

Utah Department of Transportation

Chapter I INTRODUCTION

The Utah Department of Transportation (UDOT) has undertaken an ambitious research and development program considering the size and qualifications of its research staff. Researchers have attempted, with limited success, to develop advanced new construction materials, highway designs and construction practices. However, in many cases the objectives of the research studies have not been met and the research conclusions have not been supported by objective data. We also identified several new products which have been used in construction and maintenance projects before being properly tested by the development unit. This report recommends several changes in the organization and management of the research and development program which will increase the effectiveness of UDOT research projects and insure that new products are used only after they have been properly tested.

The Research and Development (R & D) Section, within the Division of Materials and Research, is a relatively small agency. Its 1991 budget was only \$575,325. However, with the passage of a new federal transportation bill, UDOT may soon be in a position to significantly increase its research budget. Roughly half of the current research budget comes from state sources, the other half comes from Federal Highway Planning and Research (HPR) Funds. The R & D Section allocates its budget between a research group and a new product development group. The research group consists of three research engineers, a research analyst and a research technician. The new product development group consists of a development engineer, a research analyst, an implementation engineer and a librarian. The R & D Section is overseen by the research and development engineer, and has one statistician and one programmer analyst which provide support for the entire section.

The purpose of the R & D Section is to solve problems and to find better ways of operating the state's transportation system. One way this is done is by identifying innovative technology, methods, and products that can make the state highway system more durable and safe. For example, new asphalt and concrete products are being introduced which have the potential of saving the state millions of dollars in construction costs. Before they can be used, however, they must be tested by the development engineer in the lab and on small test patches in the field to make sure that the products can hold up under Utah conditions. Innovative highway designs and new highway planning and management techniques also present opportunities for improving the state's transportation system. For example, a new design for highway interchanges may allow the department to improve the efficiency and safety of the highway system and relieve congestion.

Some of Utah's transportation problems can be solved by implementing the developments of the larger transportation research programs sponsored by other states, the federal government and private institutions. For example, there are several large research institutions which are

spending millions of dollars on the development of new highway designs, intelligent vehicle highway systems and new construction materials such as latex asphalt and polymer additives for concrete. UDOT does not have the funds to develop these technologies itself. However, once they have been developed by other institutions, Utah can benefit from the technology by adapting it to Utah conditions.

Many of the state's transportation problems are unique to Utah and are not being addressed by national research institutions. These problems can only be addressed by original research sponsored by the R & D Section. While there is much the R & D Section can do to «)9» «):»implement technology developed in other states, its research engineers are poorly qualified in terms of technical expertise to conduct new research in highly advanced subjects. The necessary expertise must be provided by experts from within the department or by outside consultants at local universities and in private industry. In recent years, the department has begun contracting more and more of its advanced research to local university professors.

Audit Scope and Objectives

We were asked to evaluate the effectiveness of UDOT's research and development program. Specifically, legislators suggested that the department might benefit from a cooperative effort between the UDOT Research and Development Section and the civil engineering programs at the universities in the state. For this reason we evaluated the ability of current research staff to conduct specialized research projects and the possibility of local professors providing research services. In addition, we addressed a number of problems relating to the management of research projects. Finally, we conducted a review of the department's new product development program to determine whether the appropriate preliminary tests are being made before new materials are used in construction and maintenance projects.

Chapter II

MORE EXPERTISE NEEDED FOR HIGHLY TECHNICAL RESEARCH

A number of highly technical research projects have been assigned to in-house research staff who did not have the necessary experience and qualifications to conduct advanced research. UDOT's R & D Section is largely staffed by civil engineers and engineering associates who have transferred from the department's other operating units. Their background in general highway engineering does not give them the expertise they need for highly specialized assignments. In addition, high turnover among staff researchers has also made it difficult for UDOT to maintain a well trained and experienced research staff. Most of the studies within the last few years have experienced turnover in the principal engineer positions. Because of the lack of expertise and the high turnover among research staff, several research projects have not achieved their objectives and some have not provided sufficient evidence to support the research conclusions.

