URBAN FREEWAY BRIDGE RECONSTRUCTION PLANNING: CASE OF MOCKINGBIRD BRIDGE

By James T. O'Connor,[1] Member, ASCE, and Tamer E. El-Diraby[2]

ABSTRACT: Urban freeway bridge reconstruction is a challenging process. Sites are often located in heavily populated areas and are always congested with traffic and construction activities. Lack of adequate planning on such projects can result in tremendous waste in project cost and schedule, traffic flow efficiency, and most importantly, safety to both the traveling public and construction crews. Accordingly, a need exists to develop techniques to help plan and construct urban bridge projects more effectively. This paper documents the process of replanning a bridge project, Mockingbird Bridge. The case describes a research effort that beneficially applied several construction engineering concepts to the project. For the project, the research resulted in sizable savings in cost and duration. For the industry, the case resulted in several lessons for future projects. Among these, the primary lesson is that the integration of bridge reconstruction sequence, constructability, and traffic control plans is crucial to project success.

INTRODUCTION

The United States is undergoing a rebuilding of its decaying urban infrastructure as never previously seen. Many projects are currently in either the planning or construction stages, and Congress has recently substantially increased federal funding for such projects. These projects come with increased demands for higher levels of overall project performance, and accordingly, new challenges to the ways projects are executed. For example, public projects with shorter durations and reduced impacts to the traveling public are expected. Such challenges require that innovative methods be applied to old, persistent problems. This paper presents a case study that, in part, illustrates an improved approach to an old problem: urban freeway overpass bridge reconstruction.

Urban freeway bridge projects face unique problems due to the nature of their sites. Traffic has to be controlled within and around the project. Available right-of-way in most situations is too restricted to adequately accommodate both traffic and construction. This usually results in smaller work zones for crews and a higher level of interaction between them and traffic (Rowings et al. 1991; McCullouch et al. 1994). In addition, these projects have tremendous impacts on traffic flow both on the freeway and on adjacent streets. As a result, bridge reconstruction projects can cause serious problems for adjacent businesses.

This paper describes a study undertaken for the purpose of analyzing and replanning the construction of a major freeway overpass in Dallas, Texas, the Mockingbird Lane overpass bridge. The lessons learned from this case can provide sound insights for future bridge reconstruction projects.

NORTH CENTRAL EXPRESSWAY RECONSTRUCTION PROJECT

Built in 1955, North Central Expressway (NCE) is one of Dallas' oldest and most important highways. Running North-South, it connects downtown with the northern suburbs of Dallas. The current highway is 16.1 km long, with two lanes in each direction in the southern portion and three lanes in all other sections. The traffic volume on the highway exceeds 150,000 vehicles/day.

The Texas Department of Transportation (TxDOT) and the City of Dallas are now engaged in a massive reconstruction of the entire expressway to accommodate four lanes in each direction. Getting underway in September 1990, NCE reconstruction is expected to be completed by the year 2003 at an estimated cost of $550,000,000. The project also includes widening the frontage roads and all of the bridges crossing the expressway.

The NCE project was divided into five major contracts by area: N1, N2, M, S1, and S2. At the time that the Mockingbird Bridge was being reconstructed, N1 and N2 contracts were complete, S1 and S2 contracts were being built by one contractor, and the M contract was being built by another contractor.

Mockingbird Bridge Reconstruction Project

In widening NCE, construction crews had to demolish all its old bridges including one of the expressway's most important: Mockingbird Bridge. Mockingbird Lane, part of the S2 section of the project, crosses the expressway east-west and is a major link between many important areas of Dallas. The traffic volume on the bridge exceeds 35,000 vehicles/day.

The original bridge was a double-span monolithic concrete frame, with each span 14.6 m long. Its width, at 24.3 m, accommodated a U-turn and two lanes in each direction. The new bridge deploys double-span precast box girders. Each of the two spans is 27.6 m long. The bridge is designed to accommodate four lanes in each direction with two U-turns. The width of the new bridge varies from 48.6 to 69.3 m. The project also included rebuilding Mockingbird Lane east and west of the bridge to accommodate the new bridge traffic capacity. Frontage roads on both sides of the bridge were also rebuilt. Owing to limited space in some areas, these frontage roads were built as cantilevers over the new depressed main lanes.

