



**STATE OF ARIZONA
OFFICE OF THE
AUDITOR GENERAL**

**A PERFORMANCE AUDIT
OF THE**

**ARIZONA DEPARTMENT OF TRANSPORTATION
DESIGN AND MATERIALS SPECIFICATIONS**

MARCH 1983

**A REPORT TO THE
ARIZONA STATE LEGISLATURE**



DOUGLAS R. NORTON, CPA
AUDITOR GENERAL

STATE OF ARIZONA
OFFICE OF THE
AUDITOR GENERAL

March 31, 1983

Members of the Arizona Legislature
The Honorable Bruce Babbitt, Governor
Mr. William A. Ordway, Director
Arizona Department of Transportation

Transmitted herewith is a report of the Auditor General, A Performance Audit of the Arizona Department of Transportation, Design and Materials Specifications. This report is the last in a series of seven reports issued on the Arizona Department of Transportation and is in response to Senate Bill 1001 enacted by the Thirty-fifth Legislature, Second Special Session in 1981.

The blue pages represent a summary of the report; a response from the Arizona Department of Transportation is found on the yellow pages.

My staff and I will be pleased to discuss or clarify items in the report.

Respectfully submitted,

Douglas R. Norton
Auditor General

Enclosure

OFFICE OF THE AUDITOR GENERAL

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ARIZONA STATE LEGISLATURE

REPORT 83-4

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SUMMARY

The Office of the Auditor General has conducted a performance audit of the Arizona Department of Transportation (ADOT) Design and Materials Specifications in response to Senate Bill 1001 enacted by the Thirty-fifth Legislature, Second Special Session in 1981. This is the final audit in a series of seven audits to be completed on the Arizona Department of Transportation.

Highway construction is a major expense of State government involving approximately \$200 million of State and Federal funds annually. Highway construction is also an area which has recently been subject to simultaneous escalations in costs and decreases in revenues during a time of increasing demand. Therefore, maximizing the uses of highway construction dollars may now be more critical than ever before.

Currently, one area being examined nationally is achieving cost savings (while maintaining or improving safety and serviceability) through changes in design and materials specifications. Generally this involves small design changes or modifications for specific types of roadways or highway sites. However, because of the magnitude of the dollars involved in highway construction, even small changes can produce significant savings.

Six previous performance audits of ADOT focused on administrative and management aspects of ADOT. Because of the technical nature of the subject, the issue of potential savings through changes in design and materials specifications was not previously addressed. To address this area we contracted with the Texas Transportation Institute (TTI).*

* The Texas Transportation Institute was selected following competitive bidding which attracted nine proposals from leading engineering and design consulting firms throughout the nation. The proposals were evaluated by the Office of the Auditor General with the assistance of Dr. Rudy Jiminez of the University of Arizona who is himself a nationally recognized highway engineering expert.

TTI conducted a thorough review of ADOT's standards and specifications and compared them to 1) specifications recommended by the American Association of State Highway and Transportation Officials (AASHTO), 2) the results of the most current research on highway design and safety, and 3) practices being used by the other states to reduce costs. This review lead TTI to conclude that ". . . ADOT is one of the leading transportation agencies in this country." This conclusion notwithstanding, however, TTI recommended changes be made in ADOT's specifications to 1) produce significant cost savings 2) improve the safety of Arizona's highways, and 3) improve the procedures used by ADOT. In addition, TTI found that revisions are needed in Arizona's tort liability law as it pertains to highway engineering.

Potential Cost Savings

TTI identifies more than \$26 million in potential cost savings over the next five years through changes in three areas: geometric design, value engineering and roadside management. In addition, TTI noted a number of changes which may produce potential savings, but to which it did not project dollar amounts.

- TTI estimates that as much as \$13 million can be saved over the next five years through changes in geometric design. TTI found geometric design changes--which involve such factors as lane widths, shoulder widths and side slopes--may be appropriate for low-volume roads where no measureable safety problems have been found.
- TTI estimates that from \$10 to \$13 million can be saved over the next five years by implementing an active value engineering (VE) program. Value engineering is the systematic review of engineering design procedures and policies in order to reduce cost. This review can be performed by both the department and by contractors who are then allowed to retain a percentage of the savings. TTI found that other states report considerable savings through the use of value engineering.
- TTI estimates that \$644,000 can be saved over the next five years through changes in such areas as signals and lighting, signing and marking, roadside barriers, drainage and landscaping.

