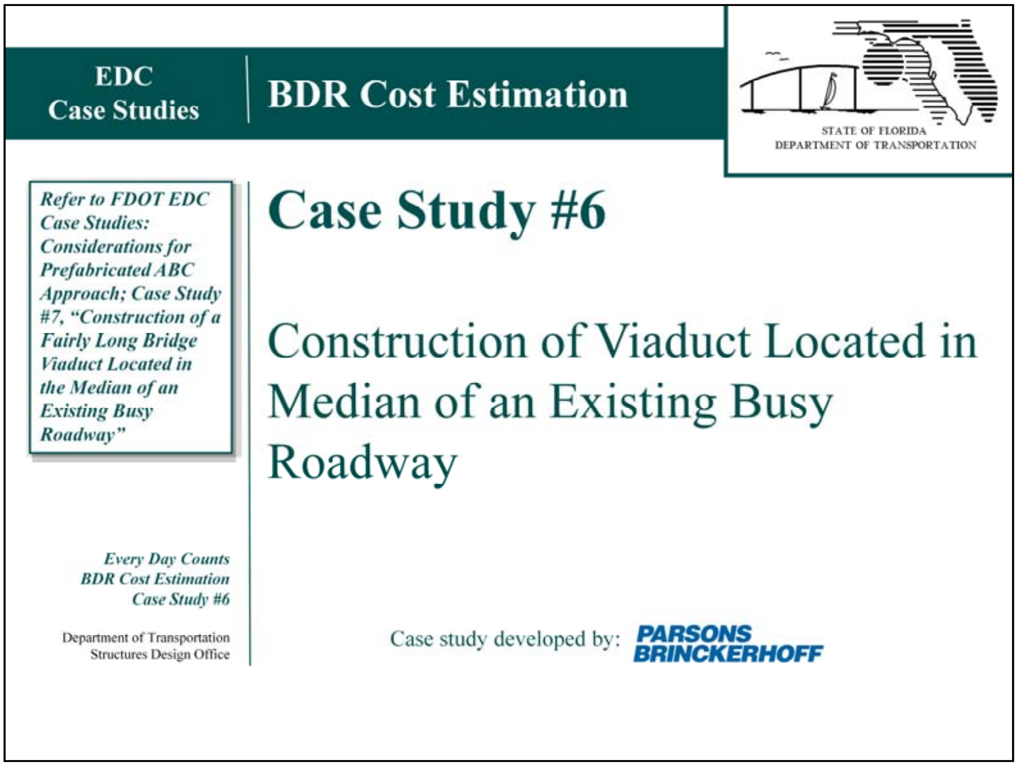
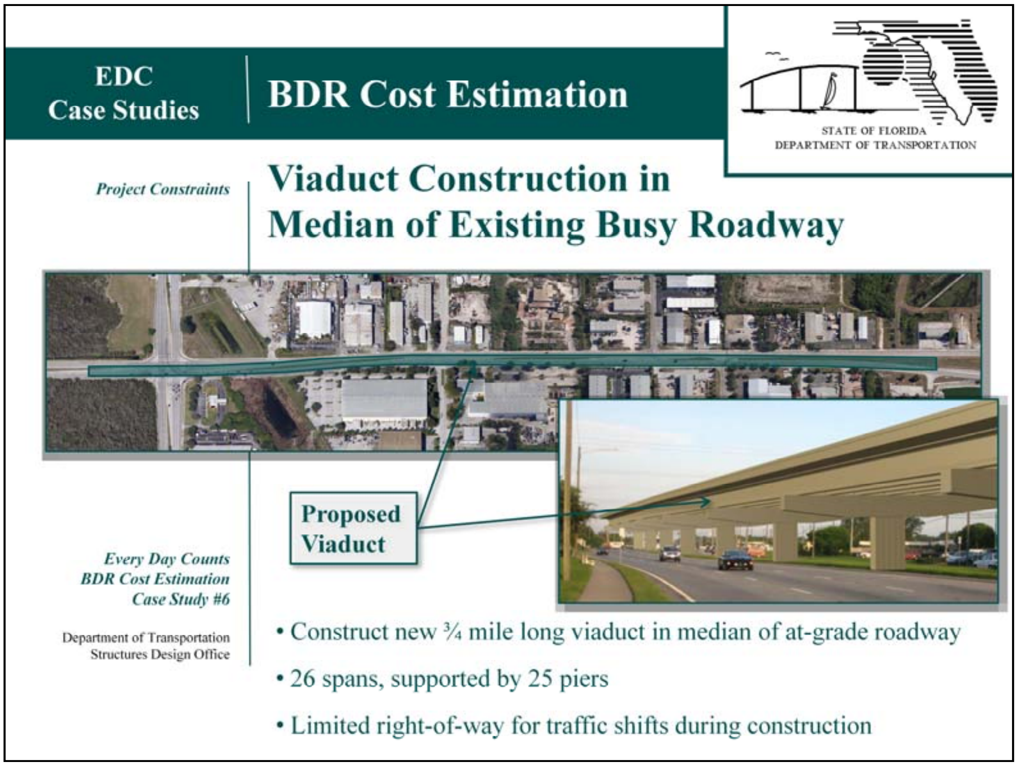
