Framework for Prefabricated Bridge Elements and Systems (PBES) Decision-Making

Executive Summary

Prefabricated bridges offer significant advantages over onsite cast-in-place construction. Among these advantages are a substantial reduction in onsite time required to construct or rehabilitate a bridge, lowest costs resulting from offsite manufacturing and standardized components, and improved safety due to reduced exposure time in the work zone. The controlled environment of offsite fabrication also ensures quality components for good long-term performance.

Careful planning, design, and implementation are required to realize the significant advantages of prefabricated bridge construction. Decision makers must consider if the job should be fast tracked, the applicability of the design, the abilities of contractors and suppliers in the target market, access to the project site, and how the construction requirements affect cost and schedule. Other important factors for success of an accelerated bridge project include the owner's and contractor's commitment to see the job through; willingness to share responsibility, control, and risk; and understanding that time is money for all players. Owners should be able to expect inexpensive, durable, and fast construction, allowing them to get more projects within available budgets, whereas contractors should be able to make a reasonable profit and have more bidding opportunities.

This report presents a framework for the objective consideration of the above-mentioned issues. As such, the framework is a decision-making tool to help answer the ultimate question of whether a prefabricated bridge is achievable and effective for a specific bridge location. The anticipated users of this framework are the representatives of the owner agency and the contractor: the decision makers for the bridge type and the implementers, including designers and project managers.

The framework can be used at various levels of detail to assist decisions. The second section of this report is a flowchart to guide a high-level assessment of whether a prefabricated bridge is an economical and effective choice for the specific bridge under consideration. The matrix in the third section provides the users with a different format and more detail than the flowchart. The fourth section consists of considerations in various categories corresponding to those in the flowchart and matrix, with discussion and references for use in making a more in-depth evaluation on the use of prefabrication. The flowchart, matrix, and considerations section may be used independently or in combination, depending on the user's desired depth of evaluation.

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I. Introduction

Prefabricated bridges offer significant advantages over onsite cast-in-place construction in several key areas. The substantial reduction in onsite time required to construct or rehabilitate a prefabricated bridge is an advantage that is critical in many cases. Offsite manufacturing minimizes the impact on bridge or roadway closure time. Reduction in onsite construction time leads to lower costs for contract administration, traffic control, environmental impact mitigation, and costs incurred by the public due to traffic congestion or detours, a concern that is continually taking on greater significance. Offsite manufacturing may have the lowest cost that can be achieved, e.g., if standardized components are used or if a large number of similar components are required in the project. A further benefit from decreased onsite construction time is the lower potential for traffic and construction accidents. Another advantage is that offsite fabrication allows greater quality control in the manufacturing of the bridge components, providing quality components for good long-term performance.

The significant advantages of prefabricated bridge construction do not come without challenges or concerns. Some of these are the lack of knowledge and experience in prefabricated bridge systems design and detailing, including connections between components; durability of the connection details; ability of the prefabricated system to accommodate curvilinear geometry; details to develop negative moment continuity; availability of prefabricators capable of producing the components; limitations on component size; availability of equipment to erect the components; and knowledge/experience of local bridge contractors with techniques needed to construct bridges built of prefabricated components.

A successful project is dependent on properly deciding whether a job should be fast track, the applicability of the design, evaluating the target market for abilities of contractors and suppliers, access to the project, and recognizing how the construction requirements affect cost and schedule. The success of an accelerated bridge project is also dependent on the owner's and contractor's attitude, the effectiveness of partnering, the commitment the players have to see the job through (including overtime from those who can make decisions), shared responsibility, and understanding that time is money for both the owner and the contractor.

Consideration of the above is particularly important as the contractors evaluate risk and safety in a market that is evolving with insurances and bonding. The give-and-take decision process can only move forward in a cost-effective manner after the owners have a clear grasp of what they need on a particular project. If difficult jobs with unrealistic schedules are advertised, there will only be one or two bidders because of the risks caused by the specifications and schedule, resulting in significantly higher costs to the owner. The owners must understand how they control cost, especially upfront. They must understand what affects the bids and what they can do to control them. Jobs that are poorly thought out and that shift all risks for the schedule and cost to the contractor will only drive up the initial bids, reduce the number of competent bidders, and slim down the chances of the project meeting the owner's expectations. The owners and the contractors need to better understand the control and direction that they can each provide to ensure a successful accelerated bridge project. With tight budgets and much work that needs to be done, owners should be able to expect inexpensive, durable, and fast construction, allowing them to get more projects done at a reasonable cost and allowing the contractors to make a reasonable profit and have more bidding opportunities.

In the United States and in other countries the bridge engineering community has successfully met these challenges and effectively implemented the use of prefabricated systems in bridge construction on numerous projects. The advantages offered by prefabricated bridge construction in quality, cost, and timeliness should always be considered when making the decision on the type of bridge construction or rehabilitation to be performed at a specific site.