Safety

In addition to potential cost savings, the review identified three design changes which should be made to increase the safety of the Arizona motorist and reduce potential liability to the State. These three changes relate to crash barriers, sign supports and the manner in which guardrails are anchored to bridges. In each of these areas TTI found design features which are not in compliance with national safety standards.

Improved Procedures

In addition to the recommendations for achieving cost savings and eliminating potential safety problems, TTI also developed numerous recommendations for improving technical procedures followed by ADOT. While some of these recommendations may ultimately translate into cost savings through improved results, no attempt was made to quantify such possible savings. Among the areas addressed in these recommendations are materials testing, compaction specifications, pavement design procedures and methods used to select projects.

Tort Liability

TTI found that in Arizona

"The liability for torts related to highway defects has gradually been shifted from no liability to absolute liability over the past twenty years."

This shift in liability has also been accompanied by increasing dollar losses and increasing numbers of claims. TTI addressed several concerns relating to liability from an engineering perspective including:

- Keeping all highway hardware up to the latest standard,
- Unknown highway defects,
- Control of access to the highway, and
- Length of time to file a claim.

INTRODUCTION AND BACKGROUND

The Office of the Auditor General has conducted a performance audit of the Arizona Department of Transportation (ADOT) Design and Materials Specifications in response to Senate Bill 1001 enacted by the Thirty-fifth Legislature, Second Special Session in 1981. This is the final audit in a series of seven audits completed on the Arizona Department of Transportation.

Highway construction is a major expense of State government involving approximately \$200 million of State and Federal funds annually. Highway construction is also an area which has recently been subject to simultaneous escalations in costs and decreases in revenues during a time of increasing demand. Therefore, maximizing the uses of highway construction dollars may now be more critical than ever before.

Currently, there is much discussion nationally regarding maximizing the uses of highway construction dollars. One area being examined is achieving cost savings (while maintaining or improving safety and serviceability) through changes in design and materials specifications. Generally this involves small design changes or modifications for specific types of roadways or highway sites. However, because of the magnitude of the dollars involved in highway construction, even these small changes can produce significant savings. For example, changes resulting in a 1 percent reduction in the overall costs of Arizona's highway construction represent a potential of \$2 million in annual savings.

Six previous performance audits of ADOT focused on administrative and management aspects of ADOT. Because of the technical nature of the subject, the issue of potential savings through changes in design and materials specifications was not previously addressed. To address this area we contracted with the Texas Transportation Institute (TTI).*

TTI conducted a thorough review of ADOT's standards and specifications and compared them to 1) specifications recommended by the American Association of State Highway and Transportation Officials (AASHTO), 2) the results of the most current research on highway design and safety, and 3) practices being used by the other states to reduce costs. This review lead TTI to conclude that ". . . ADOT is one of the leading transportation agencies in this country." This conclusion notwithstanding, however, TTI recommended changes be made in ADOT's specifications to 1) produce significant cost savings 2) improve the safety of Arizona's highways, and 3) improve the procedures used by ADOT.

The final report submitted by TTI contains 223 pages of text and more than 300 pages of technical appendices. Because of its length and technical nature the full report is not being transmitted. Instead, a summary of the major elements of the TTI report forms the substance of this report. However, ADOT has been furnished full copies of the report and additional copies of the full report are available for inspection by interested parties at the Office of the Auditor General.

The Auditor General and staff express appreciation to the Texas Transportation Institute for the consulting work performed. We also express appreciation to the Director of the Department of Transportation and his staff for their cooperation and assistance during this audit.

* The Texas Transportation Institute was selected following competitive bidding which attracted nine proposals from leading engineering and design consulting firms throughout the nation. The proposals were evaluated by the Office of the Auditor General with the assistance of Dr. Rudy Jiminez of the University of Arizona who is himself a nationally recognized highway engineering expert.