Being in the heart of Dallas, the Mockingbird construction site was congested with traffic and surrounded by existing facilities and businesses. The available work space was controlled by the extremely limited right-of-way in the location. Furthermore, the construction contract explicitly stated that four lanes of expressway traffic were to be maintained during construction. The expressway and the bridge could only be closed during the removal of the existing bridge, at which time expressway traffic could be diverted onto the frontage roads.

TxDOT is financing the entire NCE project. The Federal Highway Administration (FHWA) has not been involved because the project did not meet its minimum right-of-way specifications. However, the City of Dallas is contributing 25% of

[1]C. T. Wells Prof. of Proj. Mgmt., Dept. of Civ. Engrg., Univ. of Texas, Austin, TX 78712.

[2]Asst. Lect., Dept. of Civ. Engrg., Zagazig Univ., Zagazig, Egypt.

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the cost of right-of-way. Because of the tremendous impact of the project on the central Dallas area, a supervising committee, called North Central Expressway Mobility Task Force, was formed to overview the project and coordinate its actions. This committee includes representatives from TxDOT, the City of Dallas, the Dallas Area Rapid Transit Authority, University Park and Highland Park tenant representatives, and the two contractors involved in the project. In addition, both TxDOT's Dallas district office safety committee and Structures Division must approve all aspects of any new construction plans.

Overview of Original Sequence and Traffic Control Plan

The original reconstruction plans for S2 were completed in 1992 by a major consulting company, which required five years to develop the plans because of the complexity of the project. The plans included 1,900 drawings, 420 of which were for traffic control.

The Mockingbird Bridge reconstruction plans were too complicated. They included heavily fragmented work zones, several temporary facility components, and too many traffic shifts. In total, the plans included 16 diversions or shifts in NCE traffic, and another six diversions of Mockingbird Bridge traffic. The plans also included building a complete yet temporary bridge east of the existing bridge to carry traffic during construction.

REPLANNING MOCKINGBIRD

The owner and the contractor believed that the planned construction sequence could be improved. With 150,000 vehicles using North Central Expressway daily, any improvement could have a significant impact. The two parties agreed to reinvestigate the issue. The contract, though on unit price basis, included a ''value engineering clause'' whereby the owner and the contractor committed to cooperate in enhancing project performance, and therefore, equally shared any savings.

In May of 1994, TxDOT contracted with a research team to investigate alternatives to the planned reconstruction of the Mockingbird overpass. TxDOT specified that the study should: (1) reduce construction duration; and (2) reduce traffic interruptions.

STUDY METHODOLOGY

Several parties participated in the development of the new plan. Having stakes in developing an optimal plan, all parties participated openly and within a team approach. At the core of the process was the research team (the authors), which organized the flow of information, analyzed construction problems, evaluated alternative solutions, and produced the final plans. The broader ''project team'' included three TxDOT representatives (district manager, project manager, and a field engineer), and four contractor representatives (project manager, assistant project manager, project superintendent, and scheduling engineer). This larger team reviewed the schematic plans and controlled the final evaluation process. A major player in the process was the Mobility Task Force, which linked plan developments with local business and residential communities, the City of Dallas, and the contractor of the adjacent M portion of the project. The Mobility Task Force held periodic meetings to communicate changes in the plan and to inform various parties about future courses of action. Finally, the safety committee of TxDOT thoroughly reviewed the final plan before its implementation.

A discussion of the chronology of the study activities follows.

Information Gathering and Initial Analysis

At the start of the study, the research team visited the site to better understand space availability, traffic flow, business locations, and respective access needs.

Based on the owner's requirements and information gathered about the project, the research team realized that any reconstruction plan should balance both traffic and construction needs. Thus, the study objective was articulated to develop an integrated bridge construction plan (BCP). The concept of a bridge construction plan was formalized and was defined as a comprehensive plan for bridge construction that optimizes project-defined objectives, such as safety, schedule, cost, and traffic capacity. Specifically, a BCP includes the following major items:

- a detailed description of the bridge construction methods;
- a general project specification as regard to safety and traffic handling;
- a detailed sequence of bridge reconstruction activities; and
- detailed plans for handling traffic during construction (commonly referred to as traffic control plans).

