BY THE U.S. GENERAL ACCOUNTING OFFICE

Report To The Honorable Donald W. Riegle, Jr. United States Senate

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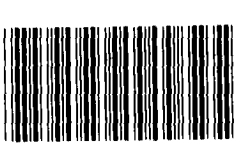
Early Decisions And Delays On The Zilwaukee, Michigan, Bridge Project

The Zilwaukee Bridge project on Interstate 75 near Saginaw, Michigan, has been controversial since its inception. The $81 million project, which is 90 percent federally funded, has been plagued by delays, revisions, and other difficulties. In August 1982, a construction mishap caused a near collapse, and work on the project has been halted until the extensive structural damage can be repaired.

This report discusses (1) the decision to replace the existing bridge, (2) consideration of alternatives to a high-level bridge, (3) the project's design phase, including the requirement that an alternate design be offered to construction contract bidders, (4) the contract bidding phase, including the rejection of the original low bid, and (5) construction problems experienced before the August 1982 near collapse. A subsequent report will discuss events surrounding the construction mishap and its potential impact on the completed bridge's maintenance and safety.



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WASHINGTON, D.C. 20548

RESOURCES, COMMUNITY,
AND ECONOMIC DEVELOPMENT
DIVISION

B-207010

The Honorable Donald W. Riegle, Jr.
United States Senate

Dear Senator Riegle:

As your September 30, 1982, letter requested, we are reviewing the Zilwaukee Bridge project, a 90-percent federally funded bridge replacement project on Interstate 75 near Saginaw, Michigan. You asked us to evaluate the decisions to replace the existing drawbridge and to build the high-level bridge; the construction contract bidding process, including the rejection of the original low bid; Federal and State highway officials' supervision, approval, and monitoring of design and construction; structural problems that resulted in the near collapse of part of the northbound bridge in August 1982; and potential maintenance and safety problems that the State may have with the bridge once it is completed.

This report is in response to your office's subsequent request that we provide an initial report covering the (1) decision to replace the drawbridge, (2) consideration of alternatives to a high-level bridge, (3) design phase, (4) bidding phase, including the rejection of the original low bid, and (5) construction problems experienced before the August 1982 near collapse. Our objectives were to examine the major decisions, problems, and controversies in these areas and determine the soundness and impact of Federal and State actions. A second report on the August mishap and its potential impact on project schedules and costs and future maintenance, safety, and service life will be provided at a later date.

BACKGROUND

The Zilwaukee project, which has experienced controversy, delays, revisions, and other difficulties, including the near collapse, is designed to replace the existing 593-foot long, four-lane drawbridge where Interstate 75 crosses the Saginaw River. The planned replacement is a 1.5-mile long, high-level bridge with a 125-foot vertical clearance over the river's shipping channel. The high-level bridge is being built to allow both vehicle and

ship traffic to move freely at the bridge. Its length is necessary to obtain the 125-foot clearance required to allow ocean-going vessels passage underneath without exceeding the maximum grade or incline that is standard for the Interstate System.

The new bridge is actually two bridges side by side, one for northbound and one for southbound traffic. Each bridge is to have four driving lanes and two shoulders. A relatively new concrete design and construction technique is being used to build the bridges. The first cost estimate for the project--which was made in 1968--was $22 million. The current contract cost is $81 million, which does not include the cost involved in repairing the damage from the near collapse and any additional contractor claims against the State. In comparison, the drawbridge, completed in 1960, cost $4.2 million. (See p. 2 of app. I for photographs of the drawbridge and the partially completed high-level bridge.)

The Federal Highway Administration (FHWA), Department of Transportation, gave the State of Michigan formal approval to build a high-level bridge in June 1968. Federal environmental requirements were met in November 1974. Construction began in October 1979, and the bridge was originally scheduled to be completed in November 1983. But because of the near collapse and other problems, the bridge is not expected to be completed before late 1985 or early 1986. Construction on the damaged structure was stopped in August 1982 and will not resume until the damage from the near collapse is repaired.

During our review, we held discussions with FHWA officials and reviewed pertinent files and other documents at FHWA's Washington, D.C., headquarters and its division office in Lansing, Michigan. We also held discussions with appropriate officials in and reviewed files at the Michigan Department of Transportation (MDOT). In addition, we discussed the project with FHWA's regional bridge engineer, MDOT's project engineer at the construction site, a spokesperson for the construction contractor, and officials of other agencies, such as the Maritime Administration, the Coast Guard, and the Army Corps of Engineers. The methodology and the support for MDOT's various cost estimates for the alternatives to a high-level bridge could no longer be located and thus were not available for our analysis. However, we discussed these estimates with FHWA and MDOT officials.

We found that many project decisions have been controversial and the project has had problems that have delayed its completion and/or increased costs. However, based on available data, additional capacity for vehicle traffic at the bridge was needed, and the decision to build a high-level bridge appears to have been reasonable, considering the cost estimates and the existing conditions at the time the decision was made. Furthermore, the various problems apparently had been overcome and the project was

progressing up until the August 1982 mishap. We believe that some of the controversy and delay could have been avoided with better and earlier communication between FHWA and MDOT. Also, broader input into the development of the bridge design using value engineering or some other systematic, cost-control program may have improved the design and reduced costs. The results of our review of the initial five areas are summarized below. A more detailed discussion is contained in appendix I. Appendix II is a chronology of events on the project.

DECISION TO REPLACE THE DRAWBRIDGE

The decision to replace the drawbridge at the Interstate 75 Saginaw River crossing resulted from several problems with the bridge. The basic problem was that a few years after the drawbridge was completed, Interstate 75 traffic was greater than MDOT anticipated and traffic volumes crossing the bridge exceeded design capacity. This problem was further compounded by increased bridge openings for navigation, leading to vehicle backups and accidents. In addition, MDOT officials considered the narrow bridge opening (150 feet compared to a 200-foot wide shipping channel), combined with a curve of the river, to be a navigation hazard which could lead to a ship/bridge accident and freeway closure. (Ships have accidentally rammed the drawbridge twice in the past and hit pilings protecting the bridge numerous times.) Further, FHWA does not consider drawbridges in keeping with the purpose and function of the Interstate System, which is designed for high-speed, uninterrupted traffic flow.

The conditions such as traffic volume exceeding bridge capacity have existed since FHWA authorized MDOT to design and construct a drawbridge replacement. For example, daily traffic volumes from 1968 to the present have exceeded the drawbridge's design daily capacity of 20,800 vehicles. In addition, the 1973 through 1975 widening of Interstate 75 between Flint and Bay City, Michigan, from four lanes to six lanes (three lanes each way) has contributed to additional congestion at the four-lane drawbridge. Although bridge openings dropped significantly in 1982 (down to 417 from 897 in 1981), the port of Saginaw remains active. According to various Federal, State, local, and shipping association officials, it is uncertain whether port activity will increase or decrease in the future. Ships have not recently hit the drawbridge, but the possibility remains.

ALTERNATIVES TO A HIGH-LEVEL BRIDGE

MDOT studied several alternatives to a high-level bridge for replacing the Interstate 75 drawbridge. They included

--rerouting traffic (either temporarily or permanently) onto the Interstate 675 business loop through downtown Saginaw,

--building a tunnel,

--widening the existing drawbridge,

--building a parallel freeway to the south and west of Saginaw and Interstate 75, and

--adjusting port operations.

MDOT considered these alternatives at various times before bridge construction started but rejected them for various reasons.

Rerouting traffic to Interstate 675 was rejected due to high costs and potential adverse impacts. This alternative would have involved increasing Interstate 675 capacity to handle the traffic of both roadways. In 1978, MDOT estimated the cost at $120 million, considerably more than the $68.5 million FHWA had programed for the high-level bridge. Also, the city of Saginaw opposed this alternative because of potential negative social, economic, and environmental impacts of widening the road and the increased traffic. Currently, Interstates 75 and 675 peak traffic periods coincide only on Friday afternoons. However, traffic on Interstate 675 is near its design capacity and diverting Interstate 75 traffic would more than double the volume.

MDOT rejected a tunnel because it was too expensive. In 1970 it estimated the construction cost at $96 million, with annual operation and maintenance costs of $620,000. At that time MDOT estimated the cost of a high-level bridge at $35 million.

Although widening the existing drawbridge was not technically feasible, MDOT considered whether additional capacity could be obtained by building a parallel three-lane drawbridge and converting the existing bridge to one-way operation. MDOT estimated this alternative to cost only $9 million in 1976 but rejected the idea because it is FHWA's policy not to construct drawbridges on the Interstate System.

MDOT rejected building a parallel freeway (crossing the Saginaw River above the port) to alleviate traffic congestion on Interstate 75 because of the cost and a long implementation period. The parallel freeway would have been a non-Interstate system route and thus eligible for 70 percent, rather than 90 percent, Federal funding. Furthermore, FHWA advised MDOT that funds available for the high-level bridge replacement could not be diverted to construct the alternate non-Interstate route. MDOT estimated that project completion could take up to 15 years because of the long times required for Federal, State, and local approvals compared with an estimated 4- to 5-year implementation period for the high-level bridge alternative.

MDOT considered that adjusting port operations was not feasible due to high costs and local opposition. In determining the estimated cost, MDOT considered relocating the port to the downstream side of the bridge, installing a conveyor system to carry goods to receiving firms upstream, and upgrading the existing crossing to six lanes. MDOT's estimate totaled about $133 million, or about twice the $68.5 million that FHWA had programed for the high-level bridge in 1978. Also, the city of Saginaw opposed this proposal because it believed the city's port activity would be damaged.

THE DESIGN PHASE

A problem in reaching agreement on an FHWA cost reduction measure extended the design phase somewhat. Specifically, at the time MDOT was involved in preliminary design work, FHWA's Region 5 had a policy that, on major bridge projects, States must offer alternate designs for bidding purposes to foster competition. Usually at least a steel design and a concrete design are to be offered to take advantage of price competition between concrete and steel materials and construction techniques.

In 1974 MDOT considered, then rejected, this FHWA regional policy position on developing alternate designs as a cost-saving measure and for 2 years worked on only one design. After MDOT submitted a preliminary plan for only a steel structure for FHWA review, FHWA put increased emphasis on the requirement for an alternate design; MDOT then agreed to develop a concrete design alternate. According to MDOT and FHWA spokespersons, the delayed start on the design work for the concrete alternate extended the design phase only a few months. However, this policy apparently fostered competition, and the contract awarded for the construction of a concrete bridge was $9.4 million less than the low bid for a steel bridge. According to FHWA, using alternate designs has resulted in nationwide savings of over $100 million during the past 4 years.

We believe that if early in the design process MDOT officials had sought FHWA's concurrence in its decision to reject FHWA's regional policy and not develop an alternate design for Zilwaukee, the delay needed to later develop the alternate may have been avoided. Also, at the start of design development, FHWA officials could have questioned whether MDOT was developing an alternate design as required by its policy.

We also identified instances where FHWA suggested design changes, but MDOT disagreed or believed that the design had progressed too far for a change, and MDOT's position prevailed. As a result, there may have been various cost-saving opportunities that were not taken advantage of during design development. For example, FHWA questioned the length of the proposed bridge approach spans and the need for haunched spans (a depth variation of 8 feet

at mid-span to 20 feet at span ends) and suggested that shorter constant depth spans would look better and be more economical. MDOT told FHWA that the longer spans were more economical and that it preferred the haunched spans for esthetic reasons. FHWA did not pursue the matter further; however, FHWA's regional bridge engineer told us that the State's position was not valid, but FHWA had no basis for questioning it further. With regard to the span lengths, MDOT officials told us that while it is true that the approach spans possibly could have been altered somewhat, they believe their position was valid. According to MDOT, they held extensive discussions with FHWA Michigan Division officials and it was agreed not to build a "forest of columns" that would have resulted if shorter spans had been used. MDOT believes that the location's topography practically dictated the proposed span lengths because of obstacles such as existing railroad tracks and crossroads.

If MDOT had used a concept such as value engineering[1] to provide a broader perspective and input during project conception or preliminary design, the Zilwaukee project may have benefited. FHWA currently encourages value engineering of projects, such as Zilwaukee, but the concept had not been widely accepted and applied to highway projects until recently. A value engineering incentive clause was added to the construction contract to allow the contractor to propose changes during construction and share in the cost savings. According to MDOT officials, the contractor has taken advantage of the clause by proposing a revised construction method for one of the bridge ramps.

BIDDING PHASE

The project's bidding phase was extended because of an FHWA national inflation fighting program. The extension added a year to the estimated project completion date. On the other hand, the extension also resulted in a $4.2-million reduction in the low bid for constructing the project. FHWA policy guidance for the program provided that if the low bid for a construction contract exceeded the State engineer's cost estimate by more than 7 percent, the bid should be rejected, unless an exception was justified. Thus, when the low bid for the project came in 34-percent greater than MDOT's estimate, FHWA reexamined the project to determine whether the contract proposal should be reissued and

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[1]Value engineering is a cost-control method that employs a systematic, multidiscipline, creative approach to identify, analyze, and establish a value for an item's function. The objective is to satisfy the required function at the lowest cost consistent with the requirements of performability, reliability, and maintainability.

modified in order to obtain more competitive bidding and resulting lower prices and concluded that the bid should be rejected. While neither FHWA nor MDOT estimated the costs of delaying construction for a year, FHWA stated that the savings anticipated from a rebid would more than offset any costs resulting from the delay necessary for redesign and readvertising. While the second advertising resulted in a low bid that was $4.2 million less than the first low bid, the actual savings will be somewhat less than this amount because price escalators for certain materials were added to the second contract proposal (in an effort to eliminate some of the risk for the bidders due to inflation and hopefully reduce their bids). To date the price escalators have added about $865,000 to the $76.8 million construction contract.

