
# REPORT OF

# THE

# STATE AUDITOR

**Department of Transportation Bridge Program**
**Performance Audit**
**September 1999**

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Members of the Legislative Audit Committee:

This report contains the results of a performance audit of the Department of Transportation's Bridge Program. This audit was conducted pursuant to Section 2-3-103, C.R.S., which authorizes the State Auditor to conduct audits of all departments, institutions, and agencies of state government.

This report presents our findings, conclusions, and recommendations, and the responses of the Colorado Department of Transportation.

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REPORT SUMMARY

J. DAVID BARBA, CPA
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# Department of Transportation Bridge Program
# Performance Audit
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This performance audit of the Department of Transportation's bridge program was conducted under the authority of Section 2-3-103, C.R.S., which authorizes the State Auditor to conduct audits of all departments, institutions, and agencies of state government. The audit was conducted according to generally accepted auditing standards. The audit work, which included gathering information through interviews, reviewing documents, and analyzing data, was performed between January and July 1999.

This report contains findings and recommendations relating to the Department of Transportation's bridge maintenance, inspection, and design efforts, as well as funding allocations for bridge work. We acknowledge the efforts and assistance extended by staff of the Department, including the transportation regions and maintenance sections. The following summary provides highlights of the comments, recommendations, and responses contained in the report.

## Overview

As of the beginning of Fiscal Year 2000 there are over 8,000 bridges in Colorado. Just under half of these, or about 3,700, are on the state or federal highway systems and are generally referred to as "on-system" bridges, while about 4,500 are on city or county roads and are typically called "off-system" bridges. Federal regulations define a bridge as a structure erected over a depression or an obstruction, such as water, a highway, or a railway, which has a track for carrying traffic or other moving loads and which has an opening of more than 20 feet. According to a 1998 edition of "Better Roads" magazine, which serves the governmental road, construction, bridge, and traffic safety industry, Colorado's on-system bridges are ranked 15$^{th}$ best in the country and off-system bridges are ranked 4$^{th}$ best. Since Colorado's bridges are in overall good condition, the focus of our audit report is directed to how the Department of Transportation can increase efficiency in managing its bridge assets and the bridge program.

The Department of Transportation's Bridge Section consists of several main functional areas, which include bridge design, inspection, information management, construction assistance, and load rating of structures. Bridge-related expenses may be paid from a variety of funding sources, including the federal Highway Bridge Replacement and Rehabilitation Program (HBRRP) and the Highway Users' Tax Fund. Fiscal Year 2000 funding allocated specifically to bridges totals about $42 million. However, bridge design, construction, and maintenance work are often done as part of larger projects, and paid for out of non-bridge-specific sources. As a result, the Department does not have information on the total, discrete costs related to bridges.

## Bridge Maintenance Activities Can Be Improved

As the State undertakes large and costly reconstruction projects in the future, bridge maintenance becomes increasingly important for cost-effective, long-range asset management. The Department has recognized this, and in March 1998 the Bridge Section provided the Department's Maintenance Section with its first "Master List of Bridge Needs," which identified maintenance needs compiled from a full cycle of bridge inspections conducted in 1996 and 1997. The Master List included over 6,200 identified maintenance activities on more than 2,300 of the State's 3,700 on-system bridges. Maintenance Section staff have indicated they are not able to accomplish all of the identified maintenance needs, and between 1996 and 1998 the bridges needing maintenance work increased by 20 percent for three regions we reviewed. However, the Section does contract some bridge maintenance activities and other highway maintenance activities to private sector companies. We believe expansion of these types of efforts can improve the Department's ability to accomplish the needed maintenance activities while keeping within statutorily set FTE limits.

**We recommend the Department of Transportation increase bridge maintenance by contracting out a greater percentage of maintenance activities, including "retainer" type contracts.**

> The Department partially agrees. T he use of private contractors for maintenance work is not always possible or cost effective and the limited resources available for maintenance will not permit all program needs to be met. However, the Department is developing a maintenance level of service program, to identify the maintenance needs of the state and will continue to look for other methods and opportunities to optimize available resources.

## Budgeting and Allocation of Federal Bridge Funds

The Federal Highway Administration (FHWA) allocates funds from its Highway Bridge Replacement and Rehabilitation Program (HBRRP) to the states for replacement or rehabilitation of bridges that meet certain criteria. On the basis of information collected during bridge inspections, each structure is given a "sufficiency rating" between 1 and 100 and may be designated as either structurally deficient (meaning one or more major components, such as the deck, is in poor condition), or functionally obsolete (meaning the bridge is not fully functional because it is too narrow, has low clearance, or is poorly aligned with the roadway). Bridges that have sufficiency ratings of 80 or less which are either structurally deficient or functionally obsolete are eligible for HBRRP funds.

For Fiscal Year 2000, the Transportation Commission had established a goal for HBRRP funds of replacing 75 percent of the structures rated structurally deficient with a sufficiency rating of less than 50 by 2020. This goal indicates the Commission intends to allocate the funds so they can be used to address the needs of the State's poorest-rated bridges. However, the Department's current

allocation method, which bases the distribution of funds on the square footage of bridges over a certain age, is not consistent with the Commission's statewide priority and may not direct funds to the regions where they are needed most. According to Department data, Region 6 has approximately half of the State's poorly rated bridge square footage but, because of the allocation based on age, has received, on average, only 17 percent of the HBRRP funds over the past several years. Furthermore, only 22 percent of the structures used in the age-based analysis meet the eligibility requirements for HBRRP funds. Therefore, **we recommend the Department provide the Commission with a breakdown of the square footage of structurally and functionally deficient bridges by region as well as other relevant information, for use in funding and allocation decisions.**

> The Department agrees. The Department looked at four possible allocation methods and chose the age criteria as the only way to forecast needs. The structurally deficient information should have been presented to the commission and will be corrected immediately.

## Bridge Inspections Could Be More Cost-Effective

Federal laws make state transportation departments responsible for maintaining bridge inspection programs that include routine inspections of all bridges on public roads. In Colorado, on-system bridges are inspected by teams of Department of Transportation inspectors, while off-system bridges are inspected by engineering consulting firms. In accordance with federal regulations, the Department has instituted a risk-based inspection program, placing bridges in poor condition on a one-year inspection cycle and allowing those that meet established criteria to be placed on a four-year cycle. Currently 21 percent of all on-system and 4 percent of all off-system bridges are on the four-year cycle. We found that 60 additional on-system and 700 additional off-system bridges that appear to meet the eligibility criteria for four-year inspections are still being inspected on a two-year cycle.

The Department spends about $1.2 million annually to inspect and report on the on-system bridges and about $1.4 million to have inspections done on off-system bridges. We estimate the Department could potentially save about $41,000 in on-system inspections and $420,000 in off-system inspections every two years by placing the bridges that we identified on a four-year cycle. The funds that might be saved from less frequent inspections could be used on bridges that need more frequent inspection or for rehabilitation or replacement. **We recommend the Department of Transportation more fully implement its risk-based inspection program by taking steps to ensure that all bridges that meet the four-year criteria are placed on a four-year inspection schedule.**

> The Department partially agrees. The Department believes this should be referred to the Attorney General's office for an opinion as to whether the State has the authority to demand that cities and counties place their bridges on the four-year cycle and if the State can become liable if the entity doesn't specifically ask to change the

cycle. If the opinion is that we can do this without assuming liability, then we will conduct this review with the cities and counties and implement the results by January 1, 2001.

## Reorganization of the Inspection Program Could Reduce Travel-Related Expenses

Due to the Bridge Section's organization, virtually all bridge inspections are conducted by staff located in Denver. As a result, highly trained inspectors spend a significant amount of time on the road. We estimate the cost of Department inspectors' time spent traveling is about $100,000 to $120,000 every year. Added to this are actual travel costs (mileage, lodging, etc.,) of about $35,000 for a total cost to the Department ranging from $135,000 to $155,000 per year. For off-system inspections, we estimate about $70,000 is spent each year for travel and about $195,000 to $240,000 to pay inspectors for the time they spend traveling.

We believe there are several ways the Department could organize its inspections to increase efficiency and reduce the costs of travel. First, the Department could place bridge inspectors in different areas of the State, thus substantially reducing the time and cost of travel. This would be consistent with other recent decentralization efforts within the Department. Second, the Department could seek to contract with private firms in outlying areas of the State, thus reducing travel time and costs for off-system inspections. Lastly, the Department could contract bridge inspections based on location of bridges rather than on ownership. Currently there is duplication in travel because state inspectors and consultants travel to the same areas of the State to inspect different bridges at different times. **We recommend the Department improve the efficiency of its bridge inspection program and reduce travel-related costs by implementing one or a combination of these alternatives.**

The Department partially agrees. There are several drawbacks to having decentralized bridge inspectors and prior attempts at decentralization have not been successful. Furthermore, no in-state firms outside the Denver area have shown an interest in conducting bridge inspections. Finally, combining inspections for on- and off-system bridges by geographic area would not necessarily reduce travel. However, the Department agrees to review the pros and cons of making changes to its inspection program.

## In-House Bridge Design Activity Needs More Accountability Measures

The Bridge Design Section is responsible for the design of all on-system structures. Three design units prepare or oversee the preparation of bridge designs for five of the Department's six transportation regions. In addition, a fourth unit currently handles only Region 1 design work. According to Department data, about 30 percent of design work is completed by in-house staff and about 70 percent is contracted out to private consulting firms.

The Department has few accountability mechanisms in place for design work conducted by in-house staff. Design Section staff do not work under formal contract or agreement with a region, they do not routinely participate in project status meetings, and their work is not subject to any type of final cost or budget review.

The Design Section has begun using written performance agreements between regions and the Design Section for some major projects to improve accountability. However, Department staff estimated that these agreements are used for less than 5 percent of in-house design projects. In addition, there are other areas where accountability for design work is lacking. For example, there is no automated, Sectionwide system to track design costs or work hours for in-house bridge designers, and there is no way to compare in-house and consultant design costs or work hours for similar projects. Without accountability tools, design work may not be completed as quickly as possible, causing increased costs. Furthermore, the Section does not have consistent historical information to use in planning and budgeting of future projects. Therefore, **the Department should institute a system to improve accountability in the Design Section, which could include increasing the use of performance agreements and comparing budgeted to actual time and costs for in-house design work.**

> The Department agrees. The Department will implement the use of performance agreements immediately for all bridge design projects completed in-house. Furthermore, the Bridge Section has designed a Bridge Project Database (BPD) which, among other functions, establishes a method to compare the budgeted and actual workhours of bridge design work. For monitoring by Region personnel, the Chief Engineer's Office will encourage the use of project review meetings to improve the accountability and quality of our bridge design program.

## Decentralizing The Bridge Design Function

In 1996 the Department began a pilot program, decentralizing two bridge design units to individual transportation regions. One of the main purposes of the pilot was to improve accountability and responsiveness of bridge designers to the regions. However, there is little information available to evaluate whether this goal has been accomplished. There are several reasons why the current pilot program does not truly test the effectiveness of decentralizing the Section. First, the regions tested are not geographically representative of all transportation regions, since both were located in metro Denver while the other transportation regions include more rural areas that extend hundreds of miles from Department headquarters. Second, the staff of the decentralized design units were not relocated to the regions but remained physically located in the Denver office. Third, neither the Department nor the Design Section set goals to use in measuring the success of the pilot program. If the Department intends to pursue the possibility of decentralizing bridge design staff, **we recommend using a fully-planned pilot approach which addresses the elements discussed above.**

The Department disagrees. The Chief Engineer's Office and the Regional Transportation Directors have decided to keep the bridge design staff centralized. However, as part of the re-engineering of the Staff Branches, specific performance measures will be developed staff patterns reviewed, and project agreements on in-house design bridge projects implemented.

## Construction Cost Estimates Could Be More Accurate

The cost of constructing a bridge that is designed in-house is estimated two separate times: once by the designer and later by the Department's Cost Estimating Office. The first estimate is used by the regions when selecting the bridge type and design; the second is used in negotiating a final contract. We found that for more than half of 13 recent projects we reviewed, the final estimate exceeded the Bridge Section's estimate by more than 30 percent. Underestimating the construction costs at the preliminary stage could result in the region's selecting a more expensive bridge than they had originally budgeted.

There are three primary reasons for the variances between final and preliminary cost estimates: (1) Design Section engineers may intentionally exclude certain items from preliminary estimates; (2) Design Section engineers may miss items that are necessary to the project; (3) Design Section engineers may not consult the cost-estimating office for cost data, but instead use sources that may be outdated. Therefore, **the Department should establish a more standardized process to improve the accuracy of preliminary construction cost estimates, including consulting with the cost-estimating office and increasing accountability for inaccurate preliminary estimates.**

The Department agrees. Effective immediately, for in-house bridge design work a more standardized process for calculating preliminary estimates, for major structures, will be established and followed. The decision to include consultant design work in this process will depend on the analysis of this process after being utilized on in-house work.

