Slide-In Bridge Construction Cost Estimation Tool Guidelines

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U.S. Department of Transportation
Federal Highway Administration

innovation · ingenuity · invention · imagination
Every Day Counts

FOREWARD AND ACKNOWLEDGEMENTS

This Slide-In Bridge Construction (SIBC) Cost Estimation Tool was developed for the Federal Highway Administration's (FHWA) Every Day Counts Initiative to promote the use of this innovative Accelerated Bridge Construction (ABC) technique to shorten project delivery, reduce user impacts, and enhance roadway safety. This document provides a general guideline for state Departments of Transportation (DOTs) to estimate the cost of SIBC for common bridge replacements.

Leidos, Inc. and Michael Baker International developed the SIBC Cost Estimation Tool.

Technical Working Group contributors include Iowa DOT, Minnesota DOT, Oregon DOT, Utah DOT, and Wisconsin DOT. Additional contributors of project data include Colorado DOT, Indiana DOT, Michigan DOT, Missouri DOT, Nevada DOT, New York DOT, Oklahoma DOT, Oregon City, and Washington DOT.

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LIST OF ACRONYMS

AADT	Annual Average Daily Traffic
ABC	Accelerated Bridge Construction
ATC	Alternative Technical Concept
DOT	Department of Transportation
EB	Eastbound
FHWA	Federal Highway Administration
NB	Northbound
RFP	Request for Proposal
ROW	Right-Of-Way
SB	Southbound
SIBC	Slide-In Bridge Construction
WB	Westbound

Chapter 1
INTRODUCTION

1.1   PROJECT OVERVIEW

Slide-In Bridge Construction (SIBC) is a relatively new, innovative, and underutilized technology. As a part of the Every Day Counts Initiative to advance innovative techniques, the Federal Highway Administration (FHWA), state highway agencies, and industry partners developed this spreadsheet-based SIBC Cost Estimation Tool. This tool implements historical cost data to facilitate the preparation of construction cost estimates for projects using SIBC technology.

1.2   SLIDE-IN BRIDGE CONSTRUCTION OVERVIEW

SIBC offers a cost-effective technique to rapidly replace an existing bridge while reducing impacts to mobility and increasing safety. SIBC is an Accelerated Bridge Construction (ABC) technology that reduces the on-site construction time associated with building bridges.

SIBC allows for construction of a new bridge while maintaining traffic on the existing bridge. The new superstructure is built on temporary supports adjacent to the existing bridge (see Figure 1-1). Once construction is complete, the road is closed, the existing bridge structure is demolished or slid to a staging area for demolition, and the new bridge is slid into its final, permanent location. Once in place, the roadway approach tie-ins to the bridge are constructed. The replacement time ranges from overnight to several weeks. A variation of this method is to slide the existing bridge to a temporary alignment, place traffic on the temporary alignment, and construct the new bridge in place.

Figure 1-1
Overhead View of the West Mesquite SIBC Project, Nevada

SIBC provides an effective alternative to phased construction, crossovers, lane reductions, or use of temporary bridges. Although the lateral slide requires a short-term full closure of traffic, owners and the public typically prefer the limited impacts of a single short-term closure when compared to the extended traffic impacts associated with phased construction.

1.2.1   Benefits

There are several fundamental benefits to using SIBC, as compared with phased construction, which include:

- Enhanced safety to both construction crews and traveling public
- Shortened on-site construction time
- Reduced mobility impacts
- Potentially reduced project costs
- Improved quality
- Improved constructability

1.2.2   Limitations

Some limitations that present challenges to SIBC include:

- Limited right-of-way (ROW) for staging
- Geometric constraints
- Lack of SIBC experience
- Profile changes
- Utility impacts

1.2.3   SIBC Reference

Refer to FHWA's *Slide-In Bridge Construction Implementation Guide* for more details on the planning and execution of projects with the lateral slide method (http://www.fhwa.dot.gov/construction/sibc/pubs/sibc_guide.pdf). See Chapter 4 for additional references from FHWA.

Chapter 2
BACKGROUND

2.1   DATA COLLECTION

The SIBC Cost Estimation Tool incorporates project data from 29 completed SIBC projects nationwide. Figure 2-1 shows the states and quantity of SIBC projects used in this tool. These projects represent all completed SIBC projects for state DOTs to date.

The quantity of projects and available data provided somewhat limited data. For example, seven of these projects were delivered using Design-Build contracting and detailed cost breakdowns were not available. However, the detailed cost data from the other 22 projects provided significant correlations, which were used to develop this tool.

Figure 2-1
SIBC Projects Used in the Development of this Tool
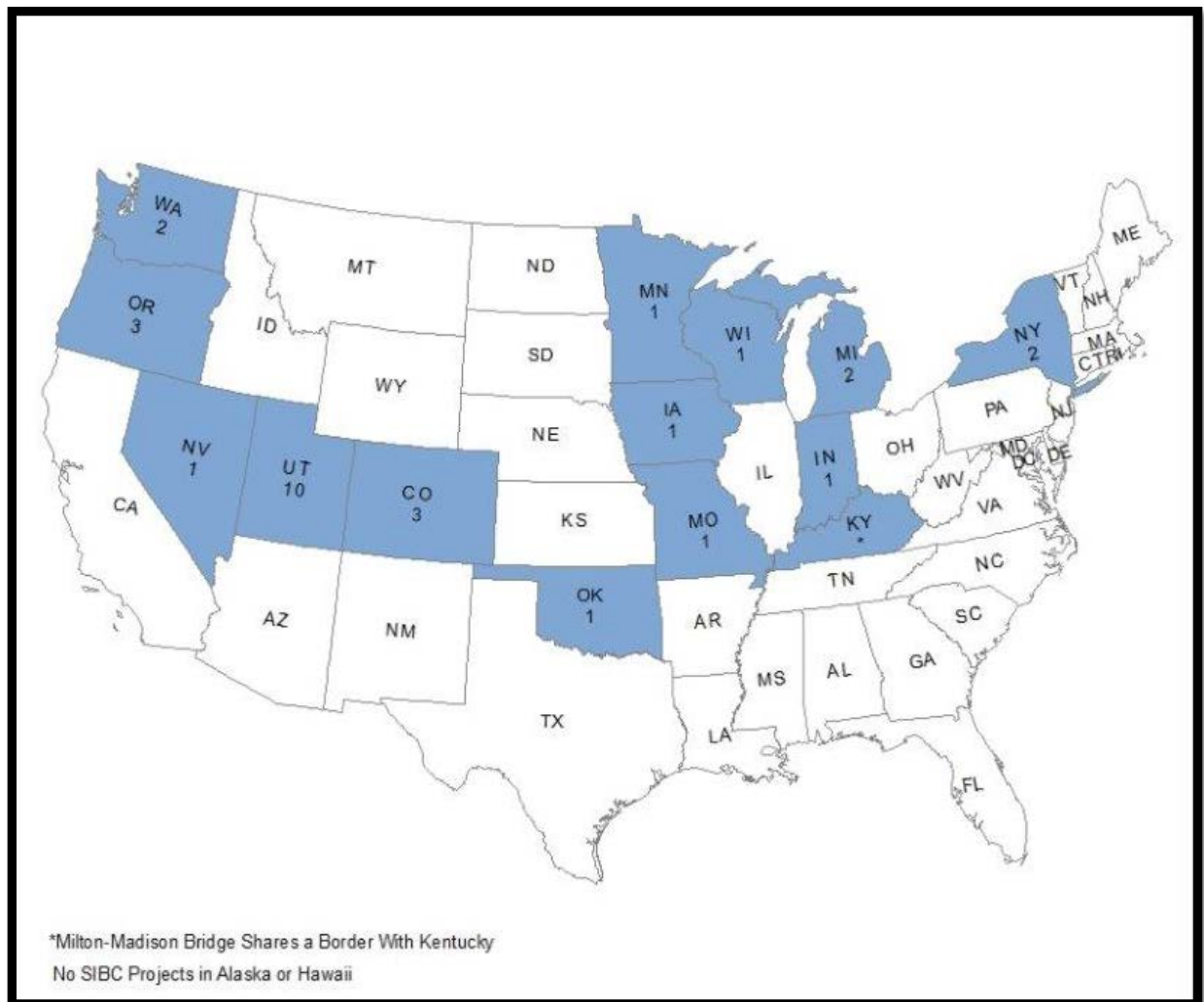
The project also utilized a technical working group that included the project team and representatives from four of the state agencies that provided project data. This group reviewed the tool and provided significant input in its development. Table 2-1 shows the members of this group.

Table 2-1
Technical Working Group

Name	Organization
Tony Lesch	Minnesota DOT
Albert Nako	Oregon DOT
Rebecca Nix	Utah DOT
James Luebke	Wisconsin DOT
Eric Perry	Leidos
AJ Yates **Michael Arens** **George Gorrill** **Linda Krueger**	Michael Baker International
Romeo Garcia	FHWA

2.2   METHODOLOGY

2.2.1   Background

The tool estimates the additional cost of using an SIBC alternative by factoring the estimated construction cost of the bridge to determine the slide cost and then adds associated construction and administrative costs. This method is user-friendly as it establishes a clear relationship between the inputs and calculations performed in the spreadsheet. The cost adjustment factors are calibrated primarily on historical data. Some adjustments based on experience were necessary when there was insufficient historical data.

Figure 2-2 describes the master equation and provides an explanation of the variables that are used. The variables will be discussed in further detail in Section 3 of this guideline.