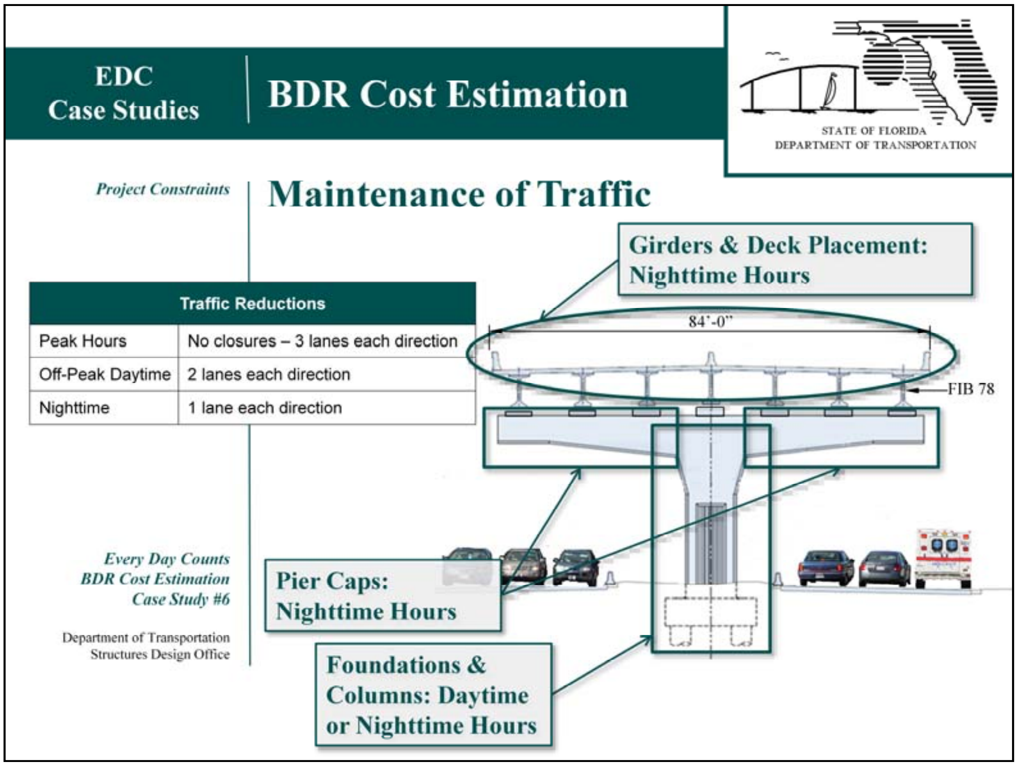