## RECOMMENDATION LOCATOR

| Rec. No. | Page No. | Recommendation Summary | Agency Addressed | Agency Response | Implementation Date |
|---|---|---|---|---|---|
| 1 | 19 | Ensure repair of bridges in a more timely manner by contracting out a greater percentage of bridge maintenance. | Department of Transportation | Partially Agree | Ongoing |
| 2 | 22 | Develop a risk-based approach for maintenance forces to conduct inspections of bridges. | Department of Transportation | Partially Agree | June 30, 2000 |
| 3 | 27 | Ensure that the Transportation Commission has accurate information on the condition of bridges for policy decisions, including the square footage of structurally and functionally deficient bridges by region. | Department of Transportation | Agree | Immediately as part of FY 2001 Budget Development |
| 4 | 30 | Ensure that the Transportation Commission has complete and accurate information about bridge needs by implementing a system to ensure current information is used in projections. | Department of Transportation | Agree | October 1, 2000 |
| 5 | 32 | Improve the accuracy of bridge projections by ensuring that completed maintenance activities are communicated to the Bridge Section and are used in analyses. | Department of Transportation | Agree | June 30, 2000 |
| 6 | 37 | Fully implement the risk-based inspection program by routinely reviewing the conditions of all on- and off-system bridges and working with local governments to place more eligible off-system bridges on a four-year cycle. | Department of Transportation | Partially Agree | January 1, 2001 |
| 7 | 39 | Consider expanding the risk-based bridge inspection program to include a three-year inspection cycle, where appropriate. | Department of Transportation | Partially Agree | October 1, 2000 |

## RECOMMENDATION LOCATOR

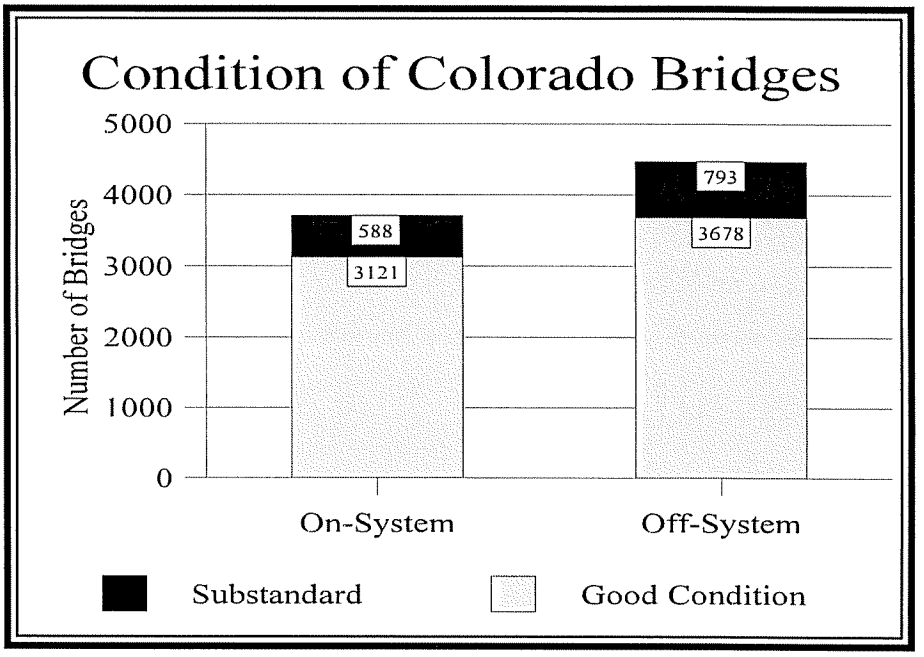
| Rec. No. | Page No. | Recommendation Summary | Agency Addressed | Agency Response | Implementation Date |
|---|---|---|---|---|---|
| 8 | 41 | Ensure that all bridges that meet one-year inspection criteria are placed on a one-year cycle. | Department of Transportation | Agree | Immediately |
| 9 | 45 | Improve efficiency and reduce bridge inspection travel costs by implementing one or more of the following options: (a) decentralize the bridge inspectors, (b) seek firms located near outlying bridges for their inspections, (c) assign inspections based on geography, regardless of whether they are on- or off-system. | Department of Transportation | Partially Agree | June 30, 2000 |
| 10 | 51 | Improve the accountability of the Bridge Design Section by increasing the use of performance agreements, evaluating the costs of in-house design work against budgeted costs, and ensuring ProDATES addresses accountability needs. | Department of Transportation | Agree | June 30, 2000 |
| 11 | 54 | Improve the time-tracking system within the Bridge Design Section by instituting an automated, standardized system. | Department of Transportation | Agree | March 1, 2000 |
| 12 | 56 | Institute a true pilot program, with measurable goals and objectives, to examine the efficiency and practicality of decentralizing bridge design functions. | Department of Transportation | Disagree | -- |
| 13 | 59 | Establish a more standardized process for calculating preliminary cost estimates by using current cost data, including all items that will be used for the bridge, and ensuring accountability of cost-estimate accuracy. | Department of Transportation | Agree | Immediately |

# Colorado Bridges and the Bridge Section

As of the beginning of Fiscal Year 2000 there are over 8,000 bridges located on the network of roads and highways throughout the state of Colorado. Just under half of these, or about 3,700, are on the state or federal highway systems and are generally referred to as "on-system" bridges, while about 4,500 are on city and county roads and are referred to as "off-system" bridges. Federal regulations define a bridge as follows:

> ... any structure, including supports, erected over a depression or an obstruction, such as water, a highway, or a railway, having a track or passageway for carrying traffic or other moving loads, and having an opening measured along the center line of the roadway of more than 20 feet....

Compared with all other states, Colorado ranks 27th in the number of on-system bridges and 23rd in off-system bridges. According to data from the Department, the overall condition of Colorado's bridges is good. A leading industry trade magazine called "Better Roads" ranks Colorado's on-system bridges as 15th best and off-system bridges as 4th best in the country in 1998. Appendix A lists the number and condition of all state, city, and county bridges in the country. The current condition of Colorado's on- and off-system bridges is depicted in the following chart.




**Source:** Department of Transportation.

Since bridge inspection data indicate that Colorado's bridges are in overall good condition, the main focus of our audit report is directed to how the Department of Transportation can manage its bridge assets and the bridge program more efficiently and effectively.

# Bridge Operations

Most activities relating to bridges are carried out by staff of the Department of Transportation's Bridge Section. The Section, which employs about 50 FTE, including structural engineers, bridge inspectors, administrative staff, and managers, consists of three main functional areas, described below:

**Design:** The Design Section, which consists of 27 FTE, produces engineering plans and specifications for new bridges, bridge rehabilitation, and small structures such as bridge rails and signs. The Section also engages in oversight of consultant design work, provides bridge engineering assistance to local governments on a limited basis, and maintains standards and specifications for bridge design work.

**Management:** This section has 12 FTE who are responsible for the following:

- Bridge Inspection staff conduct inspections of on-system (state-owned) bridges, administer contracts with private consultants for inspections of off-system (city and county) bridges, and maintain bridge inspection standards.

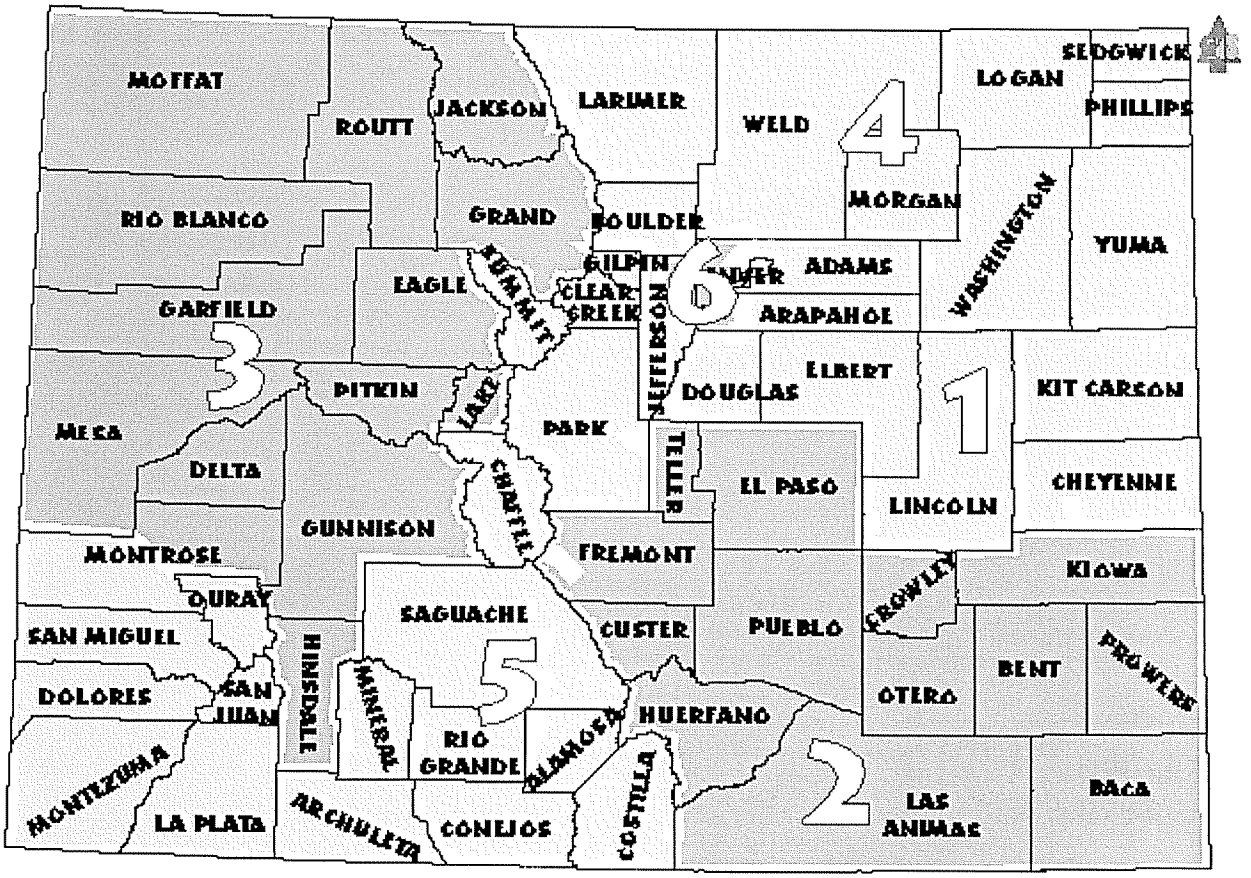
- Bridge Management is responsible for maintaining an inventory of Colorado's bridges as part of the National Bridge Inventory. The inventory is used in analyses of bridge deterioration models, including performance of specific bridge components, and comparisons of individual bridges to systemic trends.

- Technical Assistance to the Special Highway Committee of the Transportation Commission. Unit staff act as liaisons to the Committee, assisting with any matters relating to bridges or other structures.

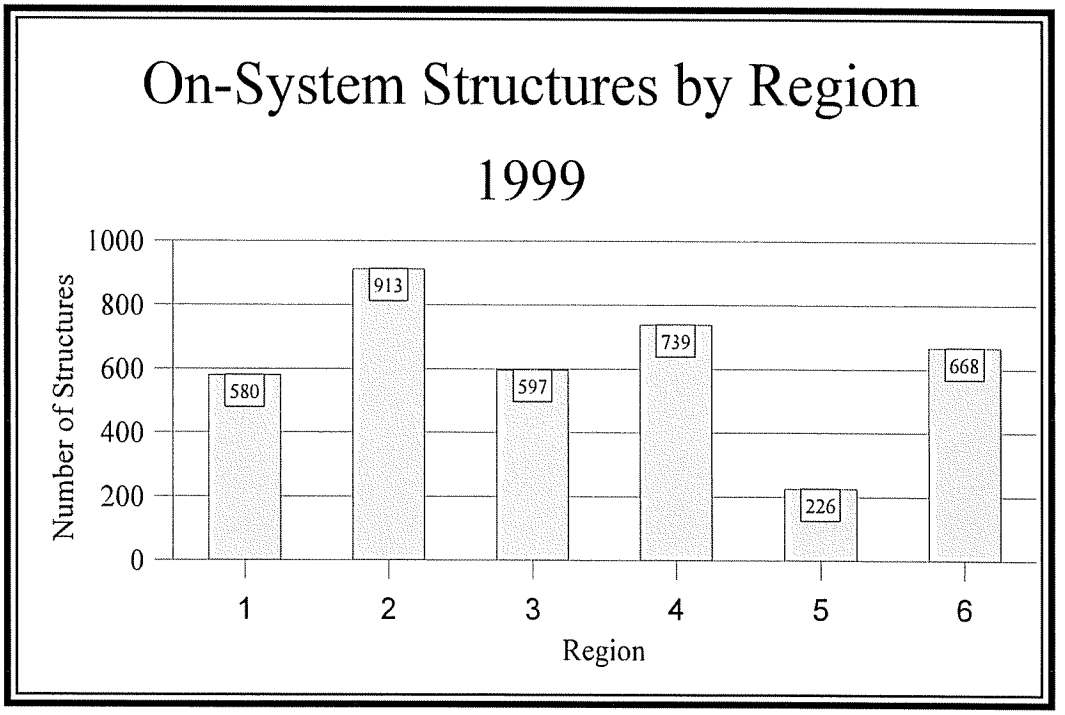
**Operations:** The Operations unit's 10 FTE are responsible for providing engineering assistance once construction has begun on a bridge and inspecting bridge components at the time of fabrication. In addition, this unit produces standards for load rating of structures (determining the maximum load a bridge can safely handle) and analyzes structures for overload permits.

Bridge construction is the responsibility of the Department's transportation regions. There are six regions, each under the general supervision of a Regional

Transportation Director. The following map shows the boundaries of the six transportation regions.



The following chart documents the number of on-system structures by region:




**Source:** Department of Transportation.

## Bridge-Related Revenues and Expenditures

Department of Transportation expenses related to bridges may be paid from a variety of funding sources, some of which are earmarked for bridges and some of which are not. The federal government provides funds for bridge-related work through the Highway Bridge Replacement and Rehabilitation Program (HBRRP). The State matches HBRRP funds at a rate of 80 percent federal, and 20 percent state and local monies, and allocates a portion of Highway Users' Tax Funds to the Bridge Section. Fiscal Year 2000 funding allocated specifically to bridges is shown in the following table.

| Fiscal Year 2000 Funding Specified for Bridge Projects | |
|---|---|
| **Funding Source** | **Amount Earmarked for Bridges** |
| Federal Highway Bridge Replacement and Rehabilitation Program - HBRRP (est.) | $24,900,000 |
| State and Local Match for HBRRP | $7,100,000 |
| Other Federal and State Funds | $9,700,000 |
| Total Bridge-Specific Funding | $41,700,000 |
| **Source:** Department of Transportation budget office. | |

Costs related to bridges are incurred primarily in the areas of bridge inspection, management and analysis of bridge data, bridge design and construction, and bridge maintenance. For Fiscal Year 1998 about $2.6 million was spent for on- and off-system bridge inspection and management of the bridge inventory; at least $3 million was spent on bridge design; and at least $1.5 million was used for bridge maintenance.

However, the costs of bridge design and maintenance, as well as construction, are also paid for out of other, non-bridge-specific funds. For example, when the Department has a large construction project that includes roadways and bridges, funding for the project will typically come from a variety of sources that may or may not include HBRRP bridge funds. In fact, federal bridge funds are allowed to be used only for bridge projects that are approved by the federal government and/or that meet federally established criteria. Similar to design and construction costs, bridge maintenance costs may be paid out of non-bridge-specific funding sources. This is because maintenance on a bridge can occur as part of maintenance on an adjoining roadway, and the bridge portion of the work is not separately accounted for and funded.

Because bridge design, construction, and maintenance work are often done as part of larger projects, the Department does not have information on the total, discrete costs related to bridges. However, in its Fiscal Year 1998 annual report the Bridge Section reported a total of over $80 million in construction costs for projects that included bridges or other structures. Bridge Section staff estimate that design costs for bridge work average about 10 to 15 percent of construction costs. Therefore, a rough estimate of the costs for structural design for Fiscal Year 1998 is about $8 million to $12 million.

