Programmatic use of ABC

Module 2:

ABC Time and Cost Estimating

Michael Culmo, PE
Chief Bridge Engineer
CHA Consulting, Inc.

This module focuses on a recommended methods for estimating time and costs for ABC projects.

The basis of this module is the FHWA manual entitled “Accelerated Bridge Construction - Experience in Design, Fabrication, and Erection of Prefabricated Bridge Elements and Systems” and the “2018 AASHTO LRFD Guide Specifications for ABC”.

Module 2: ABC Time and Cost Estimating

This module covers:

- Factors that affect costs
  - Risk, complexity, etc.
- Factors that affect speed
  - Experience, complexity, etc.
- Ways to offset ABC costs:
  - Mitigation strategies
- Common ABC contracting provisions

The second module of this workshop covers:

- Things that affect costs on ABC projects
- Things that affect the time of construction
- Common ABC Contracting Provisions

ABC Cost and Time

Normally we say:
Time = money

Meaning more time means more money

ABC is somewhat different:

Less time often means more money (higher bid), but not always

Why is this so?
Let's explore this

A common phrase in the business world is "Time is money", meaning that more time on any task typically costs more. In the ABC world, this is not necessarily the case. In many cases less time, meaning faster construction, can lead to higher costs.

In the following slides, we'll explore this phenomenon.

How Much Does ABC Construction Cost?

It depends…..

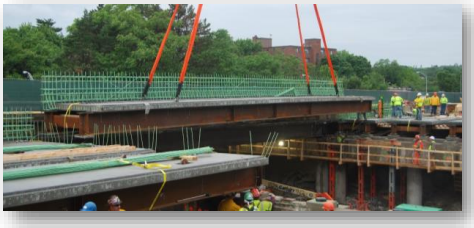
How fast is fast
- Build a bridge in a weekend: Very expensive
- Build a bridge in two weeks: Not too expensive
- Build a bridge in a month: Can be the same price

Overtime pay
- Weekends, nights

Details
- Complex details tend to be more expensive

Site conditions
- Difficult sites can lead to higher costs

Equipment
- Specialized equipment is pricey



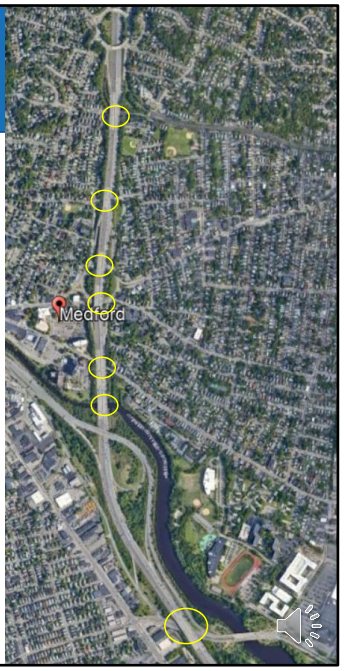
At virtually every ABC presentation to date, the first question that is typically asked is: “How much does ABC Cost?” There is not an easy answer to this question. There are several key factors that affect the costs of ABC projects:

- How fast do your “need” to get the project done?: The faster the construction, the higher the cost in most cases.
- Overtime pay: Working nights and weekends leads to higher labor costs due to overtime pay requirements.
- Details: Complex details can lead to higher prices.
- Site conditions: Small work zones can make construction more difficult and costly.
- Equipment: Specialized equipment such as self-propelled modular transporters are costly to rent.

Project Example: Very Fast

Project Information

- 93Fast14
- I-93 Just north of “Big Dig”
  - 180,000 ADT
- Bridges built in late 1950’s
- Decks were shot
- 14 Bridges
  - 7 Pairs of two: 7 NB, 7 SB
  - Most were 3-span bridges with joints
  - All are steel stringer bridges
    - Needed repairs and painting due to leaking deck joints



Let us explore an example project that was built very fast.

The project, named the 93Fast14, consisted of the replacement of 14 bridges carrying I-93 over local roads and one river in the town of Medford MA. I-93 is a very busy highway with average daily traffic volumes of approximately 180,000 vehicles. The project site is located just north of Boston.

The project initially started as a deck replacement project, but soon evolved into a superstructure replacement project. There were 14 bridges, seven in the northbound direction and seven in the southbound direction. Most of the bridges were three-span units. All were steel stringer bridges.

The goal of the project was to replace 14 bridges in 10 consecutive weekends, with a 55-hour work window. This meant that on several weekends, two bridges were replaced at a time. This is a very challenging project with a difficult site and a very tight construction window.

This project was bid as a design-build project. The base technical concept plans showed the use of modular deck beams for the new superstructure. The contractor elected to use this system for the final design.

Project Approach

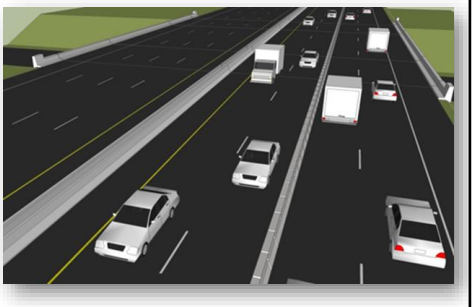
- Replace entire superstructures
- Accelerate construction to minimize mobility impacts to I-93 Traffic
- Limit work to weekends and nights
- Keep 8 lanes open during the weekday rush hours

The approach to the project was to replace the entire superstructures while minimizing impacts on travelers on I-93.

Lane closures were limited to weekends and nights. Project specifications required that eight lanes of traffic be open during weekday rush hours.

Traffic Management

- Close entire bound during weekends
  - 55-hour closure
    - Give entire other bound over to the contractor
  - Production:
    - Two bridges per weekend
- Cross overs were constructed at each end of the project limits
  - 6 miles apart



During the 55-hour weekend construction periods, the contractor was allowed to close one entire side of the Interstate and cross traffic over to the opposite side of the highway. The contractor was allowed to use this configuration for the entire six-mile limit of the project. This freed up a six-mile-long work zone for the contractor to stage equipment and materials during the weekend closure, which made the ABC project possible.

The graphic on the right depicts the traffic management configuration.

Construction Sequence

Friday night, 9:00 pm – Demolition begins

This photo shows the demolition of one of the bridges. As you can see, accelerated demolition involves a significant amount of equipment. The contractor was able to demolish a four-lane three-span bridge in under 8 hours using this approach.