An initial analysis was conducted to assess the existing project situation. Based on this analysis the following concerns were identified:

- site conditions (right-of-way, accesses, traffic volume) were very adversarial;
- sizable percentage of the business community could be negatively affected by construction;
- project duration was relatively long (662 days); and
- responsibility for approval of plans was shared among several parties

Each step of the original plan was analyzed to assess the possibility of eliminating it, combining it with another step, or at least simplifying it. The research team detected a number of redundant steps that could be eliminated.

Development of Plan Evaluation Measures

Early in the analysis many suggestions as to how to rebuild the bridge were developed by either the research team or the contractor. The research team realized the need for a system with which to evaluate these ideas before advancing to the detailed planning phase. A hierarchy-of-objective-technique (HOT) diagram was developed to better understand the major objectives of BCP and the alternative ways to achieve them.

TABLE 1. BCP Performance Measures

Objective (1)	Measurement parameter (2)
Traveler safety	Interaction with equipment
	Detour configuration
	• Lane width
	• Detour alignment
	• Detour length
Worker safety	Interaction with traffic
	• Interaction level
	• Interaction duration
	Number of traffic changes
	Proximity to accidents
Accessibility	Traffic access (to streets and ramps)
	Access to business (from highway)
	Construction equipment access to work zone
Carrying capacity	Number of lane closures
	Duration of lane closure
Project duration	% Duration saving
Project direct cost	% Budget savings

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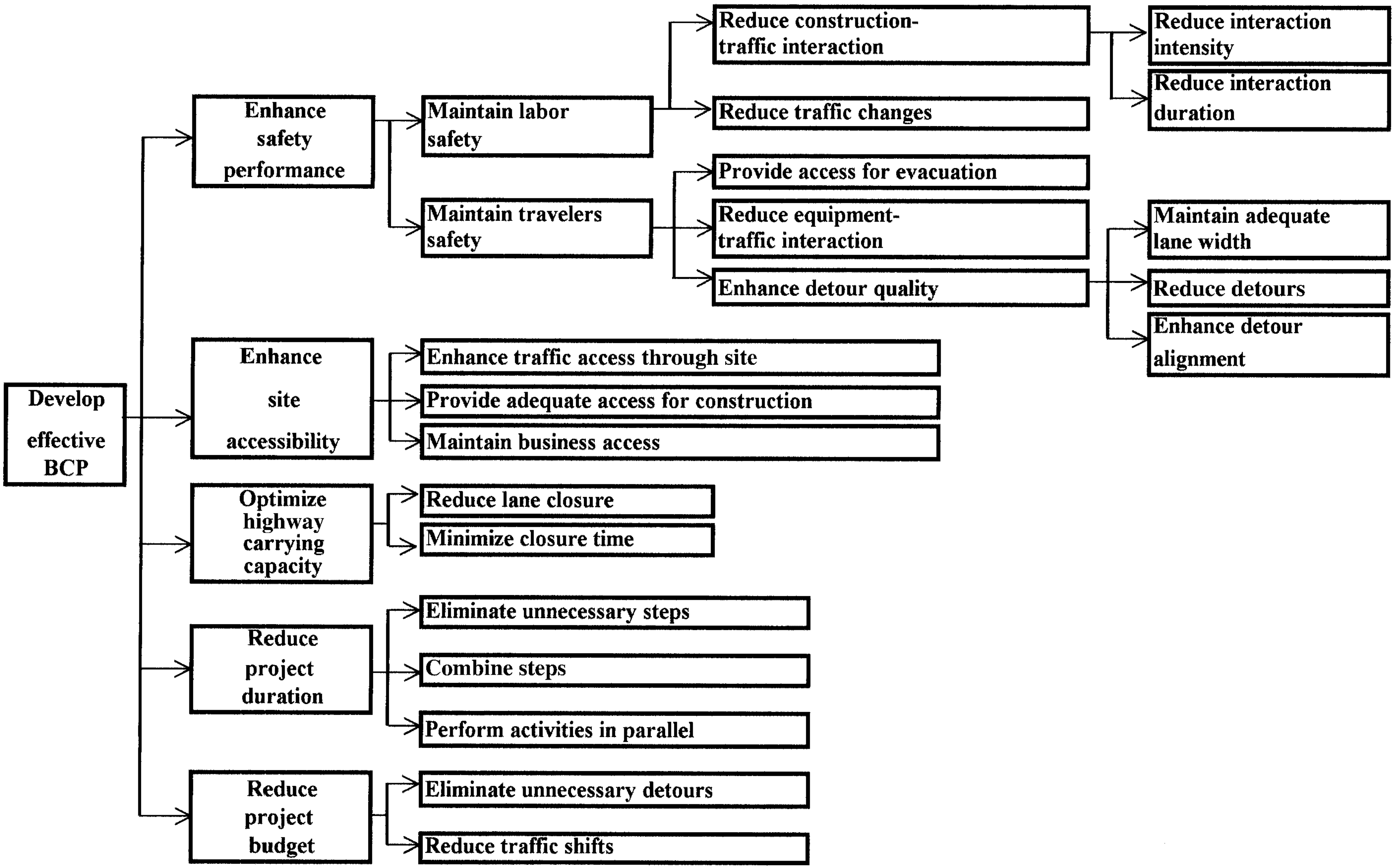


