airport
- Cincinnati/Northern Kentucky International Airport
- Cleveland Hopkins International Airport
- Colorado Springs Municipal Airport
- Columbia Regional Airport
- Denver International Airport
- Detroit Metropolitan Wayne County International Airport
- Hartsfield-Jackson Atlanta International Airport
- Memphis International Airport
- Mineta San Jose International Airport
- Phoenix Sky Harbor International Airport
- Savannah Hilton Head International Airport
- Seattle-Tacoma International Airport
- Washington Dulles International Airport
- William P. Hobby Houston Airport

Table 1-1. Summary of accelerated airport paving projects.

Project:	Airborne Airpark (DHL [formerly Airborne Express] facility in Wilmington, Ohio); Runway Reconstruction (Airborne)
Project Date:	1999
Airport Classification:	Cargo
Facility Type:	Runway
FAA Region:	Great Lakes (Wet/Freeze)
Rehabilitation Method:	Partial Reconstruction
Project Summary:	This project included reconstruction of 2,200 feet of the oldest section of Runway 4L-22R. Work closures were from 7:00 am Saturday until 10:00 pm Monday on multiple weekends to complete the project. The contractor was contacted by the owner to discuss various methods for completing this work without interrupting service, and the contractor had input into how the project was completed, including preparation of pavement cross section designs. Reconstruction included pavement removal, some subgrade work, installation of drain pipes, light can replacement, placing an 8- to 10-in drainable aggregate base layer, and placing 22 inches of PCC. The contractor worked on 25-ft by 150-ft sections at a time, and paving was completed transversely to the runway length, with diamond grinding after completion of all paving to provide a smooth-riding surface. A concrete mix was used that would reach 650 psi flexural strength before 10:00 pm Monday.

Project:	Charleston International Airport; Intersection of Runways 15-33 and 3-21 (Charleston)
Project Date:	1990
Airport Classification:	Small Hub
Facility Type:	Runway Intersection
FAA Region:	Southern (Wet/No Freeze)
Rehabilitation Method:	Reconstruction
Project Summary:	Reconstruction of the intersection of Runways 15-33 and 3-21 was accomplished in 67 days during nighttime closures. The project included the removal and replacement of 9,500 yd^2 of pavement, with 3,600 yd^2 using a proprietary rapid-setting PCC mix. An extensive pavement design study was conducted before construction, with the final pavement cross section eliminating the stabilized base layer to expedite construction. A sacrificial HMA overlay was placed prior to PCC reconstruction; this overlay was used to establish final grades for placing PCC and was removed as part of slab removal. The construction phase utilized temporary pre-cast PCC slabs to maximize the allowed closure: removal of existing PCC, placement of pre-cast slab, then removal of pre-cast slab and placement of PCC over consecutive nights. Grinding was performed at the end of the project to address grade imperfections.

Table 1-1 (continued). Summary of accelerated airport paving projects.

Project:	Cincinnati/Northern Kentucky International Airport; Taxiway M Reconstruction (Cincinnati)
Project Date:	2002
Airport Classification:	Large Hub
Facility Type:	Taxiway
FAA Region:	Great Lakes (Wet/Freeze)
Rehabilitation Method:	Reconstruction
Project Summary:	This project included the reconstruction of Taxiway M using a design cross section of 18-inch P-501 PCC on 6 inches of stabilized base (cement treated [P-306] or asphalt treated [P-401]) on 6 inches of aggregate subbase (P-209). This design was altered during construction for runway tie-in sections to 20 inches of PCC on 8 inches of aggregate base to reduce the required closure time. The project used incentives and disincentives, including a $10,000 per calendar day bonus for early completion and a $10,000 per calendar day penalty for late completion. The contractor used a mix design with additional portland cement to obtain 3-day flexural strengths of 700 psi. An accelerated schedule, with the contractor working 24 hours a day where feasible, was used to complete the runway tie-in sections.

Project:	Cleveland-Hopkins International Airport; Runway 6L-24R (Cleveland)
Project Date:	2002
Airport Classification:	Medium Hub
Facility Type:	Runway and Taxiway
FAA Region:	Great Lakes (Wet/Freeze)
Rehabilitation Method:	Reconstruction
Project Summary:	An accelerated construction schedule was used for the construction of the new Runway 6L-24R and taxiway tie-ins to existing facilities. High-early strength PCC and different pavement cross sections were specified for the existing runway and taxiway tie-ins to expedite reopening the facilities. Cracking occurred in two of the first constructed sections using the high-early strength PCC and a more conventional PCC mix was used to complete the project. The conventional PCC mix still achieved the required strength in 2 to 3 days.

Table 1-1 (continued). Summary of accelerated airport paving projects.

Project:	Colorado Springs Municipal Airport; Runway/Taxiway Patching (Colorado Springs)
Project Date:	2001
Airport Classification:	Small Hub
Facility Type:	Runway and Taxiway
FAA Region:	Northwest Mountain (Dry/Freeze)
Rehabilitation Method:	Patching/Slab Repair
Project Summary:	Slab repairs were performed on Runway 17L-35R and adjacent taxiways during overnight closures to minimize the disruption of operations. The project included penalties for not reopening by the specified time. The project included the repair of over 200 yd^2 in three weeks. A proprietary patch material was used for fast-setting repairs to allow reopening at the required time and to meet the specified performance life requirements. The owner released retention 60 days after completion of work.

Project:	Columbia (MO) Regional Airport; Runway 2-20 Repair (Columbia)
Project Date:	2001
Airport Classification:	Small Hub
Facility Type:	Runway
FAA Region:	Central (Wet/Freeze)
Rehabilitation Method:	Partial Reconstruction (inlay)
Project Summary:	A 200-ft by 50-ft section of Runway 2-20 was reconstructed in this project. A 55-hour (weekend) closure was allowed for the removal of existing pavement and placement of 15-in thick new PCC pavement. The contractor was required to successfully complete a demonstration section prior to the runway closure, including producing a sample of the mix and using the anticipated techniques that were to be used for project. Detailed phasing was utilized to expedite the schedule, and liquidated damages were established for late opening.

Table 1-1 (continued). Summary of accelerated airport paving projects.

Project:	Denver International Airport; Runway 16R-34L (Denver)
Project Date:	2003
Airport Classification:	Large Hub
Facility Type:	Runway
FAA Region:	Northwest Mountain (Dry/Freeze)
Rehabilitation Method:	New Construction
Project Summary:	This project includes the construction of the new Runway 16R-34L. Existing contracts were used to issue purchase orders that allowed major utility work to progress ahead of runway construction work that would have adversely impacted the construction schedule. To ensure adequate PCC production for the accelerated pace, two on-site batch plants were used, as well as two slip-form paving trains, with a production rate of 7,000 yd^3 per day. Paving locations were planned to facilitate the early start of required runway certification and navigational aids work. After an acceptable demonstration section, paving of the crowned section on the adjacent taxiways was performed in one pass to reduce the construction schedule. Subgrade stabilization was used for the project to provide a stable paving platform and minimize the potential of weather delays. Contract documents required close electrical subcontractor coordination to help ensure the electrical work stayed ahead of paving.

Project:	Detroit Metropolitan Wayne County International Airport, Deicing Apron (Detroit)
Project Date:	2002
Airport Classification:	Large Hub
Facility Type:	Apron
FAA Region:	Great Lakes (Wet/Freeze)
Rehabilitation Method:	Reconstruction
Project Summary:	Construction of a fourth deicing pad was required at Detroit. To complete the project before the upcoming winter season, the entire project schedule was accelerated: it was designed in 7 weeks, immediate review and award of construction work was made upon bid opening at a special meeting of the controlling board, and it was constructed in 45 days. The PCC pavement section is a standard 42-in section used at the airport, but includes an extensive underground glycol and stormwater collection system. Allocating appropriate levels of manpower and equipment by the contractor and flexibility in re-routing traffic during construction phases allowed construction to remain on schedule.

Table 1-1 (continued). Summary of accelerated airport paving projects.

Project:	Hartsfield-Jackson Atlanta International Airport; Runway 9R-27L Reconstruction (Atlanta)
Project Date:	August 1999
Airport Classification:	Large Hub
Facility Type:	Runway
FAA Region:	Southern (Wet/No Freeze)
Rehabilitation Method:	Reconstruction
Project Summary:	Reconstruction of the 9,000-ft long Runway 9R-27L was completed in 33 days. The construction removed 196,000 yd^2 of 16- to 20-in PCC and placed 200,000 yd^2 of 18- to 22.5-in PCC. A parallel taxiway was converted to a temporary runway in order to minimize aircraft operation delays during construction. The project salvaged the existing stabilized base layer to minimize subgrade and base layer work. The contractor worked continuously (24 hr/day) from project start to finish to maintain the accelerated schedule. The project also included: an extended mobilization phase (including assistance with lighting supplies), $175,000 per day penalty for late finish, fencing off the runway area to reduce delays due to necessary security, and coordination with traffic control to address haul road safety.

Project:	Memphis International Airport; Runway 18R-36L (Memphis)
Project Date:	2002
Airport Classification:	Medium Hub
Facility Type:	Runway
FAA Region:	Southern (Wet/No Freeze)
Rehabilitation Method:	Reconstruction
Project Summary:	Reconstruction work for Runway 18R-36L was completed in nine months. Runway 18R-36L is 9,300-ft long, and includes construction of a 19-in PCC pavement and associated utility work. The airport used an adjacent taxiway as a temporary runway to minimize the impact of the closure on aircraft operations. An extensive utility location program, haul road traffic study, and materials availability investigation were conducted during the planning and design process to ensure success of the construction phase. Success of the project is attributed to the extensive 2-year planning process along with teamwork and partnering. During construction, any problem or issue was resolved (or on the path to being resolved) during the same 8-hour shift in which it was identified. The project also included set-date incentives and disincentives with an extended pre-closure mobilization.

Table 1-1 (continued). Summary of accelerated airport paving projects.

Project:	Mineta San Jose International Airport; Runway 12L-30R Extension (San Jose)
Project Date:	1993
Airport Classification:	Medium Hub
Facility Type:	Runway
FAA Region:	Western Pacific (Dry/No Freeze)
Rehabilitation Method:	New Construction (extension of existing)
Project Summary:	The extension of Runway 12L-30R required addressing many city-airport concerns (noise, environmental issues, pedestrian and motorist safety, and so on). Planning and design also addressed extensive navigational aids issues and utility issues impacting the construction schedule. The City identified staff members early and clearly described the construction sequence in the bid documents; seven separate notices to proceed were included to maintain the accelerated schedule. Contract documents also required an on-site batch plant and the use of slip-form pavers to facilitate the accelerated schedule. Incentives and disincentives were specified.

Project:	Phoenix Sky Harbor International Airport; Runway 8-26 (Phoenix)
Project Date:	2002
Airport Classification:	Large Hub
Facility Type:	Runway
FAA Region:	Western Pacific (Dry/No Freeze)
Rehabilitation Method:	Reconstruction
Project Summary:	Runway operations were maintained during reconstruction and extension of Runway 8-26 by proper phasing of the work and a reduced runway length. The construction sequencing addressed the safety zones to maintain a 6,000-ft runway length with only nightly closures for work on center portion of runway. Nighttime closures with reopening by morning were required for the center portion of the runway because extended closures were deemed too costly to air carriers. A PCC specification for high-early strength PCC was established (P-503) and had provisions for strength at opening and strength at 28 days. Since the work area was used as a safety area during runway operations, the opening strength requirement was based on supporting an aircraft only in case of emergency.

Table 1-1 (continued). Summary of accelerated airport paving projects.

Project:	Savannah/Hilton Head International Airport; Intersection of Runways 9-27 and 18-36 (Savannah)
Project Date:	1996
Airport Classification:	Small Hub
Facility Type:	Runway (intersection)
FAA Region:	Southern (Wet/No Freeze)
Rehabilitation Method:	Reconstruction
Project Summary:	Reconstruction of the intersection of Runways 9-27 and 18-36 was performed at night with reopening to traffic by morning. A thickened PCC design (24-inch PCC) was developed in which the stabilized base was considered "monolithic" with the slab. Approximately one-third of the PCC placed was proprietary, rapid-hardening PCC, and temporary pre-cast panels were used to provide sufficient time to perform all removal and replacement work. An HMA overlay was placed prior to PCC work to establish final surface grades (the overlay was removed as part of slab removals but provided the final grade for PCC placement), and grinding was performed at the completion of the construction to provide a smooth surface.

Project:	Seattle-Tacoma International Airport; Runway 16R-34L Slab Replacement (Seattle)
Project Date:	Began 1994, latest occurrence in 2003
Airport Classification:	Large Hub
Facility Type:	Runway and Taxiways
FAA Region:	Northwest Mountain (Wet/No Freeze)
Rehabilitation Method:	Slab Replacement
Project Summary:	Slab replacement on Runway 16R-34L and adjacent taxiways was performed during nighttime closures (11:00 pm to 6:30 am). Since beginning this on-going project, over 620 panels (18-ft by 20-ft by 18-inches thick) have been replaced; 72 panels were replaced in 2003 over 2 to 2½ months. Although work progressed continuously, slab construction was performed on a three-night sequence by using temporary pre-cast panels: sawcut the first night; slab removal and base preparation the second night, including installation of the temporary pre-cast panels; and removal of temporary pre-cast panels and placement of new PCC on the third night. Rapid-set PCC was used to reopen the runway to traffic by morning. Extensive mix design evaluation is conducted by the contractor each year of slab replacement work. Concrete is cured with water using a sprinkler system. Opening strength is obtained in approximately 4 hours. Strength measurements are obtained from flexural strength tests. Disincentives are specified for late reopening and strength requirements.

Table 1-1 (continued). Summary of accelerated airport paving projects.

Project:	Washington Dulles International Airport; Runway 12-30 Slab Replacement (Dulles)
Project Date:	2003
Airport Classification:	Large Hub
Facility Type:	Runway
FAA Region:	Eastern (Wet/Freeze)
Rehabilitation Method:	Slab Replacement
Project Summary:	A 40-hour closure of Runway 12-30, working night and day, was used to do major patching and slab replacement work. The project originally included only nighttime work over four different weekends, but the contractor convinced the airport that the work could be done in 40 hours under a complete shutdown. Rapid-set PCC was used for the project, designed to reach 750 psi flexural strength in 6 hours. The contractor noted that once accelerators and superplasticizers were added to concrete on site, the concrete had to be placed in 20 minutes or less. Plastic and blankets were used to help hold in heat in order for the PCC to cure. The contractor stressed that slab removal is key to an operation such as this. Pre-sawing for slab removal started during the nights before the project closure, but other than that the entire project was completed in less than 40 hours. There was a $3,500 per hour penalty for missing the completion deadline.

Project:	William P. Hobby/Houston Airport; Intersection of Runways 12R-30L and 4-22 (Houston)
Project Date:	2002
Airport Classification:	Medium Hub
Facility Type:	Runway Intersection
FAA Region:	Southwest (Dry/No Freeze)
Rehabilitation Method:	Reconstruction
Project Summary:	Reconstruction of the intersection of Runways 12R-30L and 4-22 was completed in 19 days. A parallel runway was utilized during the intersection closure, but the facility did not provide all-weather capabilities. The project included the removal and replacement of 600-ft by 600-ft of intersection pavement, which was a previous rapid-setting PCC project from 1995. Reconstruction in 1995 consisted of a PCC overlay on an HMA bond-breaking layer using a rapid-setting PCC; the pavement experienced considerable cracking. The 2002 reconstruction eliminated the bond-breaking layer, using an asphalt prime coat layer because this treatment could be applied quicker than paving a bond-breaking layer; a treatment of this type had been used successfully at another Houston airport. Extensive mix design evaluation was also performed to determine the cause of deterioration of the existing pavement. To obtain better long-term performance, a PCC mix that had been used successfully at another Houston airport was used for this project.

1.4. Guidelines for Accelerated Project Techniques

Ideally, someone interested in knowing more about accelerated practices for airfield pavement construction will read this report in its entirety. Even though the documented experiences may not directly apply to a specific, planned project, they may provide insight into available techniques for different (and possibly future) projects. However, when there is an intended project in mind, a "decision tool" or selection guide has been incorporated to help select techniques that may apply to the intended project.