Another item of note is that several beams are supported by temporary shoring columns. This was done to facilitate the construction of new beam seats prior to the demolition of the bridge. Once the shoring was in place, the bottom flange of the beam was cut away to facilitate the concrete work.

Construction Sequence

Friday night – Beam removal and cutting

These photos show the removal of the beams that were over 80 feet long. Specialized equipment was used for this process, including a very large excavator equipped with a large hydraulic shear. This machine was able to lift an 80-foot beam, lay it on the ground, and shear it in half in approximately 30 seconds. From there, the pieces were lifted onto a flatbed trailer and hauled off the site immediately.

This is an example of the use of specialized equipment. The excavator used was not a normal excavator, but it did accelerate the construction significantly.

Construction Sequence

Saturday morning, 7:00 am – Demolition complete

This photo shows the aftermath of the demolition on Saturday morning. The temporary shoring columns are still in place, and the new beam seats are protected with timber. The reason that not every beam was shored is that the proposed beam spacing did not match the existing beam spacing. In the center portion of the bridge, the new beam seats fell between the existing beam seats, therefore shoring was not required.

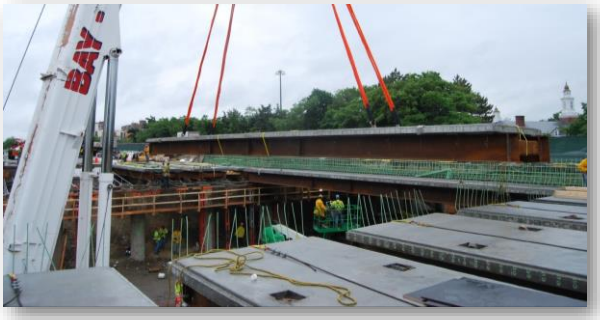
Construction Sequence

Saturday morning - Erection begins

This photo shows the beginning of the erection of the prefabricated beam elements in the far span. The photographer in the foreground is a Massachusetts DOT outreach staff person recording the construction for use on the project website.

Construction Sequence

Saturday afternoon – Erection continues



This photo was taken early on Saturday afternoon, showing the erection of a prefabricated beam element for the middle span.

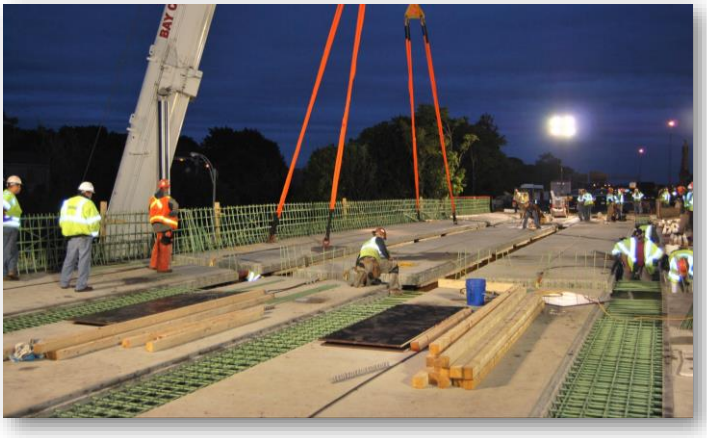
Construction Sequence

Saturday afternoon – Closure joint forming and placement of reinforcement

This photo shows the installation of reinforcing steel in the closure joints on Saturday afternoon. The contractor elected to use threaded dowel bar splicers for the projecting bars on the deck elements.

Construction Sequence

Saturday early evening – Placement of last modular deck beam



The photograph shows the final modular deck beam installation in the early evening of Saturday. The forming of the closure joints and placement of the reinforcing steel it is progressing as well.

Construction Sequence

Sunday morning – Placement of high early strength concrete in closure joints

This photograph shows the placement of high early strength concrete in the closure joints on Sunday morning. A specialized mix that was developed by the contractor was used that gained sufficient strength in under 4 hours.

The design of the closure joint was based on a concrete compressive strength of 2500 PSI. The contractor was allowed to place traffic on the bridge once this strength was achieved. The mix was still specified to have a 28-day compressive strength of 4000 PSI. With the rapid strength gain of early age concrete, it is relatively easy to achieve a strength of 2500 PSI, and the design of the reinforcing steel in the joint is barely changed.

This approach is called “interim strength design” and is included in the provisions of the *2018 AASHTO LRFD Guide Specifications for ABC*.

Construction Sequence

Sunday morning – Curing of closure joints

This photograph shows the completed bridge by mid-afternoon on Sunday. Temporary barriers were placed in the shoulders to allow for construction of the permanent barriers (a time-consuming process) after the bridge was opened to traffic.

Construction Sequence

Completed bridge

These photos show one of the completed bridges. One item of note is that there are no deck joints with these modular deck units. This design incorporated the use of link slabs that provide a jointless deck.

Project Example: Very fast

Bid cost information

- ABC was 80% more expensive than conventional construction
- Why?
  - Very tight timeframe
  - Large structures built in a weekend
  - I/Ds
    - Incentive: $1,000,000 per weekend if completed before Monday morning
    - Disincentive: $1,000,000 per weekend if not
- Why was this a cost success?
  - Conventional construction would have been 5 years
  - Built in one year
  - CEI and traffic management costs for 4 years were found to be similar to the ABC premium

As previously stated, this is an example of a very fast construction project. The cost for the replacement of these bridges was approximately 80% more than conventional construction. The reasons can be attributed to the following items:

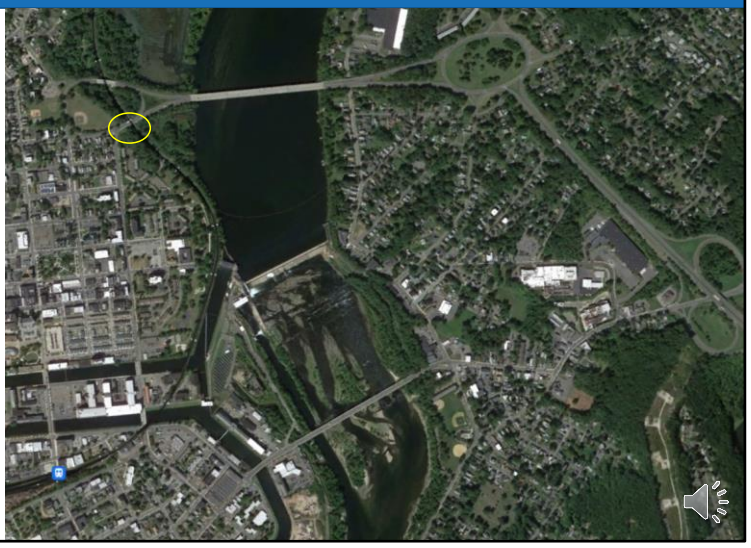
1. The construction was based on a very tight schedule.
2. These were large bridges built in a fairly tight works zone. In fact, on several weekends multiple bridges were required to be replaced, which added to the complexity.
3. There were significant disincentive clauses built into this project. If the contractor was late in opening the highway on Monday morning, a $1,000,000 disincentive fee would be assessed to the contract.