Another approach used by many other states is to contract out specialized research to local universities. Contracting with a professor is a popular approach because they often have the necessary expertise to conduct advanced research in the particular field of study and they can conduct the research at a lower cost. During the past three years, UDOT has begun to offer research contracts to some of the local universities. Since 1989 universities have completed three research projects for the department and several more are currently under way. We commend UDOT for this action and believe more should be done to continue to contract with university professors, when UDOT does not have the expertise needed.

A major concern identified in this report is that UDOT does not have qualified researchers for the advanced studies it has performed during the past six years. Chapter II identifies several instances in which UDOT has not had sufficient expertise and could have sought assistance from local university experts. For example, we found that UDOT's last two major in-house research projects could have been performed at universities within the state. In both cases, the universities had professors with expertise in the subjects being researched and had the necessary laboratory equipment. We also determined the universities could have conducted the research at a lower cost than UDOT.

However, Utah universities do not always have the ability to provide adequate expertise in some of the areas in which UDOT needs to conduct advanced research. Unlike the universities in many other states, the universities in Utah have only a few professors who are specialists in the subjects related to transportation and who are qualified to conduct advanced research. For example, the universities are limited in their ability to provide expertise in subjects related to highway materials, construction and maintenance.

UDOT can help the state's universities develop their transportation programs by continuing to offer them research contracts. The more research opportunities the local universities can offer their faculty, the more attractive those institutions will be to out of state experts who may consider coming to Utah. The department can also help the local universities by supporting efforts to establish an advanced transportation research and education center. Several universities hope that by combining their resources into a single advanced transportation institute they can create a comprehensive transportation program. This "Advanced Center for Transportation Studies" would be in a better position to serve the state and could also submit competitive proposals for federal research contracts.

While encouraging the universities to develop their capabilities in transportation, the department should also shift its internal research program away from activities which are beyond the capabilities of its in-house research staff. For example, in the past research staff have been very effective performing smaller research projects which focus on specific construction practices. Research staff have also conducted several successful studies aimed at implementing another state's research results. Testing new products in the field is also an activity which needs greater emphasis by the R & D Section. By performing small studies which are focused on specific department problems rather than advanced research with nationwide application, the department can make a much more effective use of its in-house research staff.

Researchers Lacked The Expertise Required For Three Advanced Studies

The lack of expertise among UDOT research staff was one reason why three of the department's last four major in-house studies did not achieve their research objectives. For example, a study of joint sealants for concrete roads was dropped because poor research procedures were used. In a study of asphalt rejuvenation, researchers were able to collect usable data at only three out of eight test sites and were unable to provide enough documentation to support their research conclusions. Finally, a study of the single point urban interchange also lacked the expertise needed to accomplish many of the research goals. Although there was some useful information which resulted from each of these studies, staff fell short of their research objectives because of they lacked familiarity with the research subject and had a poor understanding of the testing procedures required to collect valid data.

Concrete Joint Seal Study was Abandoned Prior To Completion

A study of concrete joint sealants was dropped without issuing a final report after staff spent over five years and \$120,260 on the project. UDOT officials said the reasons for this were (1) "gaps in the study procedure" and (2) that they had to replace the principal investigator in the middle of the study. Referring to the poor study procedure, they indicated that "subjective evaluations were performed by five persons, often independently, at different times, at different sites, using different criteria." Although some useful information had been obtained from the study, the department concluded that "a series of defensible findings would not be appropriate

under the foregoing circumstances. Without valid findings, recommendations based upon the observations alone would be very weak."

A researcher closely associated with the study suggested that the main problem with the project was that the research staff relied too much on subjective field observations. He pointed out that researchers should have performed lab tests on the different joint seal compounds in order to obtain the objective data needed to substantiate their conclusions. These tests were a part of the original study work plan but they were never completed.

The lack of expertise among the research staff seemed to be the main reason for the "gaps in the study procedure" and the "lack of valid findings". Neither of the principal investigators assigned to the study had previous experience working with concrete or joint seal compounds. The first investigator did not have a civil engineering degree, although he had achieved "associate engineer" status through the in-house training program. He had a degree in industrial design and had originally been hired to the department's Roadway Design Section. He was removed from the project after he filed a patent on the joint seal process under study. For this reason, another research engineer was assigned to oversee the study. The second principal investigator had a degree in mechanical engineering. He had been hired to the research unit directly from college two years earlier. However, after two years of additional work on the project, this second investigator transferred to another division before the project was completed.