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# Maintenance of State-Owned Bridges

## Chapter 1

According to information from the Federal Highway Administration (FHWA), the traditional approach to bridge maintenance throughout the U.S. has been to build bridges and then minimally maintain them until they become deficient or the road is expanded or improved. Bridge maintenance was performed as a part of roadway maintenance with minimum attention and resources. However, increasing traffic volumes, heavier vehicle loads, and the use of de-icing chemicals have accelerated bridge deterioration in recent years. Bridges are critical links in transportation systems and governments do not have the financial resources to replace them at the rate at which they are deteriorating. Consequently, state transportation departments across the country have recognized that ongoing maintenance is needed to preserve their tremendous investment in bridges.

### Performing Ongoing Maintenance Is More Cost-Effective Than Repairing or Replacing Bridges

The California Department of Transportation recently conducted an analysis of how different budget scenarios may affect the future condition of a bridge network. California developed a bridge health index that assigns a value to each element of a bridge, such as the deck, piers, or girders. The value of each element can be lowered or raised to reflect expected deterioration or rehabilitation of the element. The study used a bridge network asset value of $30 billion.

California bridge managers evaluated several budget scenarios on the future condition of their bridges. The study revealed that aggressively funding maintenance and preservation activities on bridges can provide substantial savings to the state over a ten-year period. Specifically, the California analysis used two different maintenance funding amounts: $10 million and $1 million. At the $1 million annual funding level, the state would save $90 million in maintenance costs over the ten-year period but allow the value of the bridge network to deteriorate by $12.3 billion. In other words, by saving $9 million annually on maintenance (compared with the $10-million scenario), the bridge network would deteriorate to the extent that the state would be forced to replace bridges totaling more than $12 billion.

Although Colorado has not performed an analysis similar to California's, the Department's Maintenance Section recently developed a Level of Service budget that

included bridges. Level of Service budgeting estimates the funding amounts needed to bring various roadway components, such as bridges, up to a desired condition level. As part of this process, the Maintenance Section reviewed the condition of all bridge elements and determined that more funding is needed for maintenance of bridge decks and expansion joints. On the basis of this analysis, the Transportation Commission earmarked $2 million of bridge funds for maintenance of these elements in Fiscal Year 2000. The funds were allocated to the six regions based on their proportionate share of bridges needing maintenance on these elements. In addition to this process, ongoing efforts to maintain all bridge elements are needed to keep pace with growing needs.

# Some On-System Bridges Are Not Maintained to the Standard the Department Has Set

In March 1998 the Bridge Section provided the Department's Maintenance Section with a comprehensive list of bridge maintenance needs. The "Master List of 1998 Bridge Needs" was compiled from a full cycle of bridge inspections conducted in 1996 and 1997. This was the first such list provided to the Maintenance Section and it included activity for each region.

In addition to the Master List, the Bridge Section provides the regions with information on more serious bridge needs on an as-needed basis. These needs are identified through inspections conducted by the Bridge Section inspectors and include specific engineering plans for fixing the problems. If the Department's maintenance forces are able to conduct the repair, they will undertake the task; however, the region may have the repair done by a private firm. According to information from the Department, more serious bridge needs are being addressed appropriately. However, the Maintenance Section is not making as much progress with activities included in the "Master List of 1998 Bridge Needs."

The "Master List of 1998 Bridge Needs" included over 6,200 recommended maintenance activities on more than 2,300 on-system bridges. This means that over 60 percent of all on-system bridges required at least one maintenance activity. According to Department records, maintenance staff completed work on 47 percent of the bridges that were identified as needing some sort of maintenance during Fiscal Year 1998 and the first half of Fiscal Year 1999.

Maintenance activities identified by the bridge inspectors ranged from cleaning and filling cracks on the bridge decks to replacing and rehabilitating deteriorated concrete

substructure elements. The most common recommendation, accounting for nearly 30 percent of the identified activities, was to conduct repairs on the bridge deck. Bridge deck repairs include activities such as sealing cracks and filling surface holes, which can be critical to the bridge. This is because any type of opening on the deck surface can allow moisture to penetrate to the substructure of the bridge, accelerating deterioration of the bridge supports.

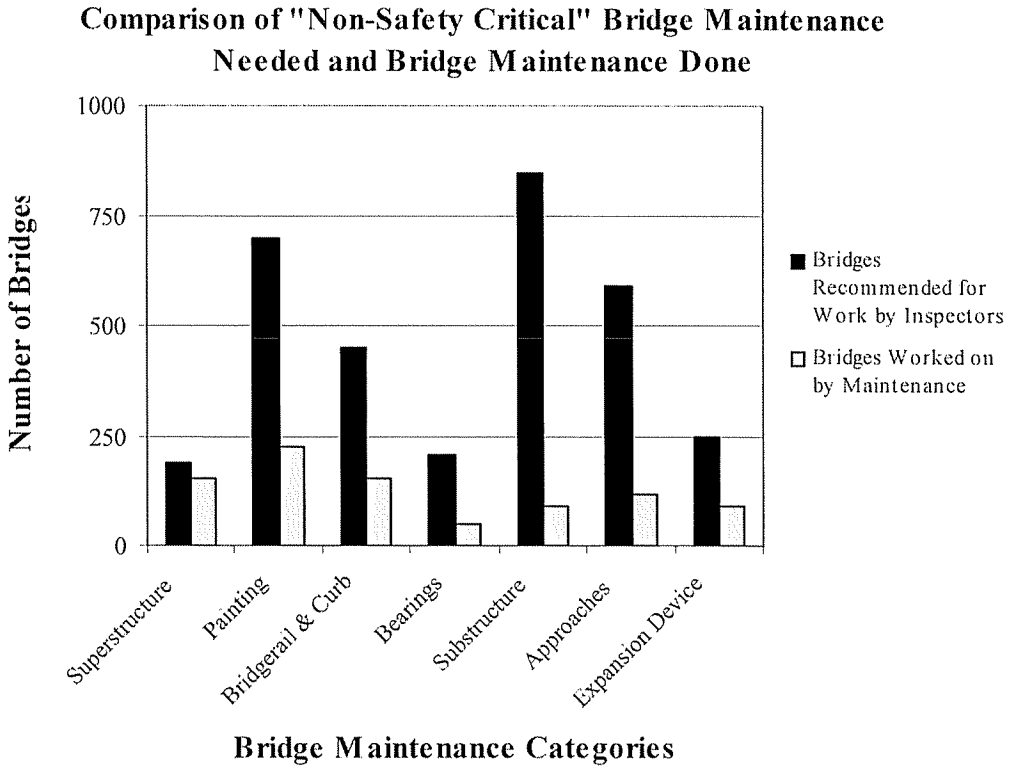
The Department's Maintenance Section Policy Manual includes a chapter on Structure Maintenance. The policy in this chapter regarding structures is "to maintain all bridges to the standard to which they were constructed or have been improved." Although most of Colorado's bridges are considered to be in good condition, there are a number of deficient bridges (currently over 240 on-system), indicating that all the State's on-system bridges are not maintained to this standard. Furthermore, 15 percent of the on-system bridges are rated at a condition level that makes them eligible for federal funds for rehabilitation or replacement.

## Bridge Maintenance Needs Are Growing

If bridge maintenance work is not conducted as needed, a backlog of work will develop. For example, we compared the bridge maintenance needs identified from the most recently completed round of inspections in Calendar Year 1998 with those from the previous inspections on the same bridges in 1996 (since most inspections occur every two years). We found an increase in the number of bridges needing maintenance work over the two-year period. Specifically, we reviewed inspection data for three regions and found the number of bridges needing maintenance work increased by 20 percent and the number of recommended maintenance activities increased by 29 percent over the period.

The Department of Transportation's Maintenance Management System (MMS) tracks maintenance activities and the estimated costs associated with those activities. It also assists maintenance personnel in planning and budgeting. Each day, maintenance forces complete a sheet that documents all the activities accomplished for that day, including activities on structures. According to the MMS, Department staff conducted maintenance activities, other than routine inspections, on over 2,000 bridges during Fiscal Year 1998 and the first half of Fiscal Year 1999. However, maintenance was not done on all the bridges included in the 1998 Master List. The following chart shows the number of bridges for which bridge inspectors recommended maintenance in the "Master List of 1998 Bridge Needs" compared with the number of bridges the Maintenance Section conducted repair work on, for a number of maintenance categories. The maintenance categories represent different components of a bridge. For example, the substructure category may include bridges that need repairs on parts of the concrete bridge support columns to prevent further

deterioration. Repair work on the different components can range in difficulty, time, and cost.




**Source:** Office of the State Auditor's analysis of Bridge Program and MMS Data.

**Note:** According to the Department, these maintenance categories are considered important, but not immediately critical for bridge safety.

# The Maintenance Section Accomplishes Some Work Through the Use of Private Firms

Section 43-1-113(4), C.R.S., limits the number of full-time-equivalent employees the Department can employ to 3,196. According to statute, "The intent of the General Assembly in enacting this limit is to provide additional moneys to finance the maintenance and improvement of the state's transportation system." In an effort to conduct needed maintenance activities on bridges, some transportation regions have entered into agreements with contractors. Frequently, contractors perform maintenance where maintenance forces do not have the time or the expertise to conduct the work themselves. Examples of these contracts include:

- Maintenance staff in one region have entered into a contract with a company to provide roadside mowing services.

- The Maintenance Section has entered into an agreement with a contractor to provide bridge approach stabilization services on an "as-needed" basis.

- One region was able to reduce overall contractual maintenance activities with one company by including up to six different maintenance projects under one agreement, thereby lowering the final cost to the State by 7.5 percent.

The Maintenance Management System (MMS) indicates that the Department used Maintenance Section contract funds for work on 7 bridges during Fiscal Year 1998 and 11 bridges in the first half of Fiscal Year 1999. The Maintenance Section has initiated agreements with private contractors to conduct a full range of maintenance work, including replacing several expansion joints on different bridges as well as minor repair and replacement work. In addition, the regions have initiated projects to repair and rehabilitate bridges using construction funds.

We believe expansion of these types of efforts can improve the Department's ability to accomplish the needed maintenance activities while keeping FTE within the statutory limits.

## Recommendation No. 1:

The Department of Transportation should repair more of the State's bridges in a more timely manner, thus preventing more deterioration and higher costs. This could be done by contracting out a greater percentage of the maintenance activities on bridges, including engaging in "retainer" type contracts to obtain lower prices for maintenance work when numerous jobs can be scheduled with a single contractor.

### Department of Transportation Response:

Partially agree. The Department agrees that we should repair the state's bridges in a timely manner thus preventing more deterioration and higher costs. However, with limited financial resources there are many projects which have to be prioritized and there are not enough revenues to address all the program needs. In addition, given the statutory limitations, utilizing private contractors for some of this work is not always possible. And even if it is possible to privatize much of this work, without further analysis, we do not believe that the conclusion can be drawn that by simply privatizing

will give us lower prices, in fact it may cost the Department more which would result in fewer resources being available to address the needs.

Currently the Department is developing a maintenance level of service program, which will identify the maintenance needs of the state, including bridge maintenance, and will provide the Department with a tool to establish optimum levels of service for each of our maintenance activities. In conjunction with this program, the Department will continue to also look for other methods and opportunities to optimize our available resources as we develop investment strategies, which will give us the highest rate of return on the dollars invested.

# Both Maintenance Section and Bridge Section Staff Inspect Bridges

On-system bridges are typically inspected every two years by highly qualified and trained inspectors from the Bridge Section. A few bridges are inspected more frequently than every two years if warranted by their condition, while some bridges are inspected every four years if they meet specific criteria established by the FHWA and the Department of Transportation. The Bridge Section inspectors conduct a thorough examination of each element on the bridge and often take photographs to accompany inspection reports.

Department of Transportation maintenance staff conduct bridge inspections that duplicate, in some respects, the inspections done by the Bridge Section inspectors. Maintenance patrol staff are not trained bridge inspectors and do not regularly accompany Bridge Section staff during bridge inspections. However, they do conduct numerous bridge inspections that review the same elements that are evaluated during formal inspections. Department maintenance forces conducted nearly 3,700 routine inspections on about 1,300 on-system bridges during Fiscal Year 1998 and the first half of Fiscal Year 1999. The 3,700 inspections represent more than 4,400 maintenance personnel man-hours and more than $125,000 in labor and equipment costs. We believe having maintenance staff perform routine bridge inspections is not the best use of resources for a number of reasons, described below.

## Maintenance Inspections Do Not Ensure That Bridges Are Kept in Good Condition

According to Maintenance Section staff, one of the reasons they inspect bridges is to identify maintenance needs so they can be addressed in a timely manner. However, we found that maintenance patrols are not effective in identifying bridge maintenance needs or ensuring that maintenance is done. We reviewed a sample of Calendar Year 1998 inspection reports by both maintenance forces and Bridge Section inspectors in one region where the maintenance patrols conduct inspections on a six-month cycle. We found that, for 69 percent of the maintenance inspections, the patrols identified either no maintenance needs or identified only part of the maintenance needs that had already been noted by the Bridge Section inspectors. Furthermore, 36 percent of the maintenance inspection reports contained identical maintenance comments for each of the six-month inspections over a one-year period.

On the basis of the inspection reports we reviewed, even when maintenance forces did report needed maintenance work, they did not routinely follow up to perform the activities identified. Maintenance Section personnel stated that they are unable to complete all the recommended maintenance activities on bridges due to lack of resources. We found that maintenance forces did not conduct maintenance activities that the Bridge Section inspectors recommended on more than 47 percent of the identified bridges. Some of the Maintenance Section's resources could have been used to complete actual maintenance work if they had not been used for inspections.

## Maintenance Reviews of Bridges Should Be Based on Need

The Maintenance Section Policy Manual directs maintenance forces to inspect bridges "frequently." We found the frequency of bridge inspections by maintenance forces varies greatly among the different regions. For example, maintenance staff in one region conducted 59 percent of the inspections, but the region has only 24 percent of the bridges; in another region where 18 percent of the on-system bridges are located, maintenance forces conducted only 1 percent of all the inspections. However, none of the maintenance forces formally prioritize their efforts to ensure that bridges in poor condition are reviewed frequently.