Figure 2-2
Methodology Equation
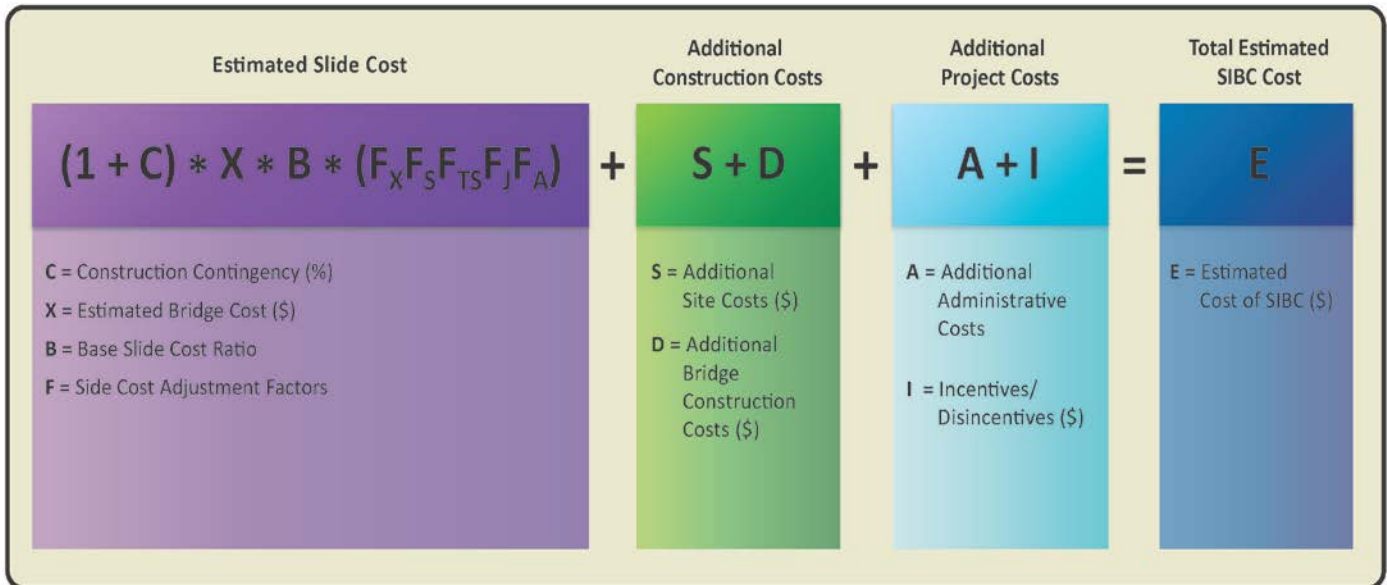
2.2.2   Description

Figure 2-3 and Figure 2-4 provide graphical representations of the data collected from historical SIBC projects for both single span and multi-span bridges. Successful and non-successful data points are shown to maximize the available data.

2.2.2.1   Generalized Relationship

Figure 2-3 and Figure 2-4 also show a linear "curve fit" of the data. This generally linear relationship is the basis for the methodology of estimation used in this tool.

$$Slide\ Cost = 20\% * Bridge\ Cost$$

The 20% value is the average ratio of bridge slide cost to total bridge cost for the data collected. This average is similar for both single span and multi-span bridges. Unsuccessful bids were not used in calculating this value. This ratio is the basis for the B, Base Slide Cost Ratio term.

2.2.2.2   Data Boundaries

Figure 2-3 and Figure 2-4 also show upper and lower boundaries. Despite some outliers, these boundaries capture the data and provide a bounded solution for typical bridges. This estimation tool uses cost adjustment factors applied to the B term to determine the appropriate value between the upper and lower boundaries. The maximum and minimum slide costs that can be obtained from the tool are shown in these figures. These are based on using the best- or worst-case factors.   The figures show the maximum limit of the estimation tool when a 10% contingency is applied.

Single Span Bridges

There is no historical data to support a slide cost greater than approximately $700,000 for single span bridges. The estimation tool includes this maximum limit (prior to applying contingency).

Multi-Span Bridges

There have been relatively few multi-span SIBC bridges. However, the available data indicates a similar cost relationship as that of single span bridges. The estimation methodology used in this tool assumes the same relationship with different boundaries. A minimum limit of $350,000 for slide costs is based on historical data. There is no maximum limit.

Figure 2-3
Single Span Bridges

Figure 2-4
Multi-Span Bridges

2.2.3   Recommended Ranges of Applicability

The available data is primarily for deck-girder bridges, although some SIBC projects included complex structures such as truss or arch bridges. This tool is intended to be used for traditional deck girder bridges with standard crossing features. The tool is not intended to be used for complex structures, deep canyons, or large river crossings. However, there may be some value in using the basic relationships of the tool as a way to compare with other methods.

Table 2-2 provides recommended ranges of applicability for the use of this tool. The tool can be used for projects that exceed these limits but the user should consider using an appropriate contingency relative to the level of uncertainty.

The projects used to establish the estimation methodology of this tool used the following slide systems:

- Industrial Rollers
- Teflon Pads
- Hydraulic Jacks
- Post-Tensioned Jacks

Two of the projects used systems that were significantly lower in cost than those used in the tool. One project used a winch system, which was five percent of the bridge cost and the other used a crane system, which was two percent of the bridge cost. These systems were used on small bridges in unique situations. This tool is not intended to be used with these systems.

Table 2-2
Recommended Ranges of Applicability

Characteristic	Single Span		Multi-Span	
	Minimum	Maximum	Minimum	Maximum
X, Estimated Bridge Cost	$500,000	$4,500,000	$1,500,000	$6,000,000
Number of Spans	1	1	2	3*
Span Length	50	200	50	200
Bridge Length	50	200	150	500

*Multi-span bridges with more than three spans have successfully utilized SIBC construction.

Chapter 3
COST ESTIMATION

3.1   TOTAL ESTIMATED SIBC COST

Cost estimation of new and innovative construction techniques can be challenging and uncertain. This tool provides the user with the ability to draw on cost data from SIBC projects across the nation. The tool can be used both as a planning tool and as a construction cost estimation tool. During the planning phase of a project, this tool can be used to develop costs for alternative comparisons. During design, this tool will assist in building cost estimates and evaluating contractor bids.

The term E, Total Estimated SIBC Cost, represents the entire additional (or delta) cost of an SIBC project as compared to traditional construction. This term captures both construction and administrative costs to provide a holistic project cost difference. To obtain the total cost of the SIBC alternative, simply add the E value to the project cost of the traditional construction alternative.

$$SIBC\ Alternative\ Estimated\ Cost = Traditional\ Construction\ Alternative\ Estimated\ Cost + E$$

The SIBC method offers many distinct benefits to the agency, namely reduction in traffic impacts and increased safety. Under certain circumstances, SIBC can also reduce overall project costs. In these situations, the E term will be negative, which indicates an overall estimated project cost savings.

Refer to the notes in Section 3.3.1, 3.3.2, and 3.4 for additional considerations of project cost savings.

3.2   ESTIMATED SLIDE COST

This portion of the methodology equation (Figure 3-1) estimates the cost for the contractor to build temporary supports and slide the bridge into place. It includes the following:
- Temporary supports, including foundations, platform ("table top"), bracing, etc.
- Equipment rental such as jacks, guides, tracks, monitoring equipment, etc.
- Vertical jacking
- Production of shop drawings, move schedules, and monitoring plan by the contractor
- Labor

Figure 3-1
Estimated Slide Cost

$$(1 + C) * X * B * (F_X F_S F_{TS} F_J F_A)$$

Many agencies choose to use a lump sum line item in the construction bid for this work – this term estimates that cost. Refer to the FHWA Slide-In Bridge Construction Guide, Appendix D for sample special provisions that cover this work. When the tool is used to estimate only the slide construction costs, such as for construction bid evaluations, the S, D, A, and I terms should be zero. Refer to Sections 3.3 and 3.4 for the definition of these terms.

Detailed descriptions of the terms used in calculating the Estimated Slide Cost are included in the following sections.

3.2.1   C, Contingency

A common practice of cost estimation is to incorporate a certain amount of additional cost as a contingency for uncertainties or unknowns. As a project moves from a planning phase to the design phase, more details are determined and project risks are identified and mitigated. As such, the contingency is typically reduced. A goal of cost estimation during the planning phase is to apply the correct amount of contingency so that future design progression does not increase the estimated project cost.

The user determines the contingency. The user is encouraged to input values in the SIBC Estimation Tool (spreadsheet) that are common practice for the associated agency. For example, during the planning phase, it would be appropriate to use a relatively high value such as 20 to 30 percent. As the project progresses and more details are known, the user can lower the value. A reasonable value to use when estimating the slide cost (to compare against contractors bids) is 10 percent.

The intention of this approach is to try to estimate costs as close to historic data as possible. However, there are inherent limitations to this tool. Users may elect to increase the contingency based on the circumstances of their particular situation and past experiences. Agencies are encouraged to identify the amount of contingency that best fits their particular situation.

> *Note: This contingency value only modifies the estimated slide cost. It does not adjust the S, D, A, or I terms (see Figure 2-2). As such, these inputs should have the appropriate contingency values applied independently. This provides the user greater flexibility to use the appropriate contingencies for items based on the individual levels of certainty.*

3.2.2   X, Estimated Bridge Cost

This term is the estimated bridge construction cost for the structure that will be slid and should not include any estimated slide costs. During the planning phase, this term may be a simple estimation such as deck area multiplied by a unit cost. During the design phase, this value should be the engineer's bridge construction cost estimate (without any slide costs). This term should not include embankment, roadway tie-in, or adjacent retaining wall costs.   The user calculates and inputs this term in the SIBC Estimation Tool (spreadsheet).

> *Note: In some situations, a user may believe this term to be unrealistically high, which will lead to an unrealistically high slide cost. In such situations, the user can reduce the value using judgment. It is not recommended to lower the value below what would typically be obtained using average unit costs of bridges in the user's state. Conversely, the initial X value could be unrealistically low. In such case, it is recommended to consider using a value that would be comparable to a value calculated by using the average unit cost.*
>
> *Refer to this link for unit bridge costs tracked by FHWA (Data is current through 2011. Users are encouraged to verify with their agency.):*
> *http://www.fhwa.dot.gov/bridge/nbi/unit_cost.cfm.*

3.2.3   B, Base Slide Cost Ratio

This is the average ratio of slide cost to bridge cost. This value, 20 percent, is empirically based and is not changed by the user. The value was determined using the winning contractor bids from previous construction projects (see Section 2.1 for details).

3.2.4   F, Slide Cost Adjustment Factors

Several cost adjustment factors can increase or decrease the cost of a bridge slide. The cost adjustment factors used in this tool include:

- Experience Factor
- Site Complexity Factor
- Temporary Shoring Factor
- Vertical Jacking Factor
- Annual Average Daily Traffic (AADT)/Undercrossing Factor

The cost adjustment factors are discussed in greater detail in the following sections. Other factors were considered during the development of this tool but were not included due to the lack of a definitive relationship.