Massachusetts Department of Transportation considered this project to be very successful, even with the significant premium on cost. The reason for this was that conventional construction would have taken five years. The cost of construction engineering and management combined with traffic management over five years would have led to an overall project cost that was similar to the premium paid for the accelerated bridge construction.

Project Example: Moderately fast

Location: Holyoke, MA

- Busy area
- Road was essentially a bypass for a busy “downtown”
- Adjacent to a major river crossing
- Detouring traffic was not an option
- There was sufficient width to stage the construction
- One-way traffic as part of a larger rotary
- The department wanted to build this in one season to avoid plowing snow through the work zone in the winter.
- ABC was used to accomplish this, but very fast construction was not necessary.



Now we will look at a project with a moderately fast construction time frame. This bridge project is also located in Massachusetts. This one-way bridge spans over a railroad near a major river crossing just north of the city of Holyoke MA. Detouring of traffic at the site would have caused significant difficulties to local travelers.

Project Example: Moderately fast

MassDOT PBE project: 3-span bridge replacement

- Project approach
  - Use staged (or phased) construction
  - ABC light (not too fast)
  - Replace the bridge in one construction season
    - Avoid snow plowing issues during the winter shutdown
- Adjacent to a very similar bridge
  - Built one year previously
  - Conventional construction
  - Staged construction
- Great opportunity for cost comparison!

The bridge is a three-span structure. The entire structure was scheduled to be replaced.

There was significant width on the bridge to maintain one lane of traffic while using two stages of construction. ABC was employed because the department desired to complete the construction prior to a winter shutdown.

This example was chosen because it is an excellent opportunity to compare accelerated bridge construction to conventional bridge construction. Within the same area, there is a nearly identical bridge crossing the same feature that was constructed a few years before. The previous bridge was built using conventional construction with staging. The photo on the right shows that bridge halfway through construction.

Project Example: Moderately fast

This is a more close-up view showing the two bridges. The conventional construction bridge is shown on the right. The proposed accelerated bridge construction structure is shown on the left.

Project Example: Moderately fast

Project Goals

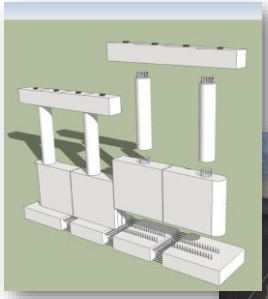
- Practice project: Try various prefabricated technologies
  - Precast footings
  - Precast pier: crash walls, columns, and caps
  - Precast integral abutments
  - Precast full-depth deck panels with post-tensioned connections
  - Precast approach slabs
- Three span continuous steel girders

This project was part of the early Massachusetts DOT accelerated bridge program. One of the goals of this project was to try out several different accelerated bridge construction technologies including:

1. Precast spread footings
2. Precast piers
3. Precast integral abutments
4. Precast full-depth deck panels with longitudinal post-tensioning
5. Precast approach slabs.

The only significant cast-in-place concrete was the sidewalks and the bridge barriers. The girders were three-span continuous steel plate girders.

Project Example: Moderately fast



The graphic on the left shows an exploded view of one of the proposed precast concrete piers.

The center photo shows the construction of one of the piers.

The right photo shows the construction of the precast deck.

Project Example: Moderately fast

Bid cost information

- Conventional construction bridge: $224 per square foot
- PBES bridge: $284 per square foot
- Understand that these are northeast prices
  - Prices in other regions will vary significantly
- Cost differential
  - ABC was 27% more than conventional construction
  - Why?
    - Complex post-tensioning system on the deck
    - We would use more simple closure joints now
- Total project costs can offset this cost increase
  - This will be discussed in Module 3

The cost per square foot for the nearby conventional construction bridge was $224 per square foot. The cost for the prefabricated bridge was $284 per square foot. It is important to understand that these are northeast bridge prices. Costs and other parts of the US may vary significantly.

Based on these numbers, the accelerated bridge construction bridge was 27% more expensive than conventional construction. The reason for the cost differential can be partially attributed to the complexity of the deck. At the time this bridge was constructed longitudinal post-tensioning was common. This system is very durable, but it is also pricey. Since this project was built, more cost-effective systems have been developed including UHPC connections and high early strength concrete connections. It is anticipated that decks without post-tensioning might be more cost-effective, bringing the cost for prefabrication more in line with conventional construction.

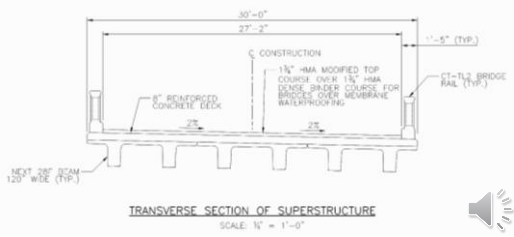
In Module 3, we will discuss ways to offset these costs by investigating total project costs.

Project Example: Comfortably fast

MassDOT PBE project:

Single Span Bridge Replacement

- Project approach
  - Close road and set up a detour
  - Accelerated construction (to a degree)
  - Use prefabricated elements
    - Precast abutments
    - Precast NEXT Beams with CIP topping
  - 60-day full closure allowed



The next project that we will look at involves a bridge built “comfortably fast”, meaning faster than conventional construction but relatively slow when compared to other accelerated bridge construction projects.

The structure is a rural single-span bridge in western Massachusetts that required full replacement. The location had a moderately long detour; however, traffic volumes were reasonable. A decision was made to accelerate the construction to a degree, using the detour. This avoided the difficulty of using staged construction.

The following prefabricated elements were used:

1. Precast spread footings
2. Precast abutment stems
3. Precast approach slabs
4. Precast NEXT Beams

Cast-in-place concrete work was limited to the deck topping and the curbs.