CONSTRUCTION PROBLEMS

Several problems have impeded construction progress and added to project costs since construction began in October 1979. The most significant were that:

--Some of the steel H-beam piles (which were driven in excess of 80 feet to bedrock to support the bridge) failed to meet loading specifications.

--Many of the individual concrete box girder segments (which are attached to each other to construct the bridge spans) developed cracks during the curing process.

--The launching girder (which is a steel truss used to transport and place the individual segments) experienced design difficulties and fabrication delays.

--The Dutch managers (who were employed by the foreign joint venture partner) had difficulty in dealing with U.S. administrative procedures (documentation, oversight, and red tape).

Although these problems apparently have been overcome, they added about $1.8 million to contract costs and may lead to some claims and/or lawsuits against MDOT which could further increase bridge costs. For example, MDOT officials believe they have solved the segment cracking problem by adding additional transverse post-tensioning. The number of steel strands stretched across the width of each segment was increased from 10 to 12, at a cost of over $222,000 for the additional strands. The problems also delayed construction, but the subsequent construction failure eclipsed the impact of this delay.

THE NEAR COLLAPSE

Shortly after midnight on August 28, 1982, while a precast concrete segment was being put in place during construction of

the northbound structure, a section of the bridge teetered, dropping over 5 feet at one end and rising about 3.5 feet at the other end. This resulted in considerable physical damage to the bridge, but no personal injuries.

Both MDOT and the contractor hired consultants to determine the cause of the failure, and construction has stopped until the damaged section can be repaired. Also, on February 18, 1983, the Subcommittee on Investigations and Oversight, House Committee on Public Works and Transportation, held a hearing in Saginaw, questioning officials of MDOT and FHWA. As mentioned previously, these matters will be discussed in more detail in our second report.

CONCLUSIONS

Our discussions with FHWA and State officials and review of pertinent data indicate that the decision to replace the drawbridge was reasonable considering the conditions at the time of the decision. A few years after the drawbridge was completed, its traffic was greater than MDOT anticipated and exceeded the bridge's design capacity. Also, the number of bridge openings for ship traffic substantially increased, causing additional problems for vehicle traffic. Furthermore, FHWA had established a policy that drawbridges are generally not appropriate for the Interstate System because they can interrupt the free flow of traffic.

The methodology and support for the State's various estimates for the alternatives to a high-level bridge could no longer be located and thus were not available for our analysis. However, based on our discussions with various officials and review of pertinent files of FHWA and MDOT, the State's choice of the high-level bridge appears to have been reasonable, based on the estimates and conditions at the time the decision was made.

Much of the controversy and questions concerning the project centers on the design and bidding phases, primarily FHWA's requirement for an alternate design and its rejection of the first low bid. The alternate design requirement and the rejection of the first low bid caused some delay in the project, but they apparently increased competition and reduced costs. We believe that the delay, resulting from the requirement for an alternate design, could have been avoided if MDOT's initial decision not to develop an alternate had been coordinated with FHWA. Also, if MDOT had used value engineering or some other broader input during design development, it may have helped improve the design and reduced costs. FHWA currently encourages value engineering, but the concept had not been widely accepted and applied at the time the Zilwaukee bridge design was developed.

The construction problems that occurred before the August 1982 near collapse slowed construction progress and increased costs, but they have apparently been overcome. The more difficult

task will be repairing the damage from the near collapse and continuing construction. At the end of this phase of our review, MDOT had not finalized the design for the repair work.

AGENCY COMMENTS AND OUR EVALUATION

In commenting on our draft report, the Department of Transportation said that the report is well documented, factual, and quite complete. The Department, however, commented that while FHWA does encourage value engineering, it also encourages alternate design as a viable solution to reducing bridge costs. According to the Department, value engineering may have reduced costs but it may not have improved the design.

We recognize that alternate design can reduce costs. A process such as value engineering also could have benefited the project, and we consider a design change that provides for the bridge to carry out its intended purpose at a lower cost to be an improvement.

MDOT COMMENTS AND OUR EVALUATION

MDOT said that it has reviewed the report in detail and is in general agreement with the statements made in all sections of the report. However, MDOT officials wanted to clarify that at the time of the initial Zilwaukee design, the value engineering method was somewhat in its preliminary stages and its formal finalization did not take place until later. We realize, and the report notes, that value engineering was not widely used until later. Our conclusion in this regard is intended as a consideration for future projects.

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As arranged with your office, unless you publicly announce its contents earlier, we plan no further distribution of this report until 7 days from its issue date. At that time we will send copies to appropriate congressional committees, agency officials, and interested parties. We will also make copies available to others on request.

Sincerely yours,

J. Dexter Peach
Director

Contents

ABBREVIATIONS

BVN/STS	Bouvy, van der Vlugt, and van der Niet/ Segmental Technology and Services, Incorporated
FHWA	Federal Highway Administration
GAO	General Accounting Office
MDOT	Michigan Department of Transportation
UMTA	Urban Mass Transportation Administration

GLOSSARY

Bridge deck	the roadway of a bridge
Cantilever	either of two beams projecting toward each other from piers to be joined to form the span of a cantilever bridge
Footing	the base on which a pier rests
Joint venture	a partnership or cooperative agreement between two or more contractors which is usually restricted to one specific undertaking
Pier	the vertical supports for bridge spans
Pile	a long slender piece of timber, steel, or reinforced concrete driven into the ground to carry a vertical load on which a footing rests
Piling	piles collectively

DISCUSSION OF THE ZILWAUKEE BRIDGE PROJECT FROM INCEPTION TO THE AUGUST 28, 1982, MISHAP

INTRODUCTION

On August 28, 1982, the Zilwaukee Bridge, under construction near Saginaw, Michigan, suffered a construction failure which resulted in a near collapse. Although no workers were injured, the accident caused extensive damage to the bridge. The bridge, an $81 million high-level structure, is designed to replace a drawbridge on Interstate 75. The largely federally funded project, which employs a relatively new design and construction technique, has experienced controversy, delays, revisions, and other difficulties throughout its development.

The State of Michigan is the project owner, and the Michigan Department of Transportation (MDOT) is the project administrator. The Federal Highway Administration (FHWA) is providing 90 percent of the project's cost under the Federal-aid highway program, and the State is providing the remaining 10 percent.

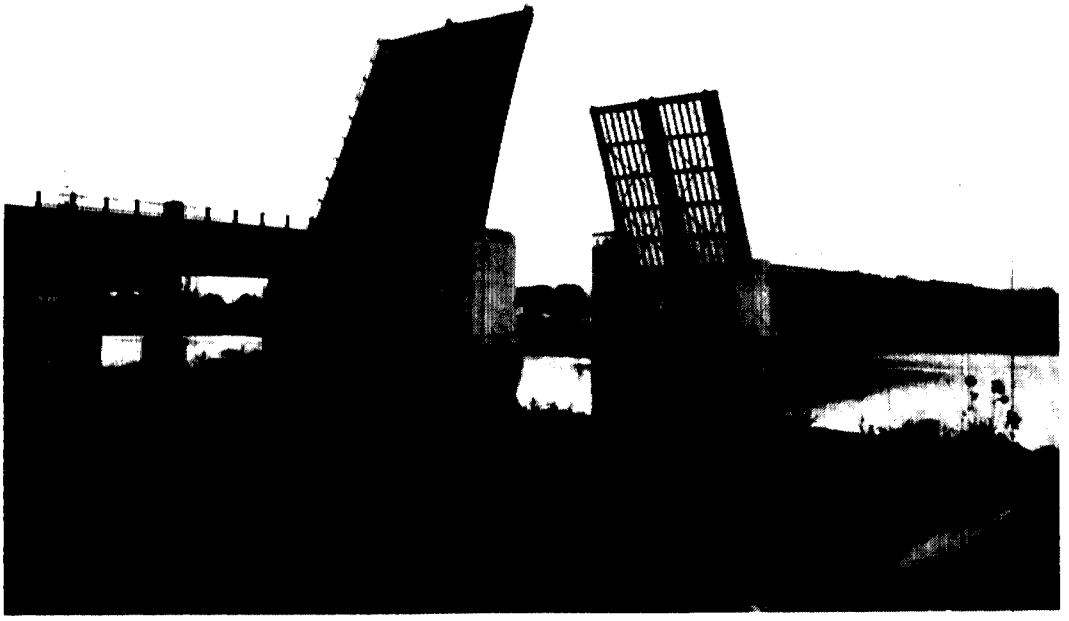
MDOT built the drawbridge in the late 1950's at a cost of $4.2 million, of which $3.6 million were Federal funds, and opened it to traffic on December 5, 1960. MDOT designed the drawbridge as part of a State freeway system, but when the 1956 Highway Act established the Interstate System, MDOT incorporated this State route into the Interstate 75 route. Before the drawbridge, travelers had to use urban bridges to cross the Saginaw River--such as the Genessee Street bridge in downtown Saginaw, 4 miles to the south of the Interstate 75 drawbridge, or the M-13 bridge in downtown Bay City, 7 miles to the north.

The drawbridge was designed to handle projected traffic for 1975; however, soon after opening, traffic volumes exceeded these projections. In addition, increased ship traffic caused more bridge openings, which led to backups and accidents. In June 1968 FHWA agreed with the State of Michigan that it was in the public interest to replace the 593-foot-long drawbridge with a fixed structure more appropriate for an interstate freeway system and authorized the State to proceed with the design and construction of a high-level bridge.

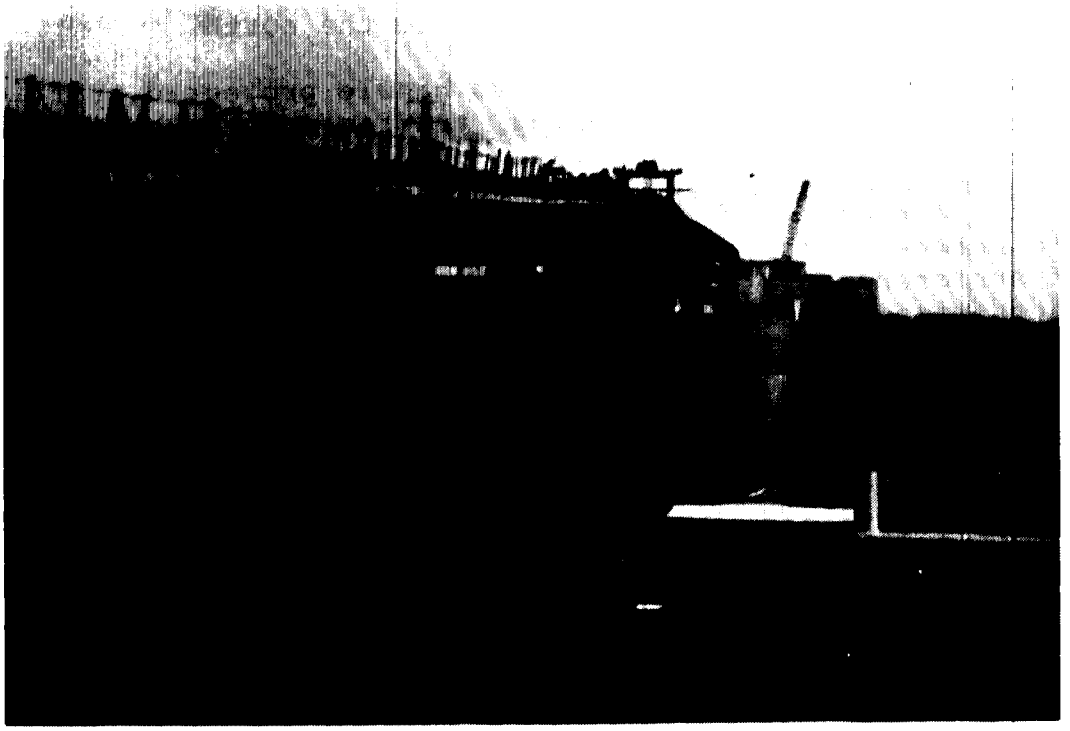
The high-level bridge, designed by State consultants in late 1977 and early 1978, is actually two structures built side-by-side. Each 1.5-mile long structure will have four 12-foot driving lanes and two 11-foot shoulders. The 1.5-mile length is necessary to obtain a 125-foot clearance over the shipping channel without exceeding a road grade or incline of 3 percent (3 feet of rise or drop for every 100 feet of distance) which is standard for the Interstate System. The 125-foot clearance allows large ships to serve Saginaw.

APPENDIX I

The Zilwaukee Bridge



The existing drawbridge



The partially completed high-level bridge

In the late 1960's, the U.S. Army Corps of Engineers requested the 125-foot clearance over the shipping channel to provide passage for ocean-going ships. In July 1978 the Coast Guard issued a permit for the bridge, noting the 125-foot vertical clearance. (The Coast Guard assumed responsibility for bridge permitting from the Corps in 1967.) Correspondence regarding the permit indicated that navigational interest wanted at least a 125-foot clearance. Coast Guard spokespersons told us that the 125-foot standard for bridges on the Great Lakes and connecting waters is based on criteria for ocean ships transmitting the Saint Lawrence Seaway, the route such ships use to enter the Great Lakes system.