Asphalt Rejuvenation Study Produced Inconclusive Test Data

The R & D Section's study of asphalt rejuvenators also did not meet the research objectives for the study because the main source of data was the subjective observations of the UDOT research staff and maintenance personnel. The researchers were unable to develop an objective test of the ability of rejuvenators to extend the life of the asphalt pavements. An attempt was made to use laboratory tests of core samples taken from the rejuvenated road surface. However, these tests were inconclusive. For this reason researchers relied on the visual observations of the research staff and maintenance crews as their main source of data. The final report states that "ratings and methods of evaluation tended to be inconsistent from one location to another, as well as from one month or year to the next." However, even though no objective data had been collected to support the claim, the research report concluded the "rejuvenation works."

In his review of the final report of the rejuvenation study, one FHWA official stated that "the weakest area of the entire research effort is a lack of performance measures for evaluating the [rejuvenation] agents" and that "the final report does not contain satisfactory documentation to reflect accomplishment of the objectives contained in the approved work plan or to technically support the conclusions reached as a part of the research effort." He concluded that "It is our opinion that the report is inadequate and unacceptable as a final report for this \$100,000 study."

UDOT Research staff tried to rewrite the report in order to satisfy the requirements of FHWA. However, by that time the principal investigator had been assigned other duties and was not in the position to conduct additional research to support the research conclusions. As a result, the revised draft of the report provided greater detail regarding the research methodology but did not provide the documentation or performance measures which were lacking in the first draft of the report.

Had this study been conducted by someone with a greater understanding of the properties of asphalt, perhaps a testing procedure could have been developed which would provide better evidence that rejuvenation extends the life of asphalt. Instead, the researcher who conducted the UDOT study was a geotechnical engineer whose expertise is in soils and foundations.

Urban Interchange Study Needed a Traffic Specialist

The department's study of the "single point urban interchange", or SPUI, is another highly technical research project which should have been conducted by specialists in the field of study. For the most part, UDOT research staff were able to provide a fairly good study comparing the operational features of the SPUI design with those of the traditional diamond interchange design. In fact, some local engineering firms have used some of the information in the report. Researchers in other states have also told us that the report has provided them with information they needed to supplement their own research.

Although the results of the research are, for the most part, positive, there are several ways in which the research did not meet its objectives because the researchers lacked expertise in traffic engineering. As in the case of the asphalt rejuvenation study and concrete joint sealant study mentioned above, some of the information in the report is based on the subjective observations of staff rather than objective data collected in the field or in the lab. While the traffic experts with whom we spoke pointed out many positive features of the report, they have also indicated that some of the conclusions are not well supported by fact. For example, the information regarding the differential costs of the SPUI vs. the diamond interchange is not well supported and appears to be the opinion of the research staff.

Having a traffic specialist on the research team also could have helped improve the quality of the data researchers were able to collect. The research team originally included a traffic specialist from another unit within the department who was going to adjust the signalization at the two test sites to a setting which would optimize the through movements of traffic. Because this specialist had to drop out of the study shortly after it began, researchers were unable to set the signals at the two test sites at their optimum levels. As a result, there was no way for researchers to know whether their results showed that the SPUI was superior to the diamond design because of its design features or whether it was because the SPUI test site had been signaled better than the diamond interchange.

Research staff also tried to have a university student develop a computerized model which could be used to simulate the traffic flow patterns of a SPUI and the diamond interchange. The graduate student was unable to accomplish this. Researchers in other states have had some success in developing computer models which can be used to analyze alternative design features for the interchange. For example a professor from Arizona State University's Center for Advanced Research in Transportation and a traffic specialist from the Arizona Dept. of Transportation have adapted several computer models which can be used to simulate the traffic movements through a SPUI. Perhaps if the department had someone with more expertise in the computerized modeling and in traffic engineering, they would have had more success in this research area.