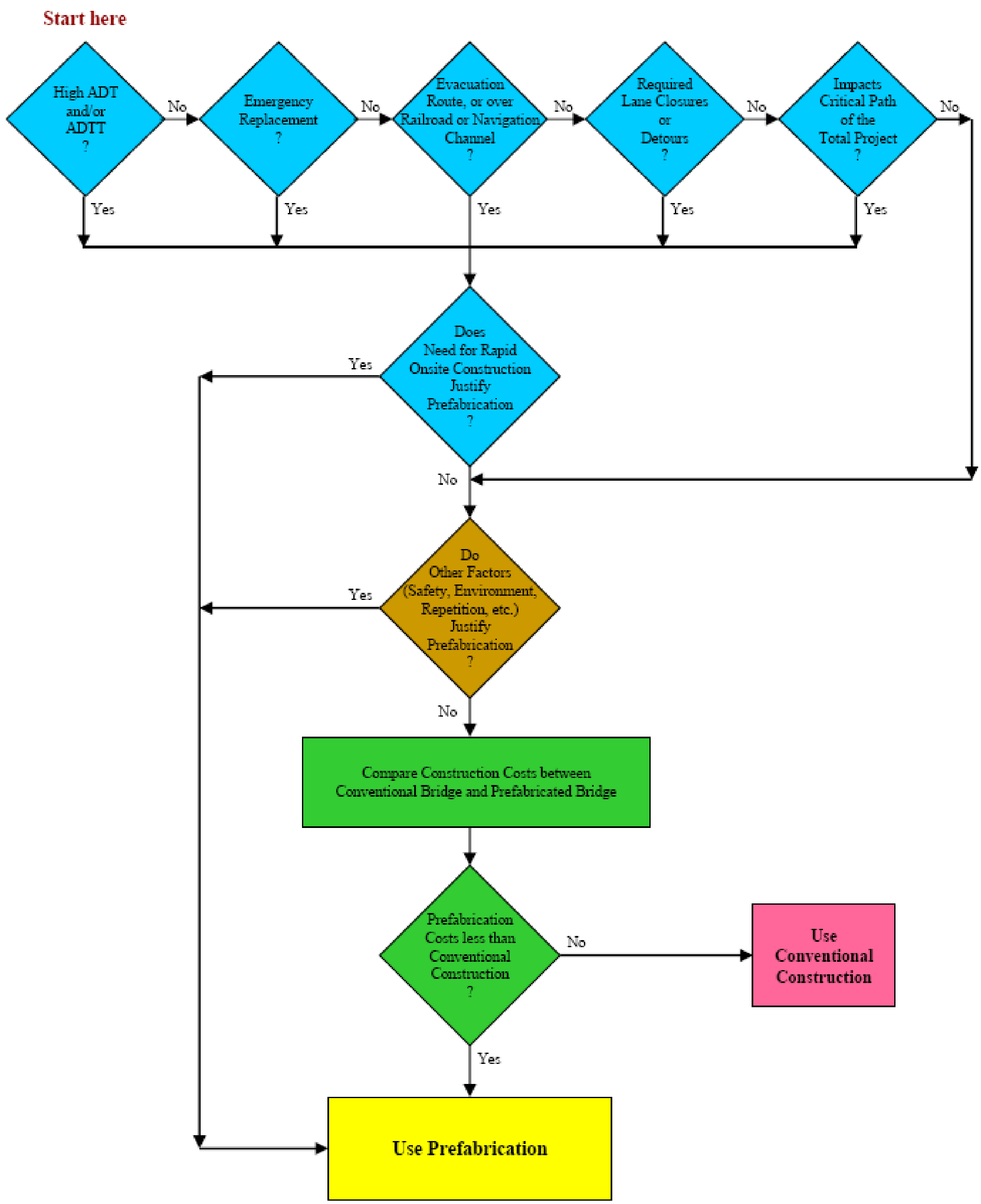
The framework presented in this report is a decision-making tool for the objective consideration of prefabrication to achieve accelerated bridge construction. It is intended to address the above-mentioned issues to help answer the ultimate question of whether a prefabricated bridge is achievable and effective for a specific bridge location. In other words, while prefabricated bridges are inherently **better**, **faster**, and **safer**, will prefabrication have **lower costs** and be **long lasting** relative to conventional construction for this particular application?

The anticipated **users of this framework** are the representatives of the owner agency and the contractor:

- The **decision makers for the bridge type**; and
- The **implementers**, including designers and project managers.

The first section of the framework, this introduction, describes the purpose, the intended users, and the format of the tool. The second section is a flowchart to assist the users in making a high-level decision on whether a prefabricated bridge might be an economical and effective choice for the specific bridge under consideration. The matrix in the third section provides the users with a different format and more detail than the flowchart to also assist in making a high-level decision; it may be used in conjunction with or as an alternative to the flowchart. The fourth section consists of considerations in various categories, with discussion and references for use in making a more in-depth evaluation on the use of prefabrication. The flowchart, matrix, and considerations section may be used independently or in combination, depending on the user’s desired depth of evaluation.