The user determines the appropriate value for each factor by either inputting information (such as AADT) or by selecting a condition and the spreadsheet supplies the appropriate value.

3.2.4.1 F_X, Experience Factor

This factor addresses the experience level of the owner, the designer, and the contractor. Lack of experience from any of these parties can result in increased construction costs and/or slower delivery. Conversely, a team with significant combined experience can decrease construction costs and speed up delivery.

The owner is responsible for determining the feasibility of using the SIBC method on a particular project. The owner must also define closure times, identify impacts to the crossed feature, pay close attention to the specifications and submittals, and have a good overall understanding of what is expected during a bridge slide. Lack of experience in these areas can result in higher costs and longer schedules.

The designer is the link between the owner and the contractor. The designer is responsible for providing the contractor with construction plans, which meet the expectations and standards of the owner. The designer must have a clear understanding of the SIBC method and its constructability. An experienced designer will be able to provide a design that the contractor can easily construct at minimal cost. An inexperienced designer may provide plans that are more difficult or costly to construct. The design may also contain more errors or problems with constructability.

The contractor is responsible for all of the construction activities associated with SIBC. A contractor with experience using the SIBC method has a better understanding of what to expect during a slide and is better equipped to anticipate potential construction problems. An experienced contractor may also have developed a more streamlined process for implementing SIBC. Conversely, inexperience leads to unpredictability. An inexperienced contractor may overbid or even underbid the project significantly. It is also likely that these contractors will encounter unanticipated construction issues, which can increase cost and delay schedule.

The following options describe the conditions and values for this factor:

- Little/No Combined Experience (1.05) – Select this option when there is little to no experience between the owner, designer, and contractor or if the experience level is unclear.
- Some Combined Experience (1.00) – Select this option when it is expected that one or more among the owner, designer, or contractor has experience using the SIBC method and all have a good understanding of the process.
- Significant Combined Experience (0.95) – Select this option when it is expected that the owner, designer, and contractor all have experience using the SIBC method.

3.2.4.2 F_S, Site Complexity Factor

This factor accounts for the complexity of site conditions on the project. It is typical for a bridge to include at least a few different site complexities, which are already accounted for in the B, Base Slide Cost Factor (see Section 3.2.3). Some of the different site conditions include (but are not limited to) soil quality, presence of water, proximity to other structures or natural formations, limited construction staging areas, and other conditions.

Figure 3-2 illustrates an example of a large site complexity that can increase the slide costs. The Oregon Route 38 project, extending from Elk Creek to Hardscrabble Creek, had significant site constraints. The project included the construction of two bridges, each on opposite ends of the same tunnel, with one bridge starting almost immediately after exiting the tunnel.

Figure 3-2
SIBC with Large Site Constraints at the OR-38 Bridge Project, Oregon

The tunnel is a good example of a large site complexity that provided a very tight staging area in which to set up the slides. These types of site constraints can significantly impact the overall percentage of the cost to slide the bridge.

The following options describe the conditions and values for this factor:

- Many/Large Site Complexities (1.10) – Bridge slides that are heavily affected by site constraints will fit into this category.
- Above Average Site Complexities (1.05) – For a bridge that has a number of site complexities outside the norm but not exceptionally large, select this option.
- Typical Site Complexities (1.00) – This option assumes a moderate number of site complexities that affect the ability of the contractor to slide a bridge.
- Below Average Site Complexities (0.95) – This option should be chosen for bridges that have some site complexities and a small effect on the bridge slide.
- Little to No Site Complexities (0.90) – These are bridges that have virtually no site complexities to complicate the slide process.

3.2.4.3 F_{TS}, Temporary Shoring Factor

Temporary shoring is one of the major expenses of the bridge sliding process. Temporary shoring can range from steel scaffolding to slide tracks supported by concrete footings. Projects that can be completed with minimal use of temporary supports can realize a very significant savings, while projects that require large foundations and complicated schemes can be very expensive.

The user should evaluate the following two conditions when selecting the value for this factor. The first condition is the amount of temporary shoring. An average amount of shoring is enough to support a bridge superstructure at the grade separation height. Some projects may require additional shoring to support an existing bridge that has been slid out of position so it can be demolished after the new bridge is in place. Projects may include shoring for approach slabs or may be exceptionally tall. Other projects may only require a small amount of shoring such as a slide track on an existing embankment to support the bridge superstructure.

The second condition is the materials that are used. A contractor with previous slide experience will most likely elect to re-use materials (such as steel beams or slide tracks) from previous SIBC projects. Others may rent a scaffolding system or use cast-in-place concrete. Materials that can be re-used from project to project typically provide the most economical solution. During the planning phase of a project, it may be difficult to determine whether a contractor will re-use materials. In these cases, the user should make an assumption based on what is known about the project and the previous experience of the construction industry in the area.

The following options describe the conditions and values for this factor:

- Large Quantity of Shoring using New Materials (1.20)
- Average Quantity of Shoring using New Materials (1.00)
- Small Quantity of Shoring using New Materials (0.80)
- Large Quantity of Shoring using Re-usable Materials (1.00)
- Average Quantity of Shoring using Re-usable Materials (0.80)
- Small Quantity of Shoring using Re-usable Materials (0.60)

The user should select the value based on the primary condition, i.e. consider whether the shoring materials will be mostly new or re-useable. The user should consider the contractors' experience and the availability of re-usable materials.

For additional details on temporary shoring, refer to the SIBC Implementation Guide, Section 3.3.

3.2.4.4 F_J, Vertical Jacking Factor

Some vertical jacking is required on almost every SIBC project. In most situations, the bridge requires a small amount of vertical jacking in order to clean surfaces, place bearings, move slide mechanisms, etc. This type of vertical jacking typically requires movements of four inches or less and is assumed to be a part of the base slide percentage (factor value of 1.00). Projects that require a large amount of jacking to lift or lower the bridge into its final position will have a significantly higher factor (factor value of 1.20).

3.2.4.5 F_A, AADT/Undercrossing Factor

The AADT/Undercrossing Factor accounts for the effects of the undercrossing feature. Specifically, it accounts for the ease (or lack thereof) of the contractor in coordinating between both ends of the structure. This factor has two scenarios – non-vehicular crossing (waterway) and a vehicular crossing (road). The following options describe the conditions and values for this factor:

- Non-Vehicular
  - Small waterway or dry creek bed (0.80)
  - Railroad (0.90)
  - Large waterway or canyon (1.00)
- Vehicular
  - AADT of 0 to 10,000 (0.6 to 0.9)
  - AADT of 10,000 to 100,000 (0.9 to 1.1)
  - AADT of 100,000+ (1.10)

The cost of railroad coordination and accommodation is not captured by this factor. If SIBC requires additional costs, these should be included in the appropriate term such as A, Additional Administrative Costs (see Section 3.4.1).

3.2.5   Number of Spans

The number of spans is not a term used in the cost estimation equation; however, it is used to apply limits based on the span configuration of the structure. Refer to Section 2.2.2.2 for details on how number of spans affects the estimation calculations.

The number of spans that are slid into place is significant as substructure units determine the amount of temporary shoring and jacking locations. The historic data indicated that the number of spans did not significantly alter the slide cost to bridge cost ratio. This suggests that as the number of spans increases, the overall cost of the bridge increases proportionally, thus the base slide ratio remains generally constant.

3.3   ADDITIONAL CONSTRUCTION COSTS

The terms S and D (see Figure 3-3) account for additional construction costs that are not included in the slide cost. The S term accounts for additional site costs such as ROW or utility relocations. The D term accounts for additional bridge costs such as girder type or span length. These cost items are physical items that become the responsibility of the agency. These items may provide ancillary benefits to the agency.

Figure 3-3
Additional Construction Costs

Each term represents a category of items that is being considered (see Sections 3.3.1 and 3.3.2). Provide supplemental calculations to document each item considered and determine how its value was calculated.

The S and D terms should only be used when tool is being used to develop estimated costs for alternative comparisons.

3.3.1   S, Additional Site Costs

This term is used to account for any site modification costs that are required for the SIBC alternative. Additional ROW may need to be purchased or a utility relocated to facilitate the temporary shoring. The SIBC alternative may require temporary or permanent retaining walls to construct the bridge, e.g., temporary soil nail walls in front of the existing abutments (and behind the proposed abutments) or permanent MSE-wrapped abutments. The user calculates and inputs this term.

> *Note: In certain situations, a negative value may be used to capture project savings when doing alternative comparisons. This will be primarily used during the planning stage of a project. For example, if roadway crossovers are being used for the base option but are not required for SIBC, then the construction cost of that work would be put in as a negative value to show a savings.*

3.3.2   D, Additional Bridge Construction Costs

This term is used to capture any additional construction costs of the bridge itself. The user calculates and inputs this term.

An SIBC structure typically requires modifications to standard bridge components. The cost of these items should be estimated to provide a true comparison. Some ideas for consideration are:

- Increased girder costs due to shallower girders required for vertical clearance in the temporary location.
- Increased diaphragm costs at supports.
- Increased substructure costs
    - Type (e.g., integral vs. semi-integral)
    - Material used for backfill (e.g., soil vs. flowable fill)
    - Tight construction clearance (e.g., traditional construction vs. building underneath an existing bridge)
    - Foundation type (e.g., piles vs. micropiles)

> *Note: This term may be used to capture cost savings due to SIBC by inputting a negative value. For example, a shorter single span bridge as compared to a larger three-span bridge.*

3.4   ADDITIONAL PROJECT COSTS

The terms A and I (see Figure 3-4) account for additional project costs that are required for SIBC. The A term accounts for additional administrative costs such as agency oversight, design engineering, and construction engineering, and inspection.   The I term accounts for any additional incentives or disincentives for the contractor.   These terms represent non-physical costs.

Figure 3-4
Additional Project Costs

Each term represents a group of items that is being considered (see Sections 3.4.1 and 3.4.2). Provide supplemental calculations to document each item considered and determine how its value was calculated.

The A and I terms should only be used in this tool to develop estimated costs for alternative comparisons.

Note: In certain situations, a negative value may be used to capture project savings when using alternative comparisons. This input will be primarily used during the planning stage of a project. For example, SIBC may reduce the overall duration of the project, which will yield savings both from a project administration and from a construction cost perspective.