FHWA Reported That UDOT Research Staff Lack Expertise

In a 1988 review of the UDOT research program, the Federal Highway Administration also reported that many of UDOT's research staff do not have sufficient expertise for many of its federally funded research projects. In that report, FHWA's local Planning and Research Engineer indicated that "Several of the [UDOT] studies, as reflected by their titles, are extremely technical in nature and require the researcher(s) to be knowledgeable in such areas as chemistry, traffic flow characteristics, etc." He then stated that "although it was concluded that the current and proposed research studies are appropriately staffed with professionals, there was some concern as to whether there is the appropriate expertise to undertake in-house research studies that are of a highly technical nature." He pointed out that "in most cases the principal study investigators are required to do a significant amount of homework to obtain the necessary knowledge to undertake a research study."

The FHWA report then gave the following suggestions for improving the research program: (1) strengthen the existing research program by hiring "researchers' or professionals with special expertise", (2) loan experts from other department units to the research unit for the duration of a study, (3) use the existing research staff as research study managers or coordinators of research conducted by outside experts who would be hired as consultants, (4) utilize the in-house staff to solve problems using the findings of the research conducted by other agencies.

UDOT, however, did not make any substantial changes to their research program as a result of the FHWA study. Their response to the FHWA study was that the advisory panels assigned to each project provided the required expertise, that staff gained sufficient knowledge of the subject matter through literature searches, and that they were already committing \$100,000 each year to university research contracts.

While the advisory panels play an important role in any research program, they can not substitute for a poorly qualified researcher who is responsible for the study design, oversight of the field and laboratory tests, and writing the report. Besides, advisory panels were already a part of the research program before the FHWA conducted its review and were not providing the needed expertise. In addition, the advisory panels we observed showed very little interest in the research projects they were supposed to be overseeing.

At the time of the FHWA review, the department did have a modest outside research program already in place. Starting in fiscal year 1989, the department has budgeted \$100,000 for university research each year. This means they were already partly implementing recommendation (3) in the FHWA report. So far, each of the studies provided by local universities have been received quite favorably by the operating entities who were supposed to benefit from the research.

Staff Turnover Has Contributed To An Inexperienced Research Staff

One reason UDOT has not been able to develop a well qualified research staff is that there has been a high turnover among research staff. Typically, research engineers remain with the R & D Section for only a few years before taking another job. As a result, few researchers have time to learn how to put together a good study design, conducting accurate field and laboratory tests, and to write a research report which can meet the requirements of the FHWA.

Three of the last four research engineers to leave the department had been in their positions for only three years before they left. Three of the engineers left the department for opportunities elsewhere. One took another position within the department. Although each told us they enjoyed working in the research unit, they felt that the research unit provided them with few opportunities for advancement and that research did not fit their long term career interests. Each said that their new jobs gave them a better opportunity for career advancement.

In its 1988 review of the research program, FHWA said that if UDOT wanted to maintain a research staff with the experience and skills to conduct advanced research, they needed to do more to retain an experienced staff committed to the research program. The FHWA report suggested that UDOT should create "a separate career ladder for the research program, and a realistic pay scale to attract and retain such specialists." The department did not accept this recommendation, however, and as a result staff turnover has continued to be a problem.

In their letter of response to the FHWA report, UDOT management indicated that they would alleviate the disruption caused by staff turnover by assigning a backup researcher to each project so that if one left, the other would be acquainted with the study and be able to continue the research. This strategy, however, has not been effective. Most research projects are not being assigned a backup researcher. Those who had been designated as the backups to a project told us that they were not familiar enough with the project to be able to take responsibility if the principal investigator were to leave.

If the department is unwilling to accept the FHWA recommendation to strengthen its research program by hiring professionals with special expertise, creating a separate career ladder for them, and a realistic pay scale, it should adopt one of the other strategies suggested by FHWA. This means the R & D Section should be limited to small projects and implementation activities and rely on universities for any advanced research studies. As suggested by the following section, this is a strategy which has been effectively used by many other states.

Other States Assign Highly Technical Research To Experts

Several other states have conducted transportation research similar to that done in Utah but have avoided many of the problems experienced by UDOT by having the research conducted

by local university experts. There are other states which have had their in-house staff do the same kinds of research projects as Utah. However, they have always selected the department's own specialists in the field of study. In states like Utah with small in-house research programs, researchers are given assignments which correspond with their level of training. These often include research assignments which do not require special expertise, such as research implementation activities, new product testing, overseeing demonstration projects, and smaller research projects of department construction methods and practices.