II. Flowchart for High-Level Decision on Whether a Prefabricated Bridge Should Be Used in This Project



III. Matrix Questions for High-Level Decision on Whether a Prefabricated Bridge Should Be Used in This Project

Question	Yes	Maybe	No
Does the bridge have high average daily traffic (ADT) or average daily truck traffic (ADTT), or is it over an existing high-traffic-volume highway?			
Is this project an emergency bridge replacement?			
Is the bridge on an emergency evacuation route or over a railroad or navigable waterway?			
Will the bridge construction impact traffic in terms of requiring lane closures or detours?			
Will the bridge construction impact the critical path of the total project?			
Can the bridge be closed during off-peak traffic periods, e.g., nights and weekends?			
Is rapid recovery from natural/manmade hazards or rapid completion of future planned repair/replacement needed for this bridge?			
Is the bridge location subject to construction time restrictions due to adverse economic impact?			
Does the local weather limit the time of year when cast-in-place construction is practical?			
Do worker safety concerns at the site limit conventional methods, e.g., adjacent power lines or over water?			
Is the site in an environmentally sensitive area requiring minimum disruption (e.g., wetlands, air quality, and noise)?			
Are there natural or endangered species at the bridge site that necessitate short construction time windows or suspension of work for a significant time period, e.g., fish passage or peregrine falcon nesting?			
If the bridge is on or eligible for the National Register of Historic Places, is prefabrication feasible for replacement/rehabilitation per the Memorandum of Agreement?			
Can this bridge be designed with multiple similar spans?			
Does the location of the bridge site create problems for delivery of ready-mix concrete?			
Will the traffic control plan change significantly through the course of the project due to development, local expansion, or other projects in the area?			
Are delay-related user costs a concern to the agency?			
Can innovative contracting strategies to achieve accelerated construction be included in the contract documents?			
Can the owner agency provide the necessary staffing to effectively administer the project?			
Can the bridge be grouped with other bridges for economy of scale?			
Will the design be used on a broader scale in a geographic area?			
Totals:			

Note: One or two of the above factors may warrant the use of prefabrication to achieve rapid and limited-impact onsite construction. Alternatively, the user may wish to assign weights to the above questions based on the unique circumstances of the project in order to determine whether prefabrication should be used. In any case, prefabrication offers advantages for projects with a majority of “Yes” responses; a more detailed evaluation using the considerations in the next section would then be appropriate.

IV. Considerations in Selecting a Prefabricated Bridge as the Construction Method of Choice

A. Rapid Onsite Construction

1. Does the bridge have high average daily traffic (ADT) and/or high average daily truck traffic (ADTT), or is it over an existing high-traffic-volume highway?

   The higher the daily traffic and particularly the daily truck traffic, the greater the safety concerns for the travelers and construction crews in the work zones. Also, traffic control costs and user delay costs can be much higher if traffic volumes are high. These safety concerns and costs can be significantly reduced by the use of prefabrication to reduce onsite construction time.

2. Is this project an emergency bridge replacement?

   Bridge replacements are either planned due to structural deficiency or functional obsolescence of an existing bridge, or emergencies due to catastrophic damage to an existing bridge. Emergency bridge replacements particularly benefit from the use of prefabricated systems because the existing bridge cannot be used and must be replaced in the least time possible in order to minimize traffic disruption.

3. Is the bridge an evacuation route, or over a railroad or navigable waterway?

   Repair or replacement of bridges on evacuation routes must be completed quickly to insure the routes are available in the event of an incident that requires the use of the route for evacuation. Railroads have downtime windows of only hours to avoid impact to railroad commerce. Similarly, a bridge that is over a navigation channel must be replaced quickly to avoid impact to port commerce. Prefabricated bridges have a particular advantage over conventional bridges for these cases because they greatly expedite on-site installation.

4. Will the bridge construction impact traffic in terms of requiring lane closures or detours?

   In many cases it may not be possible to close a bridge during construction due to the need to maintain traffic flows, such as on an evacuation route or a high-traffic-volume road that does not have a detour within a reasonable distance. In such cases, the advantages of rapid installation with prefabricated bridges can make prefabrication the solution relative to conventional construction because the quicker installation reduces lane closure time.

   Keeping all lanes open during peak traffic periods reduces traffic disruption and improves safety. Partial lane closures during off-peak traffic periods are less disruptive to traffic and improve safety for construction crews as well as travelers relative to peak-hour partial lane closures. Maintaining traffic flow will require prefabrication details that can be installed using partial lane closures, such as used for the I-95 James River Bridge deck replacement project.

5. Will the bridge construction impact the critical path for the total project?

   In order for the accelerated on-site installation of prefabricated bridges to reduce traffic control and user delay costs for a cost-effective solution, approach slabs and other roadway work along the project corridor must be completed concurrently to allow the facility to be more rapidly opened to traffic. Agencies should consider accelerated construction techniques for the entire construction corridor. As time is of the essence, accelerating the entire process will lessen overall costs.

6. Can the bridge be closed during off-peak traffic periods such as nights and weekends?

   Replacement or rehabilitation of a bridge is typically much more efficient and economical if the bridge can be closed for the entire construction period; closure eliminates the need for staged construction and maintenance of traffic through the work zone. Bridge closure improves safety for construction crews as well as travelers and allows more efficient contractor operations. The shortened onsite construction time (in hours or weekends) possible with prefabricated bridges can make closure during the entire construction time a possibility. The shortened time also reduces detour traffic control costs and user delay costs that occur due to increased vehicle miles traveled through the detour and increased vehicle hours of delay caused by queues that form along over-capacity detour routes.

   If closure for the entire construction period is not an option, efficiencies can typically be obtained by maximizing total bridge closure during off-peak traffic periods such as nights and weekends, e.g., this facilitates the installation of full-width deck panels which are typically quicker and simpler to build and install than partial-width deck panels. An example is the recent full-width full-depth deck panel installations for the Lewis and Clark Bridge across the Columbia River between Washington State and Oregon, which was done during night closures and several weekend closures. The Woodrow Wilson Bridge deck replacement several years ago is another example of the efficiencies that can be obtained with prefabrication. As demonstrated by these bridge deck replacement projects, prefabricated bridge components are particularly well suited to take advantage of the efficiencies offered by short-term closures.