In October 1979 the State awarded a $76.8 million construction contract. (Material price adjustments and other changes have increased the contract to $81.1 million.) Construction began the same month and was scheduled for completion in November 1983. The August 1982 construction mishap has delayed the estimated completion date to late 1985 or early 1986 and added to project costs. Total project costs (right-of-way acquisition, project design, construction, repair, and others) are currently estimated at over $115 million. (App. II presents a more detailed chronology of the Zilwaukee Bridge project.)

OBJECTIVES, SCOPE, AND METHODOLOGY

Based on Senator Riegle's September 30, 1982, request and subsequent discussion with his office, we are reviewing the Zilwaukee Bridge project with respect to

--the decisions to replace the existing drawbridge and to build the high-level bridge;

--the construction contract-bidding process, including the rejection of the original low bid;

--Federal and State highway officials' supervision, approval, and monitoring of design and construction;

--structural problems that resulted in the near collapse of part of the northbound bridge in August 1982; and

--potential maintenance and safety problems that the State may have with the bridge once it is completed.

As requested by Senator Riegle's office, this initial report covers the decision to replace the existing bridge through the August 28 near collapse. Our objectives were to examine major decisions, problems, and controversies surrounding the project and determine the soundness and impact of Federal and State actions. We are continuing our review, and a second report on the August mishap and its potential impact on project schedules and costs and future maintenance, safety, and service life will be provided at a later date.

We conducted our audit during the period from November 1982 to March 1983. We reviewed the June 1968 authorization of the project and subsequent events that occurred through August 1982. We held discussions with appropriate FHWA officials and reviewed pertinent documents at its Washington, D.C., headquarters and Lansing, Michigan, division offices. At the State level, we held discussions with appropriate MDOT officials and reviewed pertinent documents at its Lansing, Michigan, headquarters and at its Zilwaukee, Michigan, project offices. We also reviewed pertinent audit reports prepared by Commission Audit, MDOT's internal audit group.

We discussed the current and anticipated Port of Saginaw shipping activity with (1) officials of the Maritime Administration, Great Lakes Region Office; the U.S. Coast Guard, Detroit; and the Army Corps of Engineers' Detroit District and Waterborne Commerce Statistics Center, (2) a spokesperson of the Lake Carriers' Association, which represents U.S. Great Lakes shippers, and (3) the manager of MDOT's Port Development Section.

We discussed the project with the FHWA's Director, Office of Structures, Region 5, and a spokesperson associated with the joint venture of Stevin Construction, Incorporated, and Walter Toebe Construction Company which are building the bridge. We also visited the project site and talked with MDOT's project engineer.

We performed this review in accordance with generally accepted government auditing standards.

The State transportation agency, MDOT, was previously called the Michigan Department of State Highways and Transportation and at one time the Michigan Department of State Highways. In this report we refer to the State agency as MDOT.

DECISION TO BUILD THE HIGH-LEVEL BRIDGE

During the early 1960's, increased highway and shipping traffic resulted in temporary freeway interruptions. This problem, along with the possibility of an extended interruption of freeway service through the accidental ramming of the drawbridge, indicated a need for corrective action at the Interstate 75 Saginaw River crossing. The basic problem was that traffic volumes on a 50-mile stretch of Interstate 75, which included the bridge, were continually exceeding design capacities, indicating the need for expansion; however, widening the drawbridge was not feasible because of the mechanisms involved. Also, FHWA no longer allowed drawbridges on the Interstate System. This problem of inadequate capacity was further exacerbated during peak traffic periods by drawbridge openings for ship traffic which has precedence over vehicle traffic. Another consideration was that the bridge opening was narrower than the shipping channel, causing both a hazard to navigation and a threat to the bridge's structural integrity. MDOT recognized these problems and, in June 1968, FHWA approved MDOT's request for Federal funding to design and construct a

high-level structure to replace the drawbridge. At that time the estimated cost of the proposed bridge was $22 million. In the early 1970's, MDOT began widening Interstate 75 to provide the needed capacity.

Although FHWA had approved funding for a high-level bridge, MDOT considered various alternatives (which potentially might cost less or result in fewer negative social and environmental impacts) before deciding on a high-level structure. MDOT considered these alternatives at various times between 1970 and 1976, before starting detailed design work on the high-level structure. These considerations and decisions were made independent of FHWA.

Details on the problems that led to the decision to replace the drawbridge and the alternatives MDOT considered follow.

Traffic volume dictates the need for expansion

The population and economic expansion in southeastern Michigan and the economic and recreational expansion in northern Michigan in the early 1960's resulted in commercial and recreational traffic volumes on Interstate 75 which exceeded estimates of future year volumes and led to MDOT's 1967 request to FHWA to replace the drawbridge. Since then the problem has continued. Specifically, starting in 1968, vehicle traffic has exceeded the drawbridge's average daily traffic design volume of 20,800 vehicles in both directions, as shown below.

Year	Average daily traffic	Year	Average daily traffic
1960	5,000	1972	26,300
1961	Not available	1973	26,900
1962	11,000	1974	25,800
1963	15,000	1975	24,900
1964	17,500	1976	24,000
1965	17,500	1977	28,400
1966	19,800	1978	29,800
1967	20,000	1979	29,400
1968	21,000	1980	25,605
1969	21,000	1981	26,200
1970	22,400	1982	25,400
1971	28,900		

As illustrated on the following page, Interstate 75 traffic is considerably higher during the "summer holiday weekends." Traffic also increases on Interstate 675, indicating that some Interstate 75 travelers are using it to bypass the drawbridge. The table shows daily traffic on Interstates 75 and 675 during three holiday periods in 1982.

APPENDIX I

Memorial Day	Interstate 75	Interstate 675
Fri. 5/28	50,531	38,432
Sat. 5/29	40,671	19,530
Sun. 5/30	28,074	12,920
Mon. 5/31 (holiday)	46,825	18,548
Tues. 6/01	34,650	30,049
Independence Day		
Fri. 7/02	55,734	32,793
Sun. 7/03	49,468	18,351
Sun. 7/04 (holiday)	30,091	11,456
Mon. 7/05	50,849	15,809
Labor Day		
Fri. 9/03	50,504	37,036
Sat. 9/04	42,847	19,500
Sun. 9/05	33,138	13,608
Mon. 9/06 (holiday)	45,972	22,108
Tues. 9/07	35,341	29,979

Peak traffic periods for Interstates 75 and 675 generally coincide on Friday afternoons. Peak periods for Interstate 75 are from 4 p.m. to 9 p.m. on Friday, 8 a.m.to 1 p.m. on Saturday, and from 1 p.m. to 10 p.m. on Sunday. The peak periods on Interstate 675 are from 7:30 a.m. to 9:30 a.m. and 4 p.m. to 6 p.m., Monday through Friday.

Roadway widening north and south of the drawbridge have further aggravated the problem of traffic congestion. Before 1973 Interstate 75 had two 12-foot lanes in each direction between Flint and Bay City, Michigan. However, between 1973 and 1975, MDOT added one lane in each direction to this section of Interstate 75 to meet traffic needs. But until the high-level bridge is completed, the decrease in the roadway width from three lanes to two each way as they cross the drawbridge creates a traffic obstruction which increases accident potential, especially during summer and holiday weekends.

Navigation has had priority over vehicle traffic

The capacity problem was further exacerbated by bridge openings for navigation, leading to traffic backups and accidents.

Navigation on navigable waters such as the Saginaw River may not be unreasonably impeded by bridges. Thirty-three U.S.C. 512 provides that:

> "No bridge shall at any time unreasonably obstruct the free navigation of any of the navigable waters of the United States."

Furthermore, the Code of Federal Regulations, 33, C.F.R. 117.1(a), states that:

> "In constructing a bridge with a draw, and in undertaking to open and manage the draw so as to allow vessels to pass, the owner has recognized the right of vessels to pass through without any appeal to the national authority to protect that right."

And the courts have said that:

> "The maritime tribunals view bridges as obstruction to navigation. The right of navigation is paramount; land traffic over the bridge is subservient thereto."[1]

During the 1950's, before the drawbridge was constructed, river traffic was approximately 150 ships annually. This relatively low volume, combined with the much larger cost of a high-level structure, led to the decision to construct the drawbridge. However, by the time the bridge was completed, ship traffic, as well as vehicle traffic, had increased. In the first year of the drawbridge's operation, the number of bridge openings totaled over 700, and by 1968, vehicle traffic exceeded design capacity and has continued to do so. These increases in both river and roadway traffic led to more frequent traffic interruptions which affected more and more people.

In a 1976 study MDOT stated that when the drawbridge is open for ships, the capacity for vehicles is obviously zero, but when it is opened for ships during the periods of high traffic volumes, vehicle traffic is delayed for more than just the 5 to 7 minutes that the bridge is open. Once traffic is stopped, the volume of vehicles in the traffic jam increases until those in front of the traffic jam leave in greater numbers than those approaching the jam.

The starting and stopping which led to traffic jams has also been an accident factor. To alleviate this problem, MDOT installed signs to warn drivers when the bridge is being opened or is open. But, even with this safety precaution, the area continues to have a high accident rate. MDOT statistics indicate that the accident rate in the area of the bridge is double the average for rural freeways in Michigan.

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[1] Pennsylvania Railroad Company v. S.S. Marie Leonhardt, 202 F. Supp. 368, 376 (E.D. Pa. 1962).

In 1970 MDOT attempted to alleviate the problem until the high-level bridge was completed by requesting the Coast Guard to limit the drawbridge openings and the hours of openings. The Coast Guard denied this request on the basis that marine navigation would be unduly restricted without providing significant benefits to highway traffic. Subsequently, MDOT, in conjunction with local industry, developed a program to voluntarily restrict openings to off-peak traffic periods on summer and holiday weekends. While this has helped, the problem is not totally solved (nor was it intended to be) because river traffic is not required to use off-peak hours and current laws do not provide for reimbursing shippers for the costs of their lost time. As a result, conflicts between shipping and vehicle traffic still occur. In 1981 there were 40 shipping restriction "violations;" 13 of which occurred more than 15 minutes after the restricted time started or more than 15 minutes before it ended. In 1982 there were 27 violations; 18 of which occurred more than 15 minutes before or after the restricted time. Also, bridge openings occurring outside of the restricted periods can be dangerous to vehicle traffic and result in traffic congestion. For example, on October 4, 1980, a car went through the traffic gate at the drawbridge and hit the open span, resulting in a 2-hour closing of the bridge.

Bridge openings

As shown below, bridge openings which had been increasing since the drawbridge opened in December 1960 showed a marked decline in 1982. (As indicated, data on openings was not available for all years.) However, the port remains active, with ships hauling grain, sand, stone, and other bulk cargo to and/or from Saginaw during the mid-March through mid-December shipping season. Various Federal, State, local, and shipping association officials we talked to were uncertain whether port activity will increase or decrease in the future.

Year	Openings	Year	Openings
1960	0	1972	955
1961	743	1973	931
1962	745	1974	930
1963	741	1975	895
1964	672	1976	680
1965	897	1977	882
1966	NA	1978	984
1967	NA	1979	964
1968	719	1980	948
1969	784	1981	897
1970	NA	1982	417
1971	NA		

The reason for the 1982 drop is twofold. First, a dredge, which mined sand from Saginaw Bay and hauled it upriver to a General Motors Corporation foundry plant, ceased operations in August 1982, 4 months earlier than usual. This dredge, which in recent

years had caused about 300 of the annual bridge openings, caused 200 openings in 1982. Second, in 1982, the Corps did less dredging of the Saginaw River in the vicinity of the drawbridge, causing only 30 bridge openings compared with over 400 openings annually in 1980 and 1981. The Chief of the Corps' Construction Operations Division, Detroit District, told us that the same sections of the river are not dredged every year and that is why the dredges caused fewer openings in 1982.

A General Motors' Central Foundry Division official told us that the corporation would still receive sand by ship, but the sand would be delivered in a much larger vessel. He said that bridge openings as a result of sand deliveries to General Motors should be reduced by about 90 percent.

The Corps Construction Operations Division Chief told us that funding for Saginaw River dredging was not included in the administration's fiscal year 1983 budget. However, funding was provided under the continuing resolution when the President's budget was rejected in September 1982. In December 1982 the Congress extended the continuing resolution through September 30, 1983, and funded dredging for the river in fiscal year 1983. The Corps also plans to dredge the river in future years.

The drawbridge is a navigation hazard

The shipping channel on the Saginaw River is 200 feet wide, but the drawbridge has only a 150-foot opening. MDOT officials believe that the narrow opening, compounded by the drawbridge's location near a sharp bend in the river, makes the drawbridge a hazard to navigation. Because ships heading downstream have a tendency to swing to the west side of the channel as they come around the bend, pile clusters have been placed in the river to protect the drawbridge.

Ships have hit the piles several times and the drawbridge twice. In 1960, before the drawbridge was opened to traffic, a German freighter rammed it, causing minor damage. In October 1967 a limestone hauler rammed the drawbridge, damaging the southbound approach span. One lane was opened to traffic following a 3-day closure while repairs were made to a major supporting girder. The repairs cost over $100,000. The most recent incidents involved ships hitting the pile clusters in May and June 1979.