Figure 1-1 presents a framework for determining some of the key variables that are considered during the course of completing an accelerated PCC construction project. The purpose of this decision tool is to provide the user with practical guidance on the types of accelerated airfield rigid pavement construction projects that are feasible for a variety of facilities, rehabilitation methods, and closure times. The tool provides checklists that apply to different phases of these projects and links to case studies, which give detailed descriptions of successful projects in the various categories. This tool is developed based on lessons learned from those successful case studies.

The first sheet in this decision tool covers the selection of the facility, showing runways, taxiways, and aprons/others as the choices. However, the rest of the information for taxiways and apron/other is presented on subsequent sheets. The user begins by selecting the facility on which the work will be carried out. The next input is whether the project is new construction or reconstruction, rehabilitation (slab replacement over a large area), or slab replacement/repair (fewer than six slabs). The final factor evaluated in the decision tool is how much time is available to do the work. Closure time is divided into three groups: less than 12 hours, 12 to 60 hours, and more than 60 hours. These groups are approximately equivalent to an overnight closure, a closure between one day and one weekend long, and a closure that is longer than a weekend, and they correspond to typical timeframes that have been considered in accelerated projects.

At the bottom of the decision tree there is a switch to a matrix of information. The colored portion of the matrix identifies checklists that should be consulted for "lessons learned" from the case studies. There are checklists for project planning (P), design (D), construction (C), and other (O), Tables 1-2 through 1-5, respectively. The vertical dashed lines in this lower portion guide the user to the appropriate checklists. For example, the appropriate checklists for runway reconstruction, not in an intersection, with 12 to 60 hours available closure time, are P-1, D-1, C-1, and O-1.

The items in the checklists correspond with information provided in each of the *Guide's* sections. Below the checklist matrix are links to representative case studies, again by following the same dashed lines. The links to the case studies identified in bold text are where the case study is a direct example of the project type. For example, the Detroit case study is an example of apron reconstruction with available closure times greater than 60 hours. Within the checklists, particular sections of this portion of the report are identified in parentheses where more information and discussion are provided.

One final aspect of this tool to consider is that the case studies and lessons learned have broad applicability. For example:

- Lessons learned from projects completed under short closures may be applicable to projects performed under longer closures
- Lessons learned on slab replacement projects may be appropriate to rehabilitation projects.
- Lessons learned on rehabilitation projects may be appropriate to new or reconstruction projects.

Similarly, there is a generally assumed operational hierarchy, in which runways are the most critical (and intersections the most critical part of the runway), taxiways are next, and aprons or other areas are least critical. Lessons learned from a runway project for a given available closure time should be applicable to a taxiway project or an apron project, and lessons learned from a taxiway project should be applicable to an apron project under the same constraints. As such, the case studies shown in *italics* in the matrix portion of the decision tool, while not direct examples of that type of project, are an additional source of lessons learned.

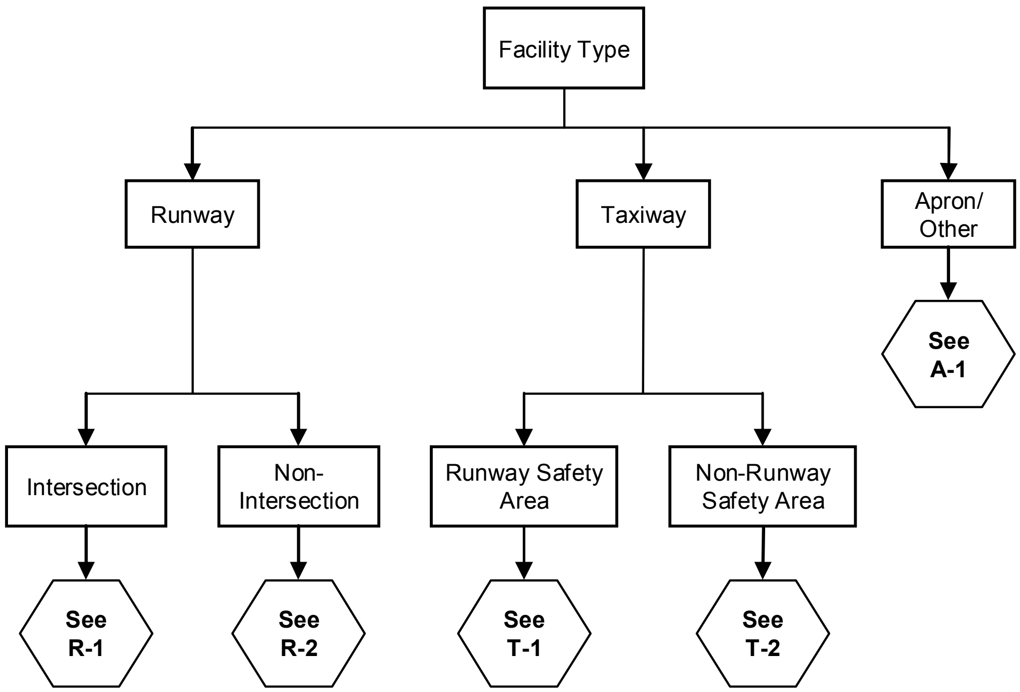


Figure 1-1. Accelerated project decision tool.

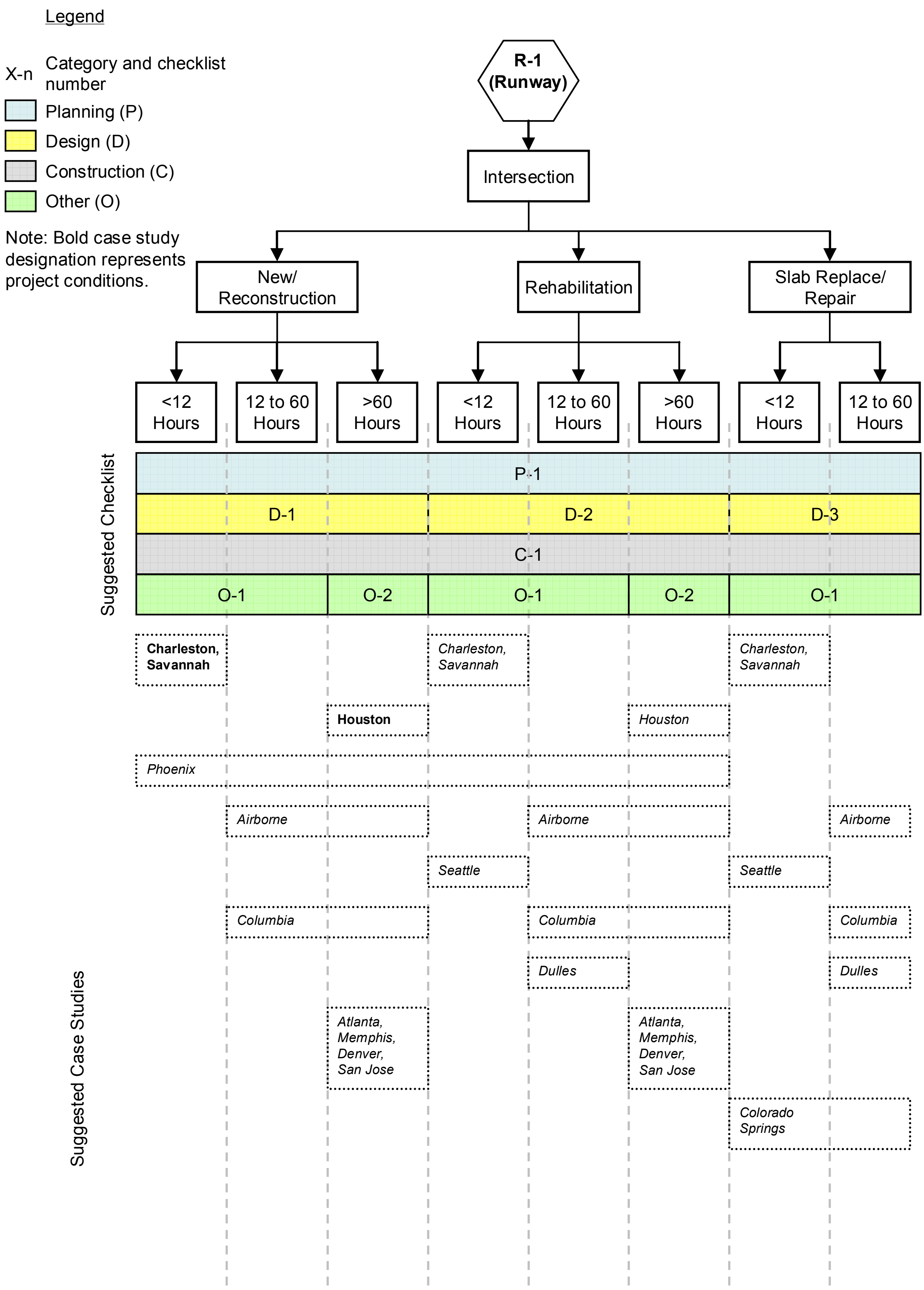


Figure 1-1 (continued). Accelerated project decision tool.

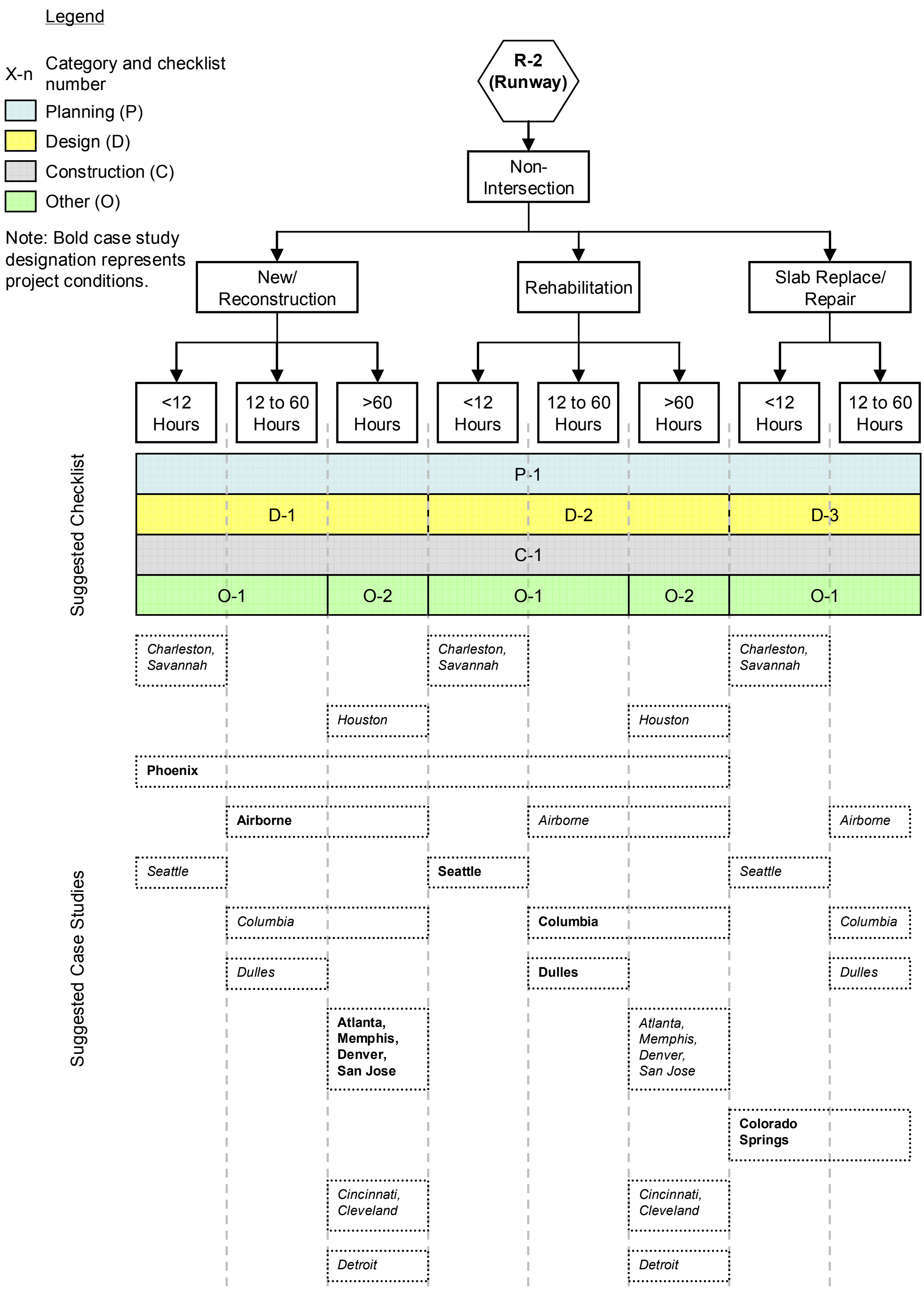


Figure 1-1 (continued). Accelerated project decision tool.

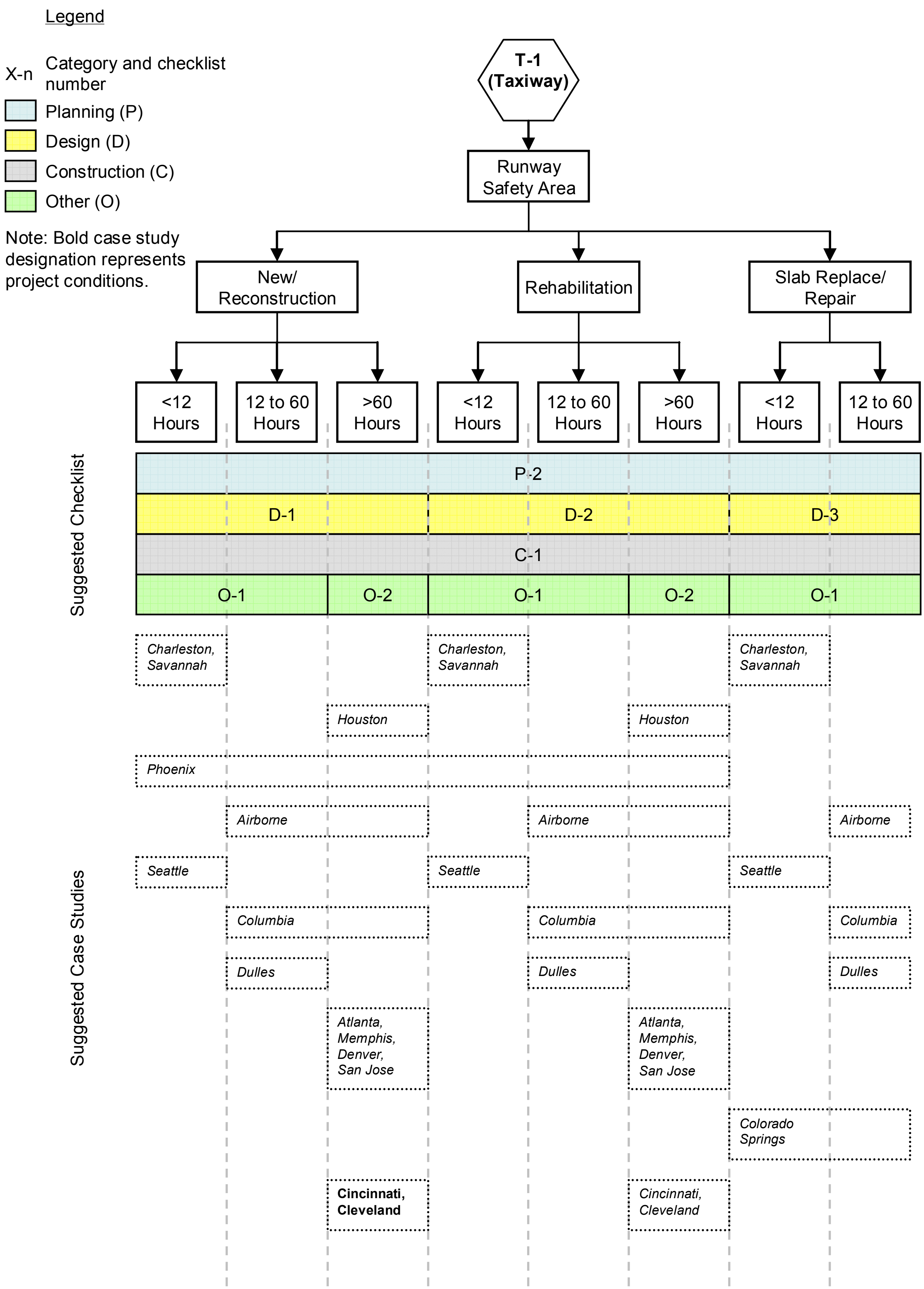


Figure 1-1 (continued). Accelerated project decision tool.