   The total construction period will be shortened by allowing as many continuous hours of off-peak bridge closure time as possible, standardizing these times so that the contractor can optimize crew work schedules and operations, and using prefabricated bridge components for construction efficiency. Significant savings can be achieved in maintenance of traffic costs, user delay costs, and contractor operations costs.

7. Is rapid recovery from natural/manmade hazards or rapid completion of future planned repair/replacement needed for this bridge?

   Prefabrication allows faster partial or total repair or replacement of bridges. This repair or replacement can be further accelerated with standardization and stockpiling of components. Such considerations should be given to bridges that require rapid recovery from natural or manmade hazards or that require rapid completion of future planned repairs or replacement. Examples include bridges susceptible to damage from hurricanes and barge allisions.

8. Is the bridge location subject to construction time restrictions due to adverse economic impact?

   The need to limit the adverse impact of the construction project on local businesses and commerce may dictate the use of prefabricated bridges for rapid onsite installation.

9. Does the local weather limit the time of year when cast-in-place construction is practical?

   Winter weather in many parts of the country limits the use of on-site cast-in-place construction because of the difficulty in achieving adequate temperatures for placing and curing concrete. Enclosing and artificially heating large areas can be problematic. The result is that it is not possible to perform cast-in-place construction work during certain portions of the year, with the result that a greater portion of activity must take place in the remaining acceptable months. This tends to not only delay completion of work but encourage higher prices as contractors are less inclined to offer lower prices during those periods when demand for their work exceeds their ability to supply labor. The above limitations are significantly lessened with the use of prefabricated components since they require very limited on-site cast-in-place concrete, e.g., for the closure joints.

B. Other Factors

1. Safety Concerns

   Do worker safety concerns at the site limit conventional methods, e.g., working adjacent to power lines or over water?

   In general, construction crew safety in the work zone is increased with reduced exposure time during the construction period. Reduced exposure time is even more important when the construction crew is exposed to unsafe working conditions at the site such as adjacent power lines or working over water. These unsafe working conditions at the site may necessitate the use of prefabricated systems to limit the amount of time the construction crews are exposed to these hazards.

2. Environmental Issues

   2.1 Is the site in an environmentally sensitive area requiring minimum disruption?

   Environmentally sensitive areas, such as wetlands or urban areas where air and water quality and noise pollution are issues, limit the amount of construction work that can be done on site, or how much time can be allotted in a season. Offsite prefabrication and rapid onsite installation can be done with limited impact to the site.

If the agency will be paying environmental mitigation costs or is under court order during the time it takes to construct the bridge, a prefabricated bridge that can be installed in much less time could substantially lower or even eliminate these costs.

2.2 Are there natural or endangered species at the bridge site that necessitate short construction time windows or suspension of work for a significant time period, e.g., fish passage or peregrine falcon nesting?

Prefabrication for rapid onsite installation provides the contractor more flexibility when environmental restrictions require short construction windows or prevent work during significant time periods. Prefabrication may also lessen the risk to the owner that obligations placed by outside agencies will not be met.

2.3 If the bridge is on or eligible for the National Register of Historic Places, is prefabrication feasible for replacement/rehabilitation per the Memorandum of Agreement?

For bridges that are on or eligible for the National Register of Historic Places, communications with the State Historic Preservation Officer should take place during the preliminary planning stage to ensure that prefabrication of components for rehabilitation is consistent with historic bridge requirements. Also, the owner will need to determine if appropriate pieces of the existing bridge can be incorporated into the new bridge. This could be monuments, parapets, stone work cladding, plaques or other significant features that could be easily added on after the new bridge is in place and the salvaged pieces removed from the old bridge.

3. Standardization

3.1 Can this bridge be designed with multiple similar spans?

Prefabricated systems are the most cost-effective solution for multiple-span bridges with similar cross sections, cross slope, and direction. Consideration should be given to standardizing the components to shorten onsite construction time, reuse formwork, and increase cost savings.

3.2 Can available state or national prefabricated bridge standards be used on this project?

Using standardized prefabricated components, e.g., a State’s precast slab span standards or precast bent cap system, at multiple locations in a bridge project can result in more economical construction since contractors are able to make more competitive bid estimates for standardized items that they have used in the past due to lower risk. Suitability and availability of existing state and national prefabricated bridge standards should be evaluated in the preliminary planning stage.

3.3 Can the bridge be constructed with regional off-the-shelf components for economy using stockpiled standards, i.e., superstructure and substructure elements and systems developed to meet regional requirements (e.g., seismic vs. non-seismic) and stockpiled at regional locations?

Further savings may be achieved through mass production and stockpiling standardized prefabricated components in regional locations. Such readily available components could substantially lower the cost of prefabricated bridges relative to the costs of conventional bridges.

Stockpiling standardized components has additional benefits in recovering from natural and manmade hazards. For example, bridges susceptible to damage due to hurricanes and barge allisions would benefit from having spare common components available immediately following an event. Ease of recovery due to availability is a significant advantage of standardized components. Owners could consider stockpiling and pre-positioning of materials.