MDOT studied several alternatives

MDOT studied several locations for a high-level bridge and considered several alternatives to a high-level bridge at various times. Its first study was made during 1968 and 1969 when it considered locations for a high-level bridge on Interstate 75. The study was issued as "Engineering Report 1786" in January 1970. Later, in 1970, MDOT made a detailed response to the Saginaw County Metropolitan Planning Commission on why building a parallel

freeway instead of a high-level bridge was not practical. MDOT next considered alternatives in the project "Environmental/Section 4(f) Statement," an analysis required to meet Federal environmental regulations. MDOT began work on this document in 1971, and it received final Federal approval in November 1974. MDOT also considered alternatives in 1976 and 1978 responses to State Transportation commissioners' requests for information. One commissioner believed that the parallel freeway was a more appropriate alternative; the other believed that Interstate 675 could be used as a bypass when the bridge was opened. The first response reevaluated the need for the high-level bridge; the latter response updated some of the prior cost estimates for previously considered alternatives. In all cases, MDOT concluded that locating a high-level bridge on an alignment slightly north of the drawbridge was the appropriate solution to solving the problems the drawbridge created. None of the considerations involved any FHWA requirement and FHWA was not involved in MDOT's resolution or final determination on the alternatives. The alternatives considered at the various times are shown on the following page.

Alternatives Discussed by MDOT

Alternative	1970 report	1970 letter	1974 statement	1976 response	1978 response
High-level bridge several miles north of existing bridge			x		
High-level bridge several miles south of existing bridge	x		x		
Tunnel	x		x	x	
High-level bridge slightly to the north of existing bridge		x	x		
High-level bridge slightly to the south of existing bridge	x		x		
High-level bridge on existing location			x		
Do nothing			x		
Parallel freeway		x	x	x	
Conveyor system				x	x
Diversion of traffic onto Interstate 675				x	x
Drawbridge expansion				x	

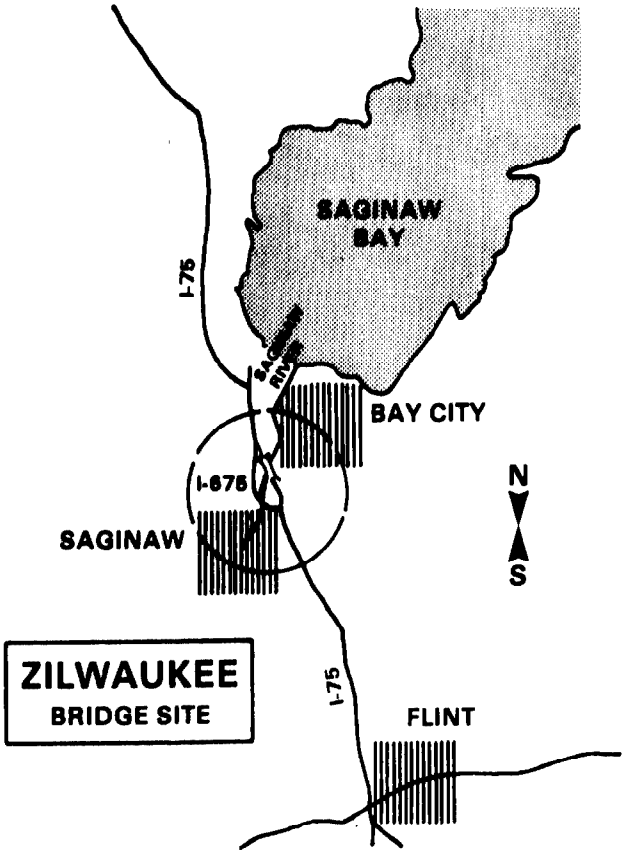
The methodology and support for the State's various estimates for the alternatives to a high-level bridge could no longer be located and thus were unavailable for our analysis. However, based on our discussions with various officials and review of pertinent FHWA and MDOT files, the State's choice of the high-level bridge appears to have been reasonable, based on the estimates and conditions at the time the decision was made.

High costs and adverse impacts caused rejection of traffic diversion to Interstate 675

A commonly suggested alternative to building the high-level bridge was to divert Interstate 75 traffic (either temporarily or permanently) to the Interstate 675 business loop through downtown

Saginaw. Interstate 675, however, is not designed to handle the Interstate 75 traffic volume, much less a combined Interstate 75/675 Interstate volume. According to MDOT officials, this alternative would require that Interstate 675 be reconstructed at a cost greater than that of the high-level bridge.

Interstate 675, about 2.3 miles longer than the stretch of Interstate 75 between the north and south Interstate 75/675 interchanges, was opened to traffic in October 1971. MDOT estimates that it takes 8 minutes to drive the entire length of Interstate 675. At the current 55 mph speed limit, it takes about 2-1/2 minutes longer to drive Interstate 675 than it does to drive the corresponding section of Interstate 75. Below is a general depiction of Interstate 75 and Interstate 675 in reference to the Zilwaukee Bridge.



MDOT officials originally believed that electronic signs and signals could be erected to temporarily route traffic from Interstate 75 onto Interstate 675 when the drawbridge was open, but they rejected this idea for two reasons. First, Interstate 675 could not handle both Interstate 75 and 675 traffic, even temporarily. Second, Interstate 75 was two lanes wide (three lanes by 1975) and the exit ramp from Interstate 75 onto Interstate 675 was only one lane. MDOT officials believed that constructing a two- (or three-) lane ramp would result in enormous accident potential as drivers in the left lane exited while drivers in the right lane(s) drove straight ahead to other exits before the drawbridge.

Permanently diverting Interstate 75 traffic to Interstate 675 would be very expensive. A 1976 MDOT reevaluation stated that if Interstate 75 traffic was permanently diverted, the interchanges at each end of Interstate 675 would have to be rebuilt so that three full lanes could travel either way. The whole of Interstate 675 would have to be rebuilt to 8 to 10 lanes to increase capacity. Such widening would require that all interchanges be reconstructed, all bridges be widened, and new rights-of-way be purchased. In 1978 MDOT estimated this alternative would cost about $120 million.

In addition to the high cost of this alternative, it was opposed by the city of Saginaw, which did not want the increased traffic. Furthermore, the State estimated that the added distance of the Interstate diversion would cost motorists $1 million a year, using a fuel cost of $0.60 per gallon for its estimate.

Tunnel considered too costly

At the request of the city of Zilwaukee, which believed that a tunnel would offer certain advantages to the city, MDOT studied a tunnel crossing. The study, included in the January 1970 report, concluded that while feasible from an engineering standpoint, the high cost of constructing a tunnel dictated against it.

After considering soil conditions, navigational demands, and other factors, MDOT concluded that the tunnel should be of the driven shield type, which involves moving a temporary steel framework and compressed air forward at the tunnel end being excavated to support the ground ahead until the permanent tunnel lining is in place. The study indicated that twin tubes would be required, each carrying a 3-lane roadway. The tunnel would be about 3,200 feet long and require extensive retaining walls on either end. The estimated cost in 1970 was $96 million, compared with $35 million for a high-level bridge. A second negative factor was an estimated operation and maintenance cost of $620,000 a year, which MDOT believed would be 6 to 10 times greater than such costs for a high-level bridge.

Because the MDOT official who prepared the study has since retired, we could not determine the methodology used to arrive at

the estimates for the tunnel alternative. However, the Route Location Engineer who prepared the January 1970 report told us that some of the estimates were based on discussions with Detroit-Windsor Tunnel Authority officials. That tunnel connects Detroit with Windsor, Canada, under the Detroit River. A tunnel engineer with FHWA's headquarters Bridge Division told us that the proposed Zilwaukee tunnel could easily have cost $100 million in 1970.

Federal guidelines precluded building a parallel drawbridge for additional capacity

The State considered the possibility of obtaining additional capacity at the present location by building a parallel drawbridge to carry an added three lanes and converting the existing bridge to a one-way operation. While the estimated cost of a parallel drawbridge and approaches with related interchange improvements was only $9 million, MDOT officials believed that FHWA policy precluded this option.

FHWA Policy and Procedure Memorandum 50-4.1 (March 1958) states that, "The construction of moveable span bridges is not in keeping with the purposes and functions of the Interstate system." FHWA considered exceptions to this policy only where a high-level bridge would result in excessive cost or is not feasible. MDOT did not consider the $22 million high-level bridge cost estimate to be excessive and did not request an exception from FHWA.

In the Environmental/Section 4(f) Statement, MDOT pointed out that FHWA stated in its original approval of the high-level bridge "* * * that the original design [drawbridge] was hazardous and an inappropriate installation for a system of freeway-type construction." MDOT also pointed out that for this reason it had rejected alternatives that could utilize the existing drawbridge.

Concerns about timeliness and funding led to the dismissal of a parallel freeway

This alternative involves a 50-mile State freeway route in the Interstate 75 traffic corridor which would bypass Saginaw to the south and the west, crossing the Saginaw River where it is not navigable and a fixed, low-level bridge would be adequate. In July 1970 MDOT advised the Saginaw County Metropolitan Planning Commission that MDOT could not divert trust fund moneys intended to replace the Zilwaukee Bridge (then estimated to cost $35 million) to a non-Interstate project. In its 1974 environmental statement, MDOT concluded that because both the parallel freeway (which was then part of the State Trunk Line Plan) and Interstate 75 would be operating near capacity by 1990, reliance on a parallel freeway to alleviate traffic problems on Interstate 75 was not feasible.

In its 1976 reevaluation of the need for the high-level bridge, MDOT again rejected this alternative because Zilwaukee project funds could not be diverted to this project and only 70 percent Federal funding would be available. It also concluded that it would be impossible to obtain the necessary local, regional, State, and Federal approvals required to construct the parallel freeway within any short-range time period. MDOT estimated that the planned route could not be opened for at least 10 years and probably completion would take closer to 15 years. (The high-level bridge completion date was estimated to be only 4 to 5 years away.)

The parallel freeway has since been eliminated from the State's trunk line plan.

An adjustment to port operations not considered a viable alternative

In its 1976 reevaluation, MDOT analyzed a proposal to close the Saginaw River to shipping at the Zilwaukee Bridge (already closed to ships about 4 miles upstream at the Interstate 675 bridge) and ship goods to upriver property owners via a conveyor system. This alternative would also have included widening the existing bridge which would then be used as a fixed structure. MDOT rejected this alternative because it questioned the feasibility of conveying all materials by some means from a loading dock north of the bridge and/or buying out landowners on the river. In the December 1978 response, MDOT estimated the combined cost of widening the existing bridge plus the port facility relocation and conveyor system at $133 million, about twice the $68.5-million amount FHWA had programed for the high-level bridge in 1978. MDOT also noted that the city of Saginaw was opposed to this proposal because it believed that this alternative could have a detrimental effect upon the city's economy.

Other alternatives also considered unsatisfactory

MDOT discussed several other alternatives which it quickly dismissed as being impractical. It rejected a major relocation to the north of the existing bridge for economic, social, and ecological reasons. This alternative required building seven additional miles of six-lane freeway and reconstructing the north Interstate 75/675 interchange. Also, adequate service would not have been provided to the Zilwaukee area, and the route would have cut through economically valuable agricultural land and ecologically valuable wetlands.

MDOT determined that a major relocation to the south was not economically or socially prudent. This potential route would have gone through the city of Saginaw and crossed extensively developed, valuable industrial and residential property. MDOT concluded that purchasing such land would be prohibitively expensive and losing such parcels was unacceptable for social reasons.

MDOT rejected a new relocation slightly to the south of the existing bridge for similar reasons. This route, through a built-up area of the city of Zilwaukee, would have affected 125 single family residences and 5 commercial properties.

MDOT dismissed the idea of building the high-level bridge on the existing alignment because it would create serious problems in maintaining Interstate 75 traffic for at least 2 years while the new bridge was under construction.

In its 1974 environmental statement, MDOT proposed a "do-nothing" alternative which it also rejected. It concluded that inaction would, due to direct and indirect social and economic costs (time delays, personal injury, property damage, and maintenance costs), over time be far more expensive to the general public than the direct costs of replacing the bridge.

DESIGN AND BIDDING PHASES

For Federal-aid bridge projects such as Zilwaukee, FHWA has the authority and responsibility for approving (1) the design, (2) advertisement for bids on the construction work, and (3) construction contract awards to the lowest bidder. For major bridge projects, FHWA often requires States to offer alternate designs for bidding purposes to promote competition and reduce project costs. Usually, this means that a concrete design and a steel design are offered to take advantage of the price competition between concrete and steel materials and construction techniques. FHWA applied this requirement to the Zilwaukee project. Also, if the low bid on a construction contract significantly exceeds the State engineer's cost estimate for the project, FHWA may require the State to reject the bid, reexamine the design, and readvertise the project. This also happened on the Zilwaukee project. Much of the controversy and questions concerning the project focus on these two events and their impact on the project.

The design development and approval process was lengthy

Through the early 1970's, concurrent with MDOT and FHWA efforts to meet Federal environmental requirements, MDOT made various studies for a steel design structure. Late in 1973 MDOT also contracted for a study of a concrete bridge design which it received in the summer of 1974. Sometime in 1974 MDOT decided to proceed with only the steel design. An MDOT Bureau of Highways, Design Division official said that top MDOT management had decided Michigan would build a steel bridge. He also related that the FHWA Division office was informally aware of this decision. In July 1976, when MDOT submitted its preliminary plan for an in-house designed steel bridge, FHWA's Division office transmitted the plan to region 5 for comment. In its September 1976 comments on the plan to the Division office, region 5 stated that it had

understood MDOT was considering a concrete design, but the submittal presented no information on this or other alternates. Region 5 also requested an MDOT study report showing alternate designs for both the main and approach spans because of the magnitude of the project and the possible potential savings. In October 1976 FHWA Division staff requested such a preliminary design report on alternates from MDOT.