An additional reason for maintenance staff conducting inspections of bridges is to check for damage from events such as vehicle accidents or flooding. We agree that conducting inspections in cases where particular circumstances warrant the review is appropriate. Furthermore, efficiently ensuring the safe condition of bridges in the course of other duties is a productive use of maintenance staff resources. However,

the Department should reduce the amount of time and resources spent by maintenance personnel for bridge inspections by developing a risk-based system for determining which bridges should be inspected by maintenance forces and when. This system could increase the efficient use of resources, such as directing maintenance efforts toward other priorities while minimizing risks to the public of deterioration in bridge components.

## Recommendation No. 2:

The Department of Transportation should modify its policy regarding the inspection of bridges by maintenance staff. The Department should develop a risk-based approach for maintenance patrols to conduct inspections of bridges that includes:

a. Discontinuing routine inspections of bridges by maintenance staff.

b. Coordinating with Bridge Section staff to identify any particular needs for maintenance inspection of bridges, such as on those in poor condition.

## Department of Transportation Response:

Partially agree.

a. Most maintenance training sessions stress the fact that regular NBI inspections should be supplemented by maintenance inspections for several reasons the main one being that problems can occur between regular inspection cycles e.g. fall outs in bridge decks, impacts by high loads that are unreported, tearing of seals, etc. None of these types of occurrences can be predicted. The CDOT Maintenance personnel are following those recommendations. Although normal maintenance items may not be done even after, or as a result of these inspections, they can identify safety hazards and structural failures, which can be addressed on a critical, need basis. However, the Department will commit to reviewing its bridge inspection program as part of our re-engineering efforts to determine if there are improvements in this program that can be economically implemented.

b. Upon implementation of the maintenance level of service program, the Department will have in place a method to link bridge maintenance activities with the Bridge needs identified by our Bridge Section staff. In addition, the Department is working on a process to electronically link our bridge maintenance activities to the overall bridge need.

# Bridge Management and Budgeting

## Chapter 2

A major role of the Bridge Management Section is to manage and organize bridge inspection reports and keep track of inventory records. The information collected from bridge inspections serves two purposes. First, it is reported to the federal government, where it is maintained in the National Bridge Inventory. The National Bridge Inventory ratings of bridges forms the basis for the prioritization of federal funding. Second, it is input into the Department's bridge management system, called Pontis, for use in projecting and prioritizing bridge maintenance, repair, and rehabilitation activities. Pontis analyses of bridge inspection data can be used for policy and funding decisions.

## The Pontis Bridge Management System

While the National Bridge Inventory is useful for determining the distribution of federal funds, it is not sufficient for the analysis and prediction of bridge needs. In the mid-to-late 1980s several states recognized the increasing gap between available funds and the needs of bridges. These states worked with the FHWA and the American Association of State Highway and Transportation Officials to develop a form of bridge management to be used for budgeting, policy, and project scheduling. The result of this effort was Pontis.

Pontis is a bridge management system with the capability of analyzing bridge condition information to project and prioritize bridge needs. Data generated through the bridge inspection process, including the current condition of the bridge overall and of individual elements, are input into Pontis and are used to estimate needed bridge work. In other words, Pontis is able to examine the preservation and functional improvement needs of each bridge, now and in the future, and define specific projects to address these needs. Pontis can schedule projects based on the current condition of the bridge, using different funding scenarios and time periods. Pontis prioritizes projects automatically based on a benefit-cost ratio, determining the most cost-effective manner and time to rehabilitate a specific bridge element, widen a bridge, or completely replace a bridge.

The Colorado Department of Transportation, along with 38 other states and several foreign countries, currently uses Pontis, although only a few have fully implemented the program. The Department uses Pontis as a centralized tool to manage all of the

on-system bridges in Colorado. However, the Bridge Section has not yet fully implemented Pontis. The Section has been gradually working toward full implementation and expects to be using Pontis as the sole bridge management system for Colorado within two to three years. Although data for every bridge are currently included in Pontis, many of the functions and capabilities described above are not yet being used.

## The National Bridge Inventory and Federal Bridge Funding

National Bridge Inventory data are used by the Federal Highway Administration (FHWA) to identify eligible projects and to allocate funds from its Highway Bridge Replacement and Rehabilitation Program (HBRRP) to the states. The program began with a focus on identifying bridges for replacement, but was later expanded to include bridge rehabilitation.

Information collected during bridge inspections is used to determine a "sufficiency rating" between 1 and 100 for each structure. The sufficiency rating formula incorporates three main aspects of a bridge: structural adequacy, functional obsolescence, and essentiality for public use. A bridge in perfect condition with ideal components would receive a sufficiency rating of 100. In addition to the sufficiency rating, bridges may be designated as either structurally deficient or functionally obsolete. A bridge that is structurally deficient has one or more major components (such as deck or substructure) in poor structural condition. A bridge that is functionally obsolete is narrow, has low clearance, or is poorly aligned with the roadway. Bridges with a sufficiency rating of 80 or less that are either structurally deficient or functionally obsolete are eligible for federal replacement or rehabilitation dollars.

State transportation departments have flexibility in selecting bridge projects subject to the eligibility constraints, but cannot use HBRRP funds to pay for small-scale or preventive maintenance projects that do not substantially improve the overall condition of a bridge. In Colorado, the Transportation Commission sets priorities for how HBRRP funds will be used. According to the Department's Fiscal Year 2000 budget, the Commission's goal for HBRRP funds is the replacement of 75 percent of the structures rated structurally deficient with a sufficiency rating of less than 50 by 2020. This goal indicates the Commission intends to allocate the funds so they can be used to address the needs of the State's poorest-rated bridges. However, the current allocation method does not direct funds to the regions where they are needed most.

# Allocation of Bridge Program Funds Is Based on Age

In July 1999 the Transportation Commission met to make decisions about Department of Transportation funding for Fiscal Year 2001. One item under discussion was the amount of HBRRP funds each transportation region should receive. To assist in this discussion, Department staff provided the Commission with information and a recommendation to allocate the funds among the regions based on the age of bridges. Specifically, the Department provided the Transportation Commission with the total square footage of all structures over 50 years of age and half the square footage of structures between 40 and 50 years old, broken down by transportation region.

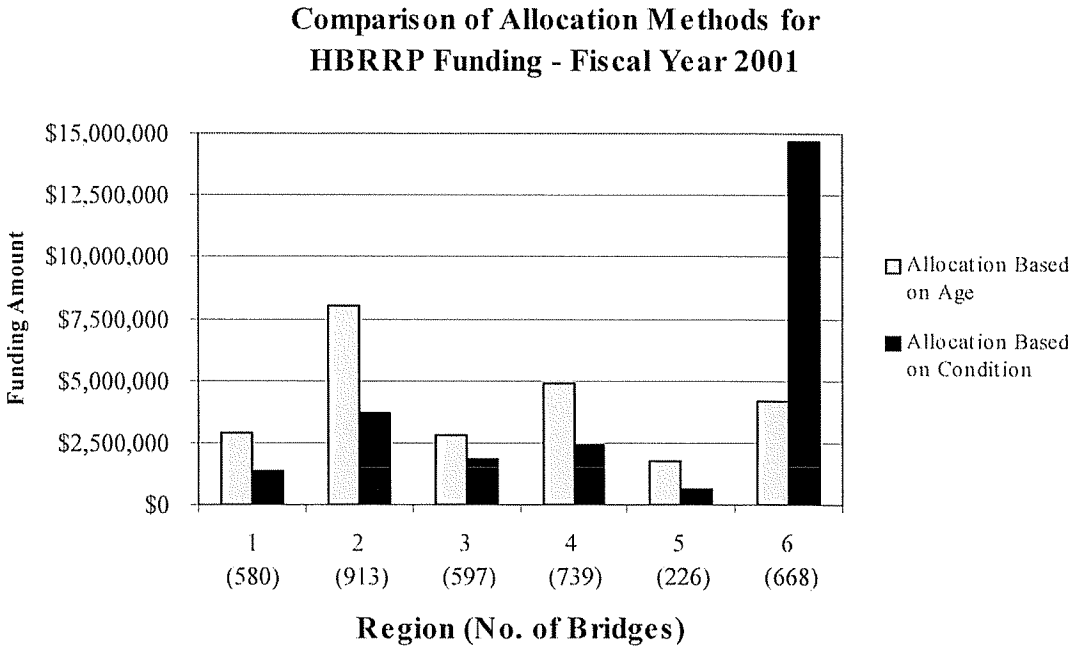
According to Department staff, the age-based allocation methodology was developed as a way to generally predict bridge needs in the future. However, the recommended allocation based on the age of bridges is not consistent with the Commission's priority for the use of HBRRP funds. Furthermore, we noted several drawbacks to using the data provided by the Department to allocate HBRRP funds among the regions. Specifically:

- The data did not reveal the condition of on-system bridges by region. All the bridges that are over 50 years old do not meet the eligibility requirements for the use of HBRRP funds. In fact, of the 836 structures included in the data recommended for use in dividing the funds, only 184, or 22 percent, met the eligibility requirements for using HBRRP funds.

- The data included tunnels and railroad bridges, which do not have sufficiency ratings, and are thus ineligible for HBRRP funds.

Furthermore, we found that allocating HBRRP bridge funds in this manner is inconsistent with the six surrounding states we contacted, all of which distribute funds using some type of condition-based method.

The Department has the capability to determine the square footage of all bridges that meet the criteria for HBRRP funding but did not provide this type of information to the Commission. We compared the Department's allocation based on age to one based on condition data. We found that while the age-based distribution provides a more even disbursement of funds, the allocation based on bridge condition resulted in Region 6 receiving most of the HBRRP funds, indicating that Region 6 has the greatest proportion of bridge square footage in poor condition. The comparison is shown in the following chart.



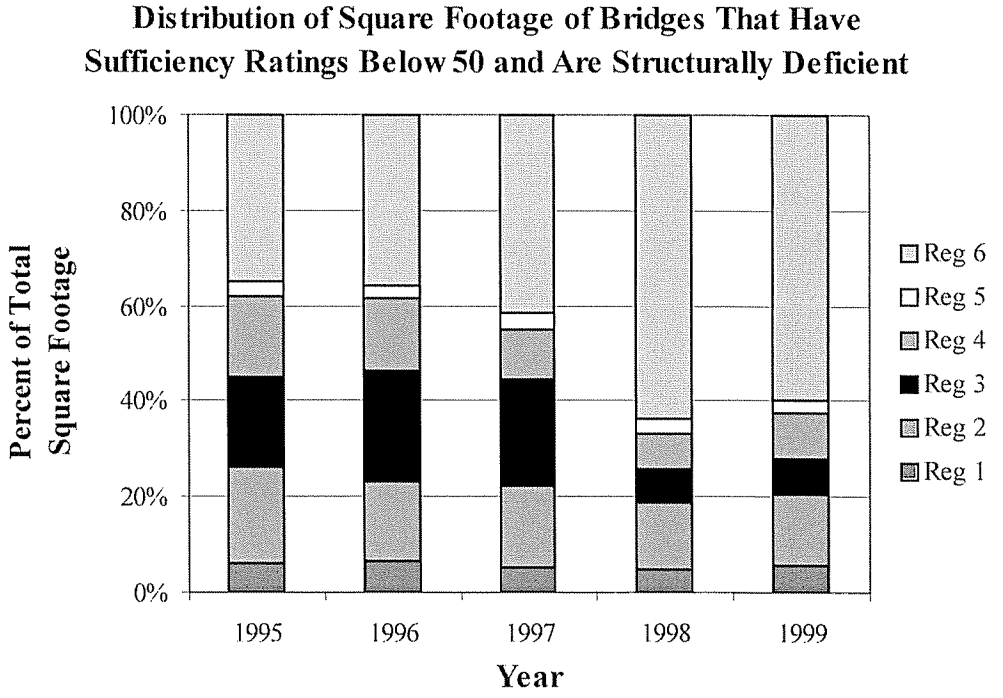

**Source:** Office of the State Auditor's analysis of bridge data from the Department of Transportation.

As noted in the description chapter, there are several sources of funds in addition to the HBRRP that the Department uses for bridge replacement and rehabilitation work, and some bridges that meet the Transportation Commission's priority criteria may be included in reconstruction or widening projects paid for out of these other funds. The Department could not provide information on the amount of funds, by source, spent strictly on bridge rehabilitation and replacement in each region over the past five years.

# Region 6 Has an Increasing Proportion of Bridge Square Footage in Poor Condition

Since 1997 the total square footage of bridges rated structurally deficient with sufficiency ratings below 50 has increased by 30 percent statewide. Most of this increase has occurred in Region 6, where the square footage rated structurally deficient and below 50 has almost doubled. However, since 1997, Region 6 has received, on average, only 17 percent of the HBRRP funds each year, while it has averaged approximately 55 percent of the State's poorly rated bridge square footage. This trend may indicate that Region 6 has not received a sufficient proportion of the

HBRRP funds. The following chart shows the increase in poorly rated bridge square footage in Region 6 compared with the other regions.




**Source:** Office of the State Auditor's analysis of bridge data from the Department of Transportation.

We looked at the allocation of HBRRP funds because they are the only funds that must be used on bridges and because they must be used for structures that meet certain criteria. Although we have noted concerns about using the age of bridges as the basis for allocating funds among the regions, the regions are selecting individual projects in accordance with federal guidelines and criteria. Our focus is on the Commission having complete information, and since the Department has the capability of accurately determining the square footage of bridges in the poorest condition by region, we believe it should provide this information to the Commission for accurate policy and funding decisions.

## Recommendation No. 3:

The Department of Transportation should ensure that the Transportation Commission has accurate information regarding the condition of the State's bridges for funding and policy decisions. For decisions regarding the allocation of HBRRP funds, the Department should provide a breakdown of the square footage of structurally and

functionally deficient bridges by region as well as other relevant information, such as which deficient bridges are already scheduled for work as part of projects that are paid for out of other funding sources.

### Department of Transportation Response:

Agree. The Department looked at four possible allocation methods: 1) Square Feet of deck of Structurally Deficient bridges with Sufficiency Ratings less than 50, 2) Numbers of Structurally Deficient bridges with Sufficiency Ratings less than 50, 3) age of bridges, and 4) Pontis. The Department opted on the age criteria, as it was the only way to forecast needs and the Pontis method was still under evaluation. The structurally deficient information should have been presented to the Commission and will be corrected immediately.