3.4.1   A, Additional Administration Costs

This term captures the additional costs for the agency to execute the project such as additional engineering time spent during design, reviewing contractor submittals, visiting the site, etc. The user calculates and inputs this term in the SIBC Cost Estimation Tool (spreadsheet).

3.4.2   I, Additional Incentives/Disincentives

This term captures the additional costs of incentivizing and disincentivizing the contractor. An example is an incentive for reduced traffic closure durations than those outlined in the contract.

Conversely, penalties may be assessed for extended traffic closure durations. The user calculates and inputs this term.

Note: The amount of disincentive is difficult to calculate as the magnitude is unknown and each contractor will bid the risk of the penalty differently. The user will have to estimate the amount of penalty that the winning contractor will bid. Some factors to consider are:

- *Performance for traffic closure durations on previous projects*
- *Contracting community experience with SIBC*
- *Competitiveness in the bidding environment*
- *Complexity in the scope of work*

For additional details on determining incentives and disincentives and SIBC schedules, refer to the SIBC Implementation Guide, Sections 2.1 and 4.2, respectively.

Chapter 4
FHWA REFERENCE MATERIAL

The following sources are a compilation of references concerning SIBC methodology for these guidelines and SIBC Cost Estimation Tool:

FHWA Home Page
http://www.fhwa.dot.gov

SIBC Website
http://www.fhwa.dot.gov/construction/sibc

SIBC Implementation Guide
http://www.fhwa.dot.gov/construction/sibc/pubs/sibc_guide.pdf

Life Cycle Cost Analysis (LCCA) and User Cost Information
http://www.fhwa.dot.gov/infrastructure/asstmgmt/lccasoft.cfm

Work Zone Road User Costs – Concepts and Applications
http://ops.fhwa.dot.gov/wz/resources/publications/fhwahop12005/sec2.htm

FHWA Bridge Unit Construction Cost Data
http://www.fhwa.dot.gov/bridge/nbi/unit_cost.cfm

Appendix A:
Sample Calculations 1

I-80; Wanship Bridge, Utah

These sample calculations are a hypothetical situation based on a real world project to illustrate how this tool could have been used during the planning and design phase of a project. The information contained herein may not necessarily reflect actual details of the project.

PROJECT DESCRIPTION

Construction Year: 2012
Owner: Utah Department of Transportation (UDOT)
Contractor: Ralph L. Wadsworth
Designer: UDOT-Bridge Design, Michael Baker International -SIBC Design
Contracting Method: Design-Bid-Build
SIBC Construction Type: Teflon pads with PT jacks

This project replaced the existing three-span eastbound (EB) and westbound (WB) bridges over SR-32 on I-80 near Wanship, UT with new single span bridges. The project included bridge replacement, overlaying I-80 several miles in each direction, and reconstruction and lowering of SR-32. By implementing SIBC, UDOT eliminated the need for construction of costly interstate crossovers and simply detoured traffic on alternate routes for the one night closure required for each bridge installation. Substandard vertical clearance with a history of bridge hits required vertical clearance improvement. UDOT made a decision to lower SR-32 profile instead of raising I-80 profile to allow SIBC to be used and to minimize impacts to I-80.

This design used full height cantilever abutments on spread footings that were constructed under the existing bridge while it remained in service. Wingwalls were constructed with block-outs to allow installation of the bridge with the block-outs filled in after the slide. Semi-integral abutments were used and the approach slabs were slid in with the bridge on sleeper slabs. Due to the existing and new bridge geometry, the sleeper slabs were located directly over the existing abutment. Enough of the exiting abutment was removed to provide a minimum of two feet of granular backfill between the top of the existing abutment and bottom of the sleeper slab. Slight adjustments were made to the abutment and end diaphragm details from the contract drawings to accommodate the slide system. A graduated disincentive was used for closure time penalties. This example draws from information provided in the SIBC Implementation Guide, Section 2.2. It illustrates how SIBC can significantly reduce traffic impacts and still be cost effective.

PLANNING PHASE ESTIMATE

Alternative Descriptions

Traditional Construction Alternative

This alternative is considered to be the baseline alternative. It is the anticipated project without any consideration of SIBC. The construction phasing would be to shift both directions of traffic to one side (i.e., EB and WB traffic on the EB route while the WB route is being reconstructed) and then the other. The proposed structure in this example is similar to the existing three-span bridge in length and width, which illustrates how the tool captures differences in bridge costs. Alternatively, the proposed structure could have been assumed to be a single span bridge with full height abutments.

Slide-In Bridge Construction Alternative

This alternative is similar to the Traditional Construction Alternative with the exception that the cost for bridges would differ due to SIBC. The proposed structure is a single span bridge with full height retaining abutments that can be constructed under the existing structure. The roadway construction is similar to the Traditional Construction Alternative. The calculations for the values used in the SIBC Cost Estimation Tool can be found in Figure A-1.

X, Estimated Bridge Cost

This value is estimated using a planning cost of $200 per square foot of deck area. This unit cost is a historical average of bridge cost in the state. The estimated area of each of the proposed bridges is 6,500 ft^2, which results in a total of 13,000 ft^2 for the bridge replacements. The Estimated Bridge Cost is $2,600,000.

$$X = 2,600,000$$

The bridge cost used is the proposed structure for the SIBC alternative. This value is used so that the estimated slide cost is based on the bridge used in the SIBC alternative.

F_X, Experience Factor

Six SIBC projects had been completed for UDOT prior to this project. UDOT Structures, which had not designed an SIBC project in-house, was slated to perform the bridge design. As a planning phase estimate, the experience of the eventual contractor and their slide designer would have been unknown. However, based on the experience of the industry it would be likely that they would have a strong understanding of the construction method as well as design and construction experience.   An appropriate Experience Factor is "Significant Combined Experience" (0.95).

$$F_X = 0.95$$

F$_S$, Site Complexity Factor

The site is relatively uncomplicated with few site complexities. The site is a diamond interchange, and the ramps are offset from the mainline in such a way that there is enough space in the ramp gore for construction of the temporary shoring for the proposed bridges. Based on this information an appropriate Site Complexity Factor is "Below Average Site Complexities" (0.95).

$$F_S = 0.95$$

F$_{TS}$, Temporary Shoring Factor

The contractor would be responsible for the temporary shoring design. The uncomplicated site would likely require an average amount of shoring to support the new superstructure at a grade separated height. Based on the high level of combined experience and ability to re-use materials, 0.80 is an appropriate value.

$$F_{TS} = 0.80$$

F$_J$, Vertical Jacking Factor

There was nothing to indicate the need for additional vertical movement of the two bridges.

$$F_J = 1.00$$

F$_A$, AADT/Undercrossing Factor

The AADT of SR-32 under I-80 is 2,845. This yields an AADT/Undercrossing Factor of 0.69.

$$F_A = 0.69$$

Number of Spans

The SIBC alternative has a single span structure.

$$1$$

This number is per bridge, not the sum of both EB and WB structures since both bridges are similar. If the bridges were not, separate SIBC cost estimations would need to be performed for each structure.

C, Contingency

In this example, the traditional project estimate includes a 20 percent contingency for construction costs not estimated. In addition, a 10 percent contingency is applied to the entire project cost estimate. In order to provide a proper comparison, the contingency value used in the spreadsheet is 20 percent and a 10 percent contingency will be applied to the entire cost of the alternative.

$$C = 20\%$$

S, Additional Site Costs

The items used to calculate this term are shown in detail in Figure A-2. The value includes cost savings from roadway crossovers, temporary retaining walls (along the phase line), and schedule savings of the contractor. It also includes cost increases from temporary retaining walls (for the abutments) and additional embankment. The negative number indicates a cost savings for the SIBC Alternative.

$$S = -\$103,000$$

D, Additional Bridge Construction Costs

The bridge in the SIBC Alternative is smaller than the bridge in the Traditional Construction Alternative. The difference in cost can be estimated using the difference in deck area and unit bridge cost. However, the bridge in the SIBC Alternative requires larger abutments than those that were typically used to establish the average unit cost. In this example, the additional concrete cost for the abutments will be added to more closely approximate the cost difference.

$$D = -\$536,000$$

A, Additional Administrative Costs

Additional agency costs include costs to design the bridge and oversee the construction. The SIBC Alternative is also estimated to have a three-month reduction in construction schedule by removing the bridges from the critical path of the project schedule. The reduction in construction duration is greater than the additional design engineering and construction management and inspection costs. Thus, the value is negative.

$$A = -\$40,000$$

I, Incentives/Disincentives

Based on previous projects, incentives were offered to the contractor for completing the slide ahead of schedule as well as disincentives for late completion of the slide. The expected value of the Incentives and Disincentive are:

- Incentive – $10,000 per hour up to 2 hours early
- Disincentive – $2,500 per hour up to 2 hours late, $5,000 per hour over 2 hours late.

Contractors may account for some disincentive in their bids to offset the costs of going over schedule. It was anticipated that the contracting community would not do this on this project due to the competitive bidding environment. Therefore, the appropriate value to use is the full incentive.

$$I = \$20,000$$

ALTERNATIVE COMPARISON

A comparison of the alternatives is shown in Table A-1 below. A 20 percent contingency for items not estimated was included, which reflects the preliminary nature of the project. In addition, a 10 percent contingency is included on the entire project. Project administration costs were estimated at 60% of the project construction costs. User costs were estimated by UDOT.

Table A-1
Comparison of Alternatives

Cost Type	Traditional Construction Alternative*	SIBC Alternative*	Notes
Construction Cost	$5,787,000	$5,787,000	
Items Not Estimated	$1,157,000	$1,157,000	20% of construction costs
Total Construction Cost	$6,944,000	$6,944,000	
Project Administration Cost	$4,166,000	$4,166,000	60% of total construction cost
Adjustment for SIBC	--	-$350,000	Value of E
Project Subtotal	$11,110,000	$10,760,000	
Project Contingency	$1,111,000	$1,076,000	10% of project subtotal
Total Project Cost	$12,221,000	$11,863,000	
User Costs	$831,000	$471,000	
Alternative Comparative Cost	$13,052,000	$12,307,000	

*Values are rounded to the nearest thousand.

Comparing the two options illustrates that SIBC provides a reduction in project costs and a significant reduction in user costs. Therefore, the SIBC Alternative is the preferred alternative.