The Massachusetts Department of Transportation wanted to investigate the use of accelerating construction on a more relaxed schedule, with the hope of reducing the overall project cost. A 60-day closure was chosen to achieve this.

Project Example: Comfortably fast

Construction:

The photo on the left shows the installation of the precast concrete spread footings. The footings were set on top of a layer of crushed stone. The gap underneath the footings was filled with flowable fill.

The photo on the right shows the completed footing in the foreground, while construction continues on the far abutment.

Note clusters of reinforcing bars projecting from the abutment footings. These bars were used to connect the short abutment stems to the footings using a simple pocket connection. The wingwall stems were connected to the footings using grouted splice couplers. Also, note that there are not a significant number of workers on site. This project was built by a local contractor using a small crew, which is another advantage of building a bridge on a comfortably fast timeline.

The new abutments were built behind the existing concrete abutments, which were used as future scour countermeasures. They were demolished to a specified elevation and capped with concrete to provide a durable shelf.

Project Example: Comfortably fast

Construction:

The photo on the left shows the installation of one of the abutment wall panels, which were cast with corrugated metal pipe voids that aligned with the reinforcing bar dowels projecting from the footings. Extra voids were cast into the elements to reduce the shipping and handling weights of these relatively thick elements.

The right picture shows one abutment with several wall panels installed.

The photo in the center shows the installation of a wing wall panel using the grouted splice couplers.

The construction of the abutments and wing walls only took several days to complete.

Project Example: Comfortably fast

Construction:

These photos show the erection of the precast concrete NEXT beams. The NEXT beam was developed by the PCI northeast bridge technical committee. There are three types of NEXT beams in use. The one shown in the photographs is the NEXT F beam. The letter F stands for “form” as the top flange acts as the form for the reinforced cast-in-place concrete deck topping. Even with a cast-in-place deck, the use of these beams is considered an accelerated construction method because forming of the majority of the deck is eliminated.

A nice feature of the NEXT F beam is that the fascia overhang can be varied to create a curved bridge. This can be seen in the photo on the left.

Project Example: Comfortably fast

Construction:

The photo on the left shows the installation of the precast concrete approach slabs. Massachusetts DOT standards for approach slabs detail the top of the slab approximately 12 inches below the roadway surface. The roadway subgrade and pavement are placed on top of the approach slab. This facilitates construction since the top of the slab need not be placed to a high degree of accuracy, facilitating the detailing and installation.

The photo on the right shows the completion of the approach slabs and the start of the deck reinforcing steel placement.

Project Example: Comfortably fast

Construction complete:

This photo shows the complete bridge. The work was completed on time in less than 60 days.

Project Example: Comfortably fast

Cost information

- Cost differential
  - ABC was 10% higher compared to conventional construction
  - Why so low?
    - Comfortable speed
    - No overtime or weekends
    - Simple details

The cost for this project was 10% higher when compared to similar bridges built with conventional construction.

There are several reasons for the relatively low cost of this accelerated bridge construction project:

1. The relaxed schedule was sufficient to proceed at a comfortable pace.
2. This resulted in no need for overtime or weekend work.
3. The design included simple details that were easy to execute.

Cost of Prefabrication?

Why is precast sometimes more expensive?

- One reason: Not part of a contractor's normal business model
- Another reason: Handling of the materials
- CIP Construction:
  1: Concrete shipped to site in ready mix truck and placed
  handled once
- Precast Construction
  1: Concrete placed in forms in the plant
  2: Element removed from the form and stacked
  3: Element lifted onto truck
  4: Element off loaded
  handled 4 times
- Each time it is handled, it costs money

In general, the use of prefabricated precast construction tends to be more expensive than cast-in-place construction. The cost of any element is a function of materials, labor, and equipment required to construct it. The difference in materials between cast-in-place elements and precast elements is essentially the same. The major difference is in the handling of the materials. A review of the handling requirements tells at least part of the story.

The concrete used in cast-in-place concrete construction is handled once, from the batch plant to the forms.

The concrete used in precast construction is handled multiple times:

1. The concrete is moved from the batch plant to the forms.
2. Once partially cured, the element is lifted from the forms and stacked for final curing.
3. When it is ready for delivery, it is lifted and placed on a truck.
4. At the project site, it is lifted and placed.

This results in 4 different handling processes. Each time it is handled, it costs money. This includes labor, rigging, and equipment.

Speed vs. Risk

- Speed of construction affects costs
- Disincentives
  - Disincentives can create RISK for the contractor
  - Disincentives can be high (up to and over 10% of the bid)
  - Failure to meet milestones = loss of $$
  - Tight milestones or high disincentives = RISK
- Risk = $$
- Why is it difficult to put a finger on ABC costs?
  - Contractors bid RISK
  - Designers do not estimate RISK

Another factor that can have a significant impact on cost is the speed of construction, especially if there are disincentive clauses in the contract.

Disincentives represent a risk to the contractor. The level of risk is commensurate with the amount of the disincentive. They can be as high as 10% of the construction price. Failure to meet a disincentive clause can result in a loss of dollars. Therefore, tight milestone schedule dates combined with high disincentive clauses represent a high risk to the contractor.

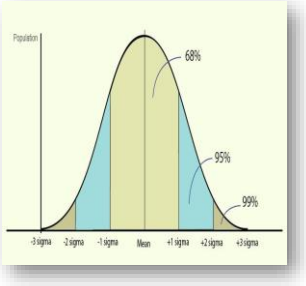
If we look at basic risk management principles, risk can simply be equated to cost.

When estimating an ABC project, it is hard for the designer to come up with an accurate cost estimate because he/she is using unit price estimating, which does not include risk. Contractors do account for risk in their estimates.

Risk 101: Risk = $$$

Risk cost = Cost of failure * Probability of Occurrence

- Known probabilities can be managed
- Unknown probabilities are difficult to estimate
- Probabilities will vary between different contractors
  - Size and experience of staff
  - Back-up equipment
  - This makes it hard to estimate during design
- Example
  - Weekend disincentive clause = $200K
  - Probability of not finishing bridge = 30%
  - Risk cost = $200k * 0.30 = $60,000



The basic principle of risk analysis is as follows:

Risk cost is equal to the cost of failure multiplied by the probability of occurrence of the failure.

Known probabilities can be managed. Unknown probabilities are more difficult. Also, probabilities can vary from one contractor to another. Several factors that affect this include the size and experience of staff and the amount of equipment that the contractor has on hand to mitigate equipment breakdown risks.