SUMMARY OF THE CONSULTANT'S REPORT

The Texas Transportation Institute (TTI) report on ADOT-Design and Materials Specifications is a comprehensive review addressing seven major areas.* The thrust of their findings, however, can be categorized into three general topics:

- Potential cost savings,
- Increased safety, and
- Improved procedures.

In the course of the work, TTI also reviewed what it perceives to be a serious problem with the State's tort liability law as it pertains to highway design and engineering.

Despite the many recommendations for changes, TTI was generally complimentary of ADOT as being ". . . a very progressive department" and ". . . one of the leading transportation agencies in this country."

Potential Cost Savings

TTI identifies more than \$26 million in potential cost savings through changes in three areas: geometric design, value engineering and roadside management. In addition, TTI noted a number of changes which may produce potential savings, but to which it did not project dollar amounts.

Geometric Design - TTI estimates that as much as \$13 million can be saved over the next five years through changes in geometric design.

* These areas are 1) geometric design, 2) materials, 3) pavement design, 4) pavement management system, 5) project selection and prioritization, 6) value engineering, and 7) roadside management.

TTI found geometric design changes--which involve such factors as lane widths, shoulder widths and side slopes--may be appropriate for low-volume roads where no measureable safety problems have been found. TTI recommendations included consideration of 11-foot rather than 12-foot minimum lane widths, reducing the width of the paved portion of shoulders and using steeper side slopes. TTI also suggests increased use of truck lanes in lieu of upgrading completely a two-lane highway to four lanes and, when possible, painting lane edge striping six inches to one foot inside the edge of the highways with unpaved shoulders to minimize damage to the edges of the pavement.

Value Engineering - TTI estimates that from \$10 to \$13 million can be saved over the next five years by implementing an active value engineering (VE) program. Although ADOT currently has a VE staff member, TTI found that Arizona is forfeiting potential savings because it has no active, ongoing VE program.

Value engineering is the systematic review of engineering design procedures and policies in order to reduce cost. This review can be performed by both the department and by contractors who are then allowed to retain a percentage of the savings. TTI found that VE is most effective when applied to standards and specifications at the preconstruction stage but can still save money at the construction stage. Other states' experiences show value engineering is particularly applicable to projects which have:

- Costs that substantially exceed the initial estimates,
- Complex design features,
- Difficult or unusual construction procedures,
- Relatively expensive materials, and
- High maintenance costs over their service lives.

Other states report considerable savings through the use of VE. The most extensive and best documented use of value engineering is done by Pennsylvania. Pennsylvania estimates that it generates \$100 in savings for each dollar invested in value engineering. Further, Pennsylvania

found that it saved 5 percent of original project costs during 1980-82. If Arizona were to obtain a similar percentage of savings TTI estimates the potential savings over the next five years could be as much as \$50 million.

Currently, ADOT has no ongoing value engineering program. Although one staff member is assigned to the function, he is performing other duties. TTI recommends the formation of a functioning VE group and, if necessary, the use of outside consultants to assist in this task. TTI also recommends that the Legislature insist on value engineering and provide additional resources, if necessary, to achieve the potential savings.

Roadside Management - TTI estimates that \$644,000 can be saved through changes in roadside management. Further, this is a net savings as TTI recommends, for safety reasons, some design changes which would actually increase some costs.

Roadside management encompasses such areas as signals and lighting, signing and marking, roadside barriers, drainage and landscaping. TTI's review of these areas leads it to project the following potential savings over the next five years.