Figure A-1
Sample SIBC Estimation Tool Output (Planning Phase)

Project: Wanship Bridge - Planning Phase   ABC
Number: 123456   2/6/2015

UDOT
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Estimated Slide Cost

Base Estimated Cost

Estimated Bridge Cost

This is the total estimated cost to construct the SIBC bridge. This estimated cost does not include the costs needed to slide the bridge into place. It also does not include any elements that would increase or decrease the cost of the project as a result of using SIBC methods.

$$X = \$2{,}600{,}000$$

Base Slide Cost Ratio

This percentage should be applied to all bridges considered for SIBC. When multiplied with the Estimated Bridge Cost (without the slide cost), the Base Slide Cost Ratio provides a base estimated slide cost for subsequent calculations.

$$B = 20\%$$

Base Estimated Slide Cost Subtotal (X*B) $520,000

Slide Cost Adjustment Factors

Experience Factor

This factor accounts for the combined level of experience of the owner, designer, and contractor in administrating and constructing a slide-in bridge project.

Little/No Combined Experience	1.05
Some Combined Experience	1.00
Significant Combined Experience	0.95

Select from the drop-down menu:

Significant Combined Experience	$F_X = 0.95$

Slide-In Bridge Construction
Cost Estimation Tool   1

U.S. Department of Transportation
Federal Highway Administration

Figure A-1 (Cont.)
Sample SIBC Estimation Tool Output (Planning Phase)

Project: Wanship Bridge - Planning Phase   ABC
Number: 123456   2/6/2015

LJDOT
Keeping Utah Moving

Cost Adjustment Factors (Cont.)

Site Complexity Factor

This factor accounts for differing site conditions that can affect the cost of SIBC. Site complexities can include soil quality, water, proximity to other structures or natural formations, limited construction staging areas, and other conditions.

Many/Large Site Complexities	1.10
Above Average Site Complexities	1.05
Typical Site Complexities	1.00
Below Average Site Complexities	0.95
Little to No Site Complexities	0.90

Select from the drop-down menu:

Below Average Site Complexities	F_S =	0.95

Temporary Shoring Factor

This factor accounts for the material and labor costs required to support the superstructure prior to and during the slide.

Large Quantity of Shoring Using New Materials	1.20
Average Quantity of Shoring Using New Materials	1.00
Small Quantity of Shoring Using New Materials	0.80
Large Quantity of Shoring Using Re-usable Materials	1.00
Average Quantity of Shoring Using Re-usable Materials	0.80
Small Quantity of Shoring Using Re-usable Materials	0.60

Select from the drop-down menu:

Average Quantity of Shoring Using Re-usable Materials	F_{TS} =	0.80

Vertical Jacking Factor

This factor is used when vertical jacking is required to move the bridge superstructure into its final position. A small amount of vertical jacking is required on most bridges to place bearings and finish superstructure placement. These small vertical movements should not be considered in this factor.

Additional Vertical Jacking Required	1.20
No Additional Vertical Jacking Required	1.00

Select from the drop-down menu:

No Additional Vertical Jacking Required	F_J =	1.00

Slide-In Bridge Construction
Cost Estimation Tool   2

U.S. Department of Transportation
Federal Highway Administration

Figure A-1 (Cont.)
Sample SIBC Estimation Tool Output (Planning Phase)

Project: Wanship Bridge - Planning Phase   ABC
Number: 123456   2/6/2015

Cost Adjustment Factors (Cont.)

AADT/Undercrossing Factor

This factor accounts for the effects of the undercrossing on a contractor's ability to slide the bridge into place. Natural ground, water, railroads, and AADT of the undercrossing can all affect the cost of SIBC.

Bridge Over Small Waterway or Dry Creek Bed	0.80
Bridge Over Railroad	0.90
Bridge Over Large Waterway or Canyon	1.00
Bridge Over Roadway: AADT = 0 - 10,000	0.6-0.9
Bridge Over Roadway: AADT = 10,000 - 100,000	0.9-1.1
Bridge Over Roadway: AADT = 100,000 +	1.10

First, select from the drop-down menu:

Bridge Over Roadway: AADT = 0 - 10,000

Then, enter AADT (if applicable - ranges need to match drop-down menu):

2845		F_A =	0.69

Modified Base Slide Ratio $(F_X*F_S*F_{TS}*F_J*F_A)$ F =   0.49

Modified Base Slide Ratio (B*F)   9.90%

Subtotal (X*B*F) $257,308

Number of Spans

Number of Spans   1

Contingency

Contingency C =   20%

A contingency is applied as a percentage of the Estimated Slide Cost. It accounts for unforeseen expenses in the construction of the bridge slide.

Total Estimated Slide Cost

$$(1 + C) * X * B * (F_X F_M F_S F_B F_{BE}) = \$308{,}769$$

Slide-In Bridge Construction
Cost Estimation Tool   3   U.S. Department of Transportation
                                                       Federal Highway Administration

Figure A-1 (Cont.)
Sample SIBC Estimation Tool Output (Planning Phase)

Project: Wanship Bridge - Planning Phase   ABC
Number: 123456   2/06/2015

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Additional Inputs

Provide Additional Calculations as Necessary

Additional Construction Costs

Additional Site Costs

Any additional specific quantifiable site costs or savings that affect the cost of SIBC. Additional site costs include right-of-way costs, utility relocations, cofferdams, and any other costs that can be specifically quantified. Additional site savings include costs that were not incurred as a result of using SIBC.

S =   -$103,000

Additional Bridge Construction Costs

Any additional specific quantifiable bridge construction costs or savings, which affect the cost of SIBC. Additional bridge construction costs include costs incurred through changes to bridge superstructure to accommodate SIBC (i.e., shallower girders, additional girder lines, concrete vs. steel, etc.) Additional bridge construction savings include costs that were not incurred as a result of using SIBC.

D =   -$536,000

Subtotal (S+D)   -$639,000

Additional Project Costs

Additional Administrative Costs

Any additional specific quantifiable administrative costs that affect the cost of SIBC. Additional administrative costs include additional design engineering costs, construction administration costs, DOT administration costs, etc.

A =   -$40,000

Incentives/Disincentives

Incentives and disincentives are determined by the agency at their own discretion.

I = $20,000

Subtotal (A+I)   -$20,000

Total Additional Costs

S + D **+** **A + I** **=** **-$659,000**

Slide-In Bridge Construction
Cost Estimation Tool   4

U.S. Department of Transportation
Federal Highway Administration

Figure A-1 (Cont.)
Sample SIBC Estimation Tool Output (Planning Phase)

Project: Wanship Bridge - Planning Phase   ABC
Number: 123456   2/06/2015
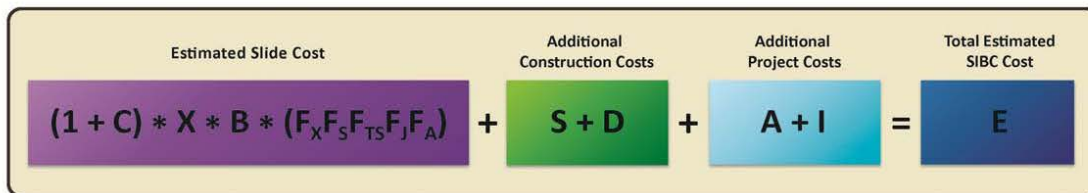
SIBC Cost Estimation Summary

Estimated Slide Cost

Estimated Bridge Cost		X =	$2,600,000
Base Slide Cost Ratio		B =	20.00%
Experience Factor, F_X		F_X =	0.95
Site Complexity Factor, F_s		F_S =	0.95
Temporary Shoring Factor, F_{TS}		F_{TS} =	0.80
Vertical Jacking Factor, F_J		F_J =	1.00
AADT/Undercrossing Factor, F_A		F_A =	0.69
Slide Cost Adjustment Factor	$(F_X*F_S*F_{TS}*F_J*F_A)$	F =	0.49
Modified Base Slide Ratio	(B*F)	=	9.90%
Number of Spans			1
Contingency		C =	20%
Total Estimated Slide Cost		=	$308,769

Additional Construction Costs

Additional Site Costs	S =	-$103,000
Additional Construction Costs	D =	-$536,000

Additional Project Costs

Additional Administrative Costs	A =	-$40,000
Incentives/Disincentives	I =	$20,000

Estimated Slide Cost		Additional Construction Costs		Additional Project Costs		Total Estimated SIBC Cost
$(1 + C) * X * B * (F_X F_S F_{TS} F_J F_A)$	+	S + D	+	A + I	=	E

Estimated Cost of SIBC	**E =**	**-$350,231**

Slide-In Bridge Construction
Cost Estimation Tool   5   U.S. Department of Transportation
                                                                    Federal Highway Administration

Figure A-2
Sample Calculations

LIDOT
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Project Name: I-80; Wanship to Coalville	Comp by: ABC	Date: 2/6/2015
Subject: Bridge Planning Calculations	Chk by: XYZ	Date: 2/6/2015
Project Number: F-I80-4(133)156		

X, Estimated Bridge Cost

Bridge Planning Unit Cost	200 $/SF		
Bridge Area, 3 Span Bridge w/Slope Paving	13000 SF		

Est. Bridge Cost - 3 Span Bridge	*Unit Cost * Bridge Area*	=	**$2,600,000**

S, Additional Site Costs

Additional Costs

Temporary Abutment Retaining Walls	=	$210,000
Additional Embankment	=	$100,000
Flowable Fill	=	$150,000

Total Additional Costs	*Sum of Addtional Costs*	=	$460,000

Cost Savings

Roadway Crossovers	=	-$344,000
Temporary Retaining Wall at Phase Line	=	-$30,000
Mobilization, MOT, Traffic Control, & General Conditions	=	-$189,000

Total Cost Savings	*Sum of Cost Savings*	=	-$563,000

Total Additional Site Costs	*Additional Costs + Cost Savings*	=	**-$103,000**

D, Additional Bridge Construction Costs

Reduction in Bridge Area for Single Span Bridge w/Full Height Abutments

Bridge Planning Unit Cost	200 $/SF
Bridge Area, Single Span w/Full Ht. Abuts.	8400 SF

Est. Bridge Cost - 3 Span Bridge	*(See Above)*	=	$2,600,000
Est. Bridge Cost - Single Span Bridge	*Unit Cost * Bridge Area*	=	$1,680,000