Widespread stockpiling of prefabricated components has not been done to date except for temporary bridge truss members. Implementation of a stockpile of components for permanent bridges as standard practice will require consideration of the most appropriate entity to own and manage the stockpile, and determination of which components would have sufficient volume and steady consumption to make stockpiling economically feasible.

3.4 If aesthetic or context-sensitive design requirements are defined in the contract documents, are there solutions that allow the use of standardized prefabrication for economy of scale?

Standardized prefabrication of bridge components for economy of scale may require consideration of fascia beams, cladding, or other details to match the local environment. Understanding the restrictions in the contract documents and discussions with the prefabricators early in the process will facilitate cost-effective solutions.

4. Site Issues

4.1 Does the location of the bridge site create problems for delivery of ready-mix concrete?

Conventional cast-in-place construction typically requires the on-site placement of concrete from a ready-mix concrete batching plant. Long haul distances from the batching plant to the bridge site can make it difficult or impossible to meet concrete discharge time limits. Continuous concrete placements can be compromised if a load is rejected since a second load to take its place may not be immediately available. These concerns must be addressed by the contractor in his bid, with the likely effect of increasing the bid price.

The above concerns are significantly lessened with the use of prefabricated components since they require very limited on-site cast-in-place concrete, e.g., for the closure joints.

4.2 Are there contractors available in the area with sufficient skill, experience, and construction capacity to perform prefabricated bridge construction?

Construction of prefabricated bridges is not inherently more difficult than conventional construction but does require some different skills and areas of experience from key people on the contractor's team such as the construction superintendent. As with any type of work, contractors with the proper training, equipment, and experience can provide the best guarantee of a successful outcome.

In addition, if there is insufficient construction capacity in the area, the owner will need to adequately advertise the project to a wider market to develop interest and get a sufficient pool of qualified bids.

4.3 Are fabricators available to economically manufacture and deliver the required prefabricated components?

The size of the project may have an impact on the economic feasibility of obtaining the specific prefabricated components that are required. For large projects, the cost benefits to be gained from prefabrication may offset cost expenditures for the prefabricator's setup to construct a specific component or expenditures for transportation of the components over long distances. For smaller projects, the cost of fabricating non-standard elements or incurring high transportation costs may not be justified.

4.4 Could options for this project include fabrication of components by the contractor adjacent to the site, in addition to off-site plant fabrication?

Including in the contract documents available right-of-way adjacent to the bridge site will facilitate rapid onsite construction at competitive costs by giving the contractor the choice of either having the prefabricated components built by a fabrication plant subcontractor and transported to the site or setting up a casting facility near the bridge site and fabricating the components using the contractor's workforce.

The available right-of-way adjacent to the bridge site may also be used to store prefabricated components for ready access when needed. For larger prefabricated components such as superstructures, available right-of-way adjacent to the bridge site is needed for preassembly.

4.5 Can prefabricated components be transported to the site over existing roads, railways, or waterways?

Available transportation routes to bring prefabricated components to the bridge site should be considered in preliminary planning since hauling constraints and feasibility will impact bid costs. Longer and heavier prefabricated components can require that conventional transportation and erection practices be modified. For transportation over highways, the hauling systems must have axle numbers and spacing such that the loads are within permit limits, and the transporter must find a route that has adequate turning radii to get longer components to the bridge site. While consideration must be given to these constraints, even cross-country transportation may prove to be the best solution, as done for the 160-ft precast concrete I-section girders for the Disneyworld monorail that were fabricated in Washington State and transported to Florida (the girders were cast in forms that adjusted to produce either straight or curved sections; specifications included simultaneous banks, curves, and elevation changes). Another example is the Third Avenue Bridge in New York City; its completed steel bridge superstructure was fabricated in Alabama and shipped by barges and installed in its final location without requiring any re-handling on land.

Preliminary planning should include a site survey for impacted intersections, allowable haul times, permit regulations, utility relocations, second party easements (municipal, railroad, airport), and ease of movement throughout congested areas including job site detours.

4.6 Is the bridge site accessible for handling of prefabricated components and use of heavy lifting equipment?

In addition to access to the bridge site, access at the bridge site must be adequate to allow longer and heavier prefabricated systems to be moved into position, and equipment must have adequate capacity to erect the heavier components. The planning stage should include these considerations for optimization of prefabricated systems for rapid onsite installation, as done in downtown Chicago with self-propelled modular transporters used to move a bridge span into final position after it was constructed adjacent to its final position.

4.7 Are prefabricated foundations and substructures a possibility for this location?

In many cases, foundation and substructure construction is the most costly and time-consuming part of constructing a bridge. To get maximum advantage from the on-site construction speed possible with prefabricated bridge installations, consideration should be given to using prefabricated components for foundations and substructures. Shallow foundations such as spread footings should be used when feasible, especially on land structures. Driven steel or precast concrete piles also provide rapid onsite installation of bridge foundations.

Soil conditions should be evaluated during preliminary planning to determine the optimum solution for foundation construction. Special construction sequencing may be required, e.g., if soil conditions require drilled shaft foundations.

Consideration should be given to constructing new foundations and substructures away from the existing substructure units to the extent that this is feasible, e.g., constructing straddle bents with foundations on either side of the existing alignment while traffic flow is maintained on the existing bridge prior to replacement.