TABLE 1

AREAS FOR POTENTIAL SAVINGS IN ROADSIDE MANAGEMENT

<u>Area</u>	<u>Potential Savings Dollars</u>
Electrical Surge Protection	NIL*
Use of Span Wire Mounted Signal When Feasible	\$ 25,000
Increasing the Lateral Placement of Certain Signs	50,000
Using High Performance Sheeting in Lieu of Lighting on Overhead Signs in Rural Areas	85,000
Redesign of Inertia Crash Cushions for the Smaller Vehicle**	(17,000)
Replacement of Slip Base Breakaway Sign Supports by a More Economical Frangible Breakaway System	NIL
Changing the Policy of Only Buying Two-Pound-Per-Foot Mild Steel Sign Supports	NIL
Redesign of Roadside Dykes to be Safer	NIL
Elimination of the Flared Terminal W-Beam End Section	100,000
End Anchorages of W-Beam at Bridges**	NIL
Slip Formed Concrete Median Barrier Design	180,000
Glare Screen Used on Concrete Median Barrier	NIL
Revision of Breakaway Cable Terminal Standards**	(4,000)
Redesign of Culvert and Pipe Headwalls in Lieu of Barrier	125,000
Roadside Mowing, Vegetation Control and Snow Removal	100,000
Irrigation Water Monitoring on Use of Drip Irrigation	NIL
Downscoping Roadside Development Standards in Urban Areas/Caretaker for Roadside Rest Areas	NIL
Roadside Development Section Staffing With Specialists	NIL
FIVE-YEAR PLAN TOTAL =	\$644,000

* NIL = less than \$500 savings per year

The bulk of the savings is on one item, slip formed concrete median barrier, which is far overdesigned in the opinion of the research team.

** Recommended for safety reasons

Other Potential Cost Savings - TTI developed other recommendations for potential cost savings but did not attempt to quantify the potential dollar amounts. Included among these recommendations were the following ones:

- Allow the use of uncrushed gravel on noncritical parts of the pavement on a project-by-project basis. Where sufficient testing shows that performance will not be sacrificed, this could create substantial savings in a few projects by allowing the use of locally available materials.

- Use a less restrictive requirement for stopping paving work due to ambient temperature. Currently ADOT requires cessation at 45°F; however, more northern states use less restrictive requirements depending upon the nature of the job.

Safety

In addition to potential cost savings, the review identified three design changes which should be made to increase the safety of the Arizona motorist and reduce potential liability to the State. These three changes relate to crash barriers, sign supports and the manner in which guardrails are anchored to bridges.

Crash Barriers - ADOT's crash barriers are "very advanced with regard to the state-of-the-art" with one small but significant exception. They do not meet deceleration standards for vehicles weighing 2,250 pounds or less. TTI reported

"An injury to the occupant of a vehicle weighing 2250 pounds or less which impacted an inertia barrier would be most difficult to defend in court since the design is outside the accepted standard for more than five years."

TTI recommends that ADOT review and update the design of the inertia barriers to comply with the AASHTO standards.

Sign Supports - TTI found the type of steel used by ADOT for sign supports was leading indirectly to potential safety problems.

To save costs ADOT buys mild steel sign posts to allow straightening and reusing bent posts. However, the sign posts do not have sufficient strength to support some of the larger signs. When more support is needed, field personnel use multiple posts. These additional posts increase the momentum change that occurs if a car strikes the sign. TTI noted ADOT signs which had momentum change values were from 330 to 550 percent greater than allowable standards and from 500 to 845 percent greater than desirable standards.

The consequences of these increased momentum change values are very serious. TTI reported that if cars hit some of these signs ". . . the driver and occupants will be killed on impact." Further, where ADOT's signs do not comply with Federal policy, TTI believes that persons injured by a car hitting these signs

". . . would have an overwhelming legal basis for a tort claim against the State of Arizona." (emphasis added)

TTI stated that ADOT could both make the signs safer and save a "substantial amount" of money by using more modern designs for sign supports.

Guardrail Anchorage - TTI found the specifications for anchoring the ends of guardrails to bridges did not meet current national safety standards. TTI felt the current design could allow ". . . an impacting vehicle to partially snag on the concrete end and be dramatically redirected in the rail on the opposite side of the roadway."

TTI recommends design changes to correct the problem.

Improved Procedures

In addition to the recommendations for achieving cost savings and eliminating potential safety problems, TTI also developed numerous recommendations for improving technical procedures followed by ADOT. While some of these recommendations may ultimately translate into cost savings through improved results, no attempt was made to quantify such possible savings. Among the areas addressed in these recommendations are materials testing, compaction specifications, pavement design procedures and methods used to select projects.