FIG. 1. BCP Analysis HOT Diagram

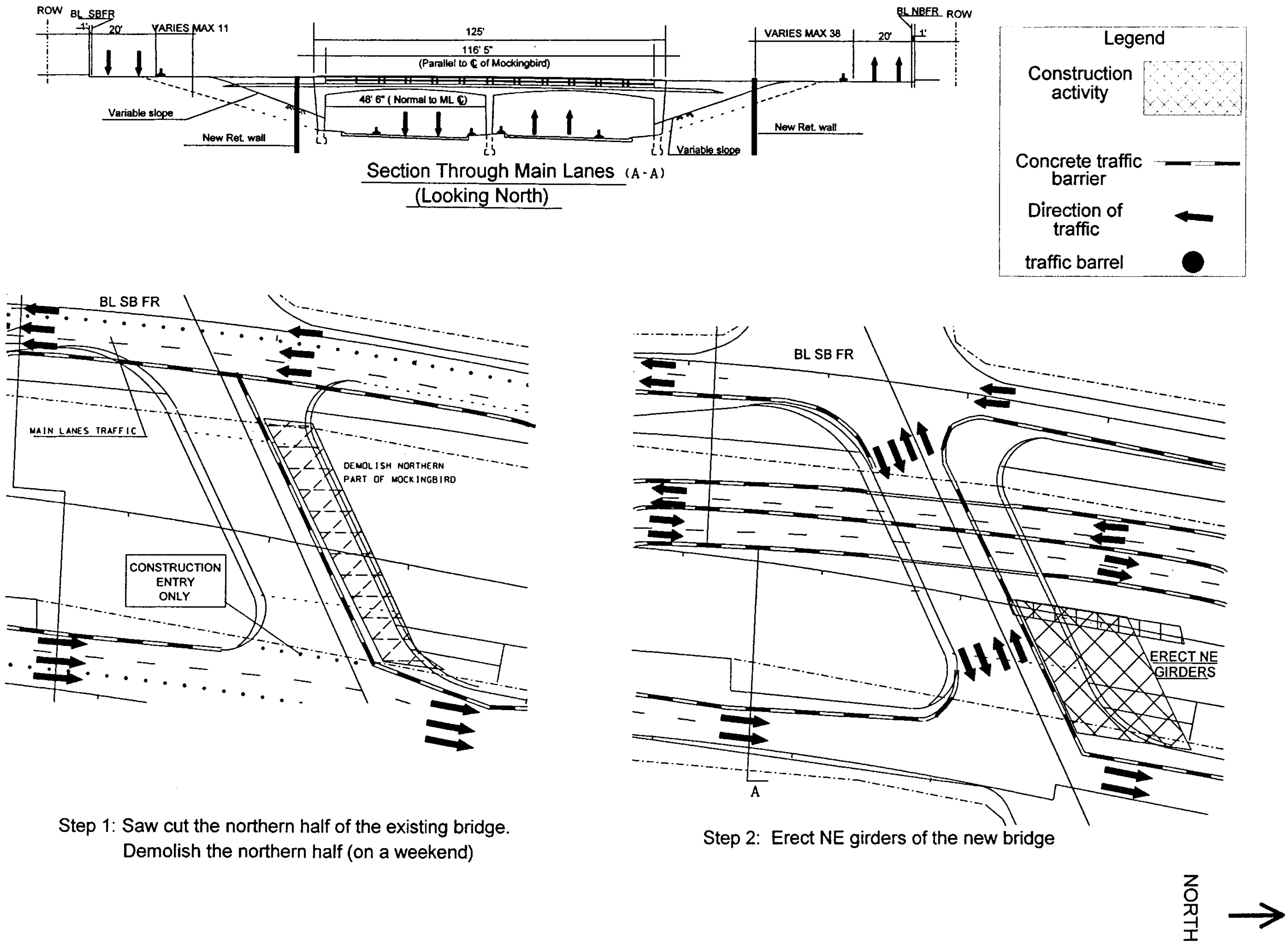
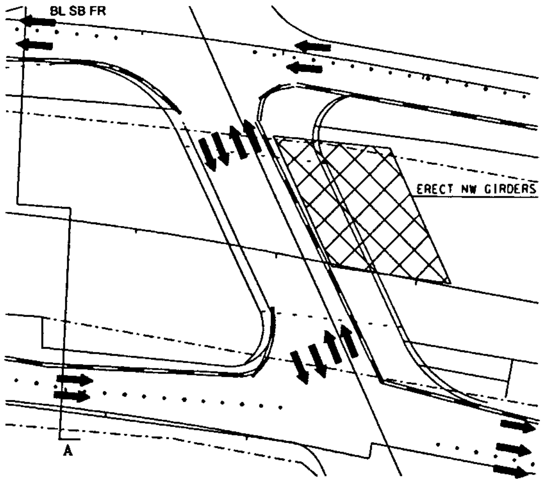
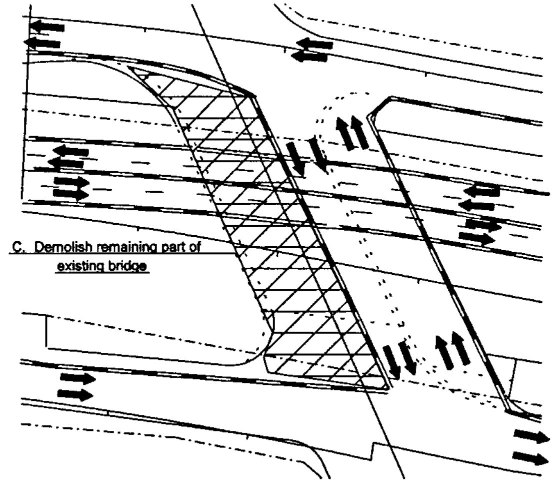