As for the use of Pontis, at the time that these various methods were being evaluated, the AASHTO contractor was updating the Pontis database. The Pontis models were run on the most recent Pontis database available in-house. The latest data, which would include any changes in the status of bridges up to the beginning of the year, was recently delivered and will be uploaded soon. Staff is working with the consultant who developed this program with the intent to implement Pontis within the Department for the FY 2002 budget cycle. This was presented to the Transportation Commission who agreed with the proposed time schedule.

## Pontis Overestimated On-System Bridge Work Through 2020

In May 1999 the Bridge Section used its bridge management system, Pontis, to provide the Transportation Commission with the estimated bridge needs of the State over a 20-year period from 2001 to 2020. This was the first time Pontis was used in such a manner. On the basis of Pontis projections, the Bridge Section reported that at an annual on-system funding level of $25 million (non-inflated), the backlog of existing and future bridge needs would not be met in the next 20 years. The $25 million consisted of federal HBRRP funds and the required state matching funds. The Pontis analysis applied this funding to the entire on-system bridge list.

However, as explained below, the Pontis analysis incorrectly included the costs of some bridges already scheduled for replacement, widening, or rehabilitation, and excluded rehabilitation and repairs already conducted that affect the condition of other bridges. Bridge staff agree that all of these elements affect the Pontis analysis. As a result, the Bridge Section's report to the Transportation Commission

overestimated the projected on-system bridge needs by at least $30 million, or 10 percent of bridge needs, through 2010.

## Pontis Did Not Have Complete Information for Analysis

We identified several problems with the information used by Pontis for its analysis of bridge needs. First, the projection included replacing or widening at least 15 structures at an estimated cost of $16 million that have either already been replaced or are currently under construction. The Bridge Section did not update Pontis with information on recently completed structures or structures currently under construction. Bridge staff did not remove these structures from the database to ensure that Pontis would not include them in its review and analysis in determining the scheduled needs of bridges.

Second, the Bridge Section's analysis included rehabilitation or replacement of bridges that are already contained in the Department's priority projects, otherwise known as "7th Pot Projects." These projects include 28 strategic projects that have been identified as high priority for the State. The funds to pay for these large projects include state sales and use tax (SB 96-1), Highway Users Tax Funds, and federal funds other than HBRRP funds. For example, the southeast I-25 corridor widening is one of the Department's priority projects with costs estimated at nearly $594 million through 2008. This project contains approximately 43 bridges that were also included in the Bridge Section's analysis of on-system bridge needs over the next ten years, thereby overestimating the scheduled bridge needs by $13 million.

Finally, the regions have conducted rehabilitation and overlay work that affects the condition of numerous bridges. However, information on this work and any changes in the conditions of bridges due to these improvements were not included in Pontis. Bridge conditions are only updated when bridge inspections are completed, so any improvements occurring since the last cycle of inspections is not reflected in the bridge inventory.

The Commission requested bridge needs information as part of the budgeting process in which it reviews the condition levels of different roadway components and allocates funding based on this information. Overestimation of projected needs could cause the Commission to direct more funds to the Bridge Section than necessary and/or prioritize bridge needs over other programs incorrectly.

We recognize that this is the first time the Bridge Section has used Pontis for this purpose and believe that Pontis can be a useful tool to manage and analyze information about the condition of Colorado's bridges. However, the Department should inform the Commission of the errors in the current Pontis analysis and

implement systems to ensure future data generated by Pontis are accurate before providing them to the Commission.

## Recommendation No. 4:

The Department of Transportation should ensure that the Transportation Commission has complete, accurate information about bridge needs by:

a. Informing the Commission of the errors that have been identified in the current analysis and of how the errors affect the overall projection of bridge needs.

b. Implementing an adequate control system to ensure that future projections of bridge needs are accurate based on current or recently completed bridge work.

c. Updating Pontis with all completed and in-progress bridge work before preparing projections.

## Department of Transportation Response:

Agree. The Department agrees and will comply with the recommendation. The official database is the National Bridge Inventory Database. It is kept up to date with new inspection information and continually reviewed for updates to the funding status of bridges. Our current process is to review the STIP for potential future projects and note bridges that are funded for design. All bid packages are reviewed to determine if there is a bridge on the project. Specific data elements are a part of the database to identify the status of funding (design, construction, and phased construction).

As for updating Pontis, at the time of the audit, the latest bridge inspection data had been had been sent to the AASHTO contractor to review the data, make necessary corrections, and then provide a Pontis data file to update the current database. That file arrived about August 17 and will be loaded soon. Once the Pontis program can be fully implemented into the Department, which is scheduled to be in place in time for the development of the FY 2002 budget, the Department will keep this database as accurate as possible including updated information based on current or recently completed bridge work.

# Recently Conducted Bridge Maintenance Is Not Accounted for in the Pontis Analysis

One outcome of the bridge inspections conducted by the Bridge Section is the identification of needed maintenance and repair activities. These activities are communicated to the regions in one of two ways. Activities that are considered critical to maintaining bridges in good condition are included in letters to regions when they are identified by the Bridge Section inspectors. Activities that are less crucial are included in an annual report to the regions. Historically, maintenance staff conduct some maintenance activities on bridges if they have the resources, knowledge, and experience for that particular job. They contract out other maintenance jobs, often those that are more costly and complicated, which they are unable to perform because of equipment or ability restrictions.

We confirmed that maintenance forces conducted some of the maintenance activities that were identified by the Bridge Section inspectors and contained in the "1998 Master List of Bridge Needs." However, the Maintenance Section does not inform the Bridge Section about the activities that are completed on bridges. As a result, the Bridge Section is unable to use recent maintenance activity data when analyzing the condition of bridges in Colorado to project needs for future maintenance, repair, and replacement of bridges. The Bridge Section has requested that they be notified by the Maintenance Section when any of the listed or unlisted activities are performed on a bridge. However, the two sections have not coordinated efforts to communicate the maintenance activities that have been conducted by maintenance forces.

The accurate projection of bridge maintenance and repair needs is dependent on complete information being communicated to and used by the Bridge Section for analysis. If information on completed bridge maintenance activities were included in the Bridge Section's analysis done by Pontis, the Department would have more accurate information on the overall condition and maintenance history of bridges. The Bridge Section's analysis of bridge needs for Fiscal Year 2001 and beyond did not account for 1998 maintenance activities on more than 1,300 bridges totaling over $710,000 in labor and equipment costs.

As the Bridge Section uses the Pontis program more for the management of bridges in Colorado, an accurate maintenance record of activities performed on bridges will enable Pontis to better track the condition and subsequent needs of individual bridges and the entire state-owned system in general.

## Recommendation No. 5:

The Department of Transportation should improve the accuracy of its projections of bridge needs by:

a. Identifying and instituting a cost-effective method to ensure that bridge maintenance activities completed by the Maintenance Section are communicated to the Bridge Section. This could consist of either a manual reporting of completed activities by the Maintenance Section to the Bridge Section or the development of an electronic link between the MMS and Pontis for reporting purposes.

b. Entering the information received into Pontis prior to preparing any analyses or projections of bridge needs.

## Department of Transportation Response:

Agree. The Department is currently exploring the feasibility of electronically linking the MMS system with the Pontis system as part of our implementation of the Pontis program within the Department. Until that is completed the Bridge Management unit will track reported bridge maintenance needs and accomplishments in a database for input in future needs analysis.

# Bridge Inspections

## Chapter 3

In 1967 the Silver Bridge in West Virginia collapsed during rush hour, resulting in the deaths of 46 people. Subsequent Congressional legislation required the Secretary of Transportation to develop and implement the National Bridge Inspection Standards. This legislation, implemented by the Federal Highway Administration (FHWA) in the early 1970s, includes specifications for inspection and inventory of public bridges that are used throughout the United States.

According to federal statutes, the Department is responsible for maintaining a bridge inspection program that includes routine inspections of all bridges on public roads in the State. The typical inspection frequency for bridges is every two years. However, federal regulations allow states to develop criteria to increase the inspection frequency for bridges that are in poor condition and decrease the frequency for bridges in good condition. The maximum time period between inspections may not exceed four years.

On-system bridges (those on state and interstate highways) are inspected by teams of Department of Transportation inspectors, while off-system bridges (those on city and county roads) are inspected by engineering consulting firms. The Department currently contracts with three consulting firms, each of which is responsible for bridge inspections in a designated area of the State - one north, one central, and one south. The Department manages all the data that results from the bridge inspections and performs a quality assurance review of all inspection reports from both in-house and consultant inspectors.

Funding for bridge inspections comes from the federal Highway Bridge Replacement and Rehabilitation Program (HBRRP). This program provides bridge funds that must be matched by the State at a rate of about 20 percent. In Fiscal Year 1998 about $2,000,000 in HBRRP funds, matched by about $600,000 from state and local sources, were used for inspection and management of both on- and off-system bridges.

The following table shows some general comparative information for on- and off-system bridges. The data indicate that on-system bridges tend to be larger and more complex than off-system structures. Due to the differences in size, it is useful to compare inspection costs on the basis of amount per bridge span and per square foot.

However, it is also important to note that while some inspection costs will vary based on the difference in bridge size, others will not.

**Costs of Bridge Inspection and Management Averages for 1997 and 1998**

| | On-System Inspected by Department of Transportation | Off-System Inspected by Engineering Consultants |
|---|---|---|
| Number of Bridges Inspected 1997 & 1998 | 3,500 | 4,700 |
| Average Number of Spans[1] per Bridge | 3 | 1.5 |
| Average Square Footage of Deck per Bridge | 8,800 | 3,000 |
| Total Cost of Inspections[2] | $2,400,000 | $2,800,000 |
| Average Cost per Bridge | $690 | $600 |
| Average Cost per Span | $230 | $330 |
| Average Cost per Square Foot of Bridge Deck | $0.09 | $0.21 |

**Source:** Department of Transportation accounting and contract data.

1. A bridge span is generally the length of the bridge between two joints or supports.

2. Total costs for the Department, which are used to calculate averages per bridge, per span, and per square foot, do not include all Departmental overhead or administrative costs.

# The Department Has Established a Risk-Based Inspection Program

The Department's bridge inspection program includes alternative inspection schedules for some types of bridges based on their conditions, structure types, and other considerations. In 1994 the Department developed standards for bridges that should be inspected every year. These standards include temporary structures and bridges with visible deterioration. Bridges are placed on a one-year inspection cycle based on the recommendation of bridge inspectors. Currently there are 106 on-

system bridges that are inspected every year by the Department's inspectors and 13 off-system bridges that are inspected annually by consultants.

In 1997 the Department developed four-year inspection criteria based, in part, on the condition of bridge components that are evaluated during routine inspections. These criteria, which conform to federal requirements and have been approved by the Federal Highway Administration (FHWA), include the following:

- Structures that are rated as 6 or above (on an 8-point scale) for the conditions of components such as decks, substructures (piers, abutments, etc.), and alignment with the roadway.
- Structures that are constructed of steel or concrete.
- Structures whose longest span does not exceed 100 feet.
- Structures whose amount of average daily traffic does not exceed 30,000 vehicles and/or 3,000 trucks.

The decision about whether to place a bridge on a four-year inspection cycle is also based on the judgment of bridge inspectors. Currently about 800 on-system bridges (about 21 percent of the 3,700 on-system) and about 180 off-system bridges (about 4 percent of the 4,500 off-system) are on the four-year inspection cycle.

We commend the Department for being proactive in implementing a risk-based inspection system in an effort to reduce inspection costs. According to FHWA officials, only 11 other states use a four-year cycle for some bridge inspections. We also have identified a number of ways in which the Department could make its bridge inspection program even more efficient.

# Some Eligible Bridges May Not Be Inspected on the Four-Year Cycle

Using the Bridge Program's own bridge inventory database, we reviewed bridge characteristics and condition information for all on- and off-system bridges in the State. In addition to the 800 on-system and 180 off-system bridges already on the four-year cycle, we identified 60 on-system and 700 off-system structures that appear to meet all of the four-year inspection criteria but are inspected every two years.

According to Bridge Section staff, there are a number of reasons for some of the on-system bridges we identified to be on a two-year cycle. Specifically:

- Some bridges, in the judgment of the bridge inspectors, need to be seen every two years, even if they meet all the established criteria. This judgment may be based on a history of problems with a bridge, the age of the bridge, whether the bridge is frequently hit by traffic, and other factors. Without reviewing each individual bridge file, Bridge Section staff were unable to determine which, if any, of the 60 bridges we identified were inspected every two years based on the judgment of the inspectors.

- Some bridges may not have been through enough routine inspections to be placed on a longer cycle. The policy of the Bridge Section is to inspect every bridge when construction is first completed, then to conduct two regular inspections on a two-year frequency before considering a bridge for less-frequent inspection. When the Bridge Program instituted the four-year cycle in late 1997, staff excluded all bridges built after 1991 to ensure this policy was adhered to. However, at this time the program could include bridges built through early 1995.

With respect to off-system bridges, federal officials we spoke with stated that the FHWA will not approve the placement of an off-system bridge on a four-year cycle if the bridge owner will not approve the change. Therefore, in 1997 the Bridge Section notified each city and county of their bridges that met the four-year criteria and requested that they respond with a letter approving placement of the eligible bridges on the four-year cycle. Any city or county that did not respond was kept on the regular two-year cycle for all bridges. A number of the larger cities and counties did not respond to the notification and only 180 off-system bridges have been placed on the four-year inspection cycle. Since 1997 the Department has made no further efforts to place off-system bridges on the less-frequent cycle. We believe several approaches might help to increase the number of off-system bridges inspected every four years. The Department could:

- Emphasize to cities and counties the benefits of placing appropriate bridges on a four-year cycle. In particular, the Department could point out that funds saved by reducing the number of inspections are available for repair and replacement of bridges.

- Change its approach to obtaining approval for moving bridges onto a four-year cycle. To date, the Department has left all bridges on a two-year cycle unless the city or county that owns the bridge has provided written approval to change the cycle. The Department could, instead, move all eligible off-system bridges to a four-year cycle unless a city or county objects to the change in writing.

# The Department Could Reallocate Resources by Using Its Risk-Based Approach More Fully

As shown in the table on page 34, the estimated average costs to inspect each on- and off-system bridge are about $690 and $600, respectively. Therefore, the Department could potentially reallocate as much as $41,400 (60 x $690) every two years by placing the 60 on-system bridges that we identified on a four-year cycle and about $420,000 (700 x $600) every two years by placing the off-system bridges that we identified on a four-year inspection cycle. The funds saved from conducting less frequent inspections could be used to inspect other bridges more frequently, if needed, or to make bridge repairs and improvements.