Materials Testing - TTI recommended two changes in materials testing to better evaluate materials susceptible to moisture damage and to improve the evaluation of materials compaction.

TTI found that moisture damage is believed to have caused (or is at least related) to some of the pavement failures in Arizona. TTI recommended that ADOT adopt on an experimental basis a more reliable test for moisture susceptibility (the Lottman procedure) which is currently being used by other states. TTI stated that

"It would take very few projects identified as being susceptible to moisture damage to justify the use of this procedure over the current method. For example, if an additional overlay project was identified in the 5-year program as being moisture sensitive requiring the use of lime or cement, it is estimated that a savings of approximately \$20,000 per centerline mile of maintenance cost (seal coats) would result within the first five years of performance."

TTI also recommended a new method for compacting laboratory samples of materials which produces results more representative of that achieved by the actual pavement.

Compaction Specifications - TTI found that ADOT's specifications adequately address undercompaction (too little) but may allow for overcompaction (too much) to occur. This has important engineering implications as the strength and durability of pavements are directly affected by the amount of compaction. Too little or too much compaction can severely weaken a pavement.

TTI recommends that ADOT consider revising their specifications to provide an upper limit on the acceptable degree of compaction. Even if an upper limit is not developed, TTI recommends current specifications be modified to encourage compaction to the desired amount, but not beyond.

Change to Mechanistic Design Procedures - TTI recommends that ADOT begin a transition from "flexible" to "mechanistic" pavement design procedures. ADOT currently uses the "flexible" design procedure which focuses on the performance of the cross-section of the highway. However, frequently there are factors which cause surface problems (such as cracking) to develop, but which do not affect the remainder of the cross section of the

highway. TTI recommends that ADOT begin using the "mechanistic" design procedure which focuses more heavily on the factors which affect surface quality.

TTI noted the following aspects of mechanistic design:

1. The general trend nationally is toward a mechanistic procedure.
2. Mechanistic design procedures are based on criteria (for example, surface quality) which are used to trigger maintenance activities. Therefore, these procedures would complement ADOT's existing pavement management and maintenance programs.
3. Mechanistic design appears to provide pavement thicknesses which are about the same as the ADOT procedure except on weak soils where surface failure, the criterion of the mechanistic design, would be greater. Therefore, costs should be similar except where justified by threats to surface quality.

According to TTI, mechanistic design will help prevent overdesign or underdesign of pavements and will generally result in a more consistent pavement life from highway to highway.

Optimizing Project Selection - To improve procedures for selecting highway projects, TTI recommended that ADOT adopt and implement optimization techniques now available and used by other states. Using computerized algorithms, these techniques permit selecting those combinations of projects that produce the greatest benefits for each given budget level. By considering different levels of improvements (and defining the costs and benefits) for each highway location under consideration, these techniques can be used to compare the many different possible combinations of projects and then select the combination which produces the greatest total benefit for a given expenditure. Experience shows the total benefits which can be achieved using optimization techniques exceed the benefits which can be obtained through a simple cost-benefit ranking and selection of projects. TTI noted that a few states now use optimization techniques and that computer programs are already available.

Tort Liability

TTI found that in Arizona

"The liability for torts related to highway defects has gradually been shifted from no liability to absolute liability over the past twenty years."

This shift in liability has also been accompanied by increasing dollar losses and increasing numbers of claims. TTI addressed several concerns relating to liability from an engineering perspective including:

- Keeping all highway hardware up to the latest standards,
- Unknown highway defects,
- Control of access to the highway, and
- Length of time to file a claim.

These concerns were addressed because the nature of TTI's review-- examining possible changes in design and materials specifications-- necessitated a review of the potential liabilities to the State that might result from such changes. These in turn lead to a review of the current tort liability provisions in Arizona as they relate to highway defects. Their findings are discussed below.