Research in Other States Is Done by University Professors and Other Experts

We conducted a survey of all of the research projects conducted by other states which were similar UDOT's last five major research projects. By consulting the transportation research information service and other similar sources, we were able to identify 12 studies (shown in Figure I below) similar in subject and scope to UDOT's last five major studies. For each study, we identified the institution at which the research was performed and the background of the principal investigator who directed the research. In every case, the other states assigned the study to researchers highly qualified in the field of study. Of the 12 studies, 9 were assigned to university faculty associated with a university research center. One project was conducted alone by a specialist from within the state transportation agency. Another was done by a team consisting of a department specialist and an outside consultant. Finally, one project was a cooperative effort between a consultant, a university professor, and a specialist from the state transportation agency.

Figure I

The differences between the research conducted by UDOT and that done by other states is clearly illustrated by two identical studies of concrete joint sealants done simultaneously in Texas and Utah. Both studies were begun in 1984. UDOT's joint seal study, as reported above, was dropped after five years at a cost of \$120,260 without a report the research findings. The Texas study was completed in two years at a cost of \$125,000 (within the time schedule and budget) and a report of the research findings was issued.

Unlike UDOT, which had in-house research staff perform the study, the Texas transportation agency assigned the study to well qualified researchers from the Center for Transportation Research at the University of Texas at Austin. The principal investigators held

Ph.D.s in Civil Engineering, had for years focused their research on concrete sealants and protective systems, and had conducted a number of studies of concrete systems for the state. Unlike the UDOT research, which UDOT officials admit produced "subjective evaluations" without "defendable findings," the Texas research provided objective data from laboratory tests which were supported by observations in the field.

In-house Researchers Are Better Suited For Less Specialized Research

There are a variety of important research activities which do not require a high level of expertise. Most states the size of Utah use their in-house research staff engineers to perform these assignments, which include implementing another state's research results, evaluating new products and their applications, monitoring the progress of experimental features and demonstration projects, and evaluating the effectiveness of current department construction and maintenance practices. UDOT's in-house research staff has been very effective in performing these kinds of research activities in the past. The R & D Section should continue to focus more on these activities and less on specialized research for which their research staff are not well qualified.

UDOT's "Pipe Corrosion Update" is a good example of a project appropriate for in-house research staff. The objectives of the study were to determine how well UDOT pipe culverts are holding up and whether existing pipe selection procedures should be modified. The background and expertise required for this study were well within the skills of a civil engineer on the research staff. The research objectives of this study were met within the project budget.

"UDOT Selection Criteria for Guardrail" is another important study which UDOT research staff are undertaking and which is well within their capabilities. This study is aimed at helping UDOT develop its own standards for guardrail selection and design. The study may help UDOT avoid the cost of abiding by the more expensive national standard yet improve highway safety and provide the department protection from liability suits. This kind of research is valuable to the department, is well within the abilities of its civil engineers, and is the kind the research staff should perform.

Utah's Universities Could Provide UDOT With Some of the Expertise It Needs

Local university faculty members were more capable than UDOT research staff of performing the department's two most recent studies. In addition, the universities could have performed these studies at a lower cost. However, there are certain fields in which neither UDOT nor the local universities have sufficient expertise. In order to meet this need, several universities are trying to add faculty who specialize in fields related to transportation. In

addition, several universities are trying jointly to develop an "Advanced Center for Transportation Studies" which would promote advanced education and research in fields related to transportation. In the future, UDOT should take more advantage of the expertise at local universities. In addition, UDOT should support university efforts to expand their transportation capabilities.

Universities Could Have Provided More Expertise and Better Equipment for Two Recent UDOT Studies

We reviewed the last two UDOT studies to determine whether universities would have been able to provide the expertise and equipment which UDOT seemed to lack. We discovered that in both cases local professors could have provided the expertise and the necessary equipment required for the study.

Utah State University Could Have Performed the Fly Ash Study. We determined that the faculty and civil engineering laboratory at Utah State University (USU) were better suited than UDOT for research into the effects of fly ash on portland cement. None of the UDOT research engineers had experience in this subject. The R & D Section also had many problems getting the equipment required to conduct the laboratory tests. USU, on the other hand, has a concrete expert on its faculty and all the required laboratory equipment in its civil engineering lab.