## Recommendation No. 6:

The Department of Transportation should more fully implement its risk-based inspection program by:

a. Routinely reviewing the characteristics and conditions of all on-system structures to ensure that all those that meet the four-year criteria are placed on a four-year cycle.

b. Routinely reviewing the characteristics and conditions of all off-system bridges to identify all that meet the four-year criteria.

c. Working with cities and counties to increase the placement of appropriate off-system bridges on the four-year cycle.

## Department of Transportation Response:

Partially agree. The two-year cycle is the established norm. The FHWA required extension of the cycle to four years to be a voluntary program. Each local entity that had four-year qualifying bridges were polled and afforded the opportunity to choose the extended cycle by documenting their choice on a form sent out to them. The form provided for both choices; retain the listed structures on a two year cycle or change them to a four year cycle. If no response was received, then the bridges remained on the two-year cycle.

The audit staff has recommended that the opposite tack be taken; inform the entities that their qualifying bridges would be automatically put on the four-year cycle unless they specifically request, in writing, that they remain on a

two-year cycle. We believe this should be referred to the Attorney General's office for an opinion as to whether the State has the authority to demand this and if the State can become liable if the entity doesn't specifically ask to change the cycle. If the opinion is that we can do this without assuming liability, then we will conduct this review with the cities and counties and implement the results by January 1, 2001.

# An Alternative Inspection Cycle Might Increase Efficiency

In addition to identifying more bridges that appear to meet the four-year criteria, we found some bridges on the two-year cycle that have characteristics and conditions very similar to those on a four-year cycle, but they do not meet all the four-year criteria. For example, we identified:

- Twenty-three on-system bridges which are inspected every two years that appear to meet all of the four-year criteria except one: the length of the maximum span is between 101 and 110 feet. Only bridges with a maximum span of 100 feet or less may be considered for four-year inspection.

- Fifty-four on-system bridges which are inspected every two years that meet all the four-year criteria except that they have inventory ratings just below what is allowed for bridges on the four-year cycle. The inventory rating provides an indicator of the load that a bridge can regularly carry without experiencing excessive wear or deterioration on its components. According to the criteria, bridges must have an inventory rating of 232 or greater to be on the four-year inspection cycle. The 54 bridges we identified have inventory ratings of 227 to 231.

Furthermore, we identified 51 on-system bridges that do not meet the Department's written criteria but are inspected every four years. Bridge Section staff stated they need to review their inspection records to determine why these bridges are on a four-year cycle. All of these factors indicate that there are bridges in good enough condition to be inspected less often than every other year, but that may need to be seen more often than every four years. Therefore, it would be beneficial to the Department to consider establishing another inspection cycle, such as every three years. Placing some bridges on a three-year or other intermediate cycle could enable the Department to realize further cost savings.

Department staff indicated they have not established an alternate schedule, such as every three years, because they do not know if the FHWA would approve the change and because the current system was designed to facilitate scheduling on a two-year cycle. We spoke with a representative of the FHWA who indicated that a three-year cycle would be acceptable as long as the criteria used to place bridges on this frequency were approved in advance. In addition, we recognize that setting up a system to schedule inspections on an additional frequency will require some time and planning for the Department. However, the effort could generate savings in inspection costs and allow the Department to focus even more on risk-based inspections.

## Recommendation No. 7:

The Department should expand its risk-based bridge inspection program by considering the implementation of an intermediate inspection cycle, such as every three years, to increase efficiency.

## Department of Transportation Response:

Partially agree. CDOT currently has an orderly method of inspecting the State's bridges, which has only been in place since 1997. Regions 2, 3 and one-half of Region 6 are inspected in the even numbered years and Regions 1, 4, 5, and the other half of Region 6 in the odd numbered years. In this way, we can group all of the needs in each region in a cycle and provide the maintenance staff with a complete list of needs for scheduling and budgeting purposes. Going to a 3 year cycle could end up "shotgunning" the regions both in inspections and maintenance needs and require more trips thus losing any efficiencies gained.

However, upon completion of a full cycle of inspections, based on the data and our experiences, CDOT will review this process to determine if an intermediate inspection cycle would increase the overall efficiency and quality of the program while reducing costs.

# The Department Should Ensure Bridges in Poor Condition Are Inspected Frequently

Federal regulations state that bridges in poor condition may need to be inspected more frequently than every two years and outline several factors that should be considered when placing bridges on more frequent inspection intervals. These factors include the age of the bridge, traffic characteristics, state of maintenance, and known deficiencies.

In 1994 the Department developed written criteria for placing bridges on a one-year cycle. According to these criteria, temporary bridges and bridges posted for load restrictions must be inspected every year. In addition, bridges with visible structure distress, visible scour (water erosion), or other foundation problems, and those with cracking in their abutments should be considered for annual inspections.

Because most of the one-year inspection criteria are not specifically tied to individual inspection elements, we were unable to evaluate bridges relative to all the criteria in the same manner that we did for the four-year criteria. However, we did review the on-system bridge database for bridges that are temporary in nature or that are load-posted (meaning the weight of vehicles passing over them is limited) because these factors are coded in bridge inspection reports. In addition to the 106 on-system bridges that are inspected annually, we found 9 bridges that meet one or both of these criteria but which are not scheduled to be on an annual inspection cycle. In addition, we reviewed inspection files for 44 on-system bridges to evaluate whether the bridges appeared to be scheduled for inspection according to the Department's criteria. We found five of the bridges are on a two-year inspection cycle but may be appropriate for more frequent inspections. Specifically:

- Two bridges had low sufficiency ratings (one at 38.2 and one at 52.3) and were designated "fracture critical." A fracture-critical bridge is one that contains members whose failure will probably cause a portion of the entire bridge to collapse.

- Two bridges have sufficiency ratings below 50; one is classified as "structurally deficient."

- One bridge has a sufficiency rating of 48.5 and it is designated "structurally deficient." The most recent inspection report dated 2/24/98 indicates "deck condition possibly factor in two rollover accidents in January 1997. Constant

maintenance problem. Should be candidate for replacement soon." However, at the time of our review, this bridge had not been replaced.

These bridges have characteristics that are consistent with the federal factors mentioned above for more frequent inspections. In addition, they are similar to other bridges that *are* inspected annually. From the bridge files we reviewed, the most common characteristics of bridges on an annual inspection cycle were those with sufficiency ratings below 50 and those designated as structurally deficient. Bridge Section staff indicated they would need to review the files for all of these bridges to determine the appropriate inspection schedule for them. However, since these bridges appear to be candidates for more frequent inspections, the Department should develop a method to ensure that all bridges needing annual inspections are identified and scheduled for such reviews.

One purpose of inspecting bridges is to identify problems so that appropriate corrective action can be taken. Inspections may lead to bridge maintenance or repairs, closure, or load posting, among other actions. However, if bridges are inspected too infrequently, these actions may not occur or may come too late. Therefore, determining and implementing the appropriate inspection schedule for all bridges is important for both public safety and cost-efficiency.

As noted above, savings realized by placing all eligible bridges on the four-year cycle and/or instituting a three-year cycle could be reallocated to other uses, such as more frequent inspections of bridges in poor condition.

## Recommendation No. 8:

The Department should ensure that all bridges that meet the one-year inspection criteria are placed on an annual inspection cycle by periodically reviewing all on- and off-system bridges to determine whether any should be moved to a one-year inspection cycle.

## Department of Transportation Response:

Agree.

# Travel-Related Expenses Represent a Significant Portion of Bridge Inspection Costs

The Department's bridge inspection program is essentially divided into two components—the on-system program and the off-system program. The on-system program is carried out by the Department's eight bridge inspectors, all headquartered in Denver, while the off-system program is handled by three private engineering firms, also located in Denver.

The current bridge program organization does not use inspectors' time as efficiently as possible. Because virtually all bridge inspections are conducted by staff located in Denver, highly trained inspectors spend a significant amount of time traveling. This results in significant travel costs for the inspection programs. According to Department data, bridge inspectors spend about 20 to 25 percent of their time traveling. We estimate the cost of this time is about $100,000 to $120,000 every year. Added to this are actual travel costs (mileage, lodging, etc.,) of about $35,000 for a total cost to the Department ranging from $135,000 to $155,000 annually. For off-system inspections, we estimate about $70,000 is spent each year for travel and about $195,000 to $240,000 to pay inspectors for the time they spend traveling. We believe there are several ways the Department could organize its inspections to increase efficiency and reduce the costs of travel.

## Decentralizing the Bridge Inspectors

The most direct method of reducing travel time and costs for bridge inspections would be to relocate inspectors to outlying areas of the State. Placing bridge inspectors in areas such as Grand Junction, La Junta, Fort Morgan, or Steamboat Springs could substantially reduce the time and cost of travel to bridges. Because inspectors would be much closer to the bridges they inspect, time now required for traveling could be spent on other higher-priority activities. In addition, by placing the inspectors in pre-determined areas of the State and not specifically within one region, inspectors would be able to maintain more constant workloads, helping to ensure that their time is productive. We found that a centralized bridge inspection program is unusual among the other states' transportation departments we contacted. Of six states who provided us information, all have at least partially decentralized programs with inspection staff located in regional areas, close to the structures they review.

According to Bridge Section staff, there are several advantages to the current arrangement of having the bridge inspectors located in Denver. We believe these advantages could be achieved in other ways or are offset by disadvantages. For example:

- Bridge files are centrally located and accessible to all bridge staff. In addition, inspectors can easily share information about bridge conditions and review techniques to ensure consistency across inspections. However, current information technology facilitates the sharing of information and files across long distances while the Department's quality assurance review process helps ensure consistency among inspections.

- Bridge inspectors are rotated among inspection assignments so that a fresh perspective on each bridge is gained with each inspection. Although relocating inspectors to the regions would eliminate this benefit, it could add an advantage in terms of inspectors becoming familiar with each bridge and its environment over time.

- Bridge Section managers can ensure that inspectors are appropriately assigned. Before the mid-1980s the Department used maintenance staff located in the regions to conduct routine bridge inspections but had difficulties with staff being assigned to activities other than inspections. This problem could be overcome in a decentralized program. Regional inspectors could report to a central bridge inspection supervisor in Denver to help ensure they are not inappropriately assigned to non-inspection duties.

The Department should determine the most cost-effective manner of organizing bridge inspectors to minimize travel costs and maximize productivity. In its recent reorganization efforts, one of the Department's goals has been to avoid relocating any staff member from his or her current work location. Consistent with this goal, Bridge Section staff have indicated they would be reluctant to move bridge inspectors to outlying regions. However, a gradual approach to changing the bridge inspection program could be developed to allow the Department to move toward a more efficient program without violating its relocation goal.

# Use of Local Inspection Firms

All off-system bridge inspections are now done by consultant engineering firms that are headquartered in Denver. Therefore, for most of their inspections, consultant staff travel from the metro area to locations throughout the State. If the Department could contract with firms in other areas, rather than just in Denver, it could reduce the amount of time and money the consultants spend on travel. We reviewed the

Department's pre-qualified consultants list and found that there are several engineering firms with bridge inspection capabilities located outside of Denver in Grand Junction, Colorado Springs, and Fort Collins. Therefore, the Department could, for example, seek to contract with a Grand Junction firm to inspect bridges on the Western Slope and with a Colorado Springs firm for inspections in southern Colorado. Although inspectors located in those cities would still need to travel to more remote locations, they would at least be headquartered closer to their areas of assignment.

## Both On- and Off-System Inspectors Travel Throughout the State

Both the Department and the consulting engineering firms we contacted group their bridge inspections into "trips" that each take about five working days to complete. The scheduling takes into account the travel time to different areas of the State and the average time needed to complete a bridge inspection. For example, one five-day trip scheduled by the Department for southwestern Colorado includes 22 structures along portions of State Highways 160 and 550. Another trip closer to Denver covers a total of 47 bridges on sections of Interstates 25, 70, and 76, as well as State Highway 224. Grouping inspections in this manner reduces the amount of time inspectors spend traveling and maximizes the time spent on actual inspections.

There is some inherent duplication in the current organization of the inspection effort because both Department and consultant inspectors travel to the same areas of the State to conduct inspections on different bridges at different times. As a result, the travel-related costs of inspections may be higher than necessary. We compared the Department's recent inspection schedules for the southwest corner of the State (Montezuma, Dolores, San Miguel, La Plata, Archuleta, Ouray, Hinsdale, and Mineral counties) with the schedules of the consultant responsible for that area. We found that between March and November 1998 consultant inspectors made four trips to inspect approximately 150 off-system bridges in these counties at an estimated cost of about $6,300. We estimate the Department will spend about $8,200 in travel-related costs in 1999 for Department staff to make seven trips to inspect about 110 bridges in the same area.

If the Department contracted based on location rather than on a bridge's status as on-system or off-system, it is possible some trips could be combined for maximum efficiency. For example, if the Department contracted out all inspections in the southwestern portion of the State, one contractor could inspect all 260 of the bridges in the southwest corner and schedule them in as few trips as possible. This arrangement would at least reduce any duplication of travel that now occurs when

both Department staff and consultant staff travel all over the State to inspect bridges that may be close to each other but have different owners.

## Recommendation No. 9:

The Department should improve the efficiency of its bridge inspection program and reduce travel-related costs by implementing one or a combination of the following restructuring options:

a. Determine the most cost-effective manner of decentralizing its bridge inspectors, including assessing the benefits of placing the inspectors in Transportation Regions or pre-determined areas. In addition, the Department could use its quality assurance function to ensure consistency among the inspectors.

b. Seek firms located in outlying areas to conduct inspections of more remote bridges.

c. Assign inspections based on geography. Have Department inspectors located in Denver inspect both on- and off-system bridges in the central area of the State and have contract firms inspect on- and off-system bridges in outlying areas. Alternatively, move Department inspectors to the regions to inspect all outlying bridges and retain a Denver-area firm to conduct inspections in the metro area.

## Department of Transportation Response:

Partially agree.

a. Prior attempts at decentralization were not successful. Often times, inspection of bridges became secondary to other work within the Region. This resulted in "scrambles" at the end of the year to complete inspections and thereby resulting in substandard inspection reports. Decentralized inspection could also lead to complacency as a result of familiarity.

   Like the aging of a human being, the aging, and deterioration, of a bridge is not noticeable to those close to the subject until one day it all of a sudden becomes apparent. Familiarity can also lead to complacency in conducting a thorough inspection. It is easy to skip an inspection item when time is running short because " I looked at it last time and it just doesn't change much". Like checking the oil level in your car, it is easy

to skip it because it was ok last week. Whereas, if a different team is inspecting the bridge, they are not likely to pass over items just because "I know it doesn't change much".