Let's review a simple risk cost analysis example:

- Let's assume that the contract has a weekend disincentive clause of $200,000
- The contractor might determine that the probability of not completing the work during the weekend period is 30%
- Therefore, the risk cost factor would be $200,000 * 0.30 = $60,000.

This contractor may then elect to increase the bid price by this amount to cover the potential for this disincentive to occur.

How Do Contractors Bid Risk?

Perform a risk analysis for critical features of the construction

- Determine the probability of failure for various functions
- Develop a Risk Register
  - A tool used in risk management used to identify potential risks in a project to stay on top of potential issues that can derail intended outcomes.

Option 1: Investigate ways to minimize risk

- Add labor
- Add equipment
- Add specialty sub-contractors
  - More experience to the team
  - Spread the risk out to more than one entity
- This all can add cost

Option 2: Bid the risk

- Increase the bid to account for risk factors

So, how do contractors bid risk? They perform a risk analysis for critical features of the construction project. Through a risk analysis, they:

- Determine the probability of failure for various functions, and apply it to the disincentives
- Many contractors will develop a risk register, which is a compilation of all the known risks that can be anticipated.

Once the risk register is established, the contractor may exercise several options with the bid:

- Option 1: Investigate ways to minimize risk by:
  - Adding more labor
  - Adding more equipment
  - Adding a specialty sub-contract to bring more experience to the team and spread the risk to other entities.
- All of this adds costs to the project

Option 2: Bid the risk, that is increasing the bid to account for risk factors and to cover potential disincentives.

How Can Owners Address Risk?

Understand that incentives and disincentives come at a price

- Pick incentives and disincentives that are commensurate with the needs

Tight schedules come at a price

- Consider relaxing the schedule if possible

Accept that some risk is inherent in ABC

- It will most likely cost more
- Look for cost savings elsewhere

36

The owner can have some influence on the cost of risks.

It's important to understand that incentives and disincentives come at a price so pick ones that are commensurate with the needs of the project.

Consider relaxing the schedule if you can. That will tend to lessen the costs.

Accept that some risk is inherent in ABC and that the project will likely cost more.

The owner can look for other ways to offset the additional cost of ABC. This will be covered in the next module.

Recommendations for Cost Premiums

These are budget level estimates based on the project examples presented today

This is heavily influenced by a number of factors that were previously discussed

	Construction Speed				
	1-2 days	4 days	9 days	16 days	1-2 Months
Complex Process Difficult site	2.0	1.8	1.7	1.6	1.5
Complex Process Moderate site	1.8	1.7	1.6	1.5	1.4
Moderate Process Difficult Site	1.7	1.6	1.5	1.4	1.3
Moderate Process Good Site	1.6	1.5	1.4	1.3	1.2
Simple Process Good Site	1.5	1.4	1.3	1.2	1.1

We have just learned that estimating ABC costs can be very difficult for the designer. There are too many unknowns that cannot be accounted for. Still, we need to develop an engineer's estimate for use in the project development and procurement processes.

The two major factors that a designer has knowledge of are; the speed of construction, and the complexity of the process and site conditions.

A simple matrix has been developed that can be used to develop a budget-level ABC adjustment factor that can be applied to the cost of conventional construction. The horizontal axis is the speed of construction. The vertical axis is the complexity of the site and the design.

This matrix is approximate and is based on the projects that we previously reviewed. As an agency deploys an ABC program, a similar matrix can be developed based on the experiences of the program and the local contractors. As contractors gain more experience, these factors can be adjusted as more bid prices come in.

Estimating ABC Construction Durations

As with cost, there are several factors that influence construction time

- Details
- Site conditions (access, staging areas)
- Specialized equipment
- Contractor familiarity
- Etc.

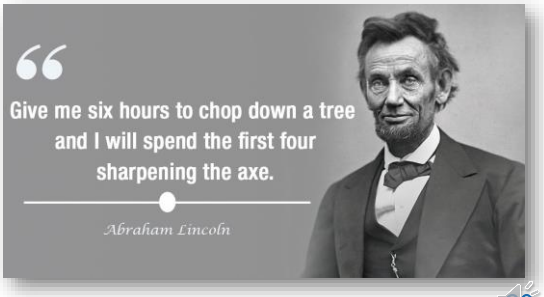
An important part of developing an ABC project is to accurately estimate the construction duration for the method chosen. This is an important step in the project development process that can play an important role in the development of incentives and disincentives. As with construction costs, estimating construction durations can be difficult and is affected by several key factors:

- The complexity of the details of the project plans can impact construction durations. Simple details tend to come together quickly, while complex details can take more time to execute.
- Site conditions can play a significant role in construction durations. The ability to store more materials and equipment on-site or near-site can affect the time for setup of equipment and movement of materials and equipment.
- The use of specialized equipment can impact construction durations. For example, larger cranes can be used to erect larger pieces, reducing the overall number of elements to install.
- The experience of the contractor with the ABC method chosen can have a significant impact on the time of construction. An example of this is the 93Fast14 project in Medford MA. The first bridge replacement on that 14 bridge project was completed right on time. Subsequent bridges were finished significantly ahead of schedule on subsequent weekends as the contractor gained valuable experience.

Pre-Construction Planning

There is significant planning time required prior to the actual ABC construction period:

- Preparing the site
- Building substructures between existing substructures
- Fabricating elements
- Developing an assembly plan
- Etc.



It is important to note that there are two aspects to the overall project schedule for an ABC project. The first is the planning phase before the accelerated construction phase.

Abraham Lincoln has been quoted as saying “Give me six hours to chop down a tree and I will spend the first four sharpening the axe”. ABC project planning is similar. Often a significant amount of time is spent preparing in planning for the actual accelerated portion of the construction. This work includes:

- Preparation of the site: This is especially true for projects using self-propelled modular transporters. Often temporary fill is required to provide a relatively level travel path.
- Building substructures between existing substructures: This is a method that is used for full bridge replacements. If it is possible to build the new substructures under the existing bridge, the accelerated portion of the project can be done very fast. For example, a common highway overpass structure type is a three-span bridge where the end spans are above the slopes leading up to the abutments. In many cases, it is possible to convert the bridge to a single-span bridge with new abutments built between the shoulder piers and the embankment abutments.
- Fabrication of elements: Ample time must be accounted for in the project schedule for the development of shop drawings and the fabrication of prefabricated elements.
- Development of an Assembly Plan: The *AASHTO LRFD Guide Specifications for ABC* recommend the development of an assembly plan by the contractor to be used as a guide for the accelerated portion of the construction. This plan often requires significant forethought, which can take time to develop.