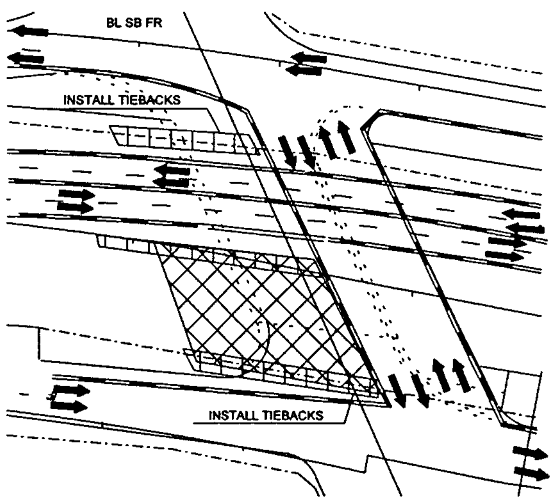
FIG. 2. Summary of Final BCP Steps



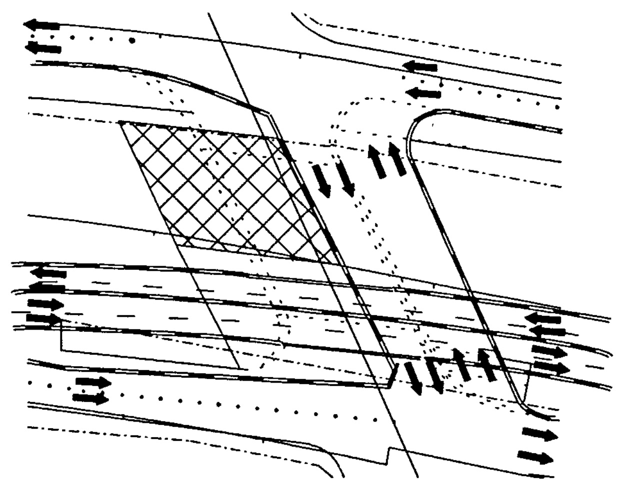
Step 3: Traffic on frontage road; erect NW girders