- Case Study #6 will investigate construction of a new viaduct located in the median of an existing busy roadway.
- The material presented herein will be a continuation of the Case Study Series entitled "Consideration for Prefabricated ABC Approach", Case Study #7. Prior to viewing this presentation, the audience is urged to view Case Study #7, as it details the basis for this case study.



- The proposed viaduct will be built in the median of an existing multi-lane, at-grade roadway.
- The bottom rendering shows the configuration of the new viaduct. It is approximately ¾ of a mile in length, and consists of 26 spans supported by 25 hammerhead piers.
- Due to the narrow existing median width, the new construction will significantly overhang the existing roadway.
- With the existing roadway operating at capacity during peak hours, and the limited right-of-way for traffic diversions, one of the largest challenges of the project will be managing traffic during construction.



- This slide shows the relationship of existing traffic with regard to the new viaduct. Since proposed construction overhangs the existing lanes, the difficulties of traffic phasing can be envisioned.
- The table shown here indicates allowable traffic reductions versus time of day.
    - During peak hours, all lanes must be open to traffic, therefore a limited amount of construction activities can be accomplished.
    - During off-peak daytime hours, two lanes in each direction must be maintained
    - And during nighttime hours, one lane must remain open in each direction
- Therefore the following assumptions will be made:
    - Foundations and columns will be constructed during daytime or nighttime hours, with limited activities occurring during peak hours.
    - Pier cap construction, girder erection, and deck placement must be conducted during nighttime hours, while lanes are shifted outside of the construction limits.

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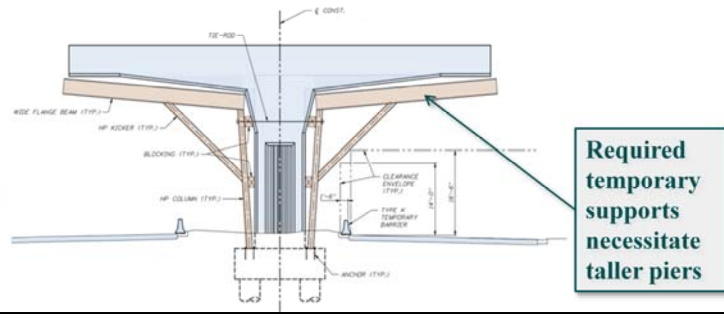
Conventional Alternative

Conventional Pier Construction

Traffic Reductions for Major Activities	
Drilled Shaft & Shaft Cap	Daytime or Nighttime, with limited Peak Hour Activities
Pier Column	Daytime or Nighttime, with limited Peak Hour Activities
Pier Cap	Nighttime
Girder Erection	Nighttime
Deck Placement & Barriers	Nighttime or Off-Peak Daytime with Lane Shifts