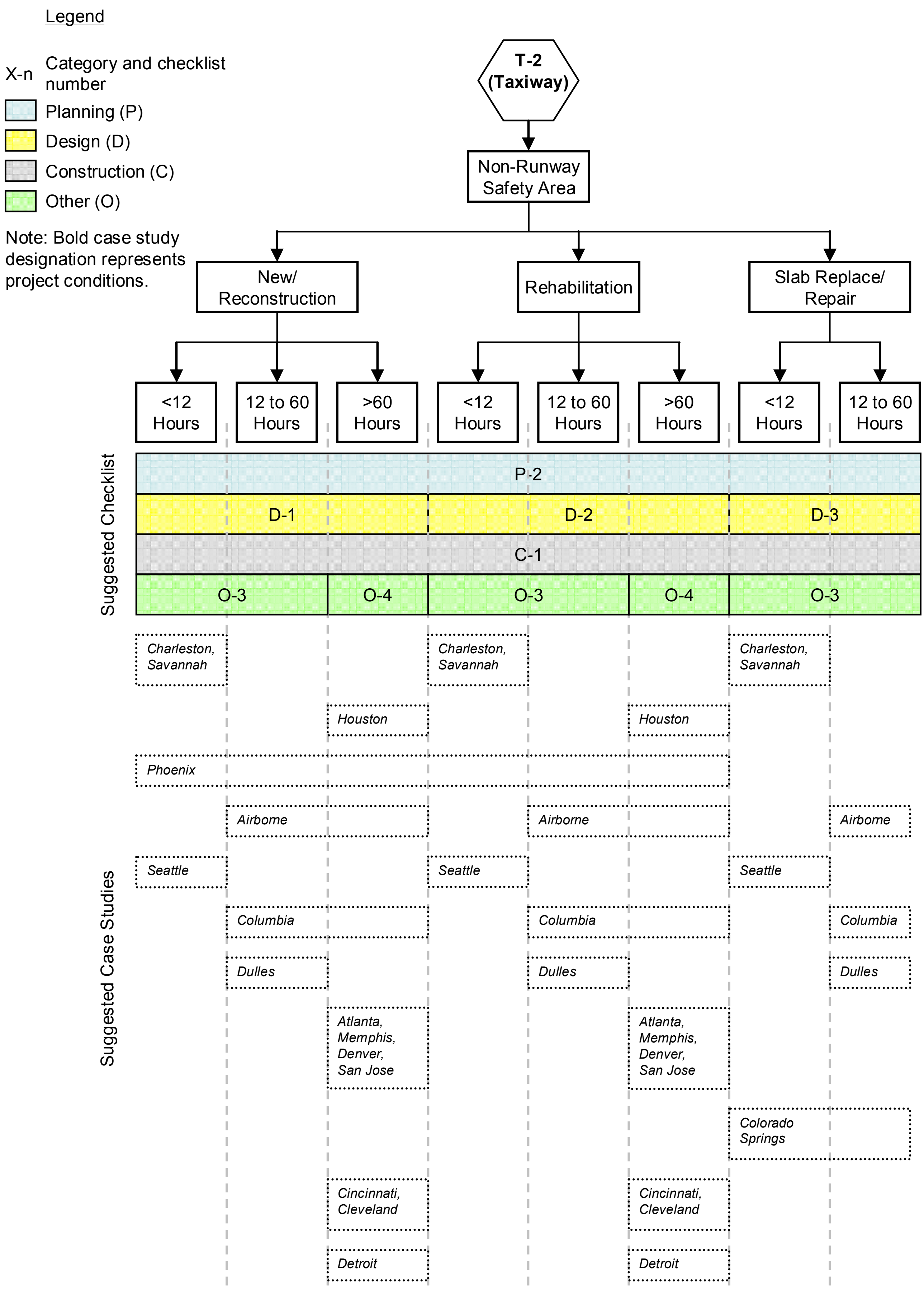


Figure 1-1 (continued). Accelerated project decision tool.

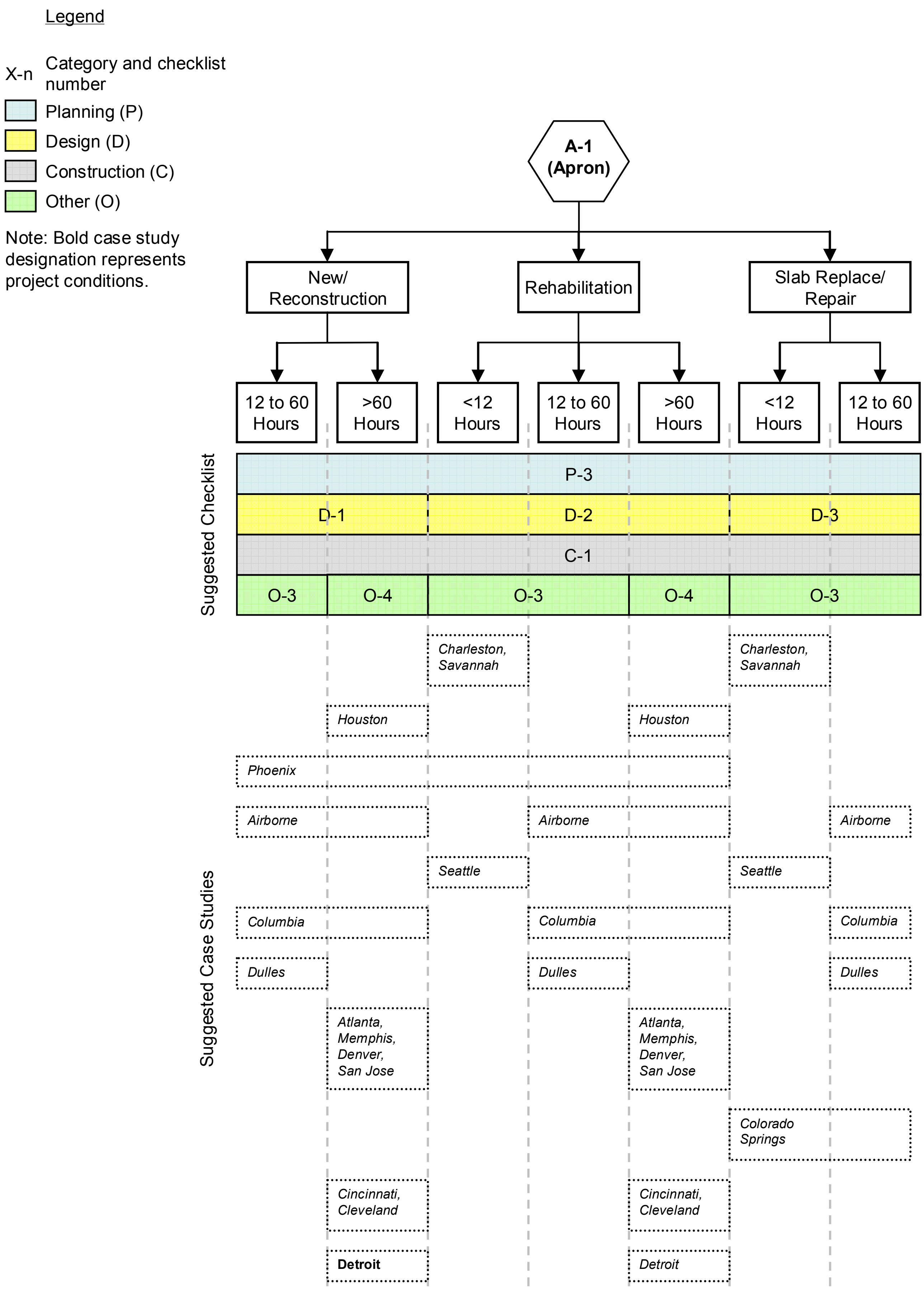


Figure 1-1 (continued). Accelerated project decision tool.

Table 1-2. Key project planning components.

<table>
<tr><th>P-1
Runway</th><th>P-2
Taxiway</th><th>P-3
Apron</th></tr>
<tr><td>☐ Coordinate with FAA early in the project, particularly with NAVAIDS, lighting, and required inspections.
☐ Consider reduced runway lengths for phasing sections.
☐ Minimize potential of future work closures; construct proposed future facilities so future construction will be outside of any runway safety area.
☐ Schedule critical work areas first, such as NAVAID areas.</td><td>☐ Coordinate with FAA early in the project, particularly with NAVAIDS, lighting, and required inspections.</td><td></td></tr>
<tr><td colspan="3">☐ Include all stakeholders early in process and continue coordination throughout entire project.
☐ Use partnering to instill team attitude with all levels (managers to field personnel) in the planning process.
☐ Identify key personnel with availability and authority to make decisions.
☐ Commit to an accelerated bid/award period.
☐ Use currently available contracts to begin portions of work.
☐ Include pre-qualification as part of the bid process.
☐ Make provisions for discretionary funds for the unforeseen, such as discretionary funds or “miscellaneous modifications” line item (Note that the FAA does not provide funding for discretionary funds).
☐ Provide an extended mobilization period prior to closure of facility to allow obtaining long-lead items.
☐ Allow for progress payments during mobilization.
☐ Assist with long-lead item stockpiling, such as light cans or reinforcing.
☐ Incorporate multiple Notices-to-Proceed to control schedule.
☐ Plan schedule for period of slowest operations.
☐ Plan schedule for best construction season.
☐ Maintain flexibility in decisions throughout the project.
☐ Use adjacent facilities to minimize impact of closure, if available.</td></tr>
</table>

Table 1-3. Key project design components.

<table>
<tr><th>D-1
New/Reconstruct</th><th>D-2
Rehabilitation
(6 to 60 slabs)</th><th>D-3
Slab Replace/Repair
(< 6 slabs)</th></tr>
<tr><td>☐ Consider use of temporary pavement surface as part of planning for reopening and as a contingency.
☐ Provide sacrificial layer or allow for grinding for establishing final grades.
☐ Evaluate haul roads for potential delays; for example, could a traffic light help minimize delay.
☐ Evaluate other local projects; could there by conflicts with obtaining supplies.
☐ Provide a stable construction platform: use stabilized base or stabilized subgrade if not typically used.
☐ Locate utilities ahead of time and have plan in place to address any unknown utilities.</td><td>☐ Consider use of temporary pavement surface as part of planning for reopening and as a contingency.
☐ Provide sacrificial layer or allow for grinding for establishing final grades.
☐ Provide a stable construction platform: use stabilized base or stabilized subgrade if not typically used.
☐ Locate utilities ahead of time and have plan in place to address any unknown utilities.</td><td></td></tr>
<tr><td colspan="3">☐ Continue sound stakeholder coordination.
☐ Determine if alternative designs are appropriate for portions of the project.
☐ Re-use existing layers if evaluation shows they are in good condition and can be protected during construction.
☐ Reduce the number of pavement layers, if possible.
☐ Evaluate requirements of design details; such as dowel bar designs and bond breaker materials.
☐ Evaluate the pavement layer types for speed of construction.
☐ Review standard details to determine potential time savings.
☐ Consider required performance factors.
☐ If possible, use standard designs and specifications to minimize required design time.
☐ Determine if proven techniques meet project requirements.
☐ Evaluate need for accelerated materials; if required make sure properties are well known and understood.
☐ Consider the project goals in determining available closure time.
☐ Evaluate requirements for opening to traffic.
☐ Develop the PCC mix design in advance but be prepared for making changes.
☐ Specify general PCC mix design requirements but leave the details to the producer.
☐ Review past PCC mix experience.
☐ Require back-up equipment to avoid potential delays.
☐ Evaluate material control/delivery requirements.
☐ Use test section to verify field properties of special PCC mixes and construction methods.
☐ Consider alternative methods to determine PCC strength.</td></tr>
</table>

Table 1-4. Key project construction components.

C-1 **All**
☐ Continue project team coordination and establish procedures for addressing Requests for Information (RFIs), Change Orders (COs), or other issues in a timely fashion. ☐ Allow for contractor value engineering input. ☐ Look for ways to simplify construction. ☐ Look for ways to improve upon past successes. ☐ Consider transverse (as opposed to typical longitudinal) paving lanes. ☐ Evaluate the use of alternative equipment. ☐ Consider available resources and possibility of teaming arrangements. ☐ Determine appropriate pavement removal methods. ☐ Consider sawcutting prior to time-critical closure for pavement removal. ☐ Pursue innovative methods and equipment to expedite pavement removal. ☐ Control material production. ☐ Monitor and make adjustments to materials, if needed. ☐ Provide sufficient equipment and labor. ☐ Provide proper curing. ☐ Obtain experience with unfamiliar materials or ensure easy to use materials.

Table 1-5. Other key project components.

<table>
<tr><th>O-1
< 12 and 12 to 60 hours
(Runway Safety Area)</th><th>O-2
> 60 hours
(RSA)</th><th>O-3
< 12 and 12 to 60 hours
(non-RSA)</th><th>O-4
> 60 hours
(non-RSA)</th></tr>
<tr><td>☐ Evaluate runway safety area requirements.</td><td>☐ Install fencing and guard locations to reduce security requirements; make work area outside AOA, if possible.
☐ Evaluate runway safety area requirements.
☐ Pre-treat backfill material to avoid delays in utility backfilling.
☐ Consider temporary measures for pavement markings and lighting.</td><td></td><td>☐ Install fencing and guard locations to reduce security requirements; make work area outside AOA, if possible.
☐ Pre-treat backfill material to avoid delays in utility backfilling.
☐ Consider temporary measures for pavement markings and lighting.</td></tr>
<tr><td colspan="4">☐ Provide dedicated security gate for construction access if working in AOA is required.
☐ If working in AOA is required, evaluate need to have all personnel badged or provide sufficient escort personnel.
☐ Review contingencies for adverse weather.
☐ Consider the use of incentives and disincentives (Note that the FAA does not provide funding for incentives).
☐ Adjust installation procedures for NAVAIDS and lighting to suit project requirements.
☐ Evaluate the scheduling of ancillary items within the closure schedule.
☐ Determine if operational procedures can be modified.
☐ Plan as best as possible for the unexpected.</td></tr>
</table>

2. PLANNING CONSIDERATIONS

2.1. Introduction

Thorough planning is a common theme in the case studies. Early planning is identified by most of the interviewees as having been instrumental in the success of the projects. Some steps in the planning phase of a project have been shown to be performed in an accelerated manner, but the greatest advantage observed in the case studies is that detailed initial planning allowed the successful completion of the accelerated construction portion of the project. In some cases, the planning stage has lasted longer than actual construction.

> Even if the planning stage is not accelerated, sound planning is essential to the success of any accelerated project.