4.8 Does the height of substructures make use of formwork to construct them inconvenient or impractical?

Prefabricated substructures offer an opportunity for rapid construction while eliminating the need for staged forming. If the structure will require multiple pour lifts, is uniform in section, or has other constraints, precast columns should be evaluated.

This method was recently used to build monorail columns at the Dallas-Fort Worth Airport. Although the columns were low- to mid-level, access was constrained around the terminals due to security and time constraints. Precast columns pieces were successfully used and bolted together with high stress rods minimizing access needs on the tarmac.

4.9 Does the height of the bridge above ground make falsework uneconomical or impractical?

Tall falsework systems required for conventional construction are not only expensive but also require substantial engineering and time for their approval and construction. Eliminating the need to provide support for cast-in-place construction of the superstructure can have significant benefits to both time and cost. Prefabricated bridges significantly limit this need, e.g., launching of entire cable-stayed bridges was recently used in France with heights approaching 1,000 feet.

4.10 Is the bridge alignment straight, skewed, or curved?

Prefabricated components can be the most cost-effective solution for any alignment, e.g., the precast concrete I-section girders in the Disneyworld monorail were cast in forms that adjusted to produce either straight or curved sections. However, straight alignments allow multiple identical components which tend to be the most economical. The alignment will impact superstructure member types, e.g., curved alignments will typically result in steel or post-tensioned segmental superstructures. Curved alignments also typically require shorter segments in order to transport over city streets.

Initial construction costs and long-term maintenance costs are typically less for bridges on straight alignments due to their simpler construction and load paths. During preliminary planning, preference should be given, if possible, to straightening the roadway alignment along the bridge length for lower life-cycle costs. This may also benefit sight lines, improve drainage, and raise design speeds while smoothing traffic flows.

4.11 Is the bridge in a location that requires seismic-resistant connections, i.e., special moment connections?

Prefabricated components are constructed in offsite controlled environments that improve the quality of the components. Attention must be given to proper design and construction of the connections between prefabricated components to ensure optimum long-term performance and to achieve lower life-cycle costs with prefabricated bridges, e.g., the design of connections for seismic loads.

4.12 Are the available connection details between prefabricated components appropriate for the bridge's environment, e.g., heavy loads, flooding, salt water splash zones, freeze/thaw, use of snowplows, ice/debris impacts on substructures, or deicing agents?

The improved quality of prefabricated components due to their controlled offsite fabrication is anticipated to extend service life, especially in harsh environments. To achieve this longer service life with lower maintenance requirements, care must be taken to properly design and construct the connection details for these components. The design of the connection details must consider the bridge's environment.

C. Costs

1. Maintenance of Traffic

Traffic management and user delay-related costs associated with bridge construction activities will significantly influence the selection of the most cost-effective bridge technology. Close cooperation with the agency's traffic analysis experts is critical to development of the traffic information described below.

1.1 Will the traffic control plan change significantly through the course of the project due to development, local expansion, or other projects in the area? How much are the agency costs per day for implementing the traffic control plan, e.g., costs for traffic control devices, flagging, maintenance of devices, lighting, temporary roadways, and maintenance of detours?

Agencies implement traffic control plans for safety and to lessen the disruptive impacts of bridge replacement on highway users; these costs can significantly add to the cost of the replacement, especially when the traffic control plan changes significantly during the project due to development, local expansion, or other projects in the area. Because prefabricated bridges can be installed in hours or days compared to weeks or months for conventional bridges, the prefabricated bridge can greatly reduce these traffic control costs.

Guidance on cost estimating of traffic control plans is available from some States, such as California ("Traffic Management Plan Effectiveness Study," California Department of Transportation Traffic Operations Division, 1993). For conventionally built bridges, such costs can range from 5% to more than 30% of construction costs, although they are typically less than 10%. Values above 10% appear to occur in the case of smaller projects, where the set-up costs of the traffic control plans may be high relative to the overall project costs. Cost savings from the reduced duration of the traffic control plan can be estimated based on the reduced number of days of traffic control cost times the average daily operating cost of such measures for comparable bridge projects.

1.2 Are delay-related user costs a concern to the agency? How much are these costs per day?

The quicker installation of prefabricated bridges will also reduce the costs to highway users associated with traffic queues and detours during the bridge installation. Users incur costs during installation due to increased vehicle miles traveled (using detours) and increased vehicle hours of delay (caused by queues that form in front of work zones or in over-capacity detours).

The FHWA's QuickZone 2.0 (see http://www.tfhrc.gov/its/quickzon.htm) or various traffic simulation models (see next paragraph on FHWA's Traffic Analysis Toolbox) can be used to measure the degree to which expediting the construction will lower vehicle miles and hours of travel. Published monetary values (see U.S. DOT's "Revised Departmental Guidance: Valuation of Travel Time in Economic Analysis" (February 11, 2003) http://ostpxweb.dot.gov/policy/Data/VOTrevision1_2-11-03.pdf) can then be attached to these performance units to estimate the savings to the highway user. (QuickZone will automatically assign values to delay.)