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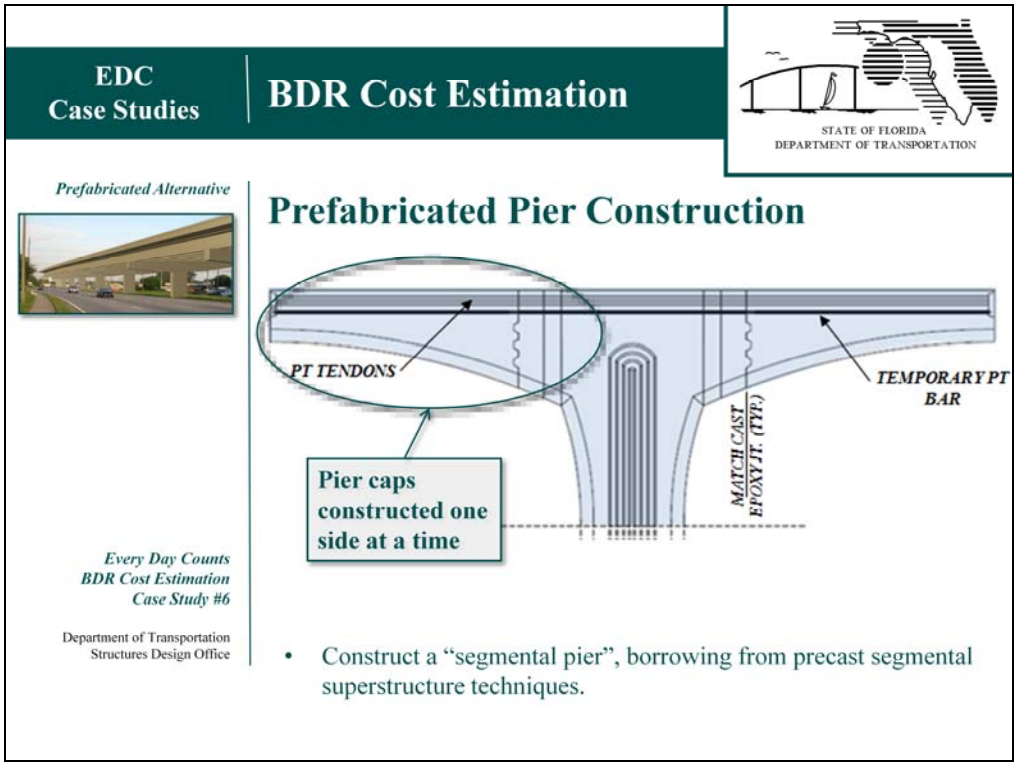
- This slide will outline a conventional construction alternative which adheres to the project constraints.
- The entire substructure will be assumed to consist of cast-in-place construction. Therefore under this option, the only prefabricated elements will be the prestressed girders.
- The table shown here outlines the major elements of construction, and reflects the traffic restrictions listed in the prior slide.
- Noteworthy items which can only be constructed during nighttime procedures are the pier caps and girder erection. This places severe limitations to the substructure construction schedule, and will require numerous nighttime traffic restrictions to just one lane in each direction.
- Conventional pier cap construction requires temporary supports for the cap overhangs to allow traffic beneath. This necessitates taller pier columns to provide minimum clearances, resulting in an overall increased vertical profile for the viaduct.



- This slide outlines an option to use non-standard prefabricated elements to construct a pier segmentally. This will achieve a shorter construction schedule while significantly reducing impacts to traffic.
- Traffic restrictions will remain identical to the conventional construction alternative, however a method of precasting the pier cap cantilevers and joining them to the cast-in-place column via match cast joints will be used. This method was described in the case study referenced at the beginning of this presentation, and will not be repeated here in its entirety.
- However as a brief recap, this is accomplished by using post-tensioning bars embedded into the cast-in-place column cap as well as the precast components. The precast pier cap segment on one side of the column is then erected and coupled with post-tensioning bars. This operation moves quickly, and several segments on the same side of the road can be erected for several piers during a single nighttime closure.
- Following this procedure, the opposite side of the pier cap is erected in the same manner. Once both sides of the cap are in place, permanent post-tensioning tendons are stressed to finish the process.
- Building the pier cap cantilever pieces is the most restrictive process of construction. Given the speed at which the precast members can be erected, multiplied by the number of piers on the job, this process will significantly benefit the construction schedule and traffic impacts.

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Compare Alternatives

Direct Cost Comparison

Summary of Direct Costs - Taken from "Bottom-Up" Cost Estimate

Item	Construction Type		Delta	Reason
	Conventional	Prefabricated		
Contractor General Conditions	$ 7,514,658	$ 6,319,115	$ (1,195,543)	6 Month Schedule Reduction
End Bents & Approach Slabs	$ 391,950	$ 391,184	$ (766)	--
Piers	$ 20,769,112	$ 20,288,620	$ (480,492)	Labor/Falsework Savings
Superstructure	$ 18,942,390	$ 18,904,888	$ (37,502)	--
Direct Costs Total:	$ 47,618,110	$ 45,903,807	$ (1,714,303)	

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- Conventional Bridge Schedule = 36 months
- Prefabricated Bridge Schedule = 30 months
- Large "general conditions" delta as a result of reduced schedule (largest savings from labor overhead)

➢ Direct cost for each alternative has been calculated by a construction estimator. The rightmost columns indicate cost deltas between alternatives, and list the prevailing reason for each difference.

➢ The largest cost difference can be seen in the top row of the table. This represents the contractor's general conditions, and reflects labor associated for permanent employees such as the project manager, the superintendent, and field engineers. It also accounts for field offices and other overhead items incurred by the contractor. This item is heavily in favor of the prefabricated alternate, and is a direct result of a reduced construction schedule.