Savings from Reducing Bridge Area	*(1680000-2600000)*	=	-$920,000

1

Figure A-2 (Cont.)
Sample Calculations

Additional Concrete for Full Height Abutments

Additional Concrete Required	640	CY
Unit Cost of Concrete	600	$/CY

Additional Concrete Cost Required $Add\ Conc.*Unit\ Cost$ = $384,000

Total Additional Construction Costs $Sum\ of\ Add.\ Bridge\ Costs$ =   **-$536,000**

A, Additional Administrative Costs

Additional Engineering for SIBC

Additional Engineering Costs   = $40,000

Schedule Reduction
Based on a 3 month reduction in schedule

Schedule Reduction Savings   =   -$80,000

Total Additional Construction Costs $Sum\ of\ Add.\ Admin.\ Costs$ =   **-$40,000**

I, Incentives/Disincentives

Total Incentive - 2 hour early completion   =   **$20,000**

User Costs

Estimated Unit User Cost	2,770	$/Day
Estimated SIBC Construction Days	170	days
Estimated Traditional Construction Days	300	days

SIBC User Costs $User\ Unit\ Cost*SIBC\ Days$ = $470,900
Traditional Construction User Costs $User\ Unit\ Cost*Trad.\ Days$ = $831,000

User Cost Savings Due to SIBC $(470900-831000)$ =   **-$360,100**

2

Design Phase Estimate

X, Estimated Bridge Cost

The estimated bridge cost was estimated using the engineer's estimate that would be used in conjunction with the bidding advertisement of the project. See Table A-2 for details.

Table A-2
Estimated Bridge Cost

Bid Item	Quantity	Unit	Unit Price	Amount
Granular Backfill Borrow	500	cu yd	$70	$35,000
Remove Bridge	1	lump	$150,000	$150,000
Reinforcing Steel Coated	360,000	lb	$1.10	$396,000
Structural Concrete	1,900	cu yd	$600	$1,140,000
Structural Steel	213,000	lb	$2.50	$533,000
Electrical Work Bridges	1	lump	$10,000	$10,000
Move Prefabricated Bridge*	1	lump	*	*
Total				$2,264,000

*This is the bid item being estimated by the tool.

This bridge cost estimate does not include the flowable fill or temporary retaining wall costs so that X term is not artificially inflated (these costs were not included in the development of the tool). Some agencies may choose to include these costs in the bridge items when bidding. However, they should not be included when estimating the slide costs.

F_X, F_S, F_J, F_A, Terms

There were no changes to these terms from the planning to design phase.

F_{TS}, Temporary Shoring Factor

This factor was increased due to the expectation that the contractor will slide the approach slabs with the bridge and short traffic closure times. Additional details on sliding approach slabs with the bridge can be found in the SIBC Implementation Guide, Section 4.2.4.2.

$$F_{TS} = 1.00$$

C, Contingency

In this example, Contingency did not need to be included as the estimation practice in UDOT is to apply a contingency to the overall project construction cost.

$$C = 0\%$$

S, D, A, I Terms

These terms are set to zero when estimating the slide cost.

Figure A-3
Sample SIBC Estimation Tool Output (Design Phase)

Project: Wanship Bridge - Design Phase   ABC
Number: 123456   2/06/2015   **UDOT** *Keeping Utah Moving*

Estimated Slide Cost

Base Estimated Cost

Estimated Bridge Cost

     $X = \$2,264,000$

This is the total estimated cost to construct the SIBC bridge. This estimated cost does not include the costs needed to slide the bridge into place. It also does not include any elements that would increase or decrease the cost of the project as a result of using SIBC methods.

Base Slide Cost Ratio

     $B = 20\%$

This percentage should be applied to all bridges considered for SIBC. When multiplied with the Estimated Bridge Cost (without the slide cost), the Base Slide Cost Ratio provides a base estimated slide cost for subsequent calculations.

Base Estimated Slide Cost Subtotal (X*B)

     $\$452,800$

Slide Cost Adjustment Factors

Experience Factor

This factor accounts for the combined level of experience of the owner, designer, and contractor in administrating and constructing a slide-in bridge project.

Little/No Combined Experience	1.05
Some Combined Experience	1.00
Significant Combined Experience	0.95

Select from the drop-down menu:

Significant Combined Experience	$F_X = 0.95$

Slide-In Bridge Construction
Cost Estimation Tool   1   U.S. Department of Transportation **Federal Highway Administration**

Figure A-3 (Cont.)
Sample SIBC Estimation Tool Output (Design Phase)

Project: Wanship Bridge - Design Phase   **ABC**
Number: 123456   2/06/2015   *UDOT*
                                                    Keeping Utah Moving

Cost Adjustment Factors (Cont.)

Site Complexity Factor

This factor accounts for differing site conditions that can affect the cost of SIBC. Site complexities can include soil quality, water, proximity to other structures or natural formations, limited construction staging areas, and other conditions.

Many/Large Site Complexities	1.10
Above Average Site Complexities	1.05
Typical Site Complexities	1.00
Below Average Site Complexities	0.95
Little to No Site Complexities	0.90

Select from the drop-down menu:

Below Average Site Complexities	F_S =	0.95

Temporary Shoring Factor

This factor accounts for the material and labor costs required to support the superstructure prior to and during the slide.

Large Quantity of Shoring Using New Materials	1.20
Average Quantity of Shoring Using New Materials	1.00
Small Quantity of Shoring Using New Materials	0.80
Large Quantity of Shoring Using Re-usable Materials	1.00
Average Quantity of Shoring Using Re-usable Materials	0.80
Small Quantity of Shoring Using Re-usable Materials	0.60

Select from the drop-down menu:

Large Quantity of Shoring Using Re-usable Materials	F_{TS} =	1.00

Vertical Jacking Factor

This factor is used when vertical jacking is required to move the bridge superstructure into its final position. A small amount of vertical jacking is required on most bridges to place bearings and finish superstructure placement. These small vertical movements should not be considered in this factor.

Additional Vertical Jacking Required	1.20
No Additional Vertical Jacking Required	1.00

Select from the drop-down menu:

No Additional Vertical Jacking Required	F_J =	1.00

Slide-In Bridge Construction
Cost Estimation Tool   2   U.S. Department of Transportation
                                                Federal Highway Administration

Figure A-3 (Cont.)
Sample SIBC Estimation Tool Output (Design Phase)

Project: Wanship Bridge - Design Phase   ABC
Number: 123456   2/06/2015   *UDOT*
                                                                          Keeping Utah Moving

Cost Adjustment Factors (Cont.)

AADT/Undercrossing Factor

This factor accounts for the effects of the undercrossing on a contractor's ability to slide the bridge into place. Natural ground, water, railroads, and AADT of the undercrossing can all affect the cost of SIBC.

Bridge Over Small Waterway or Dry Creek Bed	0.80
Bridge Over Railroad	0.90
Bridge Over Large Waterway or Canyon	1.00
Bridge Over Roadway: AADT = 0 - 10,000	0.6-0.9
Bridge Over Roadway: AADT = 10,000 - 100,000	0.9-1.1
Bridge Over Roadway: AADT = 100,000 +	1.10

First, select from the drop-down menu:

Bridge Over Roadway: AADT = 0 - 10,000

Then, enter AADT (if applicable - ranges need to match drop-down menu):

2845 F_A =   0.69

Modified Base Slide Ratio $(F_X*F_S*F_{TS}*F_J*F_A)$ F =   0.62

Modified Base Slide Ratio (B*F)   12.37%

Subtotal (X*B*F) $280,070

Number of Spans

Number of Spans   1

Contingency

Contingency   C =   0%

A contingency is applied as a percentage of the Estimated Slide Cost. It accounts for unforeseen expenses in the construction of the bridge slide.

Total Estimated Slide Cost

$$(1 + C) * X * B * (F_X F_M F_S F_B F_{BE}) = \$280,070$$

Slide-In Bridge Construction
Cost Estimation Tool   3   U.S. Department of Transportation
                                                           Federal Highway Administration

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Figure A-3 (Cont.)
Sample SIBC Estimation Tool Output (Design Phase)

Project: XXXXXXXXXXX   Name   Agency Name or Logo
Number: ######   XX/XX/20XX

Additional Inputs

Provide Additional Calculations as Necessary

Additional Construction Costs

Additional Site Costs

Any additional specific quantifiable site costs or savings that affect the cost of SIBC. Additional site costs include right-of-way costs, utility relocations, cofferdams, and any other costs that can be specifically quantified. Additional site savings include costs that were not incurred as a result of using SIBC.

$$S \ = \qquad \$0$$

Additional Bridge Construction Costs

Any additional specific quantifiable bridge construction costs or savings, which affect the cost of SIBC. Additional bridge construction costs include costs incurred through changes to bridge superstructure to accommodate SIBC (i.e., shallower girders, additional girder lines, concrete vs. steel, etc.) Additional bridge construction savings include costs that were not incurred as a result of using SIBC.

$$D \ = \qquad \$0$$

Subtotal (S+D) $0

Additional Project Costs

Additional Administrative Costs

Any additional specific quantifiable administrative costs that affect the cost of SIBC. Additional administrative costs include additional design engineering costs, construction administration costs, DOT administration costs, etc.

$$A \ = \qquad \$0$$

Incentives/Disincentives

Incentives and disincentives are determined by the agency at their own discretion.

$$I \ = \qquad \$0$$

Subtotal (A+I) $0

Total Additional Costs

$$\boxed{S + D} \ + \ \boxed{A + I} \ = \qquad \$0$$

Slide-In Bridge Construction
Cost Estimation Tool   4   U.S. Department of Transportation
                                                              Federal Highway Administration

Figure A-3 (Cont.)
Sample SIBC Estimation Tool Output (Design Phase)

Project: Wanship Bridge - Design Phase   ABC
Number: 123456   2/06/2015

LIDOT Keeping Utah Moving

SIBC Cost Estimation Summary

Estimated Slide Cost

Estimated Bridge Cost	X	=	$2,264,000
Base Slide Cost Ratio	B	=	20.00%
Experience Factor, F_X	F_X	=	0.95
Site Complexity Factor, F_S	F_S	=	0.95
Temporary Shoring Factor, F_{TS}	F_{TS}	=	1.00
Vertical Jacking Factor, F_J	F_J	=	1.00
AADT/Undercrossing Factor, F_A	F_A	=	0.69
Slide Cost Adjustment Factor $(F_X*F_S*F_{TS}*F_J*F_A)$	F	=	0.62
Modified Base Slide Ratio $(B*F)$		=	12.37%
Number of Spans			1
Contingency	C	=	0%
Total Estimated Slide Cost		=	$280,070