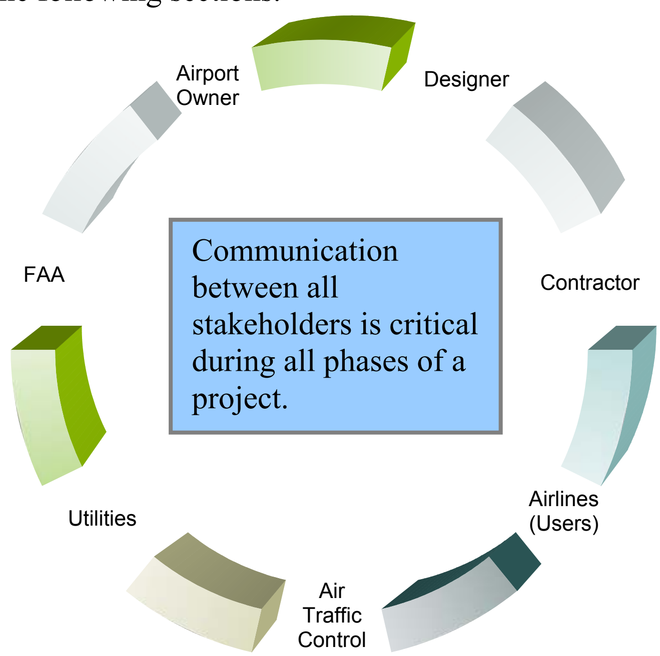
The numerous details of planning are beyond the scope of this document; however, several key issues have been extracted from the case studies. These key issues are roughly in three primary categories:

- Stakeholder Coordination.
- Procurement and Contracts.
- Phasing and Scheduling.

Each of these is discussed in greater detail in the following sections.

2.2. Stakeholder Coordination

"Stakeholders" includes the owners, designers, contractors, airlines, air traffic control tower, FAA, and utilities; in short, any party that is involved in or impacted by the project. The importance of good coordination among all stakeholders in an accelerated construction project is emphasized in nearly all of the case studies. As one interviewee stated, the three most important success factors in their project were "communication, communication, and communication."



2.2.1. Stakeholder Coordination Issues

Stakeholder coordination is an extensive task but can influence every step of a project, from initial project conception to project close-out. However, there are key stakeholder coordination issues that stand out in the review of the case studies, and include the following:

- Airline Input.
- FAA Coordination.

Airline Input

Airline input will define many aspects of a project so it should be obtained early in the project. One of the primary goals of obtaining and coordinating user input, such as from the airlines or the airport operator, is to strike a balance between minimizing the impact of the project on operations while allowing sufficient time for the required construction activities. Airlines are generally the primary user of the facility and are directly impacted (often financially) by impacts to operations. Examples of the importance of user input include the following:

- Charleston required coordination with civilian air carriers as well as the military. A complete closure of the intersection would have required the military to halt C-141 training missions and made it harder for civilian air carriers to operate economically. The economic effect of such a shutdown was estimated at over $100 million. Both civilian and military users rejected the shutdown alternative, but agreed that the runways could be closed for 8 hours each night. This would keep one runway open every day for 16 hours, accommodating most of the commercial and military operations (although some C-141 and fighter aircraft were relocated to reduce military use of the airfield during the construction).

- The initial results of coordination meetings for the Cleveland project were the development of a matrix of forecasted runway and taxiway closures, which consisted of three closure phases. Review and discussion of the matrix by the stakeholders resulted in the consolidation of the three closures (a 20-day closure and two 10-day closures) into a single 30-day closure, saving 10 days. The start of construction was also adjusted by one month based on input from the airlines during these coordination meetings.

- Coordination meetings for Phoenix determined a 90-day window in which a reduced runway length was acceptable to allow phasing of the runway reconstruction and maintain an operable runway during construction. Coordination of NOTAMS was then a significant factor during construction.

FAA Coordination

Coordination with FAA representatives is a significant issue in several case studies. Involving the FAA early in the project in Phoenix helped determine the final design approach of using a reduced runway length, rejecting the use of declared runway distances. Early cooperation with the FAA at Denver ensured that design and installation of navigational aids (NAVAIDS) met the demands of the accelerated schedule even though the stakeholders were initially unsure if this was going to be possible.

> Coordinating with the FAA can be instrumental in determining methods to reduce the impact of construction on operations and help ensure an accelerated schedule is met.

In Atlanta, cooperation and coordination with the FAA was critical to minimizing operational impacts. Issues coordinated with the FAA included maintaining the glide slope antenna for operations on the temporary runway facility and using a temporary Precision Approach Path Indicator (PAPI) system placed in the infield for visual approaches.

Close coordination with the FAA in San Jose resulted in establishing procedural guidelines for conducting construction work where interference with NAVAIDS would occur. It was agreed that the airport could operate without the runway localizers when it was necessary to perform construction in front of them. The contract documents required the contractor to move the equipment quickly if visibility deteriorated, and a method of payment for this rapid response was established.

Perhaps the Memphis project best showcases coordination with the FAA. Coordination for the Memphis runway reconstruction included the following FAA involvement:

- Assigning to the project, under a Memorandum of Understanding, a full-time representative to work on all FAA matters to maximize operations.

- Aiding in the process to allow Taxiway N to function as a taxiway serving the temporary runway (despite initial clearance conflicts with taxiing planes), working to set reasonable operating rules instead of unilaterally denying unconventional solutions, and thoroughly evaluating—within FAA guidelines—the allowable aircraft on the temporary runway.

- Modifying the rules for nighttime operations when the airport was under the control of a single ground traffic tower crew and when no commercial aircraft were operating near Taxiway N.

- Developing modified Instrument Flight Rules (IFR) by adding partial NAVAIDs to the temporary runway, allowing greater control capability.

- Assessing and allowing construction work to occur within 180 feet of an active runway, instead of the specified 200-feet requirement, in rolling increments of 2,300 feet during Visual Flight Rules (VFR) weather (limited to 190 feet toward the temporary runway).

2.2.2. Implementing Stakeholder Coordination

Lessons on implementing stakeholder coordination generally fall within three categories:

- Stakeholder Meetings.
- Identify Key Personnel.
- Partnering Sessions.

Stakeholder Meetings

Holding regularly scheduled meetings is the most common method of project coordination. These are typically weekly or bi-weekly scheduled events that occur throughout the course of the project. Some projects had multiple, regularly scheduled meetings to divide the issues into a smaller subset of topics for each meeting. For example, Denver held a second weekly meeting to specifically address quality control/quality assurance (QA/QC).

> Stakeholder coordination meetings should include all involved or affected parties and should encourage "outside the box" thinking. The goal is to determine the best approach for the specific, unique project, and not necessarily to point out how things have been done in the past.

Special meetings were also held to facilitate coordination. These meetings were not regularly scheduled throughout the project but provided valuable information. On several accelerated projects, including Denver and Memphis, the airports held constructability meetings during planning and design. Denver obtained input on paving and materials prior to bidding, with these meetings helping to establish realistic expectations for construction that were incorporated into the contract documents. Memphis held constructability meetings with trades to review construction steps, to identify potential causes for delay, and to share ideas on securing lower bids and faster delivery. By addressing issues early on, changes can be made without significant lost effort.

> Identification of a project "leader" was instrumental in the success of several cases studies. This individual should possess the following characteristics:
>
> - Knowledge of the project and airport.
> - Experience on previous construction projects.
> - Ability to make quick decisions.
> - Authority to make decisions and approve change orders.
> - Available time to thoroughly commit to the project.
> - Willingness to accept responsibility for the project.

Identify Key Personnel

Identifying and maintaining key personnel throughout the project promotes success. Integral to the success of the Atlanta and Memphis projects was the identification of individuals with the authority to make key decisions. A key individual removed the hierarchy and potential delays in decision-making; this person was involved in every aspect of the project, was knowledgeable and experienced with airport construction projects, was able to make quick decisions and, most importantly, was willing (and able) to accept responsibility for the entire project. During construction, these individuals were available at all times.

San Jose identified key staff that were to be involved early in the project planning through the completion of construction. Construction management staff was involved with reviewing contract documents and overseeing construction. With their involvement, a detailed construction sequence was clearly defined in the bid documents. San Jose attributes the quality of the project to the involvement of experienced staff and their knowledge of the complexities of the project by being involved early on.

Partnering Sessions

> Involving both upper-level personnel and field personnel in the planning process helps build trust and commitment.

Memphis took coordination one step further by holding partnering sessions to instill a sense of teamwork. As with many other large construction projects, the first formal partnering session included policy-setting representatives,. However, a second session was also held which included field personnel to spread the upper-level trust and to show the commitment to the success of the project. An additional teambuilding and awareness step taken by Memphis was the creation of a project-specific logo. The importance of promoting the project was emphasized through advertising and large display signs to instill a determination in the people involved to carry out the project.

2.3. Procurement and Contracts

Factors to consider for the procurement and contracts processes include the following:

- Commit to an accelerated procurement process.
- Use existing contracts to initiate time-critical elements.
- Consider additional requirements to the bid process.
- Allocate discretionary funds.
- Provide an extended mobilization period.
- Allow progress payments during mobilization.
- Assist with long-lead items.
- Incorporate multiple notices to proceed.

> Procurement and contract techniques can be implemented that help ensure successful construction as well as taking steps to accelerate the established process.

Commit to an accelerated procurement process. Many airport authorities typically have lengthy review times built into their standard procurement and contract award processes. Accelerating the procurement and contract phase requires a review of the typical process to identify where time can be saved, and reducing time during this process requires the full cooperation and commitment of the parties involved. For example, Detroit scheduled a special session of the Wayne County Airport Authority Board to immediately review and award the construction bids once they were received.

Use existing contracts to initiate time-critical elements. Accelerating a project can be facilitated by using existing contracts or purchase orders that have already gone through the procurement process. Many agencies have open-ended (or similar) contracts in place that can be used to negotiate work items, or existing contracts can be supplemented for additional work. For example, Denver realized that relocation of a major utility along with earthwork was going to impact the timeliness of completing the rest of the construction. They used an existing contract with a local utility company to issue a purchase order to facilitate an early start of utility design, which allowed construction on a major pipeline to proceed ahead of other portions of the project.

Consider additional (or alternate) requirements to the bid process. An alternative to the typical "low bid" system may provide assurances that the project will be completed as anticipated. The process used for Dulles is also considered a "pre-qualification" process instead of strictly a low bid process. With this format, the contractor provides a proposal with a construction plan and technical criteria that are rated rather than just providing a bid price to match the scope. Technical criteria contained in Dulles' *Contracting Manual* (Metropolitan Washington Airports Authority, 2003) include the following:

- Recent experience with contracts of similar dollar value.
- Evidence that they have the required specific technical capability and experience.
- A technical proposal that describes how they will satisfy the Authority's requirements as described in the Statement of Work.
- Schedule of their current contracts.
- Breakdown of their available equipment and workforce resources.
- The firm's latest financial statement.
- Evidence, such as a letter from an acceptable surety, showing that the firm will be able to obtain bonds in the required amounts.

This approach enables the airport to determine that the contractor is qualified for the work and that the contractor's plan meets the expectations of the project. During the selection process for Dulles' runway repair project, by having the contractor's work plan to review an exceptionally low bid was determined not to cover the entire project scope.

Allocate discretionary funds. Providing discretionary funds for possible changes during construction during the planning stage can avoid costly schedule delays during construction. Both Atlanta and Memphis established discretionary funding that was available to their project managers during construction. These funds were made available so that the project manager could cover the inevitable change order or additional work required and avoid time-consuming delays going through a conventional approval process.

Provide an extended mobilization period. An extended mobilization period helps ensure that everything is ready for construction prior to the start of the critical closure. Sufficient time should be allowed so that the logistics associated with materials, equipment, and labor can be accelerated to meet the planned construction requirements. Memphis and Atlanta both allowed lengthy mobilization periods to ensure that construction proceeded without delays once the critical closure began; Memphis allowed 5 months and Atlanta included 70 days. The Atlanta project highlights the significance of the extended mobilization period: to meet the requirements of placing 110,000 cubic yards of PCC and drilling and epoxying over 60,000 dowel bars within the 33-day schedule, mobilization included four batch plants (three on-site batch plants and an existing off-site batch plant as a backup facility), five paving machines (three paving at any one time and two serving as backups), 45 side-dump trucks, seven gang drills, and hundreds of employees.

Allow progress payments during mobilization. Both Memphis and Atlanta allowed progress payments during mobilization for stockpiled materials and mobilization of equipment. This ensured that sufficient materials and equipment were on site and ready prior to construction to avoid potential delays during construction without overly burdening the contractor. Memphis paid for aggregate and cement upon delivery to avoid potential shortages during construction.

Assist with long-lead items. Several agencies assisted with obtaining supplies, especially those with long lead-times, such as lighting and signing. As one example, Atlanta provided light cans to the contractor, which the contractor then installed and restocked on a less critical schedule.

Incorporate multiple Notices-to-Proceed. An additional contract measure is to include provisions for multiple Notices-to-Proceed (NTPs). One approach, used by both Atlanta and Memphis, is to have one NTP for the mobilization and another NTP for the construction work. In this manner, the agencies ensured that all of the preparation work was completed prior to allowing full-scale reconstruction to begin. San Jose went as far as establishing seven NTPs to control project progression.

2.4. Phasing and Scheduling

Phasing and scheduling issues can be very complex and unique to a specific airport and project. Minimizing the impact to airport operations is the central component to the phasing and scheduling of an accelerated project. Several phasing and scheduling considerations stand out in the case studies:

- Consider time on several levels (annual, weekly, daily) when evaluating schedule.
- Recognize historical weather trends.
- Maintain flexibility to change.
- Incorporate alternate facilities, if possible.
- Use a reduced runway length, if possible.
- Schedule critical work areas first, such as in-pavement lighting areas.
- Consider both future projects and operations now.

Each case study has extensive phasing and scheduling that is suited to the specific project. While many techniques are not necessarily new or unique (such as setting project milestones to help keep the project on schedule, performing non-critical "punch list" items outside of the critical closure, and so on), several ideas do stand out. The following discussion summarizes some of these ideas.

Consider Schedule on Multiple Levels

Perhaps the first consideration in phasing and scheduling is to determine if there is a "better" or "worse" time to schedule the project. This can be considered on a broad scale, such as determining the busiest (or slowest) time of the year, more narrowly, such as by considering certain days of the week, or most narrowly, down to the hours of each day. Atlanta and Memphis planned the reconstruction of their runways so that they would be completed prior to the busiest part of the year. Additionally, Atlanta planned the closure for the runway construction phase to coincide with the slowest day of the week to help with a smoother transition to the alternate facilities.

Recognize Historical Weather Trends

Planning according to historical weather trends can help minimize the impact of inclement weather on tight closure constraints. Cincinnati, Atlanta, Houston, and Memphis all considered historical climatic trends in establishing their project schedules. Although considering historical trends helps minimize risk, it does not guarantee success. For example, the Atlanta project began with five days of rain in the first ten days of runway construction despite scheduling the work for a historically dry time of year.

Dulles also considered wind direction. Since they would no longer have a cross-wind runway available they considered wind direction in selecting the time of year to close the runway.

Maintain Flexibility

Maintaining flexibility in phasing and scheduling can be advantageous at any stage of a project. Dulles had originally planned on completing repair work over the course of several weekend nighttime closures. Prior to construction, the contractor convinced the airlines and the airport to change to one full weekend closure, allowing the work to be completed more efficiently and reducing the number of shorter closures.

Cleveland's phasing changed based on user input. Three proposed shorter closures (one 20-day and two 10-day) were combined to one longer closure (30-day), saving 10 days of anticipated closure. The construction schedule was also postponed one month from the original start date to accommodate the airlines' request.

Detroit revised phasing planning during construction to help maintain the project schedule. When the schedule began to fall behind, an adjacent taxiway was used for a service road for baggage handling and aircraft operations were relocated. The flexibility demonstrated by the involved parties resulted in completely eliminating one construction phase and putting the project schedule back on track.

Incorporate Alternate Facilities

While determining the "best" timeframe for construction may help reduce user impacts, it will most likely never completely eliminate the need for a closure. While closures affect operations on any type of facility (apron, taxiway, runway), they are perhaps most significant for runways. To minimize the impact of closing runways for construction, several airports were able to provide alternate facilities. During the planning process for both Atlanta and Memphis, for example, it was decided to upgrade parallel taxiways to runways during mobilization phases to maintain the majority of the operations normally occurring on the closed runways. These upgrades included improvements to the pavements as well as providing temporary navigational aids. Although costly, Atlanta estimates that over 60 percent of the delay costs were avoided by providing the temporary runway facilities.

In addition to providing alternate facilities to minimize the effect on runway operations, Atlanta also considered taxiing operations in the phasing. Several phases were established during construction to maintain taxiing routes across the runway work area. Although this is not necessarily unique, some phases included providing temporary pavements to maintain taxi routes.