Estimated minimum durations for ABC

Example: Superstructure replacement with modular deck beams

- Weekend (50-55 hours)
- High early strength concrete or UHPC can be used for the closure joints

We will now review several project examples that demonstrate the approximate minimum durations for common ABC methods.

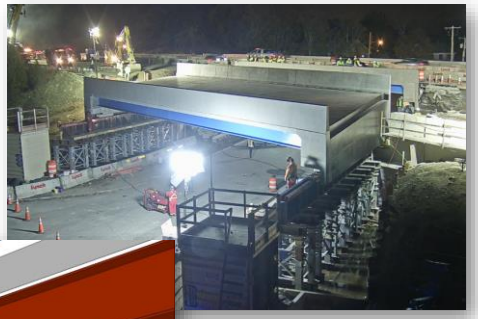
The first project includes the replacement of a superstructure using modular deck beams. The photo on the right shows the construction of one of these structures. The modular deck beams consist of two steel beams fabricated with a precast deck on top. Once the beams are erected, the deck edges are connected using closure joints cast with either high early strength concrete or ultra-high-performance concrete.

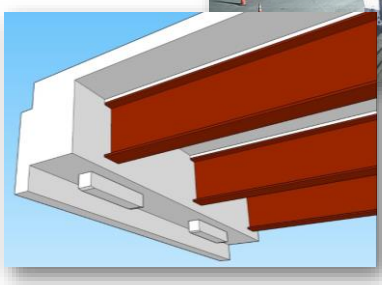
This form of ABC construction is routinely accomplished in a typical 55-hour weekend work window. This timeframe includes the demolition of the existing superstructure but does not normally include the construction of the barriers. Barriers are typically built behind temporary barriers after the bridge is re-opened to traffic

Estimated minimum durations for ABC

Example: Superstructure replacement with lateral sliding

- Weekend recommended (50-55 hours)
- Can be done in 24 hours
- Simple details are the key





Lateral sliding is becoming a more common form of ABC. The new superstructure is typically built alongside the existing bridge before the accelerated portion of the work. Once complete, the existing superstructure is demolished, and the new superstructure is slid into place on temporary rails.

This type of ABC is commonly completed on a 55-hour weekend work window. It has been accomplished in 24 hours in some cases. The key to this level of acceleration is to have the substructures built before the demolition of the existing bridge. If new substructures need to be built, a longer construction schedule would be required.

The key to this form of ABC is the simplification of details. The graphic to the left shows a common semi-integral abutment detail that is often used for lateral slide projects. This detail can accommodate the various types of lateral sliding equipment that are in use. It is also a very durable detail with no deck joints. The photo on the right shows the construction of a single-span bridge in Rhode Island using the lateral sliding method and these details.

Estimated minimum durations for ABC

Example: Superstructure replacement with SPMTs

- Weekend recommended (50-55 hours)
- Can be done in 24 hours
- Simple details are the key

Replacement of superstructures using self-propelled modular transporters was very popular in the early days of ABC. This method of construction is still feasible, but it can be more expensive than similar systems such as lateral sliding.

The construction timeframes and details can be similar to lateral sliding methods. The construction time is also similar.

The photo on the right shows the movement of a single-span superstructure in Utah. The bridge was built approximately one mile from the bridge site and moved into place in several hours.

Estimated minimum durations for ABC

Example: Deck replacement with precast full-depth deck panels

- Can be done in a weekend, but very difficult
- 5-9 days is comfortable

Deck replacements with full-depth precast concrete deck panels are also common. It is possible to replace a bridge deck in one weekend, but it can be difficult. The problem lies with the removal of the old deck. If the beams are to be salvaged, the contractor will need to take more care to not damage the beams during deck removal. This can double the time for deck removal from 8 hours per span to 16 hours per span.

It is best to allow 5 to 9 days for this work. The 9 days correspond to one week and two weekends (Friday through the following Sunday).

Estimated minimum durations for ABC

Full bridge replacement including substructures

- 30 days depending on foundations and ABC methods
  - SPMT or lateral slide install will accelerate superstructure placement
- Try to build substructures under the existing bridge
- Recommend a detailed CPM schedule to look at all aspects

As previously stated, full bridge replacements can take longer times, but ABC can still be used to dramatically reduce the overall construction time when compared to conventional construction. In most cases, 30 days will be required to complete the construction. 60 days is preferred if possible.

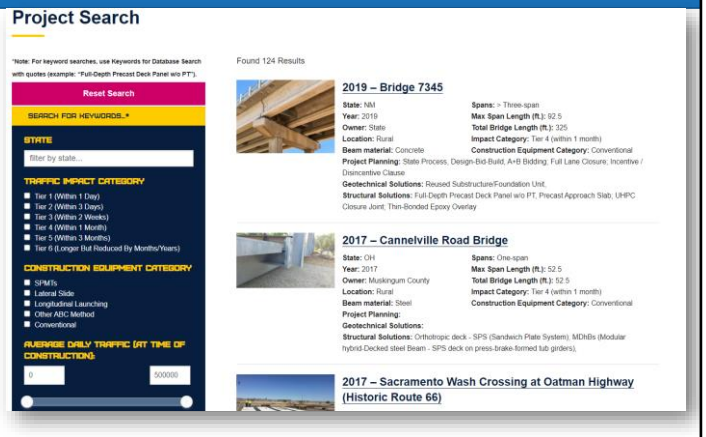
Again, this can be accelerated if the new substructures can be built before the demolition of the existing bridge. The photo shows a three-span bridge being converted to a single-span bridge by constructing a GRS-IBS system between the shoulder piers and the existing abutments. The majority of the new abutments were built before the start of the superstructure replacement.

In many cases, a detailed critical path schedule evaluation should be done to investigate a reasonable project schedule for this type of work.

Estimated minimum durations for ABC

Other sources of construction timeframe estimates:

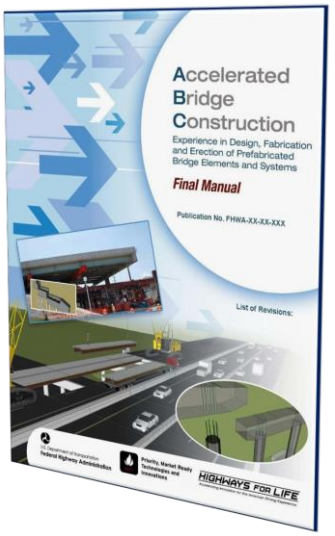
- Florida International University ABC UTC database
  - Numerous example projects that can be reviewed
  - Sorted by project type



There is another significant source of information that can be used to better estimate construction durations for ABC projects. Florida International University maintains an ABC database of projects. Users of the database can search for projects that are similar to the one being considered. They can download a whole host of information that can be used to better estimate the time required to construct a specific project.