➢ The conventional and prefabricated alternative schedules are 36 months and 30 months, respectively. Therefore, reducing the schedule by 6 months indicates a $1.2 million dollar cost savings in the contractor's general conditions, and is primarily composed of labor savings.

➢ The third row represents cost associated with pier construction. Surprisingly, cost associated with the prefabricated option is actually less than the conventional option. This is also a result of reduced labor, and will be explained in further detail on the following slide.

➢ Total price of bridge construction is approximately 4% less for the prefabricated alternative, or $1.7 million dollars. This is an interesting conclusion, as prefabricated methods are often perceived as more costly.

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Compare Alternatives

Substructure Comparison

Cast-in-Place vs. Precast Substructure Costs for Bridge Piers (foundations excluded)				
Alternative	Labor Cost	Material Cost	Equipment Cost	Total Cost
Conventional	$ 5,975,583	$ 3,328,888	$ 811,431	$ 10,115,902
Prefabricated	$ 4,420,629	$ 4,477,563	$ 739,886	$ 9,638,078
Delta	$ (1,554,954)	$ 1,148,675	$ (71,545)	**$ (477,824)**

- **Labor:** base rates, fringes, taxes, insurance
- **Material:** final installed cost for all materials
- **Equipment:** equipment necessary for installation (ownership, maintenance, operational costs)

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➢ This slide indicates how the cost of the pier columns and piers caps were determined. Cost has been divided into labor, material, and equipment costs. To gain a better comparison, all foundation costs are excluded from these numbers.

➢ Labor costs associated with the conventional alternative are approximately $1.5 million dollars higher than the prefabricated alternative. The largest factor is due to labor required for setting up and dismantling the complex falsework system to support the cast-in-place pier caps. The second factor is associated with more labor required for a greater cast-in-place concrete quantity versus the prefabricated alternate.

➢ Not surprisingly, material costs are approximately $1.1 million dollars higher for the prefabricated alternative. This is due to the higher cost of precast concrete, as well as the addition of post-tensioning versus the conventional alternate.

➢ Equipment costs are similar for both options.

➢ Total cost is given in the last column of the table, and indicates an almost ½ million dollar decrease in substructure cost for the prefabricated alternate.

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Compare Alternatives

Indirect Cost Comparison

Indirect Cost Comparison							
Alternative	Off-peak Daytime Single Lane Closure (both directions)		Nighttime Double Lane Closure (one direction)		Nighttime Double Lane Closure (both directions)		Total Indirect Costs
	Days	$/Day	Days	$/Day	Days	$/Day	
Conventional	203	$ 77,400	164	$ 49,400	201	$ 98,800	$ 43,672,600
Prefabricated	203	$ 77,400	184	$ 49,400	101	$ 98,800	$ 34,780,600

- Conventional alternative requires more double lane closures
- Prefabricated alternative saves $8.9M of indirect costs

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➢ This slide outlines the overall indirect cost associated with construction. The number and type of lane closures have been divided into three categories, and are as follows:

- ➢ off-peak daytime single lane closures for both directions of traffic
- ➢ nighttime double lane closures for a single direction of traffic
- ➢ and nighttime double lane closures for both directions of traffic

➢ As expected, the prefabricated alternative will require fewer lane closures. This is due to the ability to erect multiple pier cap segments within a single closure, as well as the lack of falsework assembly and dismantling.

➢ Overall, the prefabricated alternate saves approximately $8.9 million dollars of indirect cost.