Additional Construction Costs

Additional Site Costs	S	=	$0
Additional Construction Costs	D	=	$0

Additional Project Costs

Additional Administrative Costs	A	=	$0
Incentives/Disincentives	I	=	$0

Estimated Slide Cost		Additional Construction Costs		Additional Project Costs		Total Estimated SIBC Cost
$(1 + C) * X * B * (F_X F_S F_{TS} F_J F_A)$	+	$S + D$	+	$A + I$	=	E
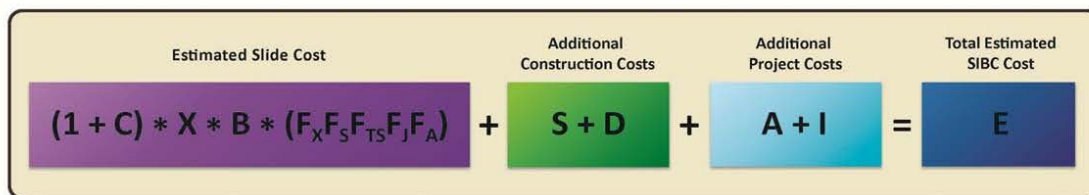
Estimated Cost of SIBC	E	=	$280,070

*Slide-In Bridge Construction
Cost Estimation Tool*   5

U.S. Department of Transportation
Federal Highway Administration

SIBC Estimation Tool Comparison

Planning Phase Estimate

During the planning phase, the slide costs were estimated to be $257,308. The bridge cost was estimated to be $2,600,000. This gives a slide cost to bridge cost ratio of 9.9 percent. If the 20 percent contingency is included, the slide costs estimate is $308,769 and the slide cost to bridge cost ratio becomes 11.9 percent.

This is a relatively low slide cost as compared to other SIBC projects. If the average cost was used (B = 20 percent) the slide costs would have been estimated at $520,000 or an additional $262,692 (without contingency included). The cost adjustment factors (F) clearly identify what contributed to the lower cost. The primary conditions that affected the cost are the ability of the contractor to use cost effective shoring and the low traffic volumes of the undercrossing.

Design Phase Estimate

During the design phase, the slide costs were estimated to be $280,070 and the bridge cost was estimated to be $2,264,000. This gives a slide cost to bridge cost ratio of 12.37 percent. These values do not include any contingency.

The actual slide cost bid by the winning contractor was approximately $312,000. By comparing the example calculations to real world results, the estimate of the tool is 89 percent of the actual bid. If the 10 percent contingency of the project is included, the slide cost estimate becomes $308,077, which is 99 percent of the actual bid.

Appendix B:
Sample Calculations 2

Larpenteur Avenue Bridge, Minnesota

These sample calculations are a hypothetical situation based on a real world project to illustrate how this tool could have been used to evaluate a contractor's Alternative Technical Concept (ATC) on a Design-Build project. The information contained herein may not necessarily reflect actual details of the project.

PROJECT DESCRIPTION

Construction Year: 2014
Owner: Minnesota Department of Transportation (MnDOT)
Contractor: Ames Construction, Inc.
Designer: Michael Baker International
Contracting Method: Design-Build
SIBC Construction Type: Hydraulic Jacks

This bridge replacement was part of a Design-Build project, which included nine bridge replacements (three bridges over I-35E, three I-35E NB bridges, and three I-35E SB bridges), roadway widening, and other improvements along the interstate corridor.

The Larpenteur Avenue Bridge carrying local traffic over I-35E was selected to be replaced using the SIBC method. The use of SIBC for this particular bridge enabled the contractor to reduce the duration of the bridge closure (over traditional construction), and to complete the construction of the bridges over I-35E and the NB bridges in the project in one construction season, leaving the SB bridges to be constructed in the following construction season. The existing four-span Larpenteur Avenue bridge carries four lanes of moderate volume traffic over six lanes of interstate (I-35E) in an urban area and was to be replaced by a proposed two-span bridge.

The proposed bridge includes a two-span pre-stressed concrete superstructure with a continuous deck, a reinforced concrete pier, and reinforced concrete semi-integral abutments. The proposed substructures are all founded on spread footings. MnDOT's standard details required a few modifications in order to accommodate the SIBC construction. The wingwalls were constructed with block-outs to allow the proposed superstructure to slide past, and these block-outs required an additional concrete pour after the slide was completed. Modifications were also made to the owner's standard semi-integral abutment diaphragm and a split diaphragm was incorporated at the pier to allow the bridge spans to continue to act as simple spans.

The contractor's team elected to utilize temporary steel pile bents to support the proposed superstructure in the temporary position adjacent to the existing bridge. While the existing bridge remained in service, the temporary steel pile bents were constructed, and the proposed bridge superstructure was constructed in the temporary position. As the deck cured on the proposed superstructure, the existing bridge was closed and demolished, and the proposed substructures were constructed. After the proposed substructure concrete and the proposed superstructure concrete achieved strength the proposed superstructure was pushed into place using hydraulic jacks.

BACKGROUND

The Request for Proposal (RFP) provided by MnDOT outlined the required criteria to replace the existing four-span Larpenteur Avenue Bridge with a new structure to accommodate increased traffic needs. The RFP provided the bidders with all requirements for the new bridge including cross section and location for construction.

The contractor proposed an Alternative Technical Concept (ATC) that included the use of SIBC technology to construct the bridge. The proposed bridge was a two-span concrete girder bridge with full height cantilever abutments. The superstructure would be constructed to the side of the existing bridge and slid into place using hydraulic jacks. The proposed ATC significantly reduced the duration of the bridge closure. The proposed ATC also enabled the construction of the bridges over I-35E and the I-35E NB bridges to be completed in the first construction season and reduced the number of times the MOT configuration would need to be changed.

These sample calculations simulate how this tool could have been used by MnDOT to evaluate the contractor's proposal. Similarly, this tool could have been used by the contractor to develop the ATC or provide an independent cost comparison.

ALTERNATIVE TECHNICAL CONCEPT EVALUATION

X, Estimated Bridge Cost

A detailed cost estimate for the bridge would not be available at this stage so an estimated bridge unit cost could be estimated. The value used is $180 per square foot of deck area. The estimated area of the proposed bridge is 14,200 ft^2. Therefore, the Estimated Bridge Cost is $2,556,000.

$$X = 2,556,000$$

F_X, Experience Factor

MnDOT did not have any SIBC experience prior to this project. The bridge slide was proposed as an ATC by the contractor/design team who had some design experience and small amount of construction experience. The combined experience gives an appropriate Experience Factor of "Little/No Experience" (1.05).

$$F_X = 1.05$$

F_S, Site Complexity Factor

The site is a grade-separated interchange with Larpenteur Avenue crossing over I-35E. Larpenteur Avenue was closed and demolished prior to construction of the new abutments. This provided the contractor with sufficient space to construct temporary shoring to support the proposed bridge at the abutments. I-35E was required to remain open to traffic, which presented a particularly restricted work zone for the construction of temporary shoring at the pier in the center median of the I-35E. Based on this information an appropriate Site Complexity Factor is "Above Average Site Complexities" (1.05).

$$F_S = 1.05$$

F_{TS}, Temporary Shoring Factor

A multi-span bridge requires more shoring than a single span bridge. Because multi-span bridges are generally more expensive than single span bridges, the Base Slide Cost Factor accounts for some additional shoring at the piers. Thus, the site required only an average amount of shoring to support the new superstructure with supports at the abutments and center pier. The contractor required new materials for the temporary shoring. An appropriate Temporary Shoring Factor is "Average Quantity of New Materials" (1.00).

$$F_{TS} = 1.00$$

F_J, Vertical Jacking Factor

The temporary shoring was designed in such a way that additional vertical movement of the bridge was not required.

$$F_J = 1.00$$

F_A, AADT/Undercrossing Factor

The AADT of I-35E under Larpenteur Avenue is 142,000. This yields an AADT/Undercrossing Factor of 1.10 for the project.

$$F_A = 1.10$$

Number of Spans

The proposed bridge is a two-span structure.

$$2$$

C, Contingency

This example was used by the agency to evaluate a contractor proposed concept and not a final design. A 10 percent contingency was included to account for unknowns in the SIBC process.

$$C = 10\%$$

S, Additional Site Costs

A fiber optic communication line required relocation away from the temporary pile foundation. The cost was estimated at $20,000. The slide would most likely require some additional cost for traffic control; however, the reduction in the overall schedule would provide savings due to reduction in traffic control. For this example, these costs are assumed to offset; although, it is likely that the reduction in schedule would provide more savings than the additional cost required by the SIBC method.

$$S = \$20,000$$

D, Additional Bridge Construction Costs

In this example, no additional bridge construction costs were included. However, additional design engineering would be required from the contractor/design team. These costs are estimated to be $30,000 and included in this term. Note that these are not physical construction costs but will be included in the contractor's bid. In a traditional delivery method (Design-Bid-Build), these costs would be included in the A term, Additional Administrative Costs.

$$D = \$30,000$$

A, Additional Administrative Costs

MnDOT calculated the Additional Administrative Costs required for the ATC. The agency had no prior SIBC experience and had not developed standards for design, plans, and specifications.   Thus, a significant amount of additional staff was required to evaluate acceptance of the SIBC design and shop drawings. Additional engineering review, construction management, and construction inspection costs were estimated at $50,000. A reduction in costs due to a shortened construction schedule will not be considered in this example.

$$A = \$50,000$$

I, Incentives/Disincentives

Incentives and disincentives were not a part of the contractor ATC and are not applicable in this example.   Note that MnDOT could have accepted the ATC with conditional approval that included incentives or disincentives.

SUMMARY

The SIBC Cost Estimation Tool calculated an Estimated Cost of SIBC (E) of $781,954 for the project. This value represents the additional cost (delta) of using SIBC methods on the bridge as compared to the baseline conditions of the RFP. This tool estimated the cost to slide the superstructure at $681,954 (with 10 percent contingency). This example illustrates that the slide cost for multi-span bridges is comparable to single span bridges in terms of the slide cost to bridge cost ratio.