Typical ABC Contracting Provisions

- Construction Specifications
  - Assembly Planning
  - Incentives/disincentives
  - Liquidated damages
  - A+B Bidding
  - Lane Rentals



We will now move on to typical contracting provisions used in ABC projects. These provisions are typically included in the contract specifications and are used to manage short-duration construction work.

The following provisions will be presented:

- Assembly Planning
- Incentives/disincentives
- Liquidated damages
- A+B Bidding
- Lane Rentals

Assembly Planning

You need instructions for the assembly of a toy

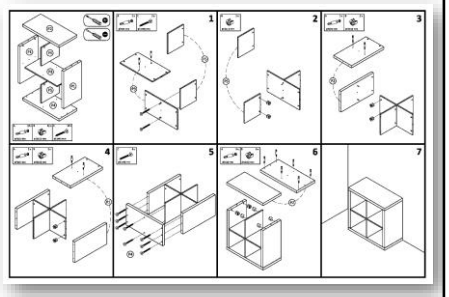
Why not for a prefabricated bridge?

8.5—ASSEMBLY OF PREFABRICATED BRIDGE ELEMENTS

The Contractor shall be responsible for the development of an Assembly Plan document. The Assembly Plan shall be considered a working drawing and shall be certified by a registered Professional Engineer with specific knowledge of the Contractor's equipment and "means and methods."

C8.5

An Assembly Plan is a step by step process for the assembly of the prefabricated elements. It is closely linked to the schedule of operations and the interim material strengths necessary for the work to progress.



If you buy a toy or furniture from a store like IKEA, you might need to assemble it. The pieces come with assembly instructions. The construction of a prefabricated bridge is no different. Careful thought must be put into the assembly process and laid out in an assembly plan document.

Article 8.5 of the Guide Specifications includes provisions for the assembly of prefabricated bridge elements. The provisions call for the development of an Assembly Plan Document. This is a step-by-step process for the assembly of the prefabricated elements at the bridge site. It is developed by the contractor since it falls under the realm of contractor means and methods.

Most bridge owners require contractors to develop erection plans for bridge girders. An assembly plan is a more detailed document that covers more than just erection.

Assembly Plan Requirements for Prefabricated Elements

8.5.1—ASSEMBLY SEQUENCE AND CONSTRUCTION METHODS

The following minimum information with regard to sequence of assembly shall be included in the Assembly Plan:

- Step-by-step assembly sequence detailing the overall construction process.
- Details of any formwork for closure joints including methods for attachment to the adjacent prefabricated elements.
- Details of all materials to be used for the construction.
- Methods and materials to be used for casting and curing concrete closure joints.
- Estimated timeframe of strength gain for concrete closure joints.
- A statement of compliance with all requirements of applicable environmental permits.
- Any weather limitations for the assembly work.

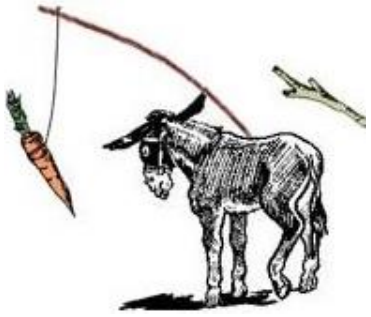
8.5—ASSEMBLY OF PREFABRICATED BRIDGE ELEMENTS
8.5.1—ASSEMBLY SEQUENCE AND CONSTRUCTION METHODS
8.5.2—LIFTING AND HANDLING PROCEDURES AND DETAILS
8.5.3—GEOMETRY CONTROL PLAN
8.5.4—INTERIM MATERIAL STRENGTH
8.5.5—POST-TENSIONING
8.5.6—ASSEMBLY SEQUENCE FOR POST-TENSIONED FULL-DEPTH DECK PANELS
8.5.7—ASSEMBLY SCHEDULE
8.6—ASSEMBLY OF BRIDGE SYSTEMS
8.6.1—ASSEMBLY SEQUENCE AND CONSTRUCTION METHODS

Article 8.5.1 of the Guide Specifications includes the recommended minimum information for the assembly sequence that should be included in an Assembly Plan. These include:

- Assembly sequence and construction methods
- Lifting and handling procedures and details
- Geometry control plan
- Interim material strength
- Post-tensioning (if applicable)
- Assembly sequence for post-tensioned full-depth deck panels (if applicable)
- Assembly schedule

The guide specification goes into significant detail on each of these assembly plan requirements.

Incentive and Disincentive Provisions



Many agencies employ the use of incentive and disincentive provisions in contracts. These provisions are sometimes referred to as the carrot and stick provisions. Incentives and disincentives are typically financial adjustments to the contract.

The carrot represents the incentive, which is used to entice a contractor to follow a certain path of construction or to meet certain requirements in the project schedule. In ABC projects, that is typically the speed of construction for a certain phase of the work. The stick represents the disincentive provisions, which are meant to financially penalize the contractor for not completing a certain task or schedule.

Incentives/Disincentives

Incentive: Used to compensate contractors for early completion

There needs to be a reason to pay for early completion

- Work on weekends → finish by Monday commute
- Work during summer → finish before school
- Completion in one season → avoid winter shut-down
- Roadway user costs → reduce cost to society (time = $$)
- Workzone safety → reduce exposure of workers and travelers to dangerous situations

Should be tied to a schedule - Not a bonus

Disincentive: Used to penalize a contractor for late completion

Incentives are typically used to financially compensate the contractor for the early completion of a task or work item. There should be a specific reason to justify an incentive payment. Incentives are not bonuses for the completion of work on time. Examples of specific reasons include:

- Eliminating a closure during a weekday commute period
- Completion of work before the end of a school holiday or break
- Completion of work during one construction season
- Reduction in roadway user costs which represents a reduction in cost to society
- Reduction in the exposure of workers and travelers to work zones

Incentives should be tied to a schedule.

A disincentive is used to penalize the contractor for not meeting the above criteria.