In December 1976 MDOT submitted a revised preliminary plan for the steel structure to FHWA and indicated that it had studied two designs for the project, resulting in the following estimates:

--A $54 million segmental concrete structure.

--A $57.5 million steel structure.

MDOT stated that rather than getting involved in a segmental concrete design and construction in which it had no experience, it had selected the more expensive steel structure based on its knowledge of design and construction of steel structures. MDOT also indicated that it had considered various other steel designs, but rejected them because of their higher construction cost.

This explanation did not satisfy region 5 which maintained that a segmental concrete box girder structure should be allowed as an alternate design. FHWA Division staff echoed region 5's concern in a March 1977 letter to MDOT stating

> "* * * it will be required that bids be taken on a segmental concrete box girder design as an alternate to a steel design for at least the central portions of the bridge where the longer spans make it significantly more economical."

At an April 1977 meeting, MDOT, FHWA headquarters, region 5, and Division officials agreed to the following:

--There would be alternate designs of steel and concrete for a main span over the river and the approaches to it.

--The project would be bid in three sections as follows

  -one of the bridge approaches would be bid using the alternate designs,

  -the other bridge approach would be bid specifying the same type of design that was awarded the contract for the first approach, and

  -the center segment would be bid using the alternate designs.

--The design of the steel structure would be by the State; the concrete structure design would be by a consulting firm

selected by the State, with all design costs eligible for Federal-aid participation.

--The structure would be four lanes wide for the full length, with full shoulders on each side rather than three lanes as originally planned.

State and Federal officials agreed to take bids on the project in three sections because at that time the Michigan State Highway Commission's policy was to limit State highway contracts to about $7 million to distribute the work to as many contractors as possible. The decision to divide the proposed bridge contract into three parts was a compromise to the policy. State officials believed that adhering to the policy would have divided the contract into an unmanageable number of projects.

MDOT's concerns about the negative impact of trucks on traffic flow led to the decision to build four traffic lanes. Originally, in June 1968, FHWA had approved a six-lane, high-level structure for Interstate funding. Then, MDOT requested FHWA approval of climbing lanes that would extend 1,000 feet beyond the crest of the bridge then taper 300 feet to merge into the next lane. In justifying this change, MDOT cited the long 3-percent grade on the approaches and on the structure which would reduce truck speeds to such an extent that the bridge capacity would be reduced to a level below projected future traffic volumes. Also, MDOT stated that slow moving vehicles would seriously impair highway safety. FHWA agreed, and in January 1970 approved costs for climbing lanes in each direction.

MDOT next decided to run the climbing lanes the full length of the structure. (The distance between the end of the truck climbing lane taper and the start of the exit ramp taper was only 72 feet and 147 feet for the northbound and southbound lanes, respectively.) MDOT communicated this change to FHWA in its July 1976 submittal of the first preliminary plan for the steel alternate. FHWA questioned the switch, and in October 1976 it requested justification for the change. MDOT responded with an analysis which concluded that (1) predicted truck speeds justify the length needed for the truck climbing lanes (2) and full-length climbing lanes will cost less than a tapered section and improve the operational characteristics of the structure. FHWA concurred with this analysis.

MDOT has not recently determined truck volume at the Zilwaukee Bridge. However, it estimated commercial traffic to account for 12 to 15 percent of the traffic in 1982.

In August 1977 MDOT submitted a second revised preliminary plan for the steel alternate to FHWA and noted that plans for a segmental concrete box girder design would be submitted as soon as available. MDOT then contracted with a Dutch firm, Bouvy, van der Vlugt, and van der Niet(BVN), and its associated company Bouvy, van der Vlugt, and van der Niet/Segmental Technology and Services, Incorporated (BVN/STS), of Indianapolis, Indiana, in November 1977 for the design and related engineering of a concrete segmental bridge.

BVN and BVN/STS had considerable experience in concrete bridge design worldwide. Many of their projects were of a magnitude similar to Zilwaukee; some had longer spans or were more complex in design. In their June 1977 proposal to MDOT, BVN and BVN/STS claimed to have the largest amount of design experience in concrete bridge design available in the United States. According to the MDOT Engineer of Design, this experience was the major factor which led to MDOT's selection of BVN and BVN/STS to design the bridge.

On January 20, 1978, 3 months later, MDOT submitted a preliminary plan for a precast segmental concrete alternate to FHWA. (The design contract required that more detailed plans be submitted in May and June 1978.) FHWA raised questions on the design of the individual box girder segments and why the concrete alternate did not consider different methods of construction other than the precast segmental method.

On February 8, 1978, FHWA headquarters, region 5, and Division officials met with MDOT along with representatives from BVN/STS. At this meeting, those in attendance agreed on the following:

--The State would let the project in a single contract rather than in three sections because this would reduce design complications and take advantage of economies of scale and competition would be sufficient without bidding the project in sections. For this project, the State Highway Commission waived the $7 million maximum on State highway contracts.

--FHWA regional and headquarters staff would review the final plans because of the size and uniqueness of the project.

--The segmental concrete alternate would consider only the precast method of construction because the consultant indicated it was the most economical approach (alternate construction would require additional design calculations and plans). The State indicated it preferred the precast method because it was quicker and it permitted the State to exercise better quality control. According to the State,

the precast method also permitted year-round construction of segments in an enclosed area during winter and other adverse weather conditions. The cast-in-place method would restrict construction to warm weather.

--The proposed design of the individual box girder segments would be acceptable if it checked out under further analysis.

For the next 3-1/2 months MDOT and FHWA resolved various questions on the design of the box girder for the concrete alternate. Then, on May 22, 1978, MDOT transmitted preliminary plans, specifications, and estimates packages to FHWA. Identical material was also sent to contractors and suppliers that might be interested in participating in the bridge project contract. Finally, on August 30, 1978, MDOT sent a final plans, specifications, and estimates package to FHWA, which approved it on September 8, 1978, for the construction of a high-level bridge.

Neither MDOT nor FHWA made a detailed review of the bridge design in the sense of checking all the details and verifying the calculations. They relied on self-assurance by the design consultant to provide a quality design. The reason for this is best explained by the complexity of the concrete bridge design which necessitates a computer program to provide a detailed analysis of the structure. Although MDOT did not have staff experienced in concrete bridge design and construction (the reason MDOT hired a consultant to design the bridge), FHWA did have some staff with concrete design/construction experience. However, neither entity had the computer program to verify the design. Furthermore, the Director, Office of Structures, FHWA Region 5, told us that the Congress did not intend that this should be FHWA's role. FHWA's role is to look for obvious errors or items that appear questionable and seek clarification or correction.

According to MDOT and FHWA spokespersons, the delayed start on the design work for the concrete alternate extended the design phase only a few months. On the other hand, the alternate design requirement apparently did foster competition and reduce costs. Specifically, there were six bids (three for concrete and three for steel) on the first advertisement and five bids (three for concrete and two for steel) on readvertisement. The low bids for the concrete alternate were $4.6 million and $9.4 million less than the competing steel alternate low bids in the first and second bidding, respectively. The bids were as follows.

APPENDIX I

Zilwaukee Bridge Project Ranking of Bids

	Alternate	Amount (millions)
First bidding	1. Concrete	$81.0
	2. Concrete	81.9
	3. Steel	85.6
	4. Concrete	87.6
	5. Steel	89.7
	6. Steel	92.1
Second bidding	1. Concrete	76.8
	2. Concrete	82.9
	3. Concrete	83.1
	4. Steel	86.2
	5. Steel	88.3

According to the Chief of FHWA's Bridge Division, using alternate bridge design has resulted in nationwide savings of over $100 million during the past 4 years since FHWA began to pursue the concept on a national scale.

First low bid rejected

In September 1978 MDOT advertised the project for bids. Its proposal package predicated bids on either a steel or concrete alternate. MDOT received bids in November 1978 and obtained a low bid of about $81 million for the concrete alternate. This bid exceeded the MDOT engineer's estimate of about $61 million by about 34 percent.

Six joint ventures of contractors submitted bids--three for concrete and three for steel structures. The joint venture of S.J. Groves and Sons Company of Minneapolis, Minnesota, and Guy F. Atkinson Company of South San Francisco, California, submitted the low bid. Bids ranged from $81 million to $87.6 million for the concrete alternate and from $85.6 million to $92.1 million for the steel alternate.

MDOT requested FHWA concurrence in awarding a contract to the low bidder and explained the discrepancy between the low bid and the engineer's estimate as being caused by a poor estimate. FHWA's Division and regional offices agreed with this explanation, citing the relatively small spread between the bids within each alternative as being indicative of good competition. FHWA headquarters did not agree and, on December 18, 1978, the Associate Administrator for Engineering and Traffic Operations outlined potential savings if the contract was rebid and recommended rejection of all bids and readvertisement.

This position followed a month-old FHWA program initiated by the Secretary of Transportation to combat escalating highway construction costs. Announced in November 1978, the program, among

other things, required bid rejection in cases where the low bid exceeds the engineer's estimate by more than 7 percent, unless an exception is justified.

Additional discussions took place, however, and culminated in a January 10, 1979, meeting between MDOT and FHWA headquarters (Chiefs, Bridge Division, Construction and Maintenance Division, and Review Branch), region, and Division officials. MDOT officials maintained that the estimate was bad, the bid was good and by a good contractor, work could start immediately, and no appreciable savings would result from rebidding the project. FHWA headquarters officials disagreed. After considering the advantages and disadvantages of rejecting the bids (potential savings through design and proposal changes versus lost time due to redesign and readvertisement) and of accepting the bids (no lost time plus some design changes could be negotiated with the low bidder and MDOT versus no cost savings and loss of integrity of FHWA's inflation fighting program), the FHWA officials concluded that the bid should be rejected.

Following this meeting, the FHWA Administrator announced his decision not to concur with the State's award of contract and requested that MDOT reject all bids, redesign the project, and readvertise it for bids as soon as possible. He based his rejection on FHWA's anti-inflation policy. He also cited a $6-million estimated cost savings that could be achieved by modifying the project plans and specifications. Although neither MDOT nor FHWA made specific estimates of the costs resulting from a year's delay, the Administrator stated his estimated savings would more than offset any costs resulting from the anticipated 1-year delay necessary for redesign and readvertising.

FHWA's Division office told MDOT that the bid should be readvertised and provided specific changes in the contract proposal for MDOT to address before final readvertisement. In response, MDOT prepared a revised plans, specifications, and estimates package including some redesign and provisions to reduce project costs, including

--a clause allowing contractors half the savings of redesigns they might propose that are acceptable to MDOT;

--an incentive/disincentive clause paying the contractors $3,000 a day for early completion and penalizing them $3,000 a day for delayed completion; and

--price adjustment clauses for reinforcing and structural steel, cement, and fuel tied to a published index to reduce the contractors risk of price increases.

On May 15, 1979, MDOT readvertised the project, again predicating bids on either a steel or concrete alternate.

The engineer's estimate for the readvertisement for the concrete alternate was $71.6 million. This $11 million increase from the $60.6 million 1978 estimate largely resulted from changes in the estimates for a few major items as shown below.

Item	Estimate 1978	Estimate 1979	Increase
	(millions)		
Segments	$26.1	$31.2	$5.1
Mobilization	4.0	7.0	3.0
Tendons & Anchors	7.5	8.4	0.9
Expansion joints	1.2	1.5	0.3
Total	$38.8	$48.1	$9.3

MDOT received bids for the second time in August 1979 and obtained a low bid of $76.8 million, or $4.2 million less than the original low bid. The joint venture of Walter Toebe Construction Company of Wixom, Michigan, and Stevin Construction, Incorporated, a European firm from the Netherlands, submitted the low bid for the concrete alternate. Basically, Toebe is responsible for the substructure (pilings, footings, abutments, and piers), the 1-1/2 inch latex overlay used for the driving surface, and the concrete barriers along both roadways; Stevin is responsible for making and erecting the segments which comprise the bridge (superstructure). Five parties submitted bids--three for concrete and two for steel structures. Bids ranged from $76.8 million to $83.1 million for the concrete alternate and from $86.2 million to $88.3 million for the steel alternate.

The low bid, which exceeded the engineer's estimate by 7.2 percent, was acceptable to FHWA which, on September 10, 1979, concurred in the State's award of a contract.

One impact of the bid rejection and rebid was a 1-year extension of the estimated project completion date due to time lost for redesign and readvertising. On the other hand, the rebid resulted in a $4.2-million reduction in the low bid for constructing the project. However, because neither MDOT nor FHWA estimated the cost of the delay, we could not determine whether the savings from the rebid offset the cost of the delay. Also, the savings on the rebid cannot yet be determined because the construction contract includes price escalators for fuel, cement, and steel, which have already added about $865,000 to the $76.8 million contract.

Another consideration is that, even if the rebid did not result in any real dollar savings in this instance, it did let contractors know that FHWA was serious in its efforts to combat accelerating construction costs and could have resulted in savings on subsequent contracts.

The design development and review process could have been improved

Better and earlier coordination and communication between MDOT and FHWA and stronger involvement by FHWA could have improved the design development and review process of this large project. The communication between MDOT and FHWA regarding the alternate design requirement is an example of how communication could have been better. As stated previously, FHWA Region 5 had a policy requiring alternate designs on projects of great magnitude, such as the Zilwaukee project, yet MDOT chose to proceed with only one design without first obtaining FHWA concurrence. Also, FHWA officials did not question whether MDOT was developing an alternate design as requested by the FHWA policy until it received the steel design 2 years later. The delay would have been avoided if the two designs had been developed concurrently.