Keeping Hardware to Standards - From an engineering viewpoint, it is not cost-effective, nor generally necessary, to keep all highway features up to the latest accepted standards. Although many claims often involve hardware not being up to the latest accepted standards, TTI noted

". . . that billions of dollars would be needed annually to keep the highway hardware current with a constantly changing vehicle size and constant upgrading of standards. . . ."

TTI also noted that the vast majority of all hardware is reasonably safe for a very high percentage of vehicles. Further, it is impossible to make hardware safe for every vehicle. For example, breakaway signs cannot be made safe for motorcyclists.

TTI stated

"It is not suggested that the State should not be responsible for unsafe features. Rather, it is suggested that the State of Arizona should not be held liable when roadside features were designed to the accepted standard at the time they were designed, for which an extensive accident history has not been observed, and which are reasonably safe for a substantial majority of all expected impacts."

Unknown Highway Defects - TTI noted that even on highways designed to standards, unsafe conditions can later develop due to accidents, weather or other factors. To correct such conditions requires that ADOT be notified and be given reasonable time to effect repairs.

Control of Access - TTI found that even though ADOT designs proper access controls into its highway system, courts have held ADOT responsible when other property owners have left fence gates open to allow cattle to graze on the highway right-of-way.

Time to File Claims - According to TTI

"The two year limitation on the filing of claims for highway defects is a serious problem in providing an adequate defense for the State. Often, claims are filed eighteen to twenty months after the incident occurs which means accurate information about the site is virtually impossible to obtain. This time gap provides the plaintiff with a substantial advantage over the State."

Suggested Guidelines - TTI suggests that the State establish guidelines governing the State's liability. TTI stated

"Providing the state a reasonable chance to defend itself through more specific limits on the conditions for which the state will be liable is a practical way to limit claims losses. The guidelines suggested in several states involved three basic tests:

1. Was the purported highway defect the direct cause of the incident?
2. Was the purported highway defect one that had an extended accident history or one of which Arizona Department of Transportation officials had been formally notified and had failed to respond in a reasonable time?
3. Was the purported highway defect designed and maintained in accordance with the standards which existed at the time of its design?"

TTI believes the area of tort liability is sufficiently serious to warrant corrective legislation. A model bill prepared by TTI to address the concerns listed above is included in TTI's full report.



ARIZONA DEPARTMENT OF TRANSPORTATION

206 South Seventeenth Avenue Phoenix, Arizona 85007

BRUCE BABBITT
Governor

March 31, 1983

WILLIAM A. ORDWAY
Director



Mr. Douglas Norton
Auditor General
111 West Monroe
Suite 600
Phoenix, AZ 85003

Dear Doug:

Thank you for the opportunity to review the performance audit of ADOT Design and Materials Specifications. This audit differed somewhat from previous audits in that it was performed by an out of state consultant. Our comments concerning the Texas Transportation Institute recommendations are attached.

As you point out, your audit report is a summary of the major elements of the Texas Transportation Institute final report. Our comments have been summarized as well and we are retaining the voluminous backup data. If you, or members of your staff, would like to review any of this data, please feel free to call me.

Again, thanks for this opportunity to comment and for the cooperation extended by you and your staff.

Cordially,

W. A. ORDWAY
Director

WAO:ejs

Attachment



COMMENTS ON THE AUDITOR GENERAL'S PERFORMANCE AUDIT

After reviewing this complex and wide-ranging audit, ADOT agrees with many of the recommendations, partially agrees with others and, in one instance, strongly disagrees. ADOT also noted a few recommendations that are currently provided for in existing ADOT Standards. The chart following these comments provides a breakdown of these four categories.

AGREE

The recommendations with which ADOT agrees cover a broad range of topics. The page number shown provides an easy reference to the Auditor General's report.

1. Redesign of inertia crash cushions for the smaller vehicle:
Page 6 & 7

ADOT's standards have been revised to accommodate this recommendation.

2. Revision of Breakaway Cable Terminal Standards: Page 6

ADOT's standards have been revised to accommodate this recommendation.

3. Roadside mowing, vegetation control and snow removal:
Page 6

The recommendations of TTI are currently being reviewed and it is anticipated that standards will be revised in accordance with these recommendations.