Project Selection for IDs

Not meant for every project

Examples of project criteria where IDs should be considered

- High traffic volumes that are generally found in urban areas
- Major reconstruction or rehabilitation on an existing facility that will severely disrupt traffic
- Major bridges or roads that are taken out of service
- Lengthy detours

Incentives and disincentives should not be used for every project. Examples of project types where incentives and disincentives can be considered include:

- High traffic volumes on roadways that are generally found in urban areas
- Major reconstruction or rehabilitation on an existing facility that will severely disrupt traffic
- Major bridges or roads that are taken out of service, creating lengthy detours

I/D Amount?

Most criteria are based on the volume of traffic and disruption

- Detour length
- Traffic backups

Disruption to the local economy is hard to quantify

Most agencies use:

- Roadway user costs (RUC)
- Agency administrative costs (similar to LDs)
- Motivation to the contractor
  - Big enough carrot to make a difference

FHWA recommended cap: 5% of total contract cost

Typically: I = D

There is no set formula for the determination of the value of an incentive or disincentive. In general, it should be based on the volume of traffic and the disruption to the area around the bridge and the people traveling across the bridge. Disruption can best be quantified by investigating detour lengths and time spent in traffic backups.

Disruption to a local economy is hard to quantify. People will often find ways to get to a specific business near a construction site. It is difficult to estimate how many people will simply avoid the area and find another nearby similar business.

Most agencies calculate incentive and disincentive payments based on roadway user costs and the costs to administer the contract. Sometimes an incentive or disincentive payment is determined by estimating the amount of motivation required to make a contractor perform in a certain manner or timeframe.

FHWA recommends several approaches to incentive/disincentive clauses:

- The maximum value of all incentive or disincentive values should be no more than 5% of the contract value.
- Agencies should try to have both an incentive and a disincentive clause, and they should be relatively equal.

As noted previously in this module, high disincentive values can lead to higher bid prices if there is a high probability of not meeting a disincentive clause. Conversely, a high incentive clause can reduce bid prices if the clause is relatively attainable.

Liquidated Damages

Used to cover the cost of managing a project by the owner

- Not the same as a disincentive

> A liquidated damages clause specifies a predetermined amount of money that must be paid as damages for failure to perform under a contract.

- Typical applied to schedule overruns
- Calculated based on costs incurred by the owner to manage the project
  - Construction inspection
  - Field offices
  - Project management
  - Etc.

Liquidated damages (LDs) are commonly used in all contracts. LDs can be best defined as:

> A liquidated damages clause specifies a predetermined amount of money that must be paid as damages for failure to perform under a contract.

They are not the same as a disincentive clause as they commonly apply to the overall project schedule. They are typically applied when a project schedule is overrun.

LDs are typically calculated based on the cost of the agency to administer a contract including:

- Cost of construction inspection forces
- Cost of field offices
- Cost of project management staff including back-office invoicing staff

A+B Bidding

Used to accelerate construction through contract provisions

- A Component = Cost to perform the work
- B Component= Cost impact to the public
  - B component only used for bidder selection.
  - The contractor is not paid this sum.
  - Similar to best value Design-Build procurement

Contractor	Bid Amount	No. Days	Road User Cost	Combined	
A	$4,300,000	130	$12,000	$5,860,000	
B	$4,900,000	110	$12,000	$6,220,000	
C	$4,450,000	115	$12,000	$5,830,000	Combined Low

Award based on this value

Payment based on this value

Source: Washington State DOT website

A + B bidding can be used to accelerate the overall duration of a project or a portion of a project. The contractor submits two values in the bid. The first is the actual cost to perform the work. The second is a value that factors in the impact of the project to the public, often a duration for the overall project or a specific phase of the project, typically based on roadway user costs.

The A component is no different than the bid price in a traditional bid. The B component is only used for bidder selection. The contractor is not paid the B value. This approach is similar to the Best Value process for most design-build projects.

The table at the bottom of the slide shows an example of how this contracting method can be used. In this example, the low bidder using a conventional bid process would be bidder A; however, Contractor A based the bid on 15 more days of disruption. Contractor C has a higher base bid price, but with a shorter duration. The sum of the two values is used to determine the successful bidder. In this case, it is Contractor C. The award is based on the combined value, but the payment for the work will be based on the A component only.

Lane Rentals

Used to minimize the amount of delays caused by construction

- Contractor is charged to take lanes
- Rates are set in the contract
  - Can vary during different periods
  - Based on user costs
- Process
  - Contractor calculates the construction cost (A) and lane rental needs (B)
  - Bid selection is similar to A+B bidding
  - The number of “free” lanes is calculated based on the bid value (B).
  - If the contractor goes over, he/she is charged a rental fee

Lane rentals are provisions that are not as common as other provisions previously discussed. They are primarily used to reduce the amount of lane closures on a project and the corresponding impacts on travelers. These provisions are typically in response to contractors who take lanes and disappear for days or weeks on end, frustrating drivers.

With lane rental provisions, the contractor is charged fees to close lanes. The fees can vary based on the time of day and the day of the week. The fees are typically based on roadway user costs.

At the time of the bid, the contractor submits the bid price, which is Component A of the bid. The contractor also submits the lane rental needs in the bid as a B component of the bid. Similar to A+B bidding, the two values are combined to determine the best value bid. The price for the project is the A component. The B component is used to establish the maximum lane rentals allowed for the construction. If the contractor exceeds the bid amount, then he/she is charged a rental fee for the lanes.

Conclusions

- Estimating cost and time is difficult due to many factors
  - Risk is a big factor
  - We are building a knowledge base that is making this a little easier
  - Consider the FIU ABC UTC project database
- Be careful when developing Incentive/Disincentive provisions
  - Should be based on a real benefit (not a bonus)
  - Limit to 5% of the contract value
  - These can lead to higher bid costs if there is a risk of the disincentive being applied
- There are several common contracting provisions that can be used to expedite construction
  - See FHWA ABC manual for more information

During this module, we explored several key processes and specifications that can be used on ABC projects.

We discussed ways to estimate both cost and time for ABC projects and explored the impact of risk on both.

We discussed contracting provisions that can be used to accelerate a construction project.

We also discussed the impact of incentive and disincentive clauses on bid prices.

By using these approaches, the agency can better manage an ABC project and program.

End of Module 2

Available ABC Program Management Modules

1. Recommended Approach to Implementing ABC in a Transportation Agency
2. ABC Time and Cost Estimating
3. ABC Decision Making Processes