Houston also was able to provide an alternate facility to minimize the impact of the runway closure required to reconstruct the intersection of two of its runways. During the closure phase for the intersection work, Houston was able to move user operations to an adjacent runway. However, this was done with some operational limitations and risk. The use of the secondary runway required load limitations on departing aircraft, and it left the airport without all-weather capabilities.

Reduced Runway Length

Phasing of the runway reconstruction work in Phoenix provided an operational runway each day, which was accomplished in three phases using a reduced runway length, as shown in figure 2-1. By extending the runway and using a reduced runway length, 5,000-foot sections at each end were reconstructed during the first two phases of construction without requiring overnight work. This left only the center 2,000 feet of the runway requiring reconstruction during overnight work in the third phase.

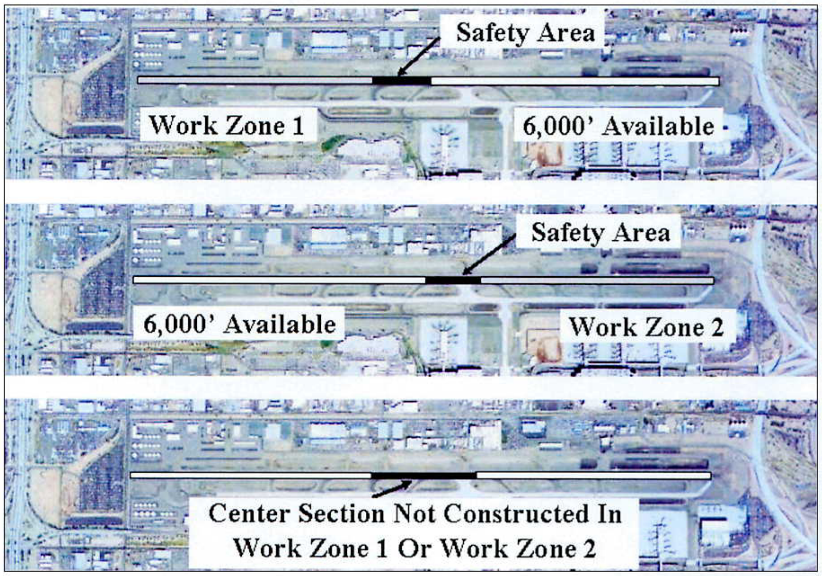


Figure 2-1. Illustration of Phoenix phasing.
(Illustration provided by Dave Folmar)

Cincinnati also used a reduced runway length to minimize the impact of construction. Cincinnati was faced with a runway closure to accommodate the necessary tie-in work to the runway during the extension and reconstruction of one of their taxiways. To minimize the reduction in operational capacity, a reduced runway length was established during the tie-in phase and they altered their operations to have as many smaller aircraft as they could use the temporarily shortened runway. This removed some of the congestion and delay in the heavier commercial flights on the primary runway.

Schedule Areas that Facilitate Other Work Items

As part of the planning process, it can be important to determine if completing particular project phases can facilitate the early start of other work. Denver scheduled paving to facilitate runway certification and navigational aid installation. By paving the center lanes of the runway and areas for navigation aids first, Denver saved at least 2 months that would have been needed at the end of the project to complete these activities. Houston also scheduled areas with lighting to be paved first to ensure that electrical work was completed within the short available closure time for reconstruction of the runway intersection.

Consider the Future

Reviewing future planning can also assist with determining when a project would be easier or more difficult to perform. For example, if an expansion in operations is anticipated, postponing construction may be more problematic. However, if other improvements or new facilities planned for a future date would make construction easier, it may be beneficial to postpone construction. Similarly, making allowances for future construction during the current closure can eliminate the need for a future closure. For example, Denver anticipated additional expansion in facilities after completion of the runway construction. To eliminate the need for a future closure of the runway, the connecting taxiways were paved beyond the runway safety area.

3. DESIGN CONSIDERATIONS

3.1. Introduction

An innovative design can help to accelerate a project in several ways, including reducing the number of construction steps or simplifying a complex process. Innovations that lead to an accelerated process can come from suppliers, designers, contractors, or the owner, among others, and may be introduced at any time during the project.

As with planning, the design phase can itself be accelerated or steps can be taken during design to facilitate accelerated construction. Design innovations can occur any time, from during the initial planning phase to the construction phase; however, there is less lost effort the earlier in a project they occur.

3.2. Development of Alternative Designs

Alternative designs should be considered as a means to accelerate construction. Several factors can be considered for using alternate designs:

Need for accelerated construction – It may be possible to differentiate between areas that require accelerated construction because of their impact on operations (such as runway tie-ins) and areas where more conventional methods can be used because they are not on the project's critical path. Both areas do not necessarily need the same design.

Time available for construction – Discussed later in this section in more detail, available closure time will greatly influence the design approach. Determining and using alternative designs can make the most of the available construction window.

Existing pavement conditions – The types of pavement layers (stabilized or aggregate) and condition of the layers—whether or not they can be salvaged—should be considered. Full reconstruction of the pavement section may not be required. Subgrade conditions can also influence alternative design decisions.

Alternative designs included in the case studies are primarily in two categories: number and type of pavement layers and pavement details.

Number and Type of Pavement Layers

Alternative designs need to meet anticipated loading requirements, as specified in FAA design procedures.

Any deviation from the recommendations in FAA advisory circulars requires prior approval from the FAA.

Several projects reduced the number of pavement layers to accelerate construction. This can be accomplished by salvaging existing layers or designing for fewer layers.

- Atlanta and Houston determined that the existing stabilized base layer was in good condition and the bond breaker used during the previous construction allowed the stabilized base to be left in place. This resulted in reconstruction of only the PCC surface, a considerable time and cost savings.

- Charleston and Savannah reconstruction projects also involved only constructing a new PCC layer. The initial design process for these projects did evaluate a conventional design using a stabilized base layer, but designers decided to increase the PCC thickness to eliminate the use of a stabilized or aggregate base, thus eliminating this step during construction.

Charleston evaluated designs using both FAA and military design methods to determine a suitable thickness for a free-edge condition and slab-on-grade. The slab-on-grade design was selected based on time constraints. The overnight closure requirement did not allow sufficient time to shape the subgrade, place a base layer, and place the surface PCC with enough time for curing to reach the specified strength by re-opening each morning. The free edge condition was evaluated for removing the dowel bars due to high bonding strength issues (and resulting slab cracking) with the proposed proprietary material. Savannah considered the design as including a "monolithic" stabilized base.

- The design for Airborne was simplified to include only two layers—an aggregate base and the PCC surface layer—because the contractor determined that the weekend closure did not allow sufficient time to construct a stabilized base. To account for the elimination of the stabilized layer, both the aggregate layer and PCC layer thicknesses were increased by 2 inches. The project kept the aggregate base layer in the design due to subgrade drainage concerns. This design was proposed by the contractor, who later proposed the use of a similar design for the Cincinnati project, discussed later in Section 4.3 (Value Engineering). While the Airborne project was not FAA-funded and didn't require FAA approval of the design, the Cincinnati project was FAA-funded and design approval was obtained.

The pavement layer type is also a consideration in some projects. Layer type considerations primarily involve decisions concerning the base layer: stabilized versus aggregate and cement-treated versus asphalt-treated.

- Cleveland provided a pavement section with an asphalt-stabilized base for time-critical runway tie-ins and a design with cement-treated base elsewhere. They felt the asphalt-treated base would allow construction to continue sooner after placing the layer than would the use of a cement-treated base (note that the contractor used a cement-treated base for tie-ins after problems occurred with the first tie-in areas constructed using the asphalt-treated base).

> Two IPRF reports—*Stabilized and Drainable Base in Rigid Pavement Systems – Report of Findings* and *Stabilized and Drainable Base for Rigid Pavement – A Design and Construction Guide*—provide additional discussion on base materials and their construction and performance.

- As noted above, for the Airborne project the contractor selected an aggregate base layer. The team considered a stabilized base, but decided that it would be too difficult to construct a stabilized base layer during the short weekend closures.

Pavement Details

The evaluation and modification of pavement details can be a basis for alternative designs. Charleston and Savannah both eliminated dowel bars for load transfer. The manufacturer of the proprietary material used for the Charleston project indicated that high bonding strengths between the material and embedded steel had been problematic on some projects and resulted in cracking. Faced with construction time constraints and a choice between non-standard load transfer devices or no load transfer, the designers chose no load transfer devices and evaluated the proposed PCC thickness for the increase in edge stress that would result by eliminating the load transfer. The elimination of dowel bars also reduced the amount of preparation work required by the contractor.

Houston evaluated the type of bond breaker to be used between the existing stabilized base and the new PCC pavement. The previous construction had used a 1.5-inch asphalt separation layer. An asphalt cement prime coat had been used at other Houston projects with success, and the design team decided that replacing the 1.5-inch separation layer with an asphalt cement prime coat would reduce construction time.

> Although alternative designs can accelerate construction, sound design practices must be considered. In considering the elimination (or modification) of standard design features, consider the impact of the modification on performance, such as the effect of eliminating a stabilized base layer on the potential for pumping of the subgrade, or the effect of no load transfer devices on faulting and slab cracking.

3.3. Performance Assessment/Risk Assessment

Accelerated paving is often associated with the use of high-early strength or rapid-setting materials; however, in some cases such materials are associated with poor long-term performance. There is also, perhaps, a general mindset that work done quickly sacrifices quality. Case studies show that high quality, long-lasting concrete pavements can be constructed using accelerated techniques. However, in making design decisions for accelerated construction there is often the need to evaluate the anticipated (or required) pavement performance and balance this with the project's constraints.

Performance Requirements

Projects must first consider what performance goals are to be achieved. "Performance" is often defined as the ability of a pavement to provide a functional, safe, riding surface for a certain number of years without needing significant maintenance or repair. Factors that affect performance are those that would cause the pavement to fail (due to load, environment, or other causes) and require major work sooner than anticipated.

Traditional airport pavement designs using the FAA design procedure are based on a 20-year design life. Thus, performance evaluations in the case studies generally considered one of three goals: meeting the standard design period, exceeding the standard design period, or not requiring a full 20-year design period. Risks become a greater issue the longer the desired performance period; with shorter performance periods project stakeholders are more willing to accept higher risks. Consider the following examples:

> FAA funding is currently provided for 20-year design periods. The costs for constructing to a longer design period become the responsibility of the owner.

- San Jose considered past difficulties completing maintenance work due to local regulations and limited access because of operational constraints. In order to minimize the likelihood of repairs they required a 30- to

40-year design.

- The owner considered slab replacement at Seattle a temporary repair. It was determined that eventually repairs would be replaced as part of major, more permanent rehabilitation or reconstruction. Therefore, long-term performance of the repairs was not a critical project requirement and the risk of early deterioration by using a high-early strength rapid-setting material was acceptable. Some replacement slabs have been replaced since the initial work due to cracking.

- Dulles also considered slab replacements as temporary repairs (the runway was planned for reconstruction 2 years later) and the long-term performance of the repairs was not a high priority. In fact, the temporary nature of the repair work did not address the cause of some of the pavement distress and some of the replacement slabs cracked in the same locations as the previous pavement; nonetheless, the repairs were sufficient to sustain operations for another 2 years.

- The patching work for Colorado Springs was expected to have a limited performance life. Additionally, runway reconstruction was planned in approximately 5 years. Although a 20-year design life was not required, Colorado Springs desired improved performance from their past experience with patching materials. Many of the previous repairs had failed within 6 months. Project specifications indicated a required service life of 10 years. One of the few materials advertising the required service life was the proprietary patching material selected for the project. Although it was a material the airport had no past experience with, the risk of using a new material was acceptable based on past poor performance of other materials.

Accounting for Risk

<u>Proven performance.</u> Several examples illustrate intentionally selecting designs or materials because they have been proven with past experience, thus minimizing the risk of unknowns:

- Memphis intentionally selected conventional materials and methods to reduce the chance of surprises during construction: they specified materials and methods with which the contractor would be familiar.

- Houston selected a material that had been proven at another local airport. The previous runway intersection reconstruction had significant material-related problems associated with using a high-early strength, rapid-setting material. To minimize the risk of having materials-related problems again, they selected a proven material.

- The apron design used for the Detroit project was based on a standard used elsewhere at the airport. The use of a standard design not only helped accelerate the design phase, but also minimized the risk of poor performance from trying something new.

<u>Mutually acceptable level of risk.</u> Stakeholder coordination is also important in agreeing upon and understanding project risks. Houston's runway intersection reconstruction had 6 months for stakeholder plan review to coordinate input from users on departure weight limitations, the risk of having no all-weather capabilities, and the potential of using alternate airports in finalizing the decision of using a secondary runway during the intersection closure.

3.4. Use of Innovative Materials

The use of high-early strength concrete is often the first (and sometimes the only) idea that comes to mind for an accelerated project. Such materials should only be used when absolutely needed, as they often come with greater performance risks, are less familiar to the contractor, and are more expensive. Such materials may be needed for certain critical areas, but may not be needed over the entire project.

The majority of accelerated projects included in the case studies used what would be considered conventional materials. Most of the projects used Type I cement and admixtures readily available on the market to meet the project requirements. The mix design considerations are discussed in a later section. However, to meet the construction time constraints, in several projects proprietary materials were selected specifically for accelerated construction.

The high early strength, rapid-setting cement used for Charleston had been typically used only for small patches and repairs before the project. Thus, it was necessary to thoroughly investigate the material properties before using it for full slab replacements. There were several challenges to using the proprietary cement:

- There was a relatively narrow blend of mix variables that would produce satisfactory strength, workability, and setting time.

- Chemical reactions between the cement and locally available aggregates and water could be unpredictable, and mix properties needed to be verified in the laboratory.

Based on laboratory testing, a mix design was developed consisting of the following elements:

- Minimum cement content – 752 pounds per cubic yard; specified 90-minute set time (the proprietary cement was available with several different set times).
- Water/cement ratio – 0.22 to 0.26.
- Slump – 5 ± 2 inches.
- Ratio of Grade 67 coarse aggregate to natural sand fine aggregate: 55/45 to 50/50.
- Minimum of 6 minutes mixing time.

The laboratory tests of this concrete mixture resulted in 500 psi flexural strength (± 50 psi) at 5 hours.

One problem that had been previously noted by the manufacturer was a very high degree of bond to steel, which prevented dowels from working normally. Therefore, the designers eliminated the load transfer devices. Eliminating the dowel bars also decreased construction time.

The temporary, pre-cast slabs included in the project (discussed in Section 3.8 (Development of Plans and Specifications)) were constructed on site using the proprietary cement PCC, allowing the batching and transporting issues to be worked out in advance of paving. During construction, the field PCC consistently achieved 500 psi flexural strength 5 hours after batching, with 7-day flexural strength exceeding 1,000 psi. The proprietary cement PCC was batched in a conventional batch plant offsite and placed using traditional procedures. Special attention was paid to adequate vibration of the PCC and to the use of evaporation retardants to avoid loss of moisture. The Savannah intersection reconstruction was completed using a similar proprietary cement for its repair material.

Colorado Springs selected a patching material that set quickly, but also retained flexibility for a longer service life. The proprietary material is mixed and heated in an oil-lined kettle (i.e., the “pot,” which is similar to a hot-pour machine), poured out while hot, and hardens as it cools. The material results in a permanent repair in less than hour, but often sets up faster than that and can set up in as little as 10 minutes with the application of water and/or ice. This material allowed repair crews to work up to 30 minutes before re-opening the runway to traffic.

Repair preparation was similar to using other conventional products. The contractor would make a square edge sawcut about 1 inch deep and about 3 inches beyond the area to be repaired. The damaged PCC would then be chipped down to sound material using 60-lb air hammers. The patch area was then cleaned out and airblasted to remove moisture and fines.

Meanwhile, pre-measured units of the repair material were melting in the pot. Immediately before placing the material, the patch area was heated with a torch. A supplied primer was then placed on the patch area, and after a 5- to 10-minute wait, the material was spread in the patch with buckets or, for large patches, placed directly in the patch from the pot. The material was placed in lifts about 1 inch deep. For areas greater than 1 square yard or where the deterioration extended too deep, a full-depth repair or slab replacement was performed instead, using conventional repair techniques and materials.