4. Uncrushed gravel: Page 6

TTI correctly points out that a substantial savings in construction costs could be obtained by using uncrushed river-run gravel. They also point out, however, that "substantial savings in construction costs may be offset by increased maintenance or rehabilitation costs in excess of the initial savings." It is ADOT's feeling that this is what would happen and the decision has been made not to use uncrushed gravel and thus reduce overall maintenance costs.

5. Compaction specifications: Page 9

ADOT agrees with TTI's comments that "under compaction" is as important as "over compaction". ADOT has an on-going program of compaction test analyses and if a problem is indicated, the specifications will be modified accordingly.

6. Tort Liability: Page 11

The TTI comments concerning tort liability are very timely and point the way to substantial savings in state funds. As TTI points out, however, additional legislation would be required in order to relieve ADOT of near-absolute liability that currently exists. ADOT is currently supporting Senate Bill 1391 which, if passed, will provide many of the features recommended by TTI.

PARTIALLY AGREE

ADOT partially agrees with the following recommendations made by TTI.

1. Value Engineering: Page 4

ADOT recognizes the importance of Value Engineering. Value Engineering is not a new application but a formalization of one segment of what has always been a part of good engineering practice. In a broad sense, Value Engineering has been practiced for many years by ADOT in the constant review of new materials, methods and alternative design features.

TTI stated that \$10 to \$13 million dollars could be saved using Value Engineering techniques on a regular basis. Analysis of the five-year construction program demonstrates that approximately \$162 million dollars of the total program could be subject to a Value Engineering analysis. Therefore, if the optimum conditions were present and Arizona could realize the same percentage of savings as demonstrated by the most successful state practicing Value Engineering, the total savings would be \$8.1 million over five years.

The actual savings would be much lower than this figure since Value Engineering is practiced to some extent today. The actual potential savings, considering the level of Value Engineering practiced to date and the level of projects on which it could be demonstrated may be \$2 to \$3 million dollars over a 5-year period. To accomplish this level of evaluation, resources in the form of space and added personnel would be required at a cost of \$200,000. per year. Over a five-year period, the cost of conducting the recommended study would be approximately \$1,000,000., leaving a net potential savings of approximately \$2,000,000.

ADOT does, however, recognize the value of a program of this type and will begin a more formalized Value Engineering program.

2. Using high-performance sheeting in lieu of lighting on over head signs in rural areas: Page 6

ADOT agrees that the use of high-performance sheeting would

provide a savings over the use of lighting. In order to realize this savings, however, sign installation must take place. Since ADOT does not plan to replace any rural illuminated signs during the next five years, or construct any new signs, there will be no savings.

3. Elimination of the flared terminal W-beam end section:
Page 6

ADOT agrees with TTI that a significant savings would be accomplished by eliminating the flare terminal W-beam end sections. The benefits in safety to the traveling public exceed the benefits associated with the cost savings. A continuing review of this item is part of ADOT's on-going procedures.

4. Redesign of culvert and pipe headwalls: Page 6

Many attempts have been made to find an economical, traffic safe headwall that does not reduce the capacity of the culvert or increase maintenance costs. Any real improvement in this difficult feature would be most welcome. Until that design is accomplished, there can be no savings associated with this recommendation.

5. Less restrictive temperature requirements: Page 7

TTI recommends a less restrictive requirement for stopping pavement work due to ambient temperatures. ADOT will examine compaction records to ascertain of the temperature restriction should be amended.

6. Materials: Page 9

TTI recommends the use of the Lottman procedure for testing asphaltic concrete aggregates and the use of the Texas Gyrotory Compactor for asphaltic concrete mix design purposes. ADOT will review each of these items to determine if they have practical application in Arizona.

7. Change to mechanistic design procedures: Page 9

Mechanistic design is a new concept which is to be the subject of a national study and possible inclusion in the AASHTO Interim Guide. ADOT will await the results of this study before making any decision on the applicability of this procedure.

8. Project selection and prioritization: Page 10

The possible use of the optimum transportation investment analysis model may have some use in Arizona. ADOT will continue to study this and other ways to improve our project selection and prioritization procedure.