In some instances FHWA made suggestions for improvements in the design, but MDOT disagreed with them or considered them to have been made too late in the process to implement. As a result, there may have been various cost-saving opportunities that were not taken advantage of in developing the design. For example, a month after receiving the design for the segmental alternate, FHWA regional staff questioned the length of the approach spans and the need for haunched spans (a depth variation of 8 feet at mid-span to 20 feet at the span ends) and suggested that shorter constant depth spans would look better and be more economical. MDOT, in responding to these concerns, told FHWA that the longer spans were more economical and it preferred the haunched spans for esthetic reasons. FHWA did not pursue the issue; however, Region 5's Director, OFfice of Structures, told us that he believes the State's position was invalid, but FHWA had no basis for questioning it. As a result, the design was not changed. With regard to the span lengths, MDOT officials told us that while it is true that the approach spans possibly could have been altered somewhat, they believe that their position was valid. According to MDOT, they held extensive discussions with FHWA Michigan Division officials and it was agreed not to build a "forest of columns" that would have resulted if shorter spans had been used. MDOT believes that the location's topography practically dictated the proposed span lengths because of obstacles such as existing railroad tracks and crossroads.

Several methods are available to better ensure that such opportunities are considered preliminary to or during the design phase. One method, the peer review, is used by the Urban Mass Transportation Administration (UMTA). Most transit authorities hire architectural/engineering firms to design construction projects. The designs are subsequently to be evaluated by UMTA for cost effectiveness and technical feasibility. In 1979 UMTA established a peer review program in an attempt to reduce costs on selected new projects. The program draws on the expertise available within the transit industry to assist UMTA and transit

authorities through either a cost-reduction effort or the transmittal of first-hand, practical data obtained from transit experience.

The reviewers, generally chief operating engineers from various transit systems, are provided a list of items to be reviewed and necessary data such as design plans and specifications. The reviewers later meet for about 2 days to obtain additional information from transit authority officials and/or their architectural and engineering consultants and make specific cost-saving recommendations, such as eliminating items or changing materials. The majority of UMTA peer reviews have been held during the conceptual phase of project development.

A more comprehensive method which FHWA now strongly encourages primarily for major, high-cost highway and bridge projects is value engineering. Value engineering is a systematic, multidisciplined, creative, and organized approach designed to optimize the value of each dollar spent. Using systematic techniques, the required function of an item is identified and analyzed and a value is established for that function. The objective is to satisfy the required function at the lowest cost, consistent with the requirements of performability, reliability, and maintainability. According to FHWA, using value engineering has produced substantial savings and several States now have a value engineering capability. In a recent report,[2] we pointed out that value engineering is more effective than UMTA's peer review program in reducing costs and recommended that UMTA implement a value engineering program for construction projects.

The Director, Office of Structures, Region 5, told us that at the time of the Zilwaukee Bridge design development and review, value engineering was not a common practice, even for large projects. He said such a method was suggested at the time the first bid was rejected, but it was then too late to use this approach.

Using value engineering or a similar concept during project conception or preliminary design may have been beneficial for the Zilwaukee Bridge, especially considering its size and cost and that the design and construction techniques were new to MDOT. A value engineering clause was added to the construction contract to allow the contractor to propose changes during construction and share in the cost savings. According to MDOT officials, the contractor has taken advantage of the clause by proposing a revised construction method for one of the bridge ramps.

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[2]"Value Engineering Has The Potential To Reduce Mass Transit Construction Costs" (GAO/RCED-83-34, Dec. 29, 1982).

DESIGN, LABOR, AND OTHER PROBLEMS HAVE HAMPERED CONSTRUCTION AND INCREASED PROJECT COSTS

Various problems have impeded the joint venture's progress and added to project costs since project construction began in October 1979. The most significant problems involved

--some steel H-beam piles (which were driven in excess of 80 feet to bedrock to support the bridge) which failed to meet loading specifications,

--many of the individual concrete box girder segments (which are attached to each other to construct the bridge spans) which developed cracks during the curing process,

--the launching girder (which is a steel truss used to transport and place the individual segments) which experienced delays and design difficulties, and

--the Dutch managers (who were employed by the foreign joint venture partner) who had difficulty in dealing with U.S. administrative procedures.

These problems were apparently overcome; however, they have increased contract or contractor costs, delayed construction and extended the contract completion date, and/or raised questions regarding maintenance and safety of the completed bridge. The problems may also lead to claims and/or lawsuits against MDOT which could further increase bridge costs. A more detailed discussion of these problems plus a description of the bridge construction/erection follows.

Bridge construction/erection is complex

The twin high-level Zilwaukee bridges will be parallel four-lane structures with full-width shoulders that MDOT believes will serve the people of Michigan for 50 to 100 years. The northbound bridge will be 8,066 feet long and have 25 spans, and the southbound bridge will be 8,090 feet long with 26 spans. Span lengths vary from 130 feet to 392 feet. Steel H-piles were driven into the ground down to bedrock to support the structures. Atop these pilings sit steel-reinforced concrete footings and twin, reinforced concrete, hollow columns (piers) with a rectangular strut, or crossbeam, at the top. These pilings, footings, and piers, along with the abutments (the supports at either end of the bridge), comprise the bridge substructure.

The superstructure (the part of the bridge above the substructure) consists of 51 spans that are each formed when concrete box girder segments are glued and, as explained later, post-tensioned together. The segments are hollow and shaped like a box with wings. The top of a segment is 73.5 feet wide, its bottom is 36 feet wide, and the webs or sides connecting the top to the

bottom are 8 feet to 20 feet deep. Each segment is an 8- or 12-foot long "slice" of the bridge, weighing from 90 to 180 tons. These segments are precast in an onsite plant and hauled to the bridge by a specially built truck. Each segment is cast against the end of the preceding one to assure a perfect fit.

A long steel truss (launching girder) fabricated by the contractor is used to erect the segments. A 117-ton crane on the girder picks segments from the delivery truck, traverses along the top of the approximately 1,200-ton launching girder carrying them forward to their appropriate location. The launching girder is moved to precise locations on the bridge according to a manual drafted by the contractor and approved by MDOT.

The segments are joined to each other by more than 325 miles of steel (longitudinal post-tensioning). These tendons (12 steel strands, 0.5 inches in diameter) connect and run through two or more segments to hold them together. As erection proceeds, segments are epoxy glued to seal the joint and temporarily post-tensioned. Then, steel strands are threaded through by machine and the segments are permanently post-tensioned. Post-tensioning is the act of pulling tight to a certain tension the steel strands, which are anchored at both ends.

The twin bridges are being erected from the north abutments southward by the free cantilever method. This involves placing a pier segment atop a pier and then attaching segments on either side of the pier segment alternating from side to side out to mid-span. A pier frame (temporary framework) helps support the superstructure while the cantilevers become unbalanced and then balanced again as segments are erected. Each pier supports two cantilevers, like wings, on each side of it. Where the two cantilevers come together, a cast-in-place joint is poured to close the gap between them and form the span.

Piling problems add $1.6 million to contract costs and extend completion date

The bridge superstructure rests on 49 mainline piers that sit atop reinforced concrete footings. Each of these 6- to 8-foot thick footings, in turn, transfers superstructure and pier column weight to 50 or more steel H-piles that are driven into the ground 80 feet to bedrock. Test loadings performed by MDOT in November 1979 to verify that individual driven piles could withstand a 200-ton design load resulted in several pile failures before achieving a loading of 400 tons (specifications required test loading of four piles to a minimum of twice the design load or a two to one safety factor). The problem was studied by MDOT and FHWA. Analysis by FHWA region and headquarters office staff concluded that individual pile stiffness (resistance to bending) was inadequate to permit driving them at the lengths involved (approximately 80 feet) to a 400-ton resistance (the capacity to withstand a physical load of 400 tons). FHWA suggested that a

heavier pile was needed to achieve the 200-ton design load. However, because lighter pile was already on site or on the way and due to the additional cost of the heavier pile (an estimated $4 million for the switch), MDOT and FHWA Division staff agreed to use the pile on hand and redesign the pile patterns using a greater number of piles and a lighter 150-ton design load for the individual piles as necessary. The redesign provides the same load-carrying capacity as the lesser number of piles with a 200-ton design load.

To accomplish this redesign, MDOT hired BVN/STS (one of the parties involved in designing the bridge) under a contract which eventually amounted to $687,000. BVN/STS redesigned the pile patterns to accommodate the increased piling by reducing the spacing between the piles and the spacing between the piles and the edge of the footing. However, at some pier locations the piling did attain the 200-ton design load and the original pier design was used. At the completion of the pile driving, 34 of the 51 piers had piles with a 150-ton design load and the remaining 17 piers had piles with the 200-ton design load.

These material and construction changes (additional piles and pile driving) added about $1.6 million to contract costs. In addition, because of its downtime while the State and FHWA were studying the problem, the joint venture requested and received an extension of the contract completion date. Both FHWA Division and MDOT staffs agreed that the lost time was not the contractors' fault and granted the 50-day extension of the November 15, 1983, completion date. Also, because much of the superstructure work is not permitted during the period of colder temperatures experienced during the winter months, they allowed a contract completion date as late as June 19, 1984.

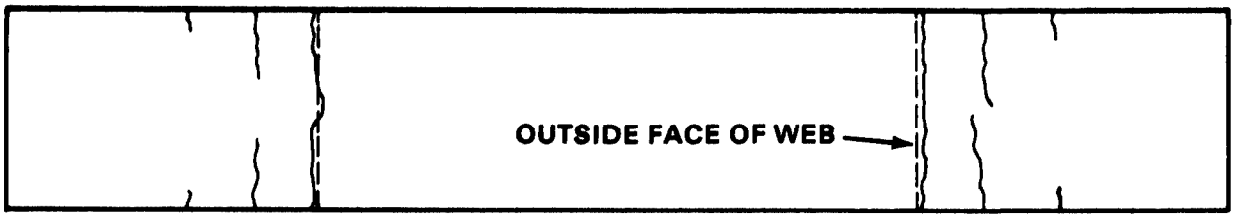
Both MDOT and FHWA Division staffs told us that the problem did not result from any error or miscalculation. They explained that determining piling specifications is an inexact science based on the best information available and you do not know if you have made the right decisions until you test a driven pile.

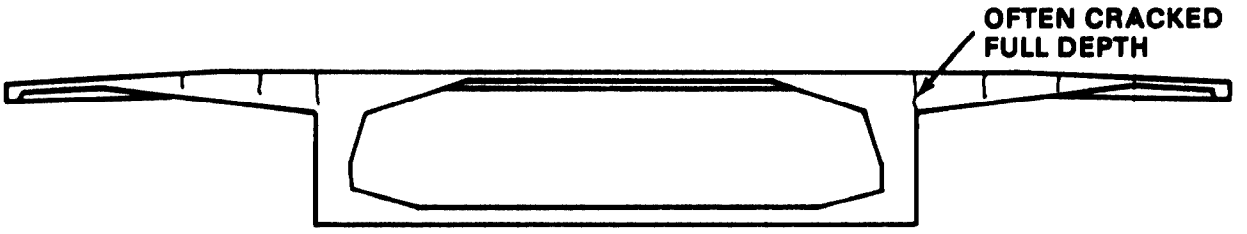
Correcting deck cracking adds $0.2 million to contract costs

The contractor began casting box girder segments in late summer 1980 and almost immediately cracks developed in the deck surfaces of the wing-like portions of the segments at the webs. To reduce the detrimental effects of the crack openings, MDOT made an October 1980 design change which added steel to the segments. Because this action did not entirely correct the problem, MDOT has taken and/or recommended actions to minimize the impact of the cracks.

According to an April 1982 MDOT report on a load testing of a concrete segment, a typical segment has a major crack in each wing

portion located nearly over the outside of the web face, with parallel cracks spaced at various distances out from the web. Occasionally, the cracks run the entire length of the 8- or 12-foot segment and often they can be seen running down the face of the segment 24 inches or more. Crack widths vary from barely visible to 0.012 inch with an average width of 0.004 inch to 0.005 inch. The report also indicated that most cracks closed completely when the workers applied the transverse post-tensioning--bundles of 0.5-inch steel strands stretched across the 73.5-foot width of the segments. Following is a graphic depiction of the typical cracking in the segments (top and side views) based on the April 1982 MDOT report.





According to the April report, the cracks are formed during the curing cycle during which the concrete hardens while the segment is still in the forms that hold and shape the concrete and are caused by a combination of shrinkage and thermal expansion and contraction. As concrete hardens it tends to decrease in volume. The MDOT Supervising Engineer, Segmental Construction, said that if the segments were completely unreinforced and could slip in the forms as they contracted, the cracks would probably not develop. However, the extensive reinforcing cage (6,000 to 10,000 pounds of steel reinforcing bars per segment, in the shape of a cage) does

not allow overall length changes in the segment, and when the tension stress in the contracting concrete gets too high, cracks form.