No vibration or floats were required for the finishing process, but the crew did use a hot iron to minimally flatten or move the patch material for final finish. Finally, a specified, high-performance aggregate was placed over the patching material before the material had cooled down to a firm consistency.

Figure 3-1. Placing patch material at Colorado Springs.

3.5. Available Closure Times

Available closure times are dictated in large part by the impact of the closure on operations. Stakeholder coordination, as discussed previously, is necessary to establish mutually agreeable times for work to take place. This process needs to be a negotiation to balance the impact on operations and the efficiency of construction. Generally, construction is completed more efficiently with longer closures. Although longer closures can impact user operations to a greater extent, they can also result in a reduction in the overall schedule and impact of construction. The reduction from a total of 40 closure days to 30 days in Cleveland is an example in which, through stakeholder coordination, the one 30-day closure saved 10 scheduled closure days. Thus, it remains important for all parties to look at all options and the impacts they have in determining the available closure time.

> The careful selection of a closure time that considers project goals and constraints is essential. Especially in operationally critical areas, closure times should be long enough to ensure success, but no longer than necessary.

The available closure time dictates the type of work that can typically be done and how much can be accomplished. Three general categories of closure times, and work that is possible within those closure times, are summarized below.

3.5.1. Overnight Closures

Overnight closures are generally less than 12 hours long, with 6 to 8 hours being common. The short amount of work time in an overnight closure restricts the extent of work that can be completed, but does not make repair work impossible. Work is generally limited to slab replacement and slab patching.

For these shorter closures, the time for the PCC to gain sufficient strength to reopen is a significant factor, but construction methods can be just as critical since a good portion of the closure is necessary for the required curing time. For example, Charleston's runway closure started at 10:00 pm and they required reopening at 6:45 am. With the material requiring 4 to 5 hours to reach sufficient strength, all placement work had to be completed by 1:45 to 2:45 am. As such, there were only approximately 4 hours for removal, preparation, and placement of the PCC.

Several projects provide lessons on overnight work, including Charleston, Colorado Springs, Phoenix, Savannah, and Seattle. Those lessons are summarized here, and are also discussed in greater detail elsewhere in this report:

- Use rapid-setting, rapid-strength PCC materials to minimize curing time and maximize preparation time.
- Early sawcutting (such as during a previous closure) allows slab removal to occur earlier in the closure period.
- Reducing the number of layers to be constructed or reconstructed shortens the overall construction time.
- Using temporary, pre-cast slabs provides some flexibility to extend preparation and placement work over multiple closures.

- Providing sufficient equipment and labor to perform the work and providing backup equipment can avoid possible problems.

- Evaluating the opening requirements to maximize the work allowed in the construction window (such as not requiring full pavement strength in areas that are outside of the main traffic area).

3.5.2. Weekend Closure

Weekend closures still provide a relatively short construction window and restrict the extent of work that can be completed, but are obviously not as restrictive as overnight closures. Weekend closures allow areas of slabs to be replaced (instead of individual slabs) and allow time for additional items of work to be performed, such as drainage improvements. As such, projects that can be completed during weekend closures include reconstruction of large sections of a runway, such as Airborne and Columbia. These same projects could take as long as 2 to 4 weeks under night closures, could have a much greater impact on operations, and could ultimately be much more expensive. Many of the considerations for overnight closures can be applied to weekend closures, but there is some leeway. For example, relatively quick PCC strength gain is still essential, but it does not have to be as aggressive as the few hours needed for overnight closures and may only need to be used for areas paved immediately prior to re-opening. Airborne required opening strength within 24 hours, while Charleston required strength gain in 4 to 5 hours.

3.5.3. Longer-than-Weekend Closures

With longer closures, more conventional designs, construction methods, and materials can be used and the types of projects that can be considered are hardly limited. For example, although Memphis was on an accelerated schedule, the paving portion of the work was performed in 12-hour shifts, 6 days a week, using conventional paving techniques and PCC materials. The emphasis during longer closures begins to focus on keeping more tasks on the track for the accelerated schedule and on planning to minimize possible delays. Key considerations during longer closures include the following:

- High level of communication needs to be maintained, decisions are addressed in a timely manner, and phases are coordinated with stakeholders.

- Weather delays can be minimized by using stabilized subgrade or stabilized base layer. Weather is more likely to be an issue with longer closures since grades can be open for a longer period. Short closures can be cancelled if poor weather is in the forecast.

3.6. Opening Requirements

Strength Requirements

Opening requirements are generally related to the PCC obtaining sufficient strength to support aircraft (or construction) traffic without damage. For example, the FAA P-501 specification sets opening requirements as a PCC flexural strength of 550 psi (compressive strength of 3,500 psi if specified) or 14 days after the PCC has been placed if strength testing is not available. However, with accelerated projects some repairs are completed and reopened in less than 14 hours, not 14 days. Although most projects could not afford 14 days for curing, the majority of projects required opening strengths of 550 psi (or very close to it). The opening requirements included opening for construction traffic. What generally varied between projects is the time that was available to achieve that strength. Some examples of varying opening requirements are:

- Savannah required 500 psi flexural strength in 4 hours.
- Seattle required 550 psi flexural strength in 5 hours.
- Airborne required 650 psi flexural strength in 24 hours.
- Cincinnati required 700 psi flexural strength in 3 days.

Exceptions have been made to the typical specified strength requirement, and these suggest that there can be flexibility in determining opening requirements for PCC.

- Phoenix required 750 psi *compressive* strength for opening during construction of the middle section of the runway. This lower strength was allowed because the area was included as part of the overrun for the reduced runway length. Although the area had to be reopened to traffic every morning, being part of the overrun the pavement was only required to support an aircraft in case of emergency; should an overrun occur the pavement would likely be damaged and it was required that the pavement be replaced, but it would support an aircraft.

- Similarly, the PCC on the cross runway construction at Savannah that was outside of the intersection but still within the active runway safety area was only required to achieve initial set. Since the pavement was not directly in the intersection this pavement only needed to support an aircraft in case of an emergency. It was anticipated that the pavement would be damaged and would need to be replaced, but it would have sufficient strength to support an aircraft.

The advantage of a flexible approach to opening strength is that the construction window is maximized by requiring less curing time prior to re-opening the active pavement area.

Temporary Pavement Surface

An innovative approach to providing a functional, safe operating surface is providing a temporary pavement surface between closures. A measure taken by several projects is providing temporary pre-cast panels that are quickly placed for reopening to traffic and quickly removed to continue with construction. Charleston, Savannah, and Seattle all used temporary, pre-cast PCC panels to provide flexibility in the construction schedule and ensure that the repaired pavement could be reopened in the morning under any circumstances. Figure 3-2 shows the temporary pre-cast panels in place during the Savannah project.

Figure 3-2. Temporary pre-cast panels at Savannah.
(Photograph provided by Gary Skoog)

The temporary pre-cast panels also serve other purposes. Charleston and Savannah used the temporary panels as the demonstration sections for the materials intended for construction, as mentioned previously. For all of these projects the temporary panels could be placed quickly in case an emergency required re-opening the runway. Finally, having the temporary, pre-cast panels provided a functional, safe pavement surface while still allowing work to be conducted over multiple nights. By being able to have work performed over multiple nights, there was time to address poor subgrade conditions and all of the preparation work did not need to be fit into one nighttime closure. The following are key elements in the use of pre-cast slabs as part of PCC panel replacement projects:

- Panel size. All three projects used multiple pre-cast panels for each slab replacement. Smaller temporary panels can be moved and placed by smaller equipment: Charleston used 12.38-foot square panels and Savannah used 8.25 x 12.33-foot panels. Smaller panels allowed the use of smaller, more mobile equipment, as illustrated in figure 3-3. The panels are sized slightly smaller than the typical slab dimensions to allow room (1 to 2 inches) for placing and removing them without damaging the adjacent pavement.

- Leveling methods. Seattle incorporated cast-in screw jack assemblies to level the slabs once they are placed. However, Charleston and Savannah depended on leveling the subgrade prior to panel placement.

- Other Features. Pre-cast panels generally are heavily reinforced, do not have load transfer between panels, and have angle iron along the panel edges to minimize edge damage during handling. Lifting anchors are embedded below the surface of the panel.

Figure 3-3. Larger crane used in Charleston (left) and smaller equipment used in Savannah (right) to place temporary pre-cast panels.
(Photographs provided by Gary Skoog)

3.7. Mix Design

As mentioned previously, in the majority of the case studies conventional PCC materials are used to obtain the required PCC strengths within the allotted time. These mixes typically had high Type I cement contents (greater than 600 pounds per cubic yard) and often contained admixtures and supplementary cementitious materials. Several general lessons are obtained from the case studies:

1. Advanced planning is essential, but be open to making changes.

    - Several trial mixes were tested for the Airborne project, with the final mix design consisting of approximately 800 pounds per cubic yard of Type I cement, a water-to-cement ratio of approximately 0.27, and a superplasticizer admixture to achieve 650 psi flexural strength in 24 hours. During construction, initial strength results allowed a reduction in cement content to approximately 767 pounds per cubic yard while still obtaining required strengths.

    - The Cleveland project initially established two mix designs: one for accelerated phases requiring high-early strength and a second, more conventional mix for non-accelerated phases. Both mix designs used Type I cement with 25 percent Grade 120 Ground Granulated Blast Furnace Slag (GGBFS). The conventional mix used 423 pounds of cement and 141 pounds of GGBFS per cubic yard, with a w/c ratio of 0.47. The high-early strength mix had 800 pounds of cementitious material per cubic yard, with 600 pounds of cement and 200 pounds of GGBFS. Both mix designs used air entraining and mid-range water reducing admixtures for slipforming at a slump of 1.25 inches. For hand work, a superplasticizer was used to increase slump to 5.25 inches. After some of the initial paving phases, the conventional mix proved to obtain sufficient strength for the accelerated phases and it was used in place of the high-early strength mix. There were also some cracked slabs in the initial paving phases that used the high-early strength mix.

- Columbia initially required the PCC mix to achieve a flexural strength of 550 psi in 8 hours, but changed the requirement to 12 hours when the final schedule didn't require such a rapid-set mix. This change in requirements allowed them to use a mix with higher cement content but without other special admixtures.

2. Specify general requirements, but leave details to the contractor.

   - Seattle specified strength requirements, opening time requirements, and general quality characteristics, but left the final mix design parameters up to the contractor. The specifications require 550 psi flexural strength in 5 hours and 650 psi flexural strength at 28 days. To develop a workable mix, the contractor performed a significant amount of materials research to ensure a proper mix design. Every year the rehabilitation work is performed, the materials are evaluated to make sure the mix will work as expected. Cement is sole-sourced to ensure uniform quality; aggregates are crushed, double washed, and kept wet; and extensive mix testing is conducted to obtain temperature gain and time of set information. The contractor has found that the cement has changed (the cement "grind" and a lower heat) over the years and this has required regular alterations to the mix design and placement times. The admixtures used have also changed, with earlier contracts using citric acid as a set retarder and commercially available admixtures used more recently. The current contractor owns and operates the ready-mix company that provides the concrete for the repair work and notes that having control over the mix design and production is a critical element in the success of the work. Additionally, temperature and time-of-set relationships are used primarily for monitoring the material during placement; slump changed so quickly during placement that the information was questionable.

3. Consider (and learn from) previous experiences.

   - The Houston intersection project was a reconstruction of a previous accelerated paving project that, in only a few years, had severe cracking and other distresses. The previous project's concrete consisted of 705 pounds of Type III cement and 140 pounds of fly ash per cubic yard, with a superplasticizer and an accelerating admixture. The specified flexural strengths were 750 psi at 24 hours and 850 psi at 28 days. Because the original amount of accelerator used was too great and the concrete lost workability before finishing could be completed, the amount of accelerator was reduced, leading to decreased 24-hour strengths. The actual 24-hour strengths ranged from 600 to 685 psi, and the 28-day strengths ranged from 840 to 960 psi. A forensic investigation found that the concrete used in the project had produced delayed ettringite crystal formations, which expanded the volume of the concrete pavement. This expansion was so great that several light bases in the intersection were damaged by shearing forces as the pavement expanded and slid relative to the base.

     The mix design used for the subsequent reconstruction was a conventional mix design that did not rely on accelerators to obtain early strength and had shown acceptable performance at another Houston airport. The required strengths were 3,750 psi (compressive) at 3 days and 5,250 psi (compressive) at 28 days. The concrete developed an average range of 4,150 to 4,260 psi (compressive) at 3 days and 6,710 to 7,740 psi (compressive) at 28 days.

Although not used for the runway intersection reconstruction, Houston has since used its past experience to develop a "high performance" PCC to help avoid cracking and material-related deterioration problems. They have adopted a ternary blend concrete (50 percent Type I portland cement, 25 percent fly ash, and 25 percent slag).

3.8. Development of Plans and Specifications

Many steps can be taken in the development of plans and specifications to facilitate accelerated construction projects. Whether in-house or through subcontracting, the task of developing plans and specifications can be accelerated by ensuring sufficient design and review staff to complete the work within an accelerated schedule. Developing plans and specifications can also be accelerated by using standard designs, details, and specifications, as long as they are verified for project conditions.

3.8.1. Preliminary Design Studies

Preliminary design studies can help provide detailed plans and specifications that help reduce the potential for delays during construction. Memphis performed several studies to assist in design as well as planning:

- A roadway traffic study was conducted to determine possible delays on the anticipated haul road. This study resulted in a traffic signal being added to an intersection to help reduce the potential for delays during critical material delivery periods.

- An extensive “soft dig” program was performed to locate utilities. Providing detailed utility location information on the project plans resulted in contractors bidding the work without contingency fees and greatly reduced the risk of encountering the unknown during excavation work.

- A site investigation, which included review of falling weight deflectometer results and developing a geotechnical exploration program, was conducted to evaluate subgrade conditions. An initial subgrade investigation allowed plans to be in place to address poor subgrade areas ahead of time.

- A review was made of what other local construction projects would be on-going at the same time. This step was taken to ensure that there would be minimal competition for construction resources from other projects that could result in possible delays or material shortages.

Reviewing other similar projects can help assure stakeholders that the project can be accomplished. Once the entire team is convinced project success is achievable, stakeholders are more likely to apply their full resources to the project. For example, personnel involved with the Memphis project visited Atlanta to discuss Atlanta’s runway reconstruction. Similarly, Phoenix studied Atlanta's runway reconstruction and visited on-going repair work at Los Angles International Airport.

3.8.2. Project Specifications

The basis for most airport pavement construction specifications is the FAA guidelines contained in Advisory Circular (AC) 150/5370-10B, *Standards for Specifying Construction of Airports*. Many agencies modify the standards to meet local needs, including the use of locally available materials as well as changes for other project-specific conditions. In reviewing the case studies, possible changes in project specifications to consider to facilitate accelerated paving include the following:

- Require backup equipment be readily available to avoid delays. Almost all projects required additional equipment to be available in case of breakdowns. The Memphis contractor also increased maintenance of the equipment to further avoid potential delays with breakdowns.

- Provide for control of material delivery. Many projects required on-site batch plants and/or backup plants. Other projects had contractor control of the material plant. San Jose considered delays from local traffic conditions and required an on-site batch plant. The contractor for Cleveland chose to erect an on-site batch plant even though contract documents did not require it to control material delivery. In Seattle, the contractor owns the ready-mix plant used for batching the PCC and is located very near the airport.

- Provide detailed phasing and scheduling (discussed previously) to keep the project on track. Denver took steps to tie all construction trades (such as electrical and paving) to completion of the milestones to ensure that no one task held up any other.

- Allow flexibility of methods and materials for the contractor. Seattle provides requirements for quality, general methods, strengths, and schedule, but allows the contractor to determine the details.

- Require construction of a test section. Several projects required demonstration sections to allow a full run through of the construction methods and verification of the project materials. Charleston and Savannah used the construction of the temporary, pre-cast slabs to demonstrate the contractor's readiness to begin construction on the runways. Seattle requires successful completion of demonstrations on less-critical taxiway sections prior to performing work on the runway. Columbia required construction of a test, so the contractor would be familiar with using an atypical mix.