UDOT's lack of qualified research personnel and equipment resulted in unnecessary expenditures of time and money. UDOT assigned the fly ash study to a civil engineer whose area of expertise is hydrology. Because he had no previous experience studying the properties of concrete mixtures, he had to spend several weeks reading in order to obtain the necessary background knowledge to begin his research. Also, the UDOT research lab lacked the equipment to conduct the fly ash study. One essential piece of equipment, a linear linear traverse device that measures air voids in concrete, cost \$21,000. The project was delayed while UDOT's procurement unit took 14 months to authorize the purchase of the device. UDOT already had its own freeze/thaw chamber which is also required for the study. However, it was in poor condition and did not operate in accordance with national testing standards established by the American Society of Testing Materials (ASTM). Consequently, the validity of its tests has been called into question by Federal Highway Administration representatives, UDOT officials, and university professors.

USU would not have had many of the difficulties encountered by UDOT because it already has faculty members recognized as experts in the use of concrete materials and the laboratory equipment required for the study. USU has a professor who is a specialist in the use of concrete and has done extensive research, consulting, and lecturing in that field. He is currently conducting a \$250,000 study of concrete durability for the National Cooperative Highway Research Program (NCHRP) which requires many of the same testing procedures and equipment as the department's fly ash study. The USU Civil Engineering lab has its own linear traverse device and personnel who are experienced in its use. The USU lab also has up-to-date

freeze/thaw equipment, which is more efficient than the UDOT equipment and operates in compliance with the ASTM standards.

At one time the department considered having USU conduct the freeze/thaw tests for its fly ash study. In December 1990 UDOT's freeze/thaw equipment began to malfunction and UDOT researchers asked USU if it would be possible to have USU lab technicians conduct the tests in Logan. USU professors responded that USU lab technicians could conduct the tests at a cost \$6,200 but that their equipment would not be available for six weeks. Because USU's equipment conducts the freeze/thaw cycles at a much faster rate than the UDOT equipment, they estimated that they would be able to complete the UDOT tests in approximately nine months. Had USU begun the tests when they originally offered to, in late January 1991, they would have the tests completed sometime in June 1991.

Because they were able to repair their own freeze/thaw equipment, UDOT researchers decided not to have USU perform their freeze/thaw tests after all. This decision, however, proved to be a costly one. UDOT continued to have problems with their equipment and had to ask FHWA to approve an extension of the project until February 1992. In the mean time, the principal investigator to the fly ash study left the department for a position in another state agency. As a result, because UDOT researchers decided not to ask USU to conduct their freeze/thaw tests, they delayed the completion of the project several months and have had to put the project on hold until another principal investigator is hired.

Brigham Young University Could Have Performed the Single Point Urban Interchange Study. The UDOT researcher who oversaw the SPUI study acknowledges that Brigham Young University (BYU) has an expert in traffic engineering who is more qualified to perform the study than UDOT's in-house research staff. This civil engineering professor received his Ph.D. from Texas A&M in transportation systems design and operations. The department hired him to design the department's SPUI study. He was also the advisor to a graduate student who developed a computerized technique for evaluating intersection capacity. Had he been given the study as an outside contractor, this professor could have used this system to measure the SPUI and diamond intersections as part of the SPUI study.

UDOT's research coordinating engineer admits that he has little experience in traffic engineering and was not really qualified to perform the study. He said he would like to have offered the study to the BYU professor but this was not possible because federal Highway Planning and Research (HPR) funds had already been budgeted for this in-house study. Once HPR funds were designated for the salaries of the in-house staff assigned to the study, the department could not offer the study to an outside consultant without finding another source of funding for the salaries of its research staff.

Local Universities Can Perform Some Research At a Lower Cost

There are many who agree that universities can provide greater expertise but complain that the cost of university research is far higher than research conducted by UDOT's own

in-house research staff. For this reason we made a comparison of the cost of conducting research at the universities with UDOT's in-house research costs. As shown in Figure II below, we found that the salaries and benefits paid to university professors tend to be higher than those paid to UDOT research engineers. However, the universities pay their support staff less than UDOT and charge a lower overhead rate. When we applied these costs to two recent studies conducted by UDOT research staff, we found that the universities would have conducted the research at a lower cost than UDOT did.