MDOT tried many variations in the curing procedure in an effort to reduce or eliminate cracks, all without success. MDOT's immediate concern was what short- and long-term effects the cracking would have on the structural performance and maintenance characteristics of the bridge. The short-term concern was that the segments were not designed to take permit loading (temporary authorization for a transporter to exceed the State's maximum highway load specifications). And, since overload permits are issued on a regular basis for vehicles that travel that portion of Interstate 75, the cracks could open under such overloads. The State's long-term concern was that corrosives could penetrate the cracks to the depth of the reinforcing steel with attendent corrosion and concrete deterioration. Citing a 1968 American Concrete Institute Journal report on crack control in reinforced concrete structures, the April 1982 report noted that a "maximum crack width of from 0.002 to 0.008 (inches) are suggested allowables in an aggressively corrosive environment." That is, they will not create problems by permitting saltwater intrusion.

Considering these concerns, MDOT identified probable crack openings under certain foreseeable loadings. Its analysis indicated that the post-tensioning system should be strengthened to reduce the detrimental effects of such crack openings. MDOT requested a design change calling for 12-strand post-tensioning instead of 10-strand for the segments. FHWA approved this design change and authorized a contract change of over $222,000 for additional transverse strands.

MDOT then proceeded to physically load test a segment to observe the results. Testing indicated that the corrective actions were adequate and provided assurance that the deck will not open to widths that would allow excessive intrusion of corrosive material. However, the report recommended that

--all cracks larger than 0.004 inches be filled,

--additional wearing surfaces not be placed on the bridge deck over the original latex concrete overlay when it wears out,

--extra attention be given to periodic bridge inspection, and

--deck cracks that occur after segment erection be repaired immediately.

Since the report, MDOT officials have taken additional precautions. They have temporarily prohibited overload permits from crossing the structure upon completion and have decided to use noncorrosive deicing materials for winter maintenance when the bridge is opened to traffic.

The problem with the wing cracking had no impact on contract completion time because actual erection of the superstructure did not begin until the following year. However, as discussed on the previous page, the change from 10- to 12-strand tendons added over $222,000 to the contract price. Also, the State's decision to use the more expensive noncorrosive deicing materials will add an undeterminable amount to winter maintenance costs. The costs for filling the cracks and the additional cost to remove the latex concrete overlay before putting down a new riding surface and extra attention for bridge inspections also are not known.

Problems in designing and fabricating the launching girder delays construction and could lead to claims against MDOT

The launching girder, a 940-foot long device, including a 200-ton capacity crane, provides Stevin the capacity to construct two cantilevers simultaneously. The girder has been an item of controversy between MDOT and FHWA even in its design phase, and more recently, between MDOT, FHWA, and the contractor after the construction contract award. Problems with its design delayed its fabrication and use and resulted in a heavier-than-anticipated device that necessitated a redesign of bridge erection procedures. Following is a photograph of the launching girder sitting on an uncompleted portion of the northbound structure.

Prior to advertising the project, FHWA tried to get MDOT to eliminate erection drawings for the bridge provided with the contract plans. FHWA's design approach was to indicate only the design requirement for the structure in its final erected condition. According to MDOT officials, after lengthy discussion with FHWA, it was agreed that erection drawings would be left in the

plans and the intent of the drawings was to show a possible erection method for the bridge. MDOT officials said that in no way was it meant to be a required method for the contractor.

The trouble began when Stevin submitted its tentative design for the girder (a longer and heavier device than contemplated by the State) to MDOT for comment in the summer of 1980. The girder was of a sufficient length so that Stevin could erect two cantilevers simultaneously and thereby speed construction. According to Stevin's project manager, the fabricator hired by Stevin to design and construct the girder had attempted to design the device to comply with the maximum loads indicated by the State in its bridge plans, but it was found that a device that would meet the State's loading criteria was not strong enough to perform the erection function.

The contractor's resolution of this problem resulted in the fabrication of a heavier-than-anticipated girder (total weight of the girder, girder legs and crane is about 1,760 tons), necessitating a redesign of the bridge and the bridge erection procedures to accommodate it. Neither FHWA nor MDOT approved the contractor's girder design. MDOT believes that this is simply a piece of contractor-furnished equipment, and the responsibility for its design, fabrication, and use is the contractor's.

Even after the contractor went ahead with the heavier design, it continued to experience problems. According to Stevin's project manager, its hired designer/fabricator had made some design errors that required a redesign of the device after fabrication was started. These problems contributed to a delay in using the girder from the spring of 1981 to fall 1981.

Although the problem involved some lost time, any precise definition of it is not possible. First of all, Stevin started the superstructure construction from the ground using cranes on trucks to minimize lost time. Yet, even this measure could not prevent the shut down of the segment casting plant in late summer 1981 when the segment storage yard became filled. Another consideration is that using the girder, once it became operational, sped construction by permitting work on two cantilevers simultaneously. At the same time, the heavier girder required special erection procedures which slowed construction. Also, as discussed in the next section, labor and other problems contributed to a construction schedule lag. Of course, this delay was insignificant compared to the delay from the near collapse.

The other impacts of the problems related to the launching girder are many and complex. Stevin paid for the girder's cost; however, Stevin intends to file a claim against the State charging that MDOT supplied incorrect loading figures. According to Stevin's project manager, the case against the State is complex and is taking a long time to compile. Also, when BVN/STS charged MDOT $135,000 for its investigation of the launching girder's effects on the bridge and its redesign of the bridge plans and

construction procedures to accommodate the heavier device, MDOT decided that $81,000 of the amount was attributable to Stevin. Its rationale was that the contractor had submitted a different design than what was shown on the plans, thus requiring additional checking and redesign requirements; therefore, these costs are the contractor's to bear. Stevin refused to sign the State's $81,000 downward adjustment to the contract amount because it relates to the anticipated claim against the State. According to MDOT officials, a recently completed audit showed that Stevin's cost for the girder was $1.9 million, with its fabricator claiming an additional $2 million.

Labor and other problems force the contractor to hire a U.S. manager to get the project on track

In addition to the launching girder problems, Stevin's efforts to carry out the superstructure work were stymied by labor and other problems. According to Stevin's project manager, most of Stevin's overseas work before this project had been in third-world countries where labor and other problems were handled differently. Stevin's only other U.S. experience involves an ongoing major contract for a Florida transit project. On the Zilwaukee project, Stevin's Dutch managers had trouble communicating well enough to get what they wanted, and they were not familiar with American ways of dealing with MDOT, labor, and subcontractor/suppliers. As a result, Stevin was not getting the productivity it expected and, by mid-1981, it had lost confidence in its handling of American administrative procedures as they related to MDOT, labor, and subcontractors/suppliers.

To solve this problem, in August 1981, Stevin hired S.J. Groves and Sons Company of Minneapolis, Minnesota, to manaage casting and erection of the box girder segments. Groves had recently completed a similar bridge project in Orgeon, on time and with no cost overruns, and was viewed as a U.S. expert by Stevin. Ironically, Groves and a joint venture partner were the low bidders on the first advertising of the project and third low bidder in the second round bidding.

The impact the management problem had on the project is not determinable. It apparently contributed to the construction activity being behind schedule; however, based on State and FHWA reports, Groves apparently got the project back on track and was beginning to gain back the lost time. The amount of Stevin's contract with Groves has not been disclosed, but the cost is to be borne entirely by Stevin, so that it should have no impact on project costs.

MDOT officials told us that they believed that Stevin's prior experience with the segmental, post-tensioned construction technique would be a positive factor in assuring a timely and uncomplicated construction period. According to the MDOT Engineer of Design, there was no reason to suppose that the foreign contractor

would experience any unusual problems not encountered by a U.S. contractor.

MISHAP SUSPENDS CONSTRUCTION

Shortly after midnight on August 28, 1982, the near collapse of a section of the northbound bridge produced or resulted in considerable physical damage to the bridge. One end of a section of the bridge deck sagged over 5 feet while the opposite end rose about 3.5 feet like a giant teeter-totter. No personal injuries resulted.

Damage is extensive

The movements and physical damage occurred around pier column 11 (the pier columns are numbered consecutively south to north) which is next to the river's south shore. The movements and damage which occurred moments after the launching girder gantry crane lifted a 157-ton segment from the transport truck, include

--the end of the newly completed about 170-foot-long south cantilever on pier 11 deflected downward over 5 feet,

--the top of pier 11 moved horizontally to the north about 8 inches,

--the span 12 (the span formed by the north cantilever on pier 11 and the south cantilever on pier 12) expansion joint located about 120 feet from pier 11, deflected upward about 3.5 feet,

--the superstructure concrete at the expansion joint in span 12 experienced severe crushing,

--the segment joints opened in many of the segments from pier 12 south to the expansion joint,

--the pier 11 footing concrete was shattered, and

--the pier 11 and expansion joint bearings were damaged.

Following the near collapse, the contractor took various actions to stabilize the structure. The contractor installed a temporary framework at pier 11 to help support the tilted superstructure, poured epoxy into the failed expansion joint, and placed temporary steel tendons in the portion of span 12 between pier 12 and the expansion joint to strengthen that portion of the span against the stress being imposed by the tilted section. About 10 days later the contractor moved two 30-ton pieces of equipment from the lower end of the tilted cantilever, which rose about 5 inches when the equipment was removed. Neither the launching girder nor the gantry crane which still holds the 157-ton segment has been moved since the failure. MDOT then halted activity

on the northbound structure except for some epoxy grouting of exposed post-tension tendons to prevent rust damage.

Consultants hired and congressional interest

Since the accident, the contractor engaged two consulting firms, T.Y. Lin of San Francisco, California, and Weis, Janney, Elsner, and Associates of Chicago, Illinois, to investigate the problem. MDOT worked with Zilwaukee Construction Engineering, Inc., and engaged an independent consultant, Howard, Needles, Tammen, and Bergendoff of Kansas City, Missouri, to investigate the cause. Zilwaukee Construction Engineering was formed out of BVN/STS, the designer of the bridge, when it (BVN/STS) was purchased by another firm. In July 1982 MDOT contracted with Zilwaukee Engineer for services provided by BVN/STS.

On February 18, 1983, the House Subcommittee on Investigations and Oversight, Committee on Public Works and Transportation, held a hearing in Saginaw, Michigan. Subcommittee members questioned MDOT and FHWA officials on the need for the bridge, its design, the bidding process, the worthiness of this type of bridge, the structural failure, and the problems anticipated in repairing and completing the bridge.

As discussed in our letter, we will discuss these and other events subsequent to the near collapse, including the consultants' findings, in a second report that we will provide at a later date.

CONCLUSIONS

Our discussions with FHWA and State officials and review of pertinent data indicate that the decision to replace the drawbridge was reasonable, considering the conditions at the time of the decision. A few years after the drawbridge was completed, its traffic was greater than MDOT anticipated and exceeded the bridge's design capacity. Also, the number of bridge openings for ship traffic substantially increased, causing additional problems for vehicle traffic. Furthermore, FHWA had established a policy that drawbridges are generally not appropriate for the Interstate System because they can interrupt the free flow of traffic.

The methodology and support for the State's various estimates for the alternatives to a high-level bridge could no longer be located and thus were unavailable for our analysis. However, based on our discussions with various officials and review of pertinent FHWA and MDOT files, the State's choice of the high-level bridge appears to have been reasonable based on the estimates and conditions at the time the decision was made.

Much of the controversy and questions concerning the project center on the design and bidding phases, primarily FHWA's requirement for an alternate design and its rejection of the first

low bid. The alternate design requirement and the rejection of the first low bid caused more delay in the project, but they apparently increased competition and reduced costs. We believe that the delay, resulting from the requirement for alternate design, could have been avoided if MDOT's initial decision not to develop an alternate design had been coordinated with FHWA. Also, if MDOT had used value engineering or some other broader input into design development, it may have helped improve the design and reduced costs. FHWA currently encourages value engineering, but the concept had not been widely accepted and applied at the time the Zilwaukee Bridge design was developed.

The construction problems that occurred before the August 1982 near collapse slowed construction progress and increased costs, but they have apparently been overcome. The more difficult task will be repairing the damage from the near collapse and continuing construction. At the end of this phase of our review, MDOT had not finalized the design for the repair work.

AGENCY COMMENTS AND OUR EVALUATION

In commenting on our draft report, the Department of Transportation said that the report is well documented, factual, and quite complete. The Department, however, commented that while FHWA does encourage value engineering, it also encourages alternate design as a viable solution to reducing bridge costs. According to the Department, value engineering may have reduced costs but it may not have improved the design.

We recognize that alternate design can reduce costs. A process such as value engineering also could have benefited the project, and we consider a design change that provides for the bridge to carry out its intended purpose at a lower cost to be an improvement.

MDOT COMMENTS AND OUR EVALUATION

MDOT said that it has reviewed the report in detail and is in general agreement with the statements made in all sections of the report. However, MDOT officials wanted to clarify that at the time of the initial Zilwaukee design, the value engineering method was somewhat in its preliminary stages and its formal finalization did not take place until later. We realize, and the report notes, that value engineering was not widely used until later. Our conclusion in this regard is intended as a consideration for future projects.