The report for the IPRF project on *Innovative Testing Standards for Acceptance Criteria for Concrete Pavements* provides information on alternate methods of determining strength.

- Evaluate strength measurement requirements. Most projects used additional cylinders and beams as the primary means of determining strength for early opening requirements. However, the contractor for Detroit supplemented this with a maturity meter to determine when paving operations could proceed using the new PCC. The Seattle contractor used temperature and time-of-set relationships to monitor placement.

3.8.3. Project Plans

Project plans can also incorporate features to assist meeting accelerated schedules.

- Provide multiple or alternative sections, if appropriate. Dulles provided two slab replacement cross sections: one design was provided for sections of the runway that contained a stabilized base layer (and was intact) and a different design was used for sections that did not have a stabilized base layer (or where the stabilized base was too deteriorated to salvage). Cincinnati ended up using a contractor-proposed alternate section for the time-critical runway tie-in areas, which reduced the number of pavement layers to be constructed and saved 2 to 3 days of closure per accelerated phase.

- Make allowances for final grades. Charleston and Savannah incorporated placing a sacrificial HMA overlay (a layer that would be removed prior to final construction) in the intersection prior to slab replacement to establish final surface grades and to correct pavement slope issues. The new PCC was then placed to the grades established by the HMA overlay. To account for roughness associated with placing individual slabs, grinding was required at the completion of the project.

- Consider modification of standard details. As discussed previously, the Charleston and Savannah designs removed the use of dowel bars, which reduced construction time and addressed bonding issues with the proprietary material. Houston revised their joint layout to facilitate paving 37.5-feet wide; the joint at 18.75 feet was sawcut, thereby reducing the paving time by reducing the number of required passes.

4. CONSTRUCTION CONSIDERATIONS

4.1. Introduction

The efforts expended in planning and design culminate in construction. However, many considerations can and should be made during the construction phase of a project. Although planning and design are often considered to be "final" by bid and start of construction, the project team should remain open to ideas to improve the project, including potential changes in design and phasing.

4.2. Contractor Communication

Communication should also remain a top priority during construction. Perhaps an offshoot of stakeholder coordination, contractor communication plays a significant role in keeping a project on track and on time once construction begins. Delays in clarifying design details, addressing unforeseen conditions, or resolving any number of construction-related issues can not only be costly in dollars, but also be costly by causing a completion deadline to be missed.

Understanding that issues will arise that require discussion and resolution is supported by the fact that in most of the case studies there were established procedures for addressing issue resolution. The timeframe for resolution varies from case study to case study, but there was a consistent commitment by the parties to resolve issues in a timely manner. Some projects established resolution times of 24 hours while others allowed more time (up to 7 days). The allowable time needs to be established based on the project schedule and the potential impact of delays. A committed effort by all parties is required to make this happen.

> Effective communication is essential during all phases of a project, but none more so than during the construction phase. Several ways to maintain good communication are:
>
> - Pre-construction meetings.
> - Regular construction progress meetings.
> - Have key people from all parties (owners, designers, contractors, and so on) on-site during construction.
> - Have an established procedure for resolving issues.
> - Share field offices (or have them in close proximity) to encourage interaction.

An important factor in resolving issues is to establish and maintain channels of communication, as many of the considerations for stakeholder coordination continue into the construction phase.

- Most of the projects included regular meetings during construction. Weekly team meetings keep the project team up to date on the project progress and issues that require action. Some projects included multiple weekly meetings. For example, Phoenix held one meeting to address primary construction issues and a second meeting to address navigation aids. Similarly, Denver had weekly construction meetings as well as weekly QC/QA meetings. This demonstrates that while maintaining communication is necessary on a number of topics, not everyone needs be involved in every meeting.

- Pre-construction meetings provide an opportunity for the project team to ensure that everyone is "on the same page." Planning and scheduling for construction can be reviewed and modified and contingency plans can be discussed. At Airborne, the contractor held pre-construction meetings to assure the owner that the proposed schedule could be maintained (he did this by providing a detailed (hour-by-hour) schedule of work). Contingency planning was also discussed and included input from field personnel. Topics included backup equipment requirements, increased maintenance to avoid equipment problems, and material supply issues (such as the possibility of requiring PCC delivery on Sundays).

- Having the key people with decision-making authority on site during construction allows faster resolution of issues. Examples of personnel commitments include:
    - Atlanta and Memphis had key personnel on site or available 24 hours a day and promoted issue resolution within 24 hours (sometimes it was immediate).
    - Houston's engineer of record was on site during all major construction (typically 15 to 18 hours a day) to quickly address and resolve all issues.
    - Seattle and Dulles had personnel on site during all closures to make immediate decisions during construction work.

> If high performance and execution is demanded of the contractor, the owner and the designer have to be willing to live up to those same standards.

Promoting communication can be just as important as establishing the appropriate channels. Memphis continued its team building in the field by housing owner, designer, and contractor staff in the same field offices to encourage interaction and communication. The philosophy was that if they were going to demand performance from the contractor, they had to be willing to live up to those demands as well. By placing the field trailers together, decision-makers were in close proximity to each other to help ensure rapid resolution of issues.

Denver also had the contractor and construction managers in the same field offices to promote communication. Additionally, the QC and QA laboratories shared on-site building space and testing equipment to minimize testing differences.

4.3. Value Engineering

Innovations or design modifications that save time and/or money can originate not only with the designer, but also with the owner or contractor. Contractors are an especially good source of design innovations or alternate methods to accelerate construction.

Simplify Construction

> Modifications or innovations should be validated by engineering to ensure conformance to project requirements and controlling regulations. FAA approval may also be necessary.

Fewer pavement layers require less construction time. FAA design generally requires the use of a stabilized base layer under PCC pavements expected to handle aircraft over 100,000 pounds. However, in order to minimize construction time, several projects decided to eliminate the stabilized layer. Airborne and Cincinnati were constructed by the same contractor and both provided additional PCC and aggregate base course thickness to eliminate constructing the stabilized base layer. For Cincinnati, this resulted in saving 2 to 3 days on each of the time-critical runway tie-in phases.

Improve on Past Successes

The Savannah slab replacement project made alterations to methods used on the Charleston project. Additional pre-cast, temporary panels (discussed in Section 3.6 Opening Requirements) were prepared to facilitate replacing more slabs during each closure. However, the slabs used in the Charleston project required a large crane which, once set up, did not have much mobility. On the Savannah project smaller slabs were constructed (Charleston used 12.38-foot square panels; Savannah used 8.25 x 12.33-foot panels), which allowed the use of smaller, more mobile equipment that could move and place these slabs much easier, as shown in figure 3-3.

Alternate Paving Techniques

Airborne paved transverse rows instead of performing individual slab replacements to maximize weekend closure productivity. To address the joint roughness of paving transversely, the contractor diamond ground the surface at the completion of the project.

To expedite construction of the 100-foot wide taxiways, the Denver contractor proposed paving the center of the taxiway in one pass. However, the pavement was designed to have a crown at the centerline and the owner was concerned that the crown could not be constructed in one pass. Paving in one pass required that the paving machine have a break in the center of the slab to install the crown. The contractor constructed a test section which was then verified by survey to confirm the proper elevation and alignment. After proving the technique successful, the contractor was allowed to continue the paving as proposed, saving the time of paving two separate lanes.

For the Phoenix runway reconstruction, the contractor asked for permission to use a dowel bar inserter (DBI) for transverse joints to expedite construction preparation, even though the project specifications did not originally allow the use of DBIs. The use of DBIs was eventually allowed, but only after the contractor completed a test section and verified by coring that they could achieve proper dowel bar alignment.

> Dowel bar alignment issues have been associated with the use of dowel bar inserters. Verification measures need to be incorporated into project specifications prior to allowing their use.

Joint Venture

Perhaps more of a planning consideration, at least on the part of the contractor, the Atlanta work was accomplished through a joint venture arrangement of several contractors. Two of the paving contractors actually had experience working together on a past accelerated project at Atlanta, which helped on the case study project. The contractor indicated that there was a very high level of cooperation; everyone had a vested interest in the project and took ownership of problems to get them solved.

4.4. Grade Preparation

> Proper construction practices, such as those summarized in the IPRF document *Best Practices for Airport Portland Cement Concrete Pavement Construction (Rigid Airport Pavement)*, are essential to long-term pavement performance.

Preparations for concrete placement are often the most time consuming and critical portion of a construction schedule. While it is critical on any project, rapid grade preparation becomes more critical the shorter the available closure to complete the work.

Pavement removal method. Two methods of removing existing pavement are generally used: saw-and-liftout and rubblization. Saw-and-lift-out generally causes less damage to both the adjacent pavement and underlying pavement layers. Pavement rubblization is generally faster than sawcutting the pavement into pieces, but may damage the underlying pavement layers or adjacent pavement.

Photograph provided by Mark Petruso

The size of the concrete pavement pieces influences the demolition process by dictating the equipment size (and force) required to break up the pavement or the capacity of lifting and hauling equipment. Sawing slabs into large pieces allows more pavement area to be removed with each piece, but also requires larger, possibly specialized equipment. Smaller pieces (generally associated with rubblization) are easier to handle and haul off with smaller, more conventional equipment, but can extend the time it takes to remove the same area of pavement.

> Conditions under which the saw-and-liftout method are best:
>
> - Underlying layer cannot be damaged.
> - Damage to adjacent pavement must be minimized.
>
> Conditions under which rubblization is the best method:
>
> - Speed is critical.
> - Large, specialized removal equipment is not available.
> - The underlying layer will not be salvaged.

The pavement removal method can be a balance of several issues:

- Speed (or productivity) of removal.
- Protection of adjacent pavement or underlying pavement layers.
- Size of remaining pavement pieces.
- Necessary equipment.

To illustrate different pavement removal methods, consider the following projects:

- On the Airborne project, the contractor felt that the saw-and-liftout method of pavement removal would be too slow and opted for pavement rubblization. They were not planning to salvage the stabilized base layer, and the removal consisted of an entire row of slabs at one time. To start removal, isolation cuts were made along each transverse edge to protect the adjacent pavement. The pavement was then rubblized with a guillotine breaker and removed with a backhoe. During placement of the new pavement, a 1-inch Styrofoam strip was placed between the new and existing pavement to help protect the new PCC during the next demolition phase.

- Although Houston re-used the existing stabilized base layer, pavement rubblization was used to remove the existing pavement. The contractor used two different methods to accomplish this. On Runway 4-22, which was a continuously reinforced concrete pavement, four hoe-rams (excavator with the bucket replaced with a hydraulic jack hammer) were placed shoulder to shoulder and "walked" together down the runway. This technique was used on that part of the project because of the amount of steel reinforcement. The end of the jack hammer had a painted line to mark the depth of the concrete pavement and prevent penetration into the underlying cement-stabilized base material base material. Along Runway 12R-30L, a guillotine breaker was used to break up the concrete pavement. This pavement was constructed over an asphalt bond breaker and only contained a nominal amount of reinforcing steel. As such, it was easier to break up and the guillotine breaker proved to be adequate.

- In Atlanta, the existing stabilized base layer needed to remain intact for use in the new pavement structure; thus, the saw-and-liftout method was employed. The existing slabs were sawcut into 7.5 by 12.5 foot pieces, and the pieces were removed with an excavator equipped with a "slab crab." Equipment generally worked from the existing PCC pavement to minimize damage to the base layer, loading the slab pieces onto flatbed trailers which then hauled them to a designated stockpile yard.

- The Charleston project did not include salvaging an existing stabilized base layer, but the slab removal did require minimizing damage to adjacent pavement. The saw-and-liftout method was used by cutting the existing 25-foot by 25-foot slabs into four 12.5-foot by 12.5-foot pieces. These large pieces required a 75-ton crane equipped with a spreader bar be used to load the pieces onto a flatbed trailer.

- Savannah employed a similar technique as Charleston, but cut the 25-foot by 25-foot slabs into smaller pieces (8 pieces instead of 4). By cutting smaller pieces, slab removal was accomplished using much smaller equipment (a forklift was used).

Photograph provided by Mark Petruso

Early sawcutting. Several projects allowed sawcutting of the pavement to be performed prior to the time-critical closure.

- In Seattle, sawcutting the pavement typically occurred the night before the anticipated pavement removal. Early sawcutting is limited to within 72 hours of the anticipated replacement work.

- Nighttime closures were allowed

during the last couple of weeks of the mobilization phase of the Atlanta runway reconstruction project to allow sawcutting to begin.

- Sawcutting at Dulles was started the night before the weekend closure. The sawcutting of slabs was allowed to be full-depth for slabs outside of the keel section and half the depth of the slab within the keel section. The sawcuts were filled with sand to prevent rocking of the slabs during the one day of runway operations after sawcutting.

<u>Other removal considerations</u>. Several projects included techniques that facilitated pavement removal, as follows:

- Consider alternate equipment. Savannah used a rock saw to make the initial sawcut for slab removal. Subsequent sawcuts were then made using conventional saws. Also, by sawing existing slabs into smaller pieces, smaller, more mobile equipment was used to remove the pavement.

- Consider sawcut location. Dulles installed 2-inch I-pins at a 45-degree angle to lift the slab pieces. However, there were problems removing some pieces due to existing cracks, with several slab pieces falling apart. It was recommended that the slab sawcut pattern consider the existence of cracks instead of using a standard grid layout.

- Consider innovation to overcome problems. Seattle attributes successful removal operations to two innovative items. First, the internal sawcuts are made at a slight angle from vertical (bottom of cut angled toward slab centerline) to help alleviate the suction that is typically encountered with removing the initial piece. Next, the contractor used specialized mining anchors which he notes were instrumental to the successful removal of the slab pieces.

4.5. Concrete Placement

While many factors play a role in the success of any PCC placement, two primary lessons come out of the case studies for accelerated PCC placement: having sufficient equipment, materials, and labor on hand and understanding the material being used.

The definition of "sufficient" varies depending on the project. Consider Atlanta and Seattle as two extremes. The Atlanta runway reconstruction ended up having 110,000 cubic yards of PCC placed and over 60,000 dowel bars drilled and epoxied within the 33-day reconstruction period. This was accomplished with four batch plants (three on-site batch plants and an existing off-site batch plant as a backup facility), five paving machines (three paving at any one time and two serving as backups), 45 side-dump trucks, seven gang drills, and hundreds of employees. At the other extreme, Seattle replaced 50 to 60 slabs in 50 days. However, they were replaced during overnight closures with rapid-set materials: if not enough material was on site for each slab (approximately 21 cubic yards) or there was not enough manpower to place the material quickly, a cold joint would form or early set would occur and require removal of the repair.

Understanding the material can also be considered from different viewpoints. Memphis purposefully used “standard” materials to allow common placement techniques and minimize surprises during construction. For the rapid-setting material used at Seattle, each year the contractor performed extensive testing prior to construction to evaluate the materials and was required to successfully complete test slabs each year in non-critical pavement areas prior to starting work on the runway. Although placement steps follow conventional practice, the allowable time frame for the activities is considerably shorter. As the contractor stated, “it looks like PCC but it isn’t.”

Some additional steps to help with successful PCC placement are as follows:

1. Control the material production.

   - Although some projects required on-site batch plants as part of the contract documents, on-site batch plants were also used for projects that did not require them. For example, the Cleveland contractor erected batch plants on site in order to meet the demand for PCC, even though it was not required in the contract documents.

   - Similar to controlling an on-site batch plant, the Seattle contractor owned the off-site ready-mix plant that supplied the rapid-set material. This allowed control of all aspects of the mix as well as the delivery rate.

2. Make material adjustments, if needed. Charleston made the decision to change the proprietary material after the first slab replacements. The material came in different set times and Charleston switched from a 20-minute set to a 90-minute set material. This allowed the crews more time to properly place, consolidate, and finish the material. Cleveland initially used a high-early strength mix for tie-in locations, but switched to their more standard mix after it proved to have adequate strength gain and the use of the high-early strength mix resulted in early-age cracking.