Step 4: a. Build northern deck of new bridge
b. Divert Mockingbird traffic onto the new bridge
c. Demolish the remaining part of the old bridge



Step 5: Erect SE girders



Step 6: Erect SW girders
Build southern deck of new bridge

NORTH

FIG. 2. (***Continued***)

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Fig. 1 shows an abstract version of that HOT diagram. Based on this HOT diagram, the team developed a list of criteria to evaluate BCP effectiveness. Table 1 shows a summary of these criteria.

Developing and Evaluating New Alternatives

The project team developed several suggestions for reconstructing Mockingbird Bridge as a result of several brainstorming sessions. A general analysis of the merits of each suggestion was also conducted during these meetings. Each party openly expressed concerns and criticisms to nearly every idea presented.

Afterwards the research team analyzed, in detail, the advantages and consequences of each proposal. In the beginning, plans with obvious safety hazards or significant undesirable impacts on traffic or business activities were eliminated. Some ideas were combined together. By the end of this analysis, two major alternative plans emerged as the most feasible ways to reconstruct the bridge.

The project team held two more meetings to evaluate the two alternatives. The performance criteria in Table 1 were applied in the analysis. One alternative was judged superior and received the initial approval of all parties involved.

Final Plan Development

The research team then concentrated on detailing the approved alternative into well-developed plans. In subsequent meetings, the owner and the contractor's detailed comments were elicited and added to the plans.

The research team utilized a variety of strategies to optimize the details of the selected alternative, of which the following proved to be of greatest significance:

1. Optimize work zone size
   - enlarge work zone areas
2. Integrate construction activities
   - perform activities in parallel
   - exploit retaining walls
   - integrate underground work
   - consider equipment space requirements and access needs
   - consider worker access to work zones
   - combine steps
   - minimize temporary activities
3. Facilitate traffic flow through the site
   - fully understand business and neighborhood concerns
   - reduce the frequency of traffic shifts
   - reduce the frequency of ramp closures
   - reduce detour work and exploit the existing facility
4. Examine safety issues closely
   - isolate traffic from construction
   - increase lane and shoulder width
   - enhance detour curve quality
   - reduce night shift work
   - study both equipment and traffic clearances
   - examine equipment maneuverability and mobility

These strategies provided the means for optimizing the BCP from all participants' points-of-view. They were effective because they integrated business, traffic, and construction needs into one solution. Future BCP developments should pursue these strategies collectively and concurrently.

The final plan was presented to the Mobility Task Force. After thorough analysis, the Task Force approved the plan for execution. Shortly thereafter, the TxDOT safety committee approved the plan.

Plan Implementation

In all, it took just two months to both develop and reach an agreement about the general construction approach. An additional three months were spent in detailing and optimizing the plan. By December 1994, the plan was approved by all concerned parties.

Actual construction started in late January, 1995. The project was executed successfully on time and within budget with no significant changes to the proposed plan.

FINAL PLAN

Plan General Concept

There were two major problems with the reconstruction of Mockingbird Bridge. The first was the question of how to demolish the old bridge and build the new one with minimum interruption to bridge traffic. The original plan tackled this problem by dividing the old bridge into six parts. Each part was to be demolished in a separate step. Immediately after the demolition of one part, a portion of the new bridge was to be built.

The new plan handled the matter in a different way. The bridge was divided into two parts: north and south. The north part was two-lanes wide and the south part was four-lanes wide. The north part was demolished first. Immediately after that, the whole northern portion of the new bridge was erected with a four-lane width. Mockingbird traffic was shifted to the new bridge, which allowed the demolition of the south part of the old bridge and the erection of the other half of the new one.