"Snooper" inspections generally require two teams; one to conduct the inspection and the other to operate the machinery and provide traffic control. Maintenance gladly provides traffic control when they can but their schedules don't always fit ours. To have the teams located in diverse geographic areas precludes mutual support such as this.

Generally, centralized inspection benefits the Department more because the inspectors communicate better with each other, assist each other, and use each other's knowledge and experience to assess unusual problems or circumstances found in the field. However, as part of the Department's re-engineering efforts it will review this program to determine if some sort of decentralization would be beneficial and cost effective.

b. The Department selects the consultants based on their response to the Request for Proposal. The Department advertises the projects widely and all qualified candidates are welcome to respond and participate in the consultant selection process. The last time that an RFP was sent out, only five firms responded. All but one, an out of state firm, was located in the Denver metro area.

c. Combining inspections may or may not reduce the number of trips. It may only change who makes the trips or it could even add trips and mileage to the program due to backtracking. However, the Department will review this program and prepare a recommendation outlining the pros and cons of each alternative as part of its review of the staffing patterns within the Staff Branches.

# Design of State-Owned Bridges

## Chapter 4

### The Bridge Design Section

The Bridge Design Section has multiple responsibilities including designing and overseeing the design of new and replacement structures, developing structural design standards, and providing consultation services to the Department's six transportation regions. The Bridge Design Section has 27 FTE, consisting of 20 engineers and 7 technicians. This staff is divided into three design units, with each unit composed of a unit leader and six to eight engineers and technicians. These design units are responsible for the bridge design work for five of the six transportation regions. In addition, there is a fourth unit of three engineers and one technician that handles only Region 1 design work. This Region 1 unit is the result of a pilot program the Department is conducting on decentralizing the bridge design function.

Department bridge designers are responsible for the design of on-system bridges and other structures. However, not all on-system bridges are designed by the Design Section. According to Department information, the Design Section has historically handled 40 to 50 percent of the bridge design workload each year. The balance of the on-system bridge design work is done by private engineering firms, also known as consultants. Individual cities and counties are responsible for the design of off-system bridges and structures. The focus of our recommendations is on the in-house design process.

In general, on-system bridge design work is initiated by the transportation regions. Regional staff usually contact the Design Section and inform them of an upcoming design need. Depending upon the amount of resources available and the scope of the project, the Design Section either accepts or rejects the work. If the project is rejected, the region solicits a consultant to design the bridge. State statute requires that design services contracts be awarded to the most qualified consultants, rather than on the basis of lowest bid. Design Section engineers oversee consultant work, reviewing design plans and meeting with the consultant periodically during the life of a project to track the status of the work and help resolve any issues that arise.

## The Design Process

The majority of projects—whether they are designed by Design Section staff or consultants—go through a basic five-step preconstruction process, as follows:

- Scope Meeting. The Design Section and the region work together to determine the resources and time required to complete the project. The Design Section's decision to accept or reject a project is based, in part, on this meeting.

- Structure Selection Report. Either the Design Section or a consultant prepares a report for the region that presents general layouts of several design alternatives with their respective preliminary construction cost estimates. Region personnel select one of the alternatives; in most cases, the least expensive alternative is selected.

- Field Inspection Review (FIR). FIR, or preliminary design, plans are produced when the design phase is about 25 percent complete and contain design information from other Department disciplines such as Right-of-Way or Hydraulics. The bridge design engineer reviews the plans and attends the FIR meeting to obtain review comments on the bridge design.

- Final Office Review (FOR). This report is prepared and presented when the design phase is about 95 percent complete. It shows near-final designs from all Department disciplines involved with the project and contains the bridge design engineer's quantity estimates for construction materials. At this point, final adjustments can be made to the bridge design before it is submitted for inclusion in the final project plans.

- Advertisement. The completed design is reviewed by the Department's cost-estimating office, which prepares a final cost estimate. The project is then opened to bidding from private construction firms.

# The Design Section Has Recognized the Need to Improve Accountability

Bridge design work is assigned to individual design units based on the location of the bridge. For example, one unit handles work for all structures in Region 2, while another handles all of Region 4 and part of Region 6. Bridge designers and region staff work together to scope projects as well as discuss budgets and deadlines. Over

the past several years, a number of changes have been made to try to improve responsiveness and accountability in the bridge design area, including the development of written agreements between design and region staff and a pilot in two of the regions involving the decentralization of the bridge design function. These efforts are consistent with the "State Department Financial Responsibility and Accountability Act," which requires that all state departments develop and maintain internal systems that ensure accountability.

While the Department has recognized that accountability is a concern, it has not been entirely successful in resolving the problem and there is still a lack of accountability in the Design Section. As a result, design work may not be completed as quickly as possible. There are several areas where accountability for design work could be improved. Specifically:

- There is no commonly used in-house mechanism to set deadlines and hold designers and management to them.

- There is no automated, Sectionwide system to track design costs or work hours for in-house bridge designers, and no way to track design costs on a project or annual basis.

- There is no way to compare in-house and consultant design costs or work hours for similar projects.

Lack of accountability mechanisms in the in-house design process is apparent when comparing it to the consultant process. If a consultant handles the work, the consultant enters into a formal contract with the transportation region, participates in mandatory status meetings, and undergoes a final cost audit by the Department's auditors. On the other hand, if the design work is undertaken by the Design Section, no contract is written and the in-house engineers are neither required to participate in status meetings nor subjected to a final audit.

# Performance Agreements Help Keep Projects on Track

In an effort to improve accountability, the Department has instituted the use of performance agreements between regions and the Design Section that set out mutually agreed-upon deadlines for numerous preconstruction milestones. Performance agreements contain deadlines for events such as the scoping meeting and items such as FIR plans. While performance agreements were introduced about two years ago, their use is not commonplace within the Section. One unit leader uses them for most major projects, but three unit leaders use them rarely or never.

Department staff estimated that, overall, performance agreements are used for less than 5 percent of in-house design projects.

For the most part, region and design staff indicated that performance agreements are beneficial because they provide all parties involved with a clear understanding of what is expected and when. Many staff noted that fewer problems occur during projects if everyone has the same, mutually agreed-upon expectations. Some region and design staff, however, expressed concern that performance agreements are simply more paperwork that detract from their other responsibilities.

Another effort that may serve the same purpose as performance agreements is the implementation of a new computer application called ProDATES. The system is designed to be used by the Regional Engineers, who have overall responsibility for each project, and "accountable" individuals in each of the divisions involved with a project. The Regional Engineer negotiates deadlines with all of the involved parties (as many as 15) and then enters these dates into the system. The dates can only be changed with the consent of the Regional Engineer, who tracks whether and how often dates are changed and/or missed. Reports reflecting each individual's conformance to deadlines may then be sent to the head of each division. While this system appears to be capable of addressing accountability concerns, it is currently only being used by one region. Department managers have estimated that the system will not be in use in all regions until early or mid-2000.

ProDATES is the most recent in a line of computerized tracking systems that the Department has attempted to implement. Previous efforts have not met with success for various reasons, mainly because they have not been utilized by all intended personnel. Until ProDATES is successfully implemented in all regions, the use of performance agreements should be strongly encouraged for all major projects.

## The Design Section Should Establish Additional Accountability Measures

For consultant design work, bi-monthly status meetings serve to keep the consultants on schedule in accordance with their contracts throughout the life of a project. Written Department policy requires regular status meetings for all consultant projects and encourages them for in-house projects. According to Department management, in-house staff are required to attend such meetings if requested by the project manager. Yet project managers seldom hold periodic status meetings for in-house projects and many Design Section staff stated they never participate in such meetings and are therefore not monitored throughout the project in the way that consultants are. Required status meetings, based on deadlines outlined in performance agreements, could help keep in-house projects on track.

Accountability could be further improved through a review of the design hours charged to a project. Currently, work-hour estimates are prepared by Design Section staff for nearly every in-house design project. While some unit leaders attempt to compare these estimated work-hours with actual hours, there is no Section-wide mechanism to accomplish this task. In contrast, for consultant work, final cost audits performed by the Department's audit division measure the difference, if any, between what the consultants agreed to bill and what they actually billed the Department. A post-audit of in-house work could serve to make the engineers more accountable and keep design costs in check.

Lack of accountability is a problem because it could result in projects not being completed on time. This, in turn, could lead to costly delays because construction costs generally rise as time progresses. Also, the fact that there is currently no Sectionwide accountability system means that the Design Section does not have complete or accurate data regarding project milestones and where delays have occurred in the past. This makes scheduling future design work difficult. Since there is no final audit of design work hours, it is difficult to tell whether designers are working as effectively as possible and there is an additional risk that in-house design costs are not being controlled. Finally, it is difficult to determine whether Department bridge designers are efficient because data are not available to make accurate comparisons with consultants.

## Recommendation No. 10:

The Department of Transportation should institute a system to improve accountability in the Design Section. This could include:

a. Increasing the use of performance agreements for major in-house design projects.

b. Ensuring that the new ProDATES system addresses accountability needs and training staff in the use of the system. The Department should ensure the system is used for major projects by all six regions by the end of Fiscal Year 2000.

c. Establishing a method to compare the budgeted and actual time and cost of in-house design work.

d. Implementing a method of in-house project monitoring for major projects, such as through structure status meetings.

## Department of Transportation Response:

Agree.

a. Only a handful of such agreements have been formally executed in the past. However, the Department supports using performance agreements and will implement their use immediately for **ALL** bridge design projects completed in-house.

b. Effective immediately the HQ Bridge Section will use ProDates if available for tracking and meeting project commitments. As the implementation of ProDates is completed in the Regions it will be used for all major in-house design projects as directed by the Chief Engineer.

c. The HQ Bridge Section has designed a Bridge Project Database (BPD) which among other functions, establishes a method to compare the budgeted and actual work hours (and therefore time and costs) of bridge design work. BPD has not been fully implemented due to pending management mandate and software development. Currently, the software is under beta testing. By March 1, 2000 the software will be fully operational, and all available data back through 1994 will be entered.

d. For monitoring by Region personnel, HQ Bridge Section employees are required to attend all status meetings when requested to by the Region project manager. These meetings have proved to be quite productive and increase accountability. However, only a few CDOT project managers have employed project status meeting on in-house design projects. The Chief Engineer's Office will discuss this with the CDOT project managers and encourage them to utilize project review meetings as they feel appropriate to improve the overall accountability and quality of our bridge design program.

# The Design Section Should Improve Its Time-Tracking System

Another element of accountability is tracking the time spent on bridge design work. A good time-tracking system can provide information over time to use in scheduling future projects and to compare the performance of units within the Design Section and with outside consultants. However, the Design Section currently lacks a system

to accurately track how design staff spend their time, including how long it takes to complete various preconstruction steps for particular types of structures.

Design Section staff typically track time using two methods. First, they fill out Departmentwide time sheets on a monthly basis, providing summary-level information about the amount of time spent on various projects. These time records, however, are not comprehensive or detailed enough to provide Section management with the data they need. Specifically, these time sheets do not provide Design Section staff with sufficient activity codes to accurately account for time spent on the various design-related activities. Designers typically engage in work related to scoping, general layout, preliminary design, final design, detailing, and various planning meetings. Also, the Department time sheets do not provide any space to describe the structure that the designer is working on.

In recent years Design Section managers have recognized the need for a more comprehensive and detailed internal time system. In an effort to collect better time data, three Design Section unit leaders have initiated their own time-tracking systems, as follows:

- One unit leader uses 10 activity codes to track engineers' time for each type of structure on which they work.

- One unit leader requires engineers to track their time using 12 activity codes and to include a brief description of the project.

- One unit leader requires engineers to track their time using 6 activity codes.

However, all of these systems vary slightly and the Region 1 unit leader does not have any separate time-tracking system in place. Therefore, the data being collected differs slightly from unit to unit, making it difficult to compile into a single historical database. It is also difficult to track the performance of Region 1 versus the rest of the Design Section without consistent and complete data. This information would have been useful in evaluating the success of the decentralization effort.

Another problem is that the current systems do not allow Design Section engineers to account for all of the time they spend on consultant oversight. This is significant because, according to Section staff estimates, in-house engineers spend approximately 20 percent of their time on consultant oversight. Currently when an engineer spends time on oversight of a consultant project, the only way to charge the time on the Departmentwide time sheets is to charge to a different "open" project. Unit leaders have attempted to address this deficiency in their individual systems with varying degrees of success.

A third problem is that the three internal time-tracking systems are completely manual. Engineers fill out time sheets that are submitted to unit leaders who then manipulate and/or summarize the data into a different format. This process requires as much as two hours of the unit leaders' time every week. In addition, since the data are not all compiled in digital form, they cannot be manipulated as a database could be, which significantly decreases the utility of the collected data.

## Recommendation No. 11:

The Department of Transportation should improve the time-tracking system within the Design Section by instituting an automated, standardized system that is used by all design units. This effort should include:

a. Collaboration among the four Design Section unit leaders to devise a single system that captures sufficient detail to provide data for projections, comparisons, and other needs.

b. A method to account for hours spent performing consultant oversight.

### Department of Transportation Response:

Agree. The Department agrees with the recommendation. Through the development and implementation of the Bridge Project Database (BPD) this should be accomplished. Among other functions, BPD provides "data for projections, comparisons, and other needs" as well as "a method to account for hours spent performing consultant oversight". Thus this system could also be used to track the hours spent by the consultants on bridge design. BPD has not been fully implemented due to pending management mandate and software development. Currently, the software is under beta testing. By March 1, 2000 the software will be fully operational, and all available data back through 1994 will be entered.

# The Value of Decentralizing the Bridge Design Function Is Not Known

A third accountability issue, mentioned previously, is the Department's pilot effort to decentralize bridge design. In 1996 the Department assigned two design units to individual transportation regions. Regions 1 and 6—which are headquartered in

Aurora and Denver, respectively—were selected for the pilot. A unit comprising four to five engineers and technicians from the Design Section was assigned to each of these regions. While the design units for Regions 1 and 6 were "decentralized" insofar as they answered directly to their respective regions, the staff remained physically located at Department headquarters in Denver. The Region 6 unit was re-centralized after 16 months. The Region 1 unit remains assigned to the region.

One of the main purposes of the pilot was to improve accountability and responsiveness of bridge designers to the regions. However, there is little information available to evaluate whether this goal has been accomplished. The Department has no information on cost savings or indicators of increased responsiveness, accountability, or efficiency from the effort. We spoke with staff at the regions as well as at the main office and obtained anecdotal information about both the pros and cons of decentralization. However, the Department did not collect measurable data in order to assess the actual benefits and costs of decentralizing bridge design functions.