Figure II

The above data shows that whenever a project requires a great deal of laboratory and field testing, which are mainly performed by graduate students, the university's research costs will be lower than those of UDOT. If a project requires little technical support, however, UDOT's relatively lower salaries for its principal investigators gives it a cost advantage. The advantage would also depend, of course, on the availability of such a specialist from within UDOT. The following sections show what happens when these costs are applied to UDOT's studies of the use of fly ash in concrete of the single point urban interchange. They show that the universities would have been able to perform these studies at a lower cost than UDOT because of the large amount of technician time and overhead costs involved.

USU Could Have Done UDOT's Fly Ash Study for Significantly Less. UDOT's budget for the fly ash study was \$74,100. We substituted USU salaries, overhead, and other research costs for the unit costs listed in the UDOT project work plan and found that USU would have charged \$33,604 for the same work. This comparison assumes USU's concrete specialist would have been available to conduct the study and that USU would have followed a work plan identical to that used by UDOT. The cost information for this comparison was provided by the USU Contracts and Grants Division. They gave us the rates for salary, benefits, and overhead which USU engineering professors had charged for other research projects during 1989 when UDOT began its fly ash study. We then applied those rates to the number of hours listed in fly ash work plan which UDOT submitted to FHWA, who funded the project.

The main advantage USU had over UDOT is that they would not have had to spend \$21,000 for a linear traverse device. Although UDOT needed to purchase this equipment before it could conduct the fly ash study, the USU civil engineering lab already had such a device. Some legislators have questioned whether both the department and the universities need to have fully equipped laboratories. It has been suggested that by coordinating the use of one other's laboratory equipment, UDOT and state universities might be able to avoid the cost of purchasing all of the same, seldom used equipment. We also question whether both UDOT and Utah State University need to have their own linear traverse device and the laboratory staff trained in its use.

UDOT research staff claim that the UDOT materials lab needed its own linear traverse device because they pay outside laboratories several thousand dollars each year to perform the tests. In addition, they point out that having their own equipment will allow them to do better analysis of the internal structure of concrete than they have been able to perform in the past. We determined that UDOT pays outside laboratories several thousand dollars each year for various tests on the linear traverse device and that some of this testing could be avoided by having the equipment in-house. However, since the time the department purchased its own linear traverse device, most of the department's tests have still been performed by outside labs because the department has not had someone trained in the use of the linear traverse device. In addition, the UDOT materials engineer indicated that even after a department employee has been trained to use the linear traverse, outside laboratories will still have to perform certain advanced tests which UDOT staff would not be competent to perform.

Even if we consider the cost of the lab equipment irrelevant, the USU budget would still have been \$19,500 less than the amount UDOT budgeted for the project. This is because roughly two thirds of the hours in the UDOT work plan were for the time research technicians spent performing laboratory tests. As a result, USU's low cost graduate students more than compensated for the higher salaries paid to the engineering professors. USU would also have charged less for overhead than UDOT. UDOT adds an overhead charge to its federal research contracts of 39% of all staff salaries and benefits. USU's overhead fee is 10% of all direct costs.

BYU Could Have Done the SPUI Study for Less. If BYU were to have charged the same rates charged on other research contracts, they would have performed the study of the single point urban interchange for \$65,757, or \$9,243 less than UDOT's \$75,000 budget. UDOT's higher costs are due to the large amount of time allocated to higher paid research technicians and

clerical staff. The cost data we obtained from the BYU Office of Research Administration shows that graduate students in engineering would have done this work for less than half of what UDOT's research technicians are paid. The savings on student rates more than offsets the much higher salary rate for professors.

One disadvantage of conducting research at the university is that professors are less likely to be available during the regular school year to perform research. It is easier for them to conduct research during the summer months when school is not in session and graduate research assistants are available. For this reason, BYU would have charged 27% for benefits during the school year and only 11% during the summer months. Had BYU done the SPUI study during the regular school year, they would have had to increase their project budget to \$69,826. This figure, however, is still lower than the \$75,000 UDOT budget.