STRONGLY DISAGREES

1. Geometric Design: Page 3

ADOT strongly disagrees with the TTI recommendations concerning changes in geometric design standards. Specifically, ADOT disagrees with the savings that TTI associates with changes in ADOT standards on lane widths, shoulder widths, sod shoulders and passing lanes.

TTI has recommended the use of minimum 6-foot shoulders with 4-foot being sod. TTI has failed to recognize that sod or earthen shoulders are not practical in desert areas. It is only at considerable expense that any grass areas are developed and in order to have sod shoulders, irrigation would have to be provided. This type of construction is totally impractical and would not be considered since the cost would be in excess of \$30 million dollars over a five-year period.

TTI has also suggested side slopes of 3:1 for fills over five feet and 4:1 for fills under five feet. This is an ideal which ADOT has not yet reached. Current standard sections for low volume roads include 1½:1 fill slopes for higher fills and vary between 4:1 and 1½:1 for intermediate fills. Considerable added cost would be experienced in construction and right of way if the flatter slopes were adopted.

Beginning as early as 1955, ADOT has had a policy of providing extra climbing lanes for trucks in lieu of full widening. ADOT will continue to carry out this policy.

TTI also recommended that ADOT adopt federal 3R standards and that if we were to do so, a considerable savings could be realized. To date, the 3R program has remained undefined regarding minimum acceptable standards. FHWA is currently working up standard guidelines which would be the minimum for federal-aid projects. ADOT has maintained the Arizona Highway System at the lowest possible cost consistent with safety and service. To achieve those standards suggested by TTI, the five-year program cost would increase by as much as \$300,000. per mile for the 3,750 miles projected for construction during the next 20 years. THE ADDITIONAL COST FOR THE NEXT FIVE YEARS, WOULD BE BETWEEN \$45 MILLION AND \$260 MILLION DOLLARS.

EXISTING PROCEDURES

There are two recommendations made by TTI that cover existing ADOT procedures.

1. Use of span-wire mounted signal: Page 6

ADOT does use span-wire mounted signals when feasible in accordance with our existing policies.

2. Increasing the lateral placement of certain signs: Page 6

It is ADOT's policy to locate signs as far from the road edge as is practical to enhance safety conditions.

3. Concrete median barrier: Page 6

This option is now made available to contractors in those construction projects where a pre-cast concrete median barrier is applicable.

SUMMARY OF TOPICS COVERED IN AUDIT

ADOT Comment	Topic	TTI Potential Savings	ADOT Conclusions
1. Agree	Redesign of Inertia Crash Cushions for Smaller Vehicles	(\$ 17,000)**	(\$ 17,000)
2. "	Revision of Breakaway Cable Terminal Standards	(4,000)**	(4,000)
3. "	Roadside Mowing, Vegetation Control and Snow Removal	100,000	100,000
4. "	Uncrushed Gravel	-	-
5. "	Compaction Specifications	-	-
6. "	Tort Liability	-	-
1. Partially Agree	Value Engineering	10,000,000	2,000,000
2. "	Using High Performance Sheeting in Lieu of Lighting on Overhead Signs in Rural Areas	85,000	- 0 -
3. "	Elimination of the Flared Terminal W-Bean End Section	100,000	- 0 -
4. "	Redesign of Culvert and Pipe Headwalls in Lieu of Barriers	125,000	- 0 -
5. "	Less Restrictive Temperature Requirements	-	-
6. "	Materials	-	-
7. "	Mechanistic Design Procedures	-	-
8. "	Project Selection and Prioritization	-	-
Strongly Disagree	Geometric Design Changes	13,000,000	*
1. Existing ADOT Procedure	Use of Span Wire Mounted Signal	25,000	- 0 -
2. "	Increase the Lateral Placement of Certain Signs	50,000	- 0 -
3. "	Slip Formed Concrete Median Barrier Design	180,000	- 0 -

Note: All figures are for a five year period.

- Unable to determine if any savings would occur.

* Additional costs - \$45,000,000 to \$300,000,000.

** Recommended for safety reasons.