Numerous other traffic analysis products are available to capture the effects of work zones and bridge closures on traveler delay costs. In July 2004, the FHWA issued a three-volume "Traffic Analysis Toolbox." The first volume in this toolbox, "Volume 1: Traffic Analysis Tools Primer," offers basic guidance and a description of the types of tools available for traffic analysis. Volumes II and III offer much more detailed guidance. All three volumes are available at the FHWA's Traffic Analysis Toolbox website, http://ops.fhwa.dot.gov/trafficanalysistools/toolbox.htm.

For very large construction projects, especially those involving multiple work zones and one or more roads or bridges that will affect a wide regional area, the agency should consider the use of regional travel demand models.

2. Contractor's Operations

   In general, contractors bid projects with the plan to complete onsite construction as quickly as possible to increase profits; this is particularly true for projects with incentives for early completion. The contractor's costs, including overhead costs to staff projects with construction crews, etc., are reduced when the duration of the construction project is reduced. Also, construction crew safety in the work zone is increased with reduced exposure times related to the construction duration.

   Contractor profits depend on an accurate assessment of risk. Increasing the options available to the contractor to achieve the rapid onsite construction, while ensuring that agency goals are met, will result in less risk to the contractor. Multiple options should result in more economical bids and profits for the contractor since risk is reduced when the contractor can optimize construction activities around the strengths of his or her operations.

   2.1 Can innovative contracting strategies to achieve accelerated construction be included in the contract documents, e.g., can incentives/disincentives be set high enough to cause the contractor to change his conventional practice to meet the reduced onsite construction schedule?

Requirements related to reduced traffic impact and time must be clearly specified in the contract documents. Innovative contracting strategies to achieve accelerated construction include incentive/disincentive, a financial bonus or penalty for delivery before or after a time set in the contract; A+B bidding, cost-plus-time based on the combination of contract bid items (A) and the time bid for construction multiplied by daily user cost (B); lane rentals, assessed rental fees for lanes taken out of service during temporary lane closures for construction; and no-excuse bonus, a modified incentive with no time adjustment for problems such as delays due to weather or utility conflicts regardless of who is responsible.

Incentives and disincentives for early completion give contractors a financial reason to change their conventional practices to accelerate construction. Contractors cannot count on incentives and, therefore, may not reduce their bid price in anticipation of receiving incentives. Disincentives are necessary but may result in higher bid prices because of the risk to contractors that they will not be able to meet the reduced construction timeline. However, in some accelerated bridge project case studies, it was found that by providing the right incentive/disincentive, the contractors were able to lower the overall total project costs when compared to conventional delivery methods.

Agencies should consider setting daily incentives/disincentives for early completion of project milestones at least equal to the reduction in daily cost of the traffic control plan to make it financially advantageous to the contractor to accelerate onsite construction to hours or days instead of weeks or months. Agencies would then achieve the reduced construction timeline at no additional cost. Consideration should also be given to including some fraction of the user delay costs. If all bidders are subject to incentive/disincentive payments that reflect some or all of user delay costs, this may create an incentive for bidders to incorporate prefabricated components into their designs.

Similarly, other contracting strategies such as A+B bidding, lane rentals, and no-excuse bonus can be used to give the contractor the financial incentive to achieve the reduced on-site construction timelines.

2.2 What is the cost for the use of innovative equipment to install the bridge in hours or days relative to incentives for early completion?

Specialized equipment may be needed to install the prefabricated bridge. Specialized equipment is now available to lift, haul, and erect heavy units, e.g., self-propelled modular transporters can reduce on-site installation time to hours or days compared to weeks or months for conventional construction. The contractor will consider the cost of this equipment relative to the profits that could be obtained from incentives for early completion and relative to the reduced risks due to reduced on-site construction time.

Also, with multiple prefabricated bridges bundled together under one contract, the cost of specialized equipment can be spread out (amortized) over a larger number of bridges, lowering its average cost per bridge. This would only be possible if the bridge construction is linear (one after another rather than concurrent) allowing a higher usage of the specialized pieces, instead of multiple units which would drive up costs.

The owner should consider payment arrangements for the specialized equipment as a separate line item in the contract to recognize the large upfront costs and to minimize the need for the contractor to finance (by being cash negative) any portion of the project.

2.3 What are contractor costs for liability insurance and bonding?

Federal and State governments require contractors to have liability insurance, which includes general liability insurance; property damage liability insurance; railroad, marine, automobile liability insurance; and workers' compensation insurance including subrogation for the owner. In addition, as of 1996 forty-nine States require the contractor to have some form of surety bond. Surety bonds include contractor bid, performance, payment, and maintenance bonds. Surety bonds are provided by licensed surety companies that commit their assets to support the performance and financial obligations of contractors and subcontractors. These bonds assure the owner that the contractor will perform according to the terms and conditions of the contract.

The shorter installation time required for prefabricated bridges can lower liability insurance and bonding costs when compared to a conventional replacement project. Insurance and bonding costs can be a significant part of construction cost, with the industry press reporting that surety bonding costs alone typically range from 0.5% to 1.35% but can exceed 3% of contract cost (Construction Business Review, 2000, Vol. 8, No. 3, pp. 38-41). Various types of liability insurance can add significantly to cost as well.

The potential savings in insurance and bonding costs associated with faster construction times can be determined by consulting with local contractors, insurers, and surety providers. Estimates may be based on the reduced number of days that coverage is required, or by other information on the effects that construction duration has on these costs. Sureties will also consider a contractor's cash flow, and they like to see projects that are cash positive. Payment schedules that allow the contractor to recoup major upfront expenses lessen the risk for which the owner ultimately pays.