There are several reasons why the current pilot program does not truly test the effectiveness of decentralizing the Section:

- The regions tested are not geographically representative of all transportation regions. The pilot regions were both located in metro Denver, while the other four transportation regions include more rural areas that extend hundreds of miles from Department headquarters. Thus the pilot may not reveal problems or situations that might occur in non-urban areas far from the Department's main offices.

- The staff of the design units for Regions 1 and 6 remained physically located in the Denver office. One of the main concerns of decentralizing is that engineers would not have access to resources and plans located at headquarters, but the pilot units did not have to function without these resources.

- Neither the Department nor the Design Section set forth goals by which to measure the success of the pilot program.

- The Region 1 unit leader does not track hours of his unit in a detailed manner, so it is difficult to compare the performance of the decentralized unit to the three centralized units in the Design Section.

If the Department intends to pursue the possibility of decentralizing bridge design staff, it should use a fully planned pilot approach that addresses the elements discussed above.

## Recommendation No. 12:

The Department of Transportation should institute a true pilot program to systematically examine the efficiency and practicality of decentralizing its bridge design function before making a final decision regarding the organization of bridge design staff. The pilot should include:

a. Measurable goals identified in advance.

b. Systems to track work hours and other relevant data in a manner that will allow comparisons between centralized and decentralized design units.

c. A set time period at the end of which the success of the pilot will be measured.

d. Physical relocation of the pilot unit(s) to the region(s) if the Department is considering physically relocating design units to the regions.

## Department of Transportation Response:

Disagree. Although there are some aspects of the recently completed pilot program which could have been improved, there was enough information and experience gathered through this pilot that a final decision regarding the organization of bridge design staff has been made. Based on this pilot the Chief Engineer's Office and the Regional Transportation Directors decided to keep the bridge design staff centralized within HQ.

However, as part of the re-engineering of the Staff Branches, specific performance measures will be developed, staff patterns reviewed and adjusted as necessary and project agreements between the Region and HQ on all in-house design bridge projects will be implemented immediately.

# The Design Section Could Improve the Accuracy of Its Construction Cost Estimates

The cost of constructing a bridge that is designed in-house is estimated two times. Early in the process a Design Section engineer calculates a preliminary cost estimate for each of the design options that is presented in the structure selection report. Unit costs needed for this estimate come from either referencing a cost data book or from consulting with the Department's cost-estimating office. Though not required to, regions generally select the design option that has the lowest preliminary construction cost estimate.

The second cost estimate is called a final cost estimate, or the engineer's estimate, and it generally is done just prior to the project going to bid. This estimate is prepared by the Department's cost-estimating office and is generally calculated independent of the preliminary estimate.

Design Section staff and management have stated that final estimates should be no more than about 20 to 30 percent higher than preliminary estimates. They believe that this is an acceptable margin of error, considering both the information available at the time of the preliminary estimate as well as the ramifications of an inaccurate estimate. We reviewed the preliminary and final cost estimates for 13 projects that included a bridge and that went out for bid in the last three fiscal years. We found that for just over half of the projects, the final estimates exceeded the preliminary estimates by more than 30 percent, as shown in the following table.

| **Variance Between Preliminary and Final Cost Estimates** | |
|---|---|
| **Variance Range** | **Number of Structures** |
| 0-30 percent | 6 |
| 31-60 percent | 3 |
| 61-100 percent | 2 |
| Over 100 percent | 2 |
| **Source:** Office of the State Auditor's analysis of data from the Bridge Section. | |

Preliminary estimates are prepared for several design alternatives for each design project. Resident Engineers and other region personnel rely on these estimates when

deciding which alternative to select. If these estimates are too low, regions may select a design that turns out to be considerably more expensive than anticipated. In addition, regions budget for bridge projects. If a project's preliminary estimate is inaccurate, this could make it difficult for the region to accurately budget for the project.

There are three primary reasons why there is significant variance between final and preliminary estimates:

- Omitted Items. Design Section engineers often exclude certain items from the preliminary estimates that later appear in the final estimate, particularly those items that are common to all of the design options for a particular project. The Section's rationale behind this is that if the region is considering which one of several options to select, it only matters how they compare relative to each other. However, this practice tends to undervalue the absolute cost of the bridge options.

- Missed Items. Design Section engineers sometimes miss altogether items that are necessary for the project. In particular, we looked at items for which Design Section staff said estimating was "especially important," such as steel pilings, concrete, reinforced steel, rails, and prestressed wire. We found engineers failed to include these items, which later appeared in the final cost estimate nearly one-fifth of the time in the projects we reviewed. While this is somewhat attributable to changes in design, it may also reflect misjudgment on the engineers' part.

- Inaccurate Cost Data. Unit costs of certain items tend to be significantly over- or under-estimated in preliminary estimates. Despite Department policy to the contrary, engineers often do not consult the cost-estimating office when calculating preliminary estimates, particularly when there is a rush to get estimates done. In such cases engineers rely solely on information contained in a "cost data" book, which could be as much as one year out of date. In the volatile construction supplies market, this can make a substantial difference. Again, considering only the items that are especially important to estimate accurately, two out of every five unit cost estimates we reviewed had variances between final and preliminary estimates that exceeded the "acceptable" threshold of 30 percent.

To help ensure that decisions about bridge projects are based on the most accurate information available, the Department should improve its preliminary cost-estimating process to address these issues.

## Recommendation No. 13:

The Department of Transportation should establish and follow a more standardized process for calculating preliminary estimates. Specifically, this process should:

a. Include all items that the engineer knows, or has a reason to believe, will be used for the bridge. The practice of not including items that are common to all design options should be discontinued.

b. Utilize the most up-to-date cost data available at the preliminary phase in order to reduce the discrepancies in unit cost estimates. This means that the Department's cost-estimating office should be consulted on as many preliminary estimates as is practicable, with particular attention paid to items with volatile costs.

c. Hold Design Section engineers accountable for the accuracy of their preliminary estimates. The extent and frequency of estimating errors should be tracked and used in annual performance evaluations.

## Department of Transportation Response:

Agree. CDOT agrees that a more standardized process for calculating preliminary estimates, for major structures, should be established and followed. Effective immediately the following process will be followed for in-house projects. Structure Selection Reports shall contain a complete summary of the known structure quantities for the options considered. When the report is submitted to the Region, it will also be submitted to the CDOT Cost Estimating Unit who will provide the preliminary cost estimate for use by the Region for final structure selection and budgeting. The bridge design engineer will include cost data (obtained from CDOT's cost data publications) in the report to make preliminary comparisons of options, but the estimate used for final selection and budgeting should come from the CDOT Cost Estimating Unit.

This will address in-house bridge design work. The decision to include consultant design work in this process will depend on the analysis of this process after being utilized on in-house work and the review of any increased resources needed in the CDOT Cost Estimating Unit versus benefits received. The preliminary estimate and final bridge cost will be tracked by BPD and a historical database thereby established. Bridge designers will be held accountable for providing complete summaries of the known quantities. Accountability for the accuracy of the cost estimates used by the Regions for

budgeting is the responsibility of the CDOT Cost Estimating Unit. As part of our quality assurance program, this information will be periodically reviewed and appropriate recommendations made and implemented to improve the overall accuracy and quality of our project cost estimating process.

# APPENDIX A

## COMPARISON OF BRIDGES 1998

| State | Total Interstate & State Bridges | Total Substandard Number | Total Substandard Percent | Total City/County Bridges | Total Substandard Number | Total Substandard Percent | Total All Bridges | Combined Total Substandard Number | Combined Total Substandard Percent |
|---|---|---|---|---|---|---|---|---|---|
| Alabama | 5,529 | 1,356 | 25% | 10,049 | 3,364 | 33% | 15,578 | 4,720 | 30% |
| Alaska | 782 | 175 | 22% | 135 | 45 | 33% | 917 | 220 | 24% |
| Arizona | 4,254 | 147 | 3% | 2,341 | 211 | 9% | 6,595 | 358 | 5% |
| Arkansas | 6,941 | 1,109 | 16% | 5,405 | 2,048 | 38% | 12,346 | 3,157 | 26% |
| California | 12,037 | 1,746 | 15% | 12,101 | 2,681 | 22% | 24,138 | 4,427 | 18% |
| **Colorado** | **3,709** | **588** | **16%** | **4,471** | **793** | **18%** | **8,180** | **1,381** | **17%** |
| Connecticut | 2,900 | 148 | 5% | 1,234 | 226 | 18% | 4,134 | 374 | 9% |
| Delaware | 783 | 166 | 21% | 7 | 4 | 57% | 790 | 170 | 22% |
| Dist. Columbia | 202 | 74 | 37% | 12 | 7 | 58% | 214 | 81 | 38% |
| Florida | 6,237 | 1,525 | 24% | 4,737 | 1,539 | 32% | 10,974 | 3,064 | 28% |
| Georgia | 5,827 | 1,034 | 18% | 8,540 | 2,517 | 29% | 14,367 | 3,551 | 25% |
| Hawaii | 734 | 371 | 51% | 396 | 172 | 43% | 1,130 | 543 | 48% |
| Idaho | 1,249 | 262 | 21% | 2,249 | 430 | 19% | 3,498 | 692 | 20% |
| Illinois | 8,053 | 2,178 | 27% | 17,552 | 3,686 | 21% | 25,605 | 5,864 | 23% |
| Indiana | 5,593 | 871 | 16% | 12,426 | 3,789 | 30% | 18,019 | 4,660 | 26% |
| Iowa | 4,036 | 484 | 12% | 21,118 | 6,672 | 32% | 25,154 | 7,156 | 28% |
| Kansas | 5,158 | 1,141 | 22% | 20,923 | 6,134 | 29% | 26,081 | 7,275 | 28% |
| Kentucky | 9,021 | 2,790 | 31% | 4,606 | 1,808 | 39% | 13,627 | 4,598 | 34% |
| Louisiana | 7,928 | 2,389 | 30% | 5,760 | 2,521 | 44% | 13,688 | 4,910 | 36% |
| Maine | 1,946 | 560 | 29% | 314 | 186 | 59% | 2,260 | 746 | 33% |
| Maryland | 2,699 | 672 | 25% | 2,039 | 702 | 34% | 4,738 | 1,374 | 29% |
| Massachusetts | 3,449 | 1,378 | 40% | 1,529 | 585 | 38% | 4,978 | 1,963 | 39% |
| Michigan | 4,292 | 1,645 | 38% | 6,421 | 2,933 | 46% | 10,713 | 4,578 | 43% |
| Minnesota | 3,453 | 415 | 12% | 9,226 | 1,742 | 19% | 12,679 | 2,157 | 17% |
| Mississippi | 5,283 | 1,668 | 32% | 11,117 | 5,857 | 53% | 16,400 | 7,525 | 46% |
| Missouri | 9,568 | 2,752 | 29% | 13,278 | 6,194 | 47% | 22,846 | 8,946 | 39% |
| Montana | 2,541 | 322 | 13% | 1,837 | 584 | 32% | 4,378 | 906 | 21% |
| Nebraska | 3,456 | 321 | 9% | 12,265 | 4,525 | 37% | 15,721 | 4,846 | 31% |
| Nevada | 1,007 | 58 | 6% | 373 | 55 | 15% | 1,380 | 113 | 8% |
| New Hampshire | 1,419 | 347 | 24% | 911 | 469 | 51% | 2,330 | 816 | 35% |
| New Jersey | 2,385 | 565 | 24% | 3,931 | 1,361 | 35% | 6,316 | 1,926 | 30% |
| New Mexico | 2,940 | 966 | 33% | 658 | 270 | 41% | 3,598 | 1,236 | 34% |
| New York | 7,769 | 2,292 | 30% | 11,728 | 5,599 | 48% | 19,497 | 7,891 | 40% |
| North Carolina | 17,140 | 5,837 | 34% | 620 | 180 | 29% | 17,760 | 6,017 | 34% |
| North Dakota | 1,097 | 80 | 7% | 3,451 | 1,179 | 34% | 4,548 | 1,259 | 28% |
| Ohio | 11,555 | 3,542 | 31% | 18,721 | 8,852 | 47% | 30,276 | 12,394 | 41% |
| Oklahoma | 7,385 | 1,523 | 21% | 15,517 | 8,102 | 52% | 22,902 | 9,625 | 42% |
| Oregon | 2,628 | 572 | 22% | 3,824 | 746 | 20% | 6,452 | 1,318 | 20% |
| Pennsylvania | 16,317 | 6,186 | 38% | 6,869 | 3,071 | 45% | 23,186 | 9,257 | 40% |
| Rhode Island | 603 | 362 | 60% | 148 | 97 | 66% | 751 | 459 | 61% |
| South Carolina | 8,186 | 1,660 | 20% | 846 | 343 | 41% | 9,032 | 2,003 | 22% |
| South Dakota | 1,791 | 137 | 8% | 4,141 | 1,321 | 32% | 5,932 | 1,458 | 25% |
| Tennessee | 7,373 | 1,672 | 23% | 11,828 | 3,311 | 28% | 19,201 | 4,983 | 26% |
| Texas | 32,000 | 5,800 | 18% | 16,900 | 7,900 | 47% | 48,900 | 13,700 | 28% |
| Utah | 1,718 | 604 | 35% | 935 | 395 | 42% | 2,653 | 999 | 38% |
| Vermont | 1,072 | 329 | 31% | 1,578 | 688 | 44% | 2,650 | 1,017 | 38% |
| Virginia | 11,266 | 3,445 | 31% | 1,098 | 403 | 37% | 12,364 | 3,848 | 31% |
| Washington | 3,113 | 753 | 24% | 4,067 | 870 | 21% | 7,180 | 1,623 | 23% |
| West Virginia | 6,413 | 2,657 | 41% | 154 | 114 | 74% | 6,567 | 2,771 | 42% |
| Wisconsin | 4,769 | 666 | 14% | 8,552 | 2,014 | 24% | 13,321 | 2,680 | 20% |
| Wyoming | 1,937 | 126 | 7% | 854 | 331 | 39% | 2,791 | 457 | 16% |
| | | | | | | | | | |
| **TOTALS** | **279,543** | **68,466** | **24%** | **309,792** | **109,626** | **35%** | **589,335** | **178,092** | **30%** |

**Source:** "Better Roads" Magazine, November 1998. Colorado data were confirmed with the Department of Transportation.

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