The second problem involved keeping four running lanes on the expressway at all times of construction. Because the old plan divided the bridge into six parts, the new bridge columns on the east side were to be constructed early in the project. These columns were in the middle of the east side of the existing Mockingbird Bridge. This meant that the east side could no longer be used to carry NCE traffic. During the construction of the west side, a new detour outside the bridge was to be constructed. This required the construction of a complete detour east of the bridge along with a temporary bridge to overpass it. During the construction of the detour and the bridge, NCE traffic was to be diverted onto the frontage roads several times.

In the new plan, traffic was put under the east span before any columns were built. At the same time, a complete detour was constructed under the west span of Mockingbird. For most of the project, traffic used this detour.

Construction Sequence

The final plan included 11 steps instead of the original 16 steps. Fig. 2 schematically explains the construction sequence. Briefly, the sequence of steps was as follows:

1. Shift Mockingbird traffic to the southern portion of the bridge. Saw cut the northern portion of the existing bridge, then demolish it on a weekend (divert NCE traffic onto frontage roads). Build a detour beneath the west span.
2. Shift NCE traffic west; build north east corner of the new bridge.
3. Shift NCE traffic onto frontage road (on a weekend); build north west portion of the new bridge.
4. Shift Mockingbird traffic to the new bridge; demolish the remaining part of the old bridge on a weekend (divert NCE traffic onto frontage roads).
5. Put NCE traffic back on the west side. Build southeast

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corner of the new bridge. Build a detour beneath the east span.
6. Shift NCE traffic east; build southwest corner of the new bridge.

ADVANTAGES OF NEW BCP

The new plan had 33% fewer steps and resulted in more than $450,000 in direct cost savings (15% of the direct cost allotted to Mockingbird Bridge portion of the S2 project). The cost of plan development (including time allotted by TxDOT and contractor personnel) was only 1/6 of this amount, which means a 15:1 return on investment. More significantly, more than 200 days were saved from Mockingbird Bridge schedule, about 30% of the total bridge construction duration. Such time savings had tremendous impacts on traveler user costs, estimated at around $200,000 each day of the S2 project (Harrison et al. 1998).

The new BCP reduced the total number of detours, ramp closures, and lane drops, which provided more accessibility to traffic through the site. Furthermore, due to the reduction of project duration and the elimination of several detours, the interruption to business access around the project was reduced significantly, both in frequency and duration. Finally, the plan provided a safer work environment to both the travelers and construction crews by the admission of TxDOT's safety committee.

CONCLUSIONS AND RECOMMENDATIONS

This paper presents an overview of the procedures and highly successful results of an actual case study of planning the reconstruction of a freeway overpass bridge in a congested urban setting. The study resulted in tremendous savings to the project in terms of cost, schedule, and traffic flow. Without counting savings in user cost, the benefit-cost ratio of the owner's investment in the study was over 15:1.

The case has led to several conclusions and recommendations. The keys to the success of the Mockingbird Bridge BCP development included the following:

- awareness of the critical contribution of the BCP to the overall success of urban freeway reconstruction projects; the sooner this occurs, the greater the likelihood of overall project success;
- integration of traffic safety, traffic control planning, construction sequencing, and constructability into one initiative;
- importance of generating several BCP approaches and not being complacent with the first scheme developed;
- importance of a team approach, particularly with contractor participation in the process.

The involvement of owner, contractor, and researchers in a single team to analyze bridge construction planning proved to be beneficial and cannot be overemphasized. During the development of the new plan, every project team meeting was essentially a discussion of constructability and safety and every party presented genuine concerns, creative solutions, and valuable criticism throughout. Such a collective effort resulted in an optimum BCP that balanced the often conflicting objectives of urban bridge construction, and at the same time, satisfied the needs of each project party. Furthermore, the mutual understanding of project needs and challenges extended the team atmosphere into the field activity. Thus, the shared design of BCP was a catalyst for a continuing healthy partnering relationship.

Finally, it should be noted that in order to support comprehensive bridge construction planning, there is an industry-wide need for implementable approaches toward evaluating multiple BCP schemes. The criteria listed in Table 1 were very helpful in quantifying the evaluation process. Nonetheless, the evaluation of BCP is definitely an area that needs enhancement. Traditionally, several important issues are usually at stake, yet, design teams have lacked any objective tool with which to evaluate them. A more comprehensive model needs to be developed to help design teams define and quantify BCP objectives.

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