3. Owner Agency's Operations

Agency overhead costs to staff projects, e.g., construction engineering and inspection support, are reduced when the duration of construction projects is reduced. Prefabricated bridges, with their rapid onsite installation, can significantly reduce these project costs.

3.1 Can the agency provide the necessary staffing to effectively administer the project?

The use of prefabricated bridges to accelerate construction cannot be approached in a conventional manner by the owner. The owner will need to commit to working multiple shifts, odd hours, and under the same constraints as the contractor. This will extend to the higher levels of the organization to facilitate decision making and problem solving to maintain the flow of the project. This will also extend to lab work, in-place testing, and document review and approval. Depending on the schedule of the project, the contractor's entire operation may be working hours other than 8 a.m. to 5 p.m. Monday through Friday, and the owner will need to staff the project according to the requirements of the project in order to provide proper and timely administration.

3.2 Can the bridge be grouped with other bridges for economy of scale?

The manufacturers of the prefabricated components may be able to offer lower unit costs if they can spread their fixed costs over many bridges and/or reuse the formwork repeatedly. In general, a contractor will want to recoup his investments in special equipment and new formwork almost immediately. The bundling of projects will provide an attractive incentive for a contractor to acquire new or special equipment when he can recoup his investment without pricing his bid out of the market. This could, in turn, substantially lower the cost of the prefabricated bridges relative to the costs of conventional bridges, which may not be as subject to scale economies.

3.3 Will the design be used on a broader scale in a geographic area?

Contractors submit more competitive bids on innovative projects when they know the changes from conventional construction will be used multiple times in the future. Standardization of prefabricated components, especially when the standards are available online, gives assurance that these components will be used on a broader scale.

3.4 Can adequate time be allocated from project award to site installation, to allow for prefabrication of components to occur concurrently with site preparation? Alternatively, can arrangements be made to fabricate and stockpile the components in advance of the contract?

Significant cost savings can be realized from short on-site construction timelines. However, preliminary planning must include consideration of the time required to make the prefabricated components prior to their rapid onsite installation. Adequate time must be allocated from award of contract to on-site installation. Alternatively, consideration could be given to whether it would be possible to fabricate and stockpile components prior to contract award. This becomes even more appropriate if the design is common for an area, and is used multiple times.

4. Service Life

Prefabricated components are constructed in offsite controlled environments that improve the quality of the components due to reduced dependence on weather, established materials suppliers for consistent quality of materials, standardized plant operations for consistent quality of production, and off-the-critical-path construction that allows time for optimum concrete curing for good long-term performance. When combined, the resulting systems are built more reliably, at a lower cost, while providing higher durability.

The potential weak link in prefabricated systems is the connections between components, e.g., the closure joint between deck panels, column to cap, or footing/drilled shaft to column. Transverse and longitudinal deck closure joints are the biggest challenge to achieving long-term durability with minimum maintenance and rideability/smoothness requirements. Whereas the prefabricated components are constructed in controlled environments, the closure joint construction is exposed to the variability inherent in field construction. Connection details must be properly designed using quality materials, be easily constructed, and be backed by a solid quality control/quality assurance plan to have the assurance of good, dependable long-term performance. In addition to the proper design of these passively reinforced, welded or bolted, or post-tensioned joints to distribute loads laterally without distortion, the joints should be filled with an appropriate high-performance non-shrink cementitious grout or custom-designed concrete mix, and the interface between the prefabricated components and closure joint should be properly sealed to prevent moisture or chloride penetration.

A number of effective connection details are currently available and being used. In addition, various research projects are being conducted to further improve connection details and prefabricated systems. Information on currently available effective connection details and on prefabricated bridge construction costs is being compiled and will be available on the FHWA prefabricated bridges website at http://www.fhwa.dot.gov/bridge/prefab/ in the near future.

The following models are available for life-cycle cost evaluations of a bridge over its service life:

- National Cooperative Highway Research Program (NCHRP) Bridge Life-Cycle Cost Analysis (BLCCA) model (NCHRP Report 483, http://www4.trb.org/trb/crp.nsf/All+Projects/NCHRP+12-43), and
- National Institute of Standards and Technology (NIST) Bridge LCC Version 1 model, available at no cost (http://www.bfrl.nist.gov/bridgelcc/welcome.html).

V. Conclusion

For a variety of reasons as discussed above, a prefabricated bridge can be the cost-effective construction method of choice to achieve rapid onsite bridge installation. The use of prefabrication can reduce traffic and environmental disruption and improve work-zone safety, in addition to offering other advantages depending on site constraints. A regimented evaluation of the true requirements for the bridge and an unbiased review of the total costs and benefits of this viable option will lead the owner to the most effective course of action.

Outcome	Yes	No
Prefabrication for this bridge?		
Reasons:		

VI. Available Resources

General Information:	http://www.fhwa.dot.gov/bridge/prefab/
Projects constructed to date:	http://www.fhwa.dot.gov/bridge/prefab/projects.htm
Publications:	http://www.fhwa.dot.gov/bridge/prefab/pubs.htm
Research:	http://www.fhwa.dot.gov/bridge/prefab/research.htm
Calendar of upcoming events:	http://www.fhwa.dot.gov/bridge/prefab/calendar.htm