Using SIBC, MnDOT was able to shorten the construction schedule, which reduced traffic impacts and provided the added benefit of increased safety for both the contractor and travelling public. MnDOT was also able to use the project to gain institutional knowledge and experience with ABC. Ultimately, MnDOT determined that these benefits outweighed the additional costs required and elected to approve the ATC.

Figure B-1
Sample SIBC Estimation Tool Output

Project: Larpenteur Avenue Bridge - ATC Evaluation   ABC
Number: 123456   2/06/2015

Estimated Slide Cost

Base Estimated Cost

Estimated Bridge Cost

This is the total estimated cost to construct the SIBC bridge. This estimated cost does not include the costs needed to slide the bridge into place. It also does not include any elements that would increase or decrease the cost of the project as a result of using SIBC methods.

$$X = \$2,556,000$$

Base Slide Cost Ratio

This percentage should be applied to all bridges considered for SIBC. When multiplied with the Estimated Bridge Cost (without the slide cost), the Base Slide Cost Ratio provides a base estimated slide cost for subsequent calculations.

$$B = 20\%$$

Base Estimated Slide Cost Subtotal (X*B)

$$\$511,200$$

Slide Cost Adjustment Factors

Experience Factor

This factor accounts for the combined level of experience of the owner, designer, and contractor in administrating and constructing a slide-in bridge project.

Little/No Combined Experience	1.05
Some Combined Experience	1.00
Significant Combined Experience	0.95

Select from the drop-down menu:

Little/No Combined Experience

$$F_X = 1.05$$

Slide-In Bridge Construction
Cost Estimation Tool   1   U.S. Department of Transportation
                                                              Federal Highway Administration

Figure B-1 (Cont.)
Sample SIBC Estimation Tool Output

Project: Larpenteur Avenue Bridge - ATC Evaluation   ABC
Number: 123456   2/06/2015

Cost Adjustment Factors (Cont.)

Site Complexity Factor

This factor accounts for differing site conditions that can affect the cost of SIBC. Site complexities can include soil quality, water, proximity to other structures or natural formations, limited construction staging areas, and other conditions.

Many/Large Site Complexities	1.10
Above Average Site Complexities	1.05
Typical Site Complexities	1.00
Below Average Site Complexities	0.95
Little to No Site Complexities	0.90

Select from the drop-down menu:

Above Average Site Complexities

F_S =   1.05

Temporary Shoring Factor

This factor accounts for the material and labor costs required to support the superstructure prior to and during the slide.

Large Quantity of Shoring Using New Materials	1.20
Average Quantity of Shoring Using New Materials	1.00
Small Quantity of Shoring Using New Materials	0.80
Large Quantity of Shoring Using Re-usable Materials	1.00
Average Quantity of Shoring Using Re-usable Materials	0.80
Small Quantity of Shoring Using Re-usable Materials	0.60

Select from the drop-down menu:

Average Quantity of Shoring Using New Materials

F_{TS} =   1.00

Vertical Jacking Factor

This factor is used when vertical jacking is required to move the bridge superstructure into its final position. A small amount of vertical jacking is required on most bridges to place bearings and finish superstructure placement. These small vertical movements should not be considered in this factor.

Additional Vertical Jacking Required	1.20
No Additional Vertical Jacking Required	1.00

Select from the drop-down menu:

No Additional Vertical Jacking Required

F_J =   1.00

Slide-In Bridge Construction
Cost Estimation Tool   2

U.S. Department of Transportation
Federal Highway Administration

Figure B-1 (Cont.)
Sample SIBC Estimation Tool Output

Project: Larpenteur Avenue Bridge - ATC Evaluation   ABC
Number: 123456   2/06/2015

Cost Adjustment Factors (Cont.)

AADT/Undercrossing Factor

This factor accounts for the effects of the undercrossing on a contractor's ability to slide the bridge into place. Natural ground, water, railroads, and AADT of the undercrossing can all affect the cost of SIBC.

Bridge Over Small Waterway or Dry Creek Bed	0.80
Bridge Over Railroad	0.90
Bridge Over Large Waterway or Canyon	1.00
Bridge Over Roadway: AADT = 0 - 10,000	0.6-0.9
Bridge Over Roadway: AADT = 10,000 - 100,000	0.9-1.1
Bridge Over Roadway: AADT = 100,000 +	1.10

First, select from the drop-down menu:

Bridge Over Roadway: AADT = 100,000 +

Then, enter AADT (if applicable - ranges need to match drop-down menu):

142000 F_A =   1.10

Modified Base Slide Ratio $(F_X * F_S * F_{TS} * F_J * F_A)$ F =   1.21

Modified Base Slide Ratio (B*F)   24.26%

Subtotal (X*B*F) $619,958

Number of Spans

Number of Spans   2

Contingency

Contingency   C =   10%

A contingency is applied as a percentage of the Estimated Slide Cost. It accounts for unforeseen expenses in the construction of the bridge slide.

Total Estimated Slide Cost

$$(1 + C) * X * B * (F_X F_M F_S F_B F_{BE}) = \$681,954$$

Slide-In Bridge Construction
Cost Estimation Tool   3

U.S. Department of Transportation
Federal Highway Administration

Figure B-1 (Cont.)
Sample SIBC Estimation Tool Output

Project: Larpenteur Avenue Bridge - ATC Evaluation   ABC
Number: 123456   2/06/2015

Additional Inputs

Provide Additional Calculations as Necessary

Additional Construction Costs

Additional Site Costs

Any additional specific quantifiable site costs or savings that affect the cost of SIBC. Additional site costs include right-of-way costs, utility relocations, cofferdams, and any other costs that can be specifically quantified. Additional site savings include costs that were not incurred as a result of using SIBC.

| S | = | $20,000 |

Additional Bridge Construction Costs

Any additional specific quantifiable bridge construction costs or savings, which affect the cost of SIBC. Additional bridge construction costs include costs incurred through changes to bridge superstructure to accommodate SIBC (i.e., shallower girders, additional girder lines, concrete vs. steel, etc.) Additional bridge construction savings include costs that were not incurred as a result of using SIBC.

| D | = | $30,000 |

Subtotal (S+D) $50,000

Additional Project Costs

Additional Administrative Costs

Any additional specific quantifiable administrative costs that affect the cost of SIBC. Additional administrative costs include additional design engineering costs, construction administration costs, DOT administration costs, etc.

| A | = | $50,000 |

Incentives/Disincentives

Incentives and disincentives are determined by the agency at their own discretion.

| I | = | $0 |

Subtotal (A+I) $50,000

Total Additional Costs

$$ S + D \; + \; A + I \; = \; \$100,000 $$

Slide-In Bridge Construction
Cost Estimation Tool   4   U.S. Department of Transportation
                                                           Federal Highway Administration

Figure B-1 (Cont.)
Sample SIBC Estimation Tool Output

Project: Larpenteur Avenue Bridge - ATC Evaluation   ABC
Number: 123456   2/06/2015
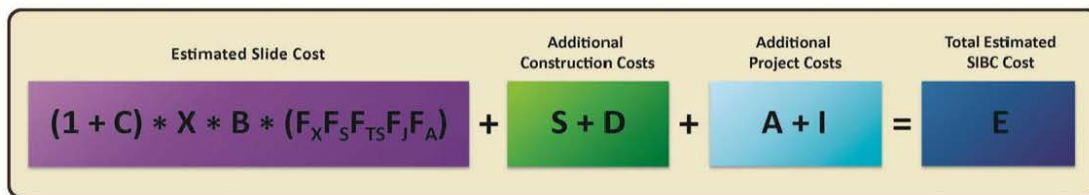
SIBC Cost Estimation Summary

Estimated Slide Cost

Estimated Bridge Cost	X =	$2,556,000
Base Slide Cost Ratio	B =	20.00%
Experience Factor, F_X	F_X =	1.05
Site Complexity Factor, F_s	F_S =	1.05
Temporary Shoring Factor, F_{TS}	F_{TS} =	1.00
Vertical Jacking Factor, F_J	F_J =	1.00
AADT/Undercrossing Factor, F_A	F_A =	1.10
Slide Cost Adjustment Factor $(F_X*F_S*F_{TS}*F_J*F_A)$	F =	1.21
Modified Base Slide Ratio $(B*F)$	=	24.26%
Number of Spans		2
Contingency	C =	10%
Total Estimated Slide Cost	=	$681,954

Additional Construction Costs

Additional Site Costs	S =	$20,000
Additional Construction Costs	D =	$30,000

Additional Project Costs

Additional Administrative Costs	A =	$50,000
Incentives/Disincentives	I =	$0

$$(1 + C) * X * B * (F_X F_S F_{TS} F_J F_A) + S + D + A + I = E$$

Estimated Slide Cost	Additional Construction Costs	Additional Project Costs	Total Estimated SIBC Cost

Estimated Cost of SIBC   E = $781,954

Slide-In Bridge Construction
Cost Estimation Tool   5   U.S. Department of Transportation
                                                                     Federal Highway Administration

Figure B-2
Sample Calculations

Project Name: Larpenteur Avenue Bridge	Comp by: ABC	Date: 2/6/2015
Subject: Bridge Planning Calculations	Chk by: XYZ	Date: 2/6/2015
Project Number:		

X, Estimated Bridge Cost

Bridge Planning Unit Cost	180 $/SF		
Bridge Area, 2 Span Bridge	14200 SF		

Est. Bridge Cost - 2 Span Bridge	*Unit Cost * Bridge Area*	=	**$2,556,000**

S, Additional Site Costs

Fiber Optic Cable Relocation	=	$20,000
Total Additional Site Costs	=	**$20,000**

D, Additional Bridge Construction Costs

Additional Engineering (Part of Contractor Bid)	=	$30,000
Total Additional Bridge Construction Costs	=	**$30,000**

A, Additional Administrative Costs

Engineering Review	=	$15,000
Construction Management & Inspection		$35,000

Cost savings from schedule reduction is unavailable

Total Additional Construction Costs	*Sum of Add. Admin. Costs*	=	**$50,000**

I, Incentives/Disincentives

No Incentives or Disincentives

1