3. Provide multiple crews. Providing sufficient personnel and equipment to maintain the accelerated schedule is a necessity. As mentioned for Atlanta, several paving crews were working at any given time. Generally, two crews were paving the mainline runway pavement and one was paving the taxiway tie-ins. Detroit used multiple crews as well. They used a slip-form paving crew for the main paving and another crew for the handwork around the deicing collector drains.

4. Maintain equipment. Many projects required backup equipment as part of the contract documents. An additional step taken by the Memphis contractor was to perform more frequent maintenance to ensure the equipment did not break down during operation.

5. Provide sufficient curing. Proper curing is particularly important with rapid-set materials, as these materials are more prone to cracking from shrinkage.

    - Airborne considered various alternatives and decided on a resin-based curing compound. An additional step the contractor took to assist with proper curing was to use the Federal Highway Administration's (FHWA's) HIPERPAV. HIPERPAV (HIgh PERformance PAVing) is a software program developed by FHWA to provide guidance for the design and construction of PCC pavements and help the user identify and prevent performance problems.

    - Charleston used evaporation retardants to avoid loss of moisture. The proprietary material used was a high-early strength, rapid-setting material; thus, shrinkage cracking was a primary concern.

    - Seattle provides water curing (using sprinklers) for an initial time period (approximately 90 minutes). They have experimented with and without using a spray-on curing compound after the initial water curing and have not seen a noticeable difference for the material that is used for their repairs.

6. Obtain experience placing the material. While the projects studied primarily used conventional methods to place the materials, the properties of the materials dictate the time requirements for placing and finishing and the requirements for curing. Several projects require demonstration sections; others learned that demonstration sections should be included when they had not been. Building trial or demonstration sections allows the entire construction process to be tested rather than solely relying on experience from laboratory testing.

    - As stated previously, Seattle required that demonstration slabs be constructed in non-critical pavement areas before construction began on the runway. The contractor also performed extensive laboratory testing of the mix design to determine temperature and set time relationships to determine the material handling timeframe.

    - Charleston and Savannah used the temporary, pre-cast slabs as demonstration slabs. This helped the contractor obtain experience with the material prior to conducting work in the intersection of the runways.

    - If experience with the material is not easily obtained prior to using it under the time constraints of a closure, use a product that is easy to understand. Although the contractor did not have experience with the patching material used at Colorado Springs, after using the product they stated that the material was "error proof" and "easy" for their employees to use.

5. OTHER ISSUES TO CONSIDER

5.1. Introduction

Many additional issues can influence the success of an accelerated paving project. As time becomes more critical, what may be considered small details on "normal" projects can become major obstacles when the clock is ticking on a pavement closure. Issues which should be addressed in order to improve the probability of success of an accelerated paving project include the following:

- Safety and security considerations.
- Adverse weather.
- Incentive/disincentive.
- Ancillary issues (electrical, lighting, and so on).

5.2. Safety and Security Considerations

> All airport construction projects must adhere to FAA guidelines and regulations. However, in certain special cases and where adequate research has been done to evaluate potential hazards, the FAA may be willing to make exceptions. In all cases, such exceptions must be approved by the FAA in advance.

5.2.1. Security Considerations

Security considerations related to construction are those measures that are undertaken primarily to eliminate or reduce the potential for delay from the employee and vehicle checks required to enter a secure airside. Security is an issue in any airfield operations area (AOA), but steps can be taken to reduce the potential for checkpoint delays without compromising airport security. Some of the steps taken in the case studies include:

1. Minimize security requirements by removing the work from within the AOA.

   - To minimize the need for security checks and potential delays in hauling operations, the Atlanta project "moved" the project site outside the security perimeter by placing temporary fencing around the perimeter of the runway reconstruction site. The necessary gaps in the fencing at the cross taxiways were manned by operations personnel to provide both security and traffic coordination. The personnel were in vehicles and a system was worked out to signify whether the taxiway was being used for aircraft movement (and the haul road traffic had to stop) or if the construction traffic could cross the taxiway: if the vehicle was parked on the taxiway, construction traffic could cross; if the vehicle was parked off of the taxiway construction traffic had to stop.

2. Provide dedicated site access and pre-approved escorts.

   - For the Detroit deicing pad project, a single gate was used for construction access. All construction vehicles were inspected and escorted by Operations, but the contractor reimbursed the airport for the escorts as part of the contract. All foremen, supervisors, and inspectors were badged and provided oversight of the rest of their non-badged crew.

- A separate (new) gate was also used at Denver. All private vehicles were parked outside the security gate and workers were bused onto the site.

- Columbia established a construction staging area with a dedicated security gate. The contractor provided a security guard throughout construction.

3. Ensure that all employee badging and vehicle permitting is complete prior to construction.

- The contractor for Seattle had all employees badged and vehicles (particularly PCC delivery trucks) permitted to reduce delays getting through security locations.

5.2.2. Safety Considerations

While there are many aspects of construction safety on an airfield construction project, the safety considerations discussed in this report are primarily those that influence aircraft traffic and construction area interaction.

Runway Safety Area. Construction within the safety area of an active runway is an issue for many projects. Requiring the work to be performed during a short closure, revising the pavement section, using rapid-setting materials, and providing temporary, pre-cast panels are examples of measures that have been used by different case study airports, and these alternatives are discussed elsewhere in this report.

Memphis accommodated work within the runway safety area by obtaining FAA approval for construction work to occur within the specified 200-foot construction requirement. Approval was obtained to work within 180 feet of the primary runway while upgrading the adjacent taxiway to runway standards and within 190 feet of the temporary runway during primary runway reconstruction in rolling increments of 2,300 feet under Visual Flight Rules (VFR) weather. This restriction waiver allowed construction of the connecting taxiways without extensive closures of either the primary runway or the temporary runway. FAA's relaxation of the 200-foot construction requirement resulted in a direct, positive impact on airport capacity, and it is certain that without the FAA's cooperation the project could not have been completed within the 9-month schedule.

The cross-wind runway pavement at Savannah within the safety area (250 feet to each side of the centerline) of the primary runway was constructed using rapid setting material during overnight closures. However, for the pavement areas outside of the immediate intersection, the pavement was only required to have set, and full opening strength was not required. The material was determined to have sufficient strength to support an aircraft if there were a need, but it was expected that the pavement would be damaged and need to be replaced if an aircraft load did occur (which never occurred). This allowed a longer time during each closure for the contractor to increase production during the closure. Phoenix similarly specified a lower strength required for opening for the pavement within the overrun since it was intended to support an aircraft only in an emergency.

Denver did not allow construction within the runway safety area of the active runway, but the electrical vault work was close enough that equipment could potentially penetrate the FAA Part 77 surface. To make sure that equipment did not penetrate the surface during construction, survey stakes were established indicating the height to which equipment were limited.

Other Safety Issues. Other issues that can be project-specific should not be forgotten. For example, during construction San Jose imposed a work restriction due to jet blast concerns, which required the contractor to vacate the project area for one flight a day. For all other flights, jet blast was a concern, but was not problematic. No other special procedures were required. Conditions may exist on other projects that may seem to be a problem, but with proper consideration can be addressed.

5.3. Adverse Weather

Adverse weather conditions during construction are inevitable. Planning for these conditions in advance is the best way to mitigate their effect.

Although poor weather cannot be predicted or entirely avoided, steps can be taken to minimize the probability of delays due to weather. Most of these considerations have previously been discussed in Sections 2 and 3 (Planning Considerations and Design Considerations, respectively) of this *Guide*, and are summarized below:

- Minimize the risk of inclement weather by scheduling the project during a time of year with historically better weather.

- Since poor weather cannot be controlled, make allowances for weather days in the project schedule.

- To minimize the effects of poor weather, provide a stable platform during construction by using a stabilized subgrade or stabilized base. This consideration is more suitable for longer closure times, where having the grade open to weather for extended periods of time increases the risk of weather delays; short closure periods may not provide sufficient time to include these items.

- Provide appropriate specifications if construction is expected to occur during periods of inclement weather.

As with most construction projects, there should be a time to allow for a "go" or "no-go" decision prior to beginning work that could have disastrous results if poor weather occurred. For example, Charleston cancelled several nights of construction work due to poor weather rather than risk rain while slabs were being removed and replaced. Although they did not have poor weather on any nights that construction did occur, they had materials available to cover the slab areas if needed. In this case, they had a tent structure available, but there were doubts that it would have worked during a thunderstorm.

5.4. Incentive/Disincentive

The FAA does not provide funding for incentives, and the costs for providing incentives become the responsibility of the owner. However, for every case study in which incentives were used, the owner felt it was money well spent to complete the project ahead of schedule.

Many of the case studies incorporated incentive and disincentive clauses in the contract documents. Although the FAA does not participate in funding incentives, airport owners have found it beneficial to include these clauses as additional insurance that the project will meet the anticipated schedule. On the Memphis runway reconstruction, for example, the use of a bonus was identified by the owner as one of the biggest contributors to the project's success. A $1.5 million bonus was offered if the runway was ready for a flight check on the specified date (October 1), and another $1 million was offered if the runway and associated taxiways were opened in fully operational condition a month later. There were no provisions for extensions, including weather, labor disputes, civil unrest, and so on.

On the other hand, liquidated damages, as outlined in Table 5-1, would be assessed if the contractor failed to perform services within the times specified in the contract. If multiple milestones were missed, liquidated damages would be imposed concurrently. The contractor earned both bonuses, and as noted above the bonuses were completely funded by the owner.

Table 5-1. Summary of liquidated damage penalties for Memphis.

Milestone	Completion Date	Liquidated Damages
Runway 17-35 switchover	January 31, 2002	$25,000 per day or any portion thereof
Runway 17-35 closures	As required	$1,000 per hour or any portion thereof
Preparation for Runway 18R-36L flight check	October 1, 2002	$100,000 per day or any portion thereof
Runway 18R-36L and associated taxiways operational	October 31, 2002	$100,000 per day or any portion thereof
Project completion	December 31, 2002	$2,000 per day or any portion thereof

Note: no liquidated damages were applied for the project.

On the Phoenix project, the prime contractor was exposed to both liquidated damages and bonuses. Phoenix included provisions for a bonus of $200,000 per day for early completion (capped at $4 million) and liquidated damages consisted of $50,000 per day for late completion.

Cincinnati also provided incentives and disincentives and adjusted them by the critical nature of the phase: the two runway tie-in phases that impacted operations had a $10,000 per day bonus or penalty associated with them, while there were penalties of $1,000 and $2,500 per day associated with the last two phases, with no offsetting bonus.

A project does not necessarily need a traditional incentive clause to reward a timely, quality project; for example:

- The Airborne project did not specifically have an incentive clause, but the owner agreed to pay the premium overtime for the weekend closures to ensure the project was completed on time.

- The runway patching project at Colorado did not have an incentive clause, but the owner was so pleased with how the project went that retention—which was normally held for 1 year—was released after 60 days.

Although incentives were not included in all of the projects, disincentives were widely used. Liquidated damages in the Atlanta project were tied to specific project milestones, as shown in Table 5-2. It was made clear to the contractor that these damages would be assessed if the contractor failed to perform services within the times specified in the contract, but the project was finished 2 days early and no penalties were assessed.

Table 5-2. Summary of liquidated damage penalties for Atlanta.

Milestone	Liquidated Damages
Completion of stockpiling materials and mobilization requirements	$75,000 per day for first 10 days; consideration of Termination for Default after 10 days
Open temporary Runway 9S-27S (completion of Phase I, Stage II)	$200 per minute
Completion of Phase I, Stage II Taxiways R7 and N6 cross-over	$25,000 per day
Completion of Phase II, Stage II Taxiways R3 and N2 cross-over	$25,000 per day
Completion of Phase II, Stage II Taxiways R11and N10 cross-over	$25,000 per day
Completion of work within 200-ft of Runway 9R-27L and reopen to traffic (all Phase II work)	$175,000 per day
Completion of all work under Phase III	$10,000 per day

Seattle had liquidated damages tied to both the morning opening requirement and the overall project duration. If the runway was not reopened at the required time each morning, liquidated damages of $10,000 per hour or any portion thereof would be assessed; a penalty of $3,000 per day was established for not completing the work within the 50-day schedule. Additional payment penalties were tied to the opening and 28-day PCC strengths.

5.5. Ancillary Issues (Electrical/Lighting/Other Issues)

Ancillary issues can have a significant impact on the timeliness and success of the project. These issues include items such as electrical, lighting, and navigational aids, but can also include such aspects as pavement markings and other utilities.

5.5.1. Electrical/Lighting/Navigational Aids

Ensure adequate supplies. Ensuring adequate supplies is primarily a planning consideration. Memphis and Atlanta provided extended mobilization phases to stockpile required materials, with Atlanta further assisting by providing the light cans for construction.

Adjust installation procedures to suit project requirements. Alterations to conventional installation procedures are often necessitated by the project, such as in the following examples:

- Airborne utilized flexible couplings to accommodate transverse paving lanes. Electrical conduit was run along the centerline of the runway to the edges of the "strip" that was being paved. During construction of the next row of slabs, a flexible coupling was used to connect to the previous section of conduit. Using a flexible coupling provided some latitude with conduit placement.

- Seattle allowed two (non-consecutive) runway lights and one light per taxiway to be temporarily removed during slab replacements. For slabs that contained lights, if time did not allow for the new light to be installed and PCC placed the night the old pavement was removed, a temporary wiring connection had to be made at the light location to keep the remaining lighting operational. The temporary pre-cast panels would then be used and the light installation and slab placement would be completed the following night. Installation of the new lights generally followed two steps: light can bases were set in rapid-set PCC during the first part of the night and then the PCC placement completed later in the closure after the electrical connections were made.

- Charleston anchored light cans with reinforcing bar "hoops" to the subgrade to ensure proper location was maintained during slab replacement.

Consider the scheduling of ancillary work. In establishing the project phasing and scheduling, whether the ancillary items are required to be part of the accelerated phase or when they should occur within the accelerated phase should be considered. As previously mentioned, Houston paved the areas containing lighting first to help ensure that all the electrical work would be completed within the short closure for the intersection. Performing this work during a later closure would have been problematic. However, Cincinnati allowed lighting to be completed after reopening of the accelerated tie-in areas. This lighting was primarily for the taxiway and doing the work after completion of the tie-in did not significantly impact the runway.

Adjust operational procedures. Although not always easily accommodated, allowing alternate operations can sometimes facilitate construction. Relocation of the navigational aids at San Jose included the runway localizers to allow proper clearance from the runway thresholds. FAA representatives expressed concerns about the localizer electronic signal, since construction activities took place in the electronic path. With close coordination with the FAA, it was agreed that the airport could operate without the localizers when it was necessary to perform construction in front of them. The contract required the contractor to move the equipment quickly if visibility deteriorated, and a method of payment for this rapid response was established.

Plan for the unexpected. Dulles required an electrician to be on-site at all times in case there were any electrical outages, thus ensuring that they were prepared should anything unexpected happen.

5.5.2. Other Issues

Other utility work. Memphis provided pre-treated backfill material (code "L" treated subgrade) to allow immediate backfilling during utility work without worrying about moisture content. This helped ensure that the additional utility work during reconstruction did not delay paving operations.

Pavement markings. In Cincinnati, the airport used sand to cover the permanent markings on a temporarily closed pavement to save time and to avoid the rough surface from marking removal. They also used sand bags to temporarily cover lights that could not be turned off separately.

6. CONCLUSION

This volume presents the overall "lessons learned" from 16 accelerated or "fast-track" airfield PCC paving projects. These lessons learned are extracted from interviews, reports, and other data collection efforts that are summarized in the case studies presented in Volume II. The case studies span a range of applications, including runways, taxiways, and aprons, and with closure times ranging from overnight to over 2 years.

Given the varied experiences, project types, and closure times represented in the case studies, an engineer, designer, owner, or contractor who is considering an accelerated project may use this report to learn about the experiences of others, and find information that will be helpful in their own project. Along those lines, in addition to the lessons learned, a decision tool is presented that can be used to identify applicable case studies and lessons learned for a range of facility types and available closure times.