APPENDIX II

ZILWAUKEE BRIDGE PROJECT CHRONOLOGY

Month	Year	Event
	1946	The Federal Government approves the State of Michigan's "inter-regional" highway system master plan which calls for a drawbridge over the Saginaw River near Zilwaukee.
	1954	The Federal Government pledges to pay 60 percent of bridge costs.
	1956	The Congress authorizes the Interstate System program.
February	1957	Bureau of Public Roads (now the Federal Highway Administration) agrees to pay 90 percent of bridge costs.
May	1957	State lets the contracts for the drawbridge.
March	1958	The Federal Government decides movable span bridges, which includes drawbridges, are not in keeping with the purpose and function of the Interstate System.
December	1960	State opens the Zilwaukee drawbridge to traffic (cost $4.2 million).
March	1965	State gives location/design approval for Interstate 675 business loop.
March	1965	State requests Army Corps of Engineers to establish bridge hours restricting shipping.
November	1967	Bureau of Public Roads gives State verbal approval for construction of a high-level bridge.
February	1968	State starts construction on Interstate 675 business loop.
June	1968	FHWA gives State written approval for construction of a high-level bridge.
July	1969	City of Zilwaukee officials indicate they would prefer a tunnel to a high-level bridge.
January	1970	State highway department issues Engineering Report 1786 covering replacement of the Interstate 75 drawbridge with a $35-million, high-level bridge.

January	1970	The Congress passes the National Environmental Policy Act requiring environmental impact statements. Section 4(f) of the Department of Transportation Act requires Federal approval of the use of public and recreational lands for highway purposes.
February	1970	Michigan Highway Commission (now State Transportation Commission) approves Engineering Report 1786.
November	1970	U.S. Department of Transportation requests the Department of the Interior comments on the approval of the use of section 4(f) lands for the Zilwaukee Bridge project.
July	1971	FHWA requests State to prepare a combination environmental impact/section 4(f) statement to include coverage of issues raised by Department of the Interior and Department of Housing and Urban Development.
October	1971	State opens Interstate 675 business loop to traffic. (Interstate 675 is a penetrator route into Saginaw which operates with traffic volumes near capacity. Since Interstate 75 traffic is at congestion levels during peak hours, Interstate 675 cannot handle its regular load plus that of Interstate 75 during bridge openings.)
June	1973	State submits draft environmental impact/section 4(f) statement to FHWA.
Late	1973	State hires STS consultants to prepare a study of a segmental concrete bridge.
April	1974	FHWA regional administrator transmits final environmental impact/section 4(f) statement for a high-level bridge to FHWA headquarters.
November	1974	Secretary of Transportation approves environmental impact/section 4(f) statement.
Late	1974	STS consultants submit a report on a concrete segmental bridge with an estimated cost of $30 million for the superstructure only.
July	1976	State submits Preliminary Plan A for a steel bridge to FHWA division office in Michigan which forwards it to Region 5.

September	1976	FHWA Region 5 transmits its comments to the division and requests State to prepare a study report considering alternate designs because of the magnitude of the project and the potential savings possible.
October	1976	FHWA division transmits its comments to the State, including a request to investigate various alternative designs.
December	1976	State submits Preliminary Plan B (revising Plan A steel structure) to FHWA Michigan division which forwards to Region 5. State includes response to review comments and notes that it also considered a precast segmental structure estimated to cost $3.5 million less but selected the steel structure based on its knowledge of design and construction of steel structures.
January	1977	FHWA Region 5 transmits Plan B to FHWA headquarters.
February	1977	FHWA headquarters transmits comments on Plan B to FHWA Region 5 (no comment on alternate design).
February	1977	FHWA Region 5 transmits its own and headquarters comments to FHWA Michigan division, including that State should investigate alternate construction scheme because it is considered feasible to bid a concrete segmental box girder design as an alternate to a steel design for at least part of the bridge.
March	1977	FHWA Michigan division requires that State take bids on a segmental concrete box girder design as an alternative to a steel design for at least the central parts of the bridge.
April	1977	FHWA headquarters, regional, and division staff meet with State staff and resolve matters concerning the design and bidding of the bridge, including that there will be designs for both a steel and a concrete structure.
June	1977	BVN/STS submits proposal to design and detail a precast segmental concrete structure (other proposals received from Howard, Needles, Tammen, and Bergendoff and T.Y. Lin).
August	1977	State submits Preliminary Plan C for a steel structure to FHWA division which forwards it to Region 5.

November	1977	State contracts with BVN/STS and BVN for the design and preparation of plans for a precast segmental concrete bridge (contract amount $567,000).
January	1978	State submits a Preliminary Plan for a segmental structure to FHWA.
February	1978	FHWA approves Preliminary Plan C (steel alternate) for further development but requires additional documentation on the concrete structure.
July	1978	Coast Guard issues a bridge permit for a structure over the Saginaw River at Zilwaukee with a minimum 125 feet underclearance.
September	1978	FHWA approves plan, specifications, and estimates package.
September	1978	State advertises project (steel or concrete).
November	1978	State has first letting--low bidder was Groves-Atkinson (joint venture) with a low bid of $81 million for a concrete structure
January	1979	FHWA denies concurrence and requires rejection of all bids and a readvertisement of the project after some changes in the contract proposal.
May	1979	State readvertises the project (steel or concrete).
August	1979	State has second letting--low bidder was Toebe-Stevin (joint venture) with a bid of $76.8 million for a concrete structure.
September	1979	Michigan Transportation Commission approves low bid of $76.8 million.
October	1979	Michigan Administrative Board approves contract with Toebe-Stevin.
October	1979	Contractor starts construction (test piles).
March	1980	State contracts with BVN/STS for providing an onsite consultant, training of State staff, and reviewing construction contractor items (contract amount $393,000) with services to commence on October 15, 1979.
July	1981	State amends March 1980 service contract with BVN/STS for redesign of footings and services related to the erection girder (contract amount $294,000).

August	1981	Contractor hires S.J. Groves and Sons Company to manage casting and erection of concrete box girder segments.
February	1982	State notifies FHWA Michigan division that BVN/STS might be acquired by Henningson, Durham, and Richardson, but Zilwaukee Construction Engineering, Inc., will continue the BVN/STS contract work.
April	1982	State issues report on cracking of the deck portion of the precast concrete segments. The cracking problem developed almost immediately after the contractor began casting segments in late summer 1980.
July	1982	State contracts with Zilwaukee Construction Engineering, Inc., for work previously contracted to BVN/STS in March 1980 and June 1981 (contract amount $316,000) with services to commence on March 1, 1982.
August	1982	A section of the northbound structure teeters and almost collapses during construction, dropping about 5 feet on one end and rising about 3.5 feet on the other end.
September	1982	State hires Howard, Needles, Tammen, and Bergendoff to perform construction and inspection services related to the mishap, including determining its cause (estimated cost up to $100,000). The contractor hired T.Y. Lin to investigate the cause. Zilwaukee Construction Engineering is also investigating the mishap.
February	1983	The Subcommittee on Investigations and Oversight, House Committee on Public Works and Transportation, holds a hearing in Saginaw, Michigan, on the project.

APPENDIX III

U.S. Department of Transportation

Assistant Secretary for Administration

400 Seventh St., S.W. Washington, D.C. 20590

JUL 11 1983

Mr. J. Dexter Peach
Director, Resources, Community
and Economic Development Division
U.S. General Accounting Office
Washington, D.C. 20548

Dear Mr. Peach:

This is in response to your letter requesting Department of Transportation (DOT) comments on the General Accounting Office (GAO) draft report, "Early Decisions and Delays on the Zilwaukee, Michigan Bridge Project," dated May 25, 1983.

The GAO concluded in this report that:

1. Some of the controversy and delay surrounding the Zilwaukee Bridge could have been avoided with better and earlier communications between the FHWA and the Michigan Department of Transportation.

2. Broader input into the development of the bridge design using value engineering or some other systematic cost-control program may have improved the design and reduced costs.

In general, the draft report is well documented, factual, and quite complete. However, the controversy alluded to with regard to the Federal Highway Administration (FHWA) requirement for alternate designs on the Zilwaukee project would be put into better perspective if the cost savings in the past 4 years using the alternate design concept were cited in the text of the report as they are on page 20 of Appendix 1. Also, value engineering may have reduced costs, but it may not have improved the design.

On page 6 of the summary, value engineering is cited as the solution to economical construction of highway bridges, but there is no mention of the alternate design concepts as a viable solution to reducing the bridge costs. While the FHWA does encourage value engineering, as acknowledged on page 8, it also encourages alternate designs. Here again, the cost savings cited on page 20 of Appendix 1 would stress the importance of the alternate design concept in reducing bridge costs.

If we can further assist you, please let us know.

Sincerely,

Robert E. Farman

Enclosure

GAO note: Page references in this letter refer to the draft report and do not necessarily agree with the page numbers in the final report. As suggested, the cost savings attributed to the alternate design concept have been included in the text of the report on page 5. The Department's other comments and our evaluation thereof have been inserted in the report on page 9 of the letter and page 36 of appendix I.

APPENDIX IV

June 6, 1983

Mr. J. Dexter Peach, Director
Resources, Community, and Economic
Development Division
U. S. General Accounting Office
441 G Street, N. W., Room 4915
Washington, D.C. 20548

Dear Mr. Peach:

Review of "Early Decisions and Delays
on the Zilwaukee Michigan Bridge Project" Report

Thank you for sending me a copy of the draft report entitled, "Early Decisions and Delays on the Zilwaukee, Michigan Bridge Project" for the Department's review.

Department personnel have reviewed the report in detail and are in general agreement with the statements made in all sections of the report. We feel, however, that some clarification and additions would add to the quality of the report and suggest that revisions be made as follows:

Page 2, Line 11 states, "the bridge is not expected to be completed before November 1984, a year later than estimated." We understand that at the time of the audit preparation this statement was probably correct. Since that time we have scheduled measures for the repair to be completed in November 1983 with an anticipated completion date for the entire structure estimated to be late 1985 or early 1986. A correction should be made to the above line to reflect this recent information.

Page 2, last paragraph states, "broader input into the development of the bridge design using value engineering or some other systematic cost control program may have improved the design and reduced costs." We would like to add the remark that during the time of initial design of the structure, the value engineering system was a method somewhat in its preliminary stages and formal finalization of this engineering tool did not take place until later. During the revisions made to the first contract, a value engineering clause was added as part of the specifications for the second contract and the contractor has taken advantage of this possibility by submitting a revised construction method for Ramp H, proposing to cast it in place rather than erect it with precast segments.

Page 5, last line and page 6, line 1 states, "FHWA questioned the length of the proposed bridge approach spans and the need for haunched spans and suggested that shorter constant depth spans would look better and be more economical." We wish to clarify the decision by MDOT regarding the span length by stating that the existing topography of the proposed location practically dictated the proposed span lengths because of the presence of obstacles such as existing railroad tracks, existing crossroads (M-13, Westervelt Road), and other obstacles. This determination is evidenced by the fact that the span lengths for the steel and concrete alternates were practically identical. While it is true that the approach spans could possibly have been altered somewhat, we feel that the State's position regarding the span lengths as proposed was valid and wish to add that extensive discussions with the the FHWA bridge division engineer were held and that agreement was reached not to build a "forest of columns" that would have resulted if shorter span lengths had been used.

Page 7, line 7 states, "many of the individual concrete box girder segments developed cracks during the curing process." While it is true that cracks developed as shown in the sketch on page 29 of Appendix I, we would like to point out that this problem was overcome by increasing the transverse post-tensioning.

Appendix I, page 2, line 23: We have the same remark regarding the anticipated completion date as we indicated in our remarks pertaining to page 2, line 11.

Appendix I, page 17, line 10 states, "had a $20 million limit on state highway contracts." The Department policy at that particular time was to limit state highway contracts to approximately $7 million. The intent of the policy was to distribute the construction work amongst as many contractors as possible to provide additional employment in the Michigan contracting industry. The initial decision by the Department to divide the proposed bridge contract into three segments was a compromise to this policy since holding the $7 million limit would obviously have divided the contract into an unmanageable number of projects.

Appendix I, page 18, penultimate paragraph: Same remarks as shown on the preceding item.

Appendix I, page 19, first paragraph states, "the State indicated it preferred the precast method because it was quicker and it permitted the State to exercise better quality control." We would like to see the clarification added that indicates that climatic conditions as they exist in the Saginaw, Michigan area would allow the construction and building of precast segments in an enclosed area during adverse weather conditions while the cast-in-place method would have restricted construction within seasonal limits.

Appendix I, page 24, line 4 discusses the variation in depth for longer spans and we already have explained our objection to this statement under page 6, lines 1 and 2.

APPENDIX IV

Appendix I, page 32, first paragraph refers to the erection drawings for the bridge provided with the contract plans and states, "FHWA's design approach was to indicate only the design requirement for the structure in its final erected condition." While we agree that there was lengthy discussion regarding this item between Departmental and FHWA personnel, it is our understanding that agreement was reached to leave erection drawings in the plans and that the intent of that drawing was to show a possible erection method for the structure, but that in no way was it meant to be a binding method for the contractor.

Appendix I, page 33, last paragraph, line 2 states, "Stevin paid for the girder's cost, about $4 million." It is the Department's understanding from a recently conducted audit that the cost to the contractor was $1.9 million, while the fabricator is claiming an additional $2 million.

We wish to thank your office for giving the Department the opportunity to review and comment on the copy of your draft report and we understand that the draft copies will remain the property of the United States General Accounting Office and will not be publicized or improperly disclosed by this Department.

Sincerely,

James P. Pitz
Director

GAO note: Page references in this letter refer to the draft report and do not necessarily agree with the page numbers in this final report. The suggested clarifications generally have been made in the text of the report and/or appendix I as appropriate. The overall comment on the report and the clarifications on the availability of the value engineering concept at the time of the bridge's initial design have been inserted and evaluated in the "MDOT comments and our evaluation" sections of the report on page 9 of the letter and page 36 of appendix I.

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