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Compare Alternatives

Cost Summary

Alternative	Direct Costs	Indirect Costs	Direct + Indirect
Conventional	$ 47,618,110	$ 43,672,600	$ 91,290,710
Prefabricated	$ 45,903,807	$ 34,780,600	$ 80,684,407
Delta	$ (1,714,303)	$ (8,892,000)	$ (10,606,303)

- Conventional has 6 month longer construction schedule
- Prefabricated alternate less costly due to:
  - Direct cost: shorter construction duration, elimination of complex pier cap falsework
  - Indirect cost: fewer lane closures
- **Prefabricated scenario $10.6M less, or 12%**

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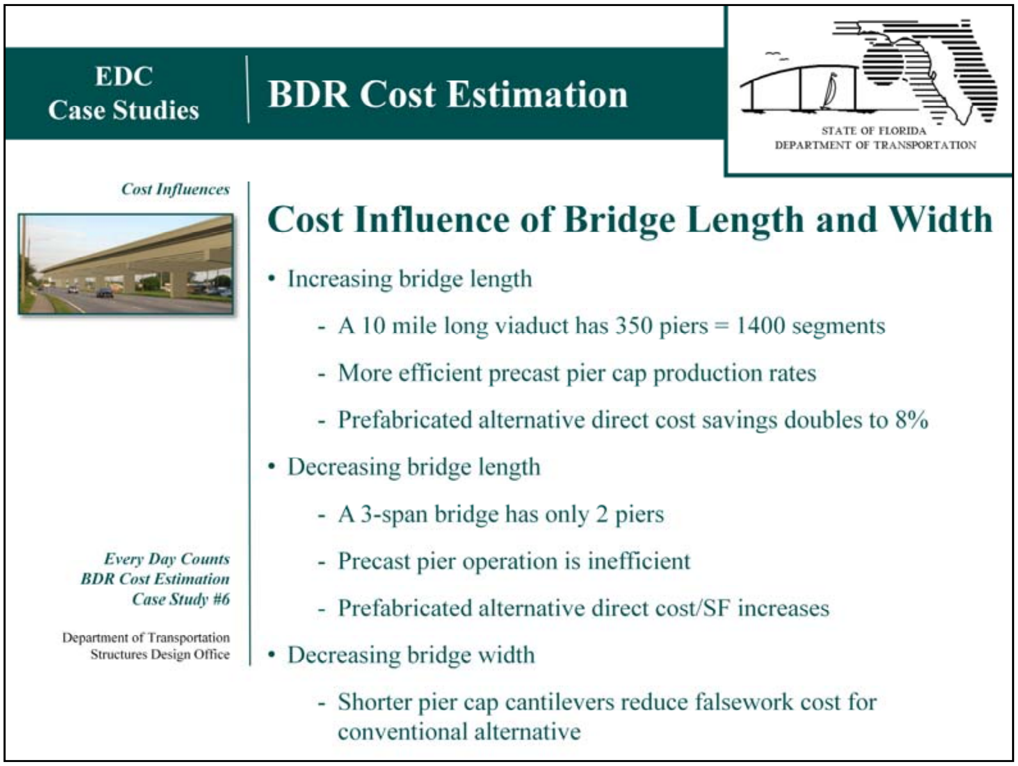
➢ In summary, the total direct and indirect costs are shown here for each scenario.

➢ The prefabricated alternative indicates a cost advantage in both categories. Direct cost savings are primarily due to a shortened construction schedule and elimination of the complex pier falsework system required for the conventional option. Indirect cost savings were realized due to fewer required lane closures.

➢ Therefore the prefabricated alternative produces an overall savings of $10.6 million dollars.



- This slide presents three scenarios of how the direct cost is influenced by changes in the bridge length and width.
- If one were to assume a very long viaduct, say 10 miles in length:
    - There would be 350 piers resulting in 1400 precast segments.
    - This larger amount of segments allow more efficient precast pier production rates and a greater direct cost savings can be achieved.
    - This is approximated as an 8% savings in direct cost using prefabricated construction or about double that of the ¾ mile long viaduct.
- In contrast, if one assumed bridge construction shortened to only three spans:
    - There would be only 2 piers resulting in 8 precast segments.
    - With only 8 segments, the upfront cost of the precast pier operation and inefficiencies of working through a learning curve significantly increases the total direct cost per square foot of the prefabricated alternative.
- Lastly, if we assume the bridge width decreases, the pier cap cantilevers shorten resulting in a reduction in cost of the falsework for the cast-in-place pier cap. Therefore, a more narrow bridge benefits the conventional alternative.