University Research Requires Additional Oversight Costs. One disadvantage of university research is that it requires additional administrative costs for the department which would not be incurred if the research were conducted in-house. While the additional expense is not recorded by the UDOT cost accounting system, our estimates show that the department needs to add an additional 4% to an outside research project to cover the departments costs for administration and project oversight. The director of Washington's transportation research agency, which conducts a great deal of university research, told us that he also spends about 4% for contract administration and oversight. As a result, administrative costs add about \$2,500 to the cost of the average UDOT research project. However, even when these costs are added, BYU and USU still would have performed the studies of fly ash and of the single point urban interchange for several thousand dollars less than the UDOT budgets for these projects.

UDOT Research Projects Usually Exceed the Budget. A comparison of research unit costs does not fully explain the advantage of performing research at the universities because the UDOT researchers almost always spend much more than what is budgeted. For example, UDOT research staff actually spent 57% more than the budgeted amount on the asphalt rejuvenation study and the concrete joint sealant study went 61% over budget. The research unit has already spent its budget for the fly ash study even though it still has not been completed. They have requested that the budget be increased another \$16,200 to \$90,300. The universities, on the other hand, are more likely to remain within their budgets because they are under a fixed contract. In the past, university researchers have rarely needed to exceed their budgets. When they have, the university civil engineering departments have covered the excess because they support research activities as an essential part of education.

Ability of Universities to Meet UDOT's Research Needs Is Limited

The research capabilities of universities in the state are still limited in some subjects important to the Department of Transportation. Unlike other states with advanced institutes of transportation research, Utah has no single university which has a strong transportation program

within its engineering department. However, both Utah State University and the University of Utah are in the process of hiring additional faculty with expertise in transportation. In addition, Utah State University is leading an effort to establish an advanced transportation research institution. We believe that UDOT should encourage the in-state universities to continue to expand their capabilities in transportation.

UDOT's current research and development engineer is a strong supporter of using local universities for research projects which require a special expertise. For the past three years, the R & D Section has steadily increased the number of research contracts to local university professors. In fact, two of the R & D Section's most successful research projects in 1991 were those conducted by local university professors. These were a study of construction cost overruns by four BYU professors and a study of roadside revegetation by a professor from Weber State University.

The UDOT research and development engineer said that he would increase the number of research projects performed by the universities if they had specialists in the fields most important to the department. He said there are a number of local professors who have expertise in planning, administration, and traffic engineering but these are not areas in which UDOT has the greatest need for research. He said the department needs to increase its research in materials, construction and maintenance because these are the areas in which the department has the greatest expense. However, the local civil engineering programs are quite weak in these areas.

Several local universities have recently formed a cooperative research institute called the Advanced Center for Transportation Studies (ACTS) which they hope will improve their ability to meet UDOT's research and educational needs. Under the administrative direction of Utah State University, this consortium of universities intends to help UDOT employees earn master's and Ph.D. degrees in transportation. The ACTS also plans to draw on the expertise from several civil engineering departments to conduct advanced research for UDOT.

The aim of the ACTS is to do what has already been accomplished by the Utah Water Research Laboratory located on the USU campus: to establish a nationally recognized research center which can attract expert talent from all over the country. As the Water Research Lab, the ACTS would receive much of its funding from large federal research contracts. The center would also provide UDOT with the same level of advanced research and education in transportation which the USU Water Research Lab currently provides in water studies to other state agencies.

UDOT would certainly benefit from an advanced research institution in transportation similar to the USU Water Research Lab. Other state agencies which have had research done by the Water Research Lab tell us that having a local institution of this caliber is of tremendous benefit. They say that the lab provides them access to some of the best water experts in the country and that it conducts research at a relatively low cost because much of the field testing and laboratory work is performed by graduate students. However, employees from one state agency said that one research project conducted by the Water Research Lab failed to address their agency's problem. They warned that the contracting state agency needs to keep actively involved in any university research in order to make sure the researchers stay on track.

The ACTS has a long way to go before it can provide the same level of expertise which is now offered by the USU Water Research Lab. The department can encourage this effort by supporting cooperative research and educational efforts between the department the universities. The department should encourage its employees to pursue advanced degrees in transportation and university programs should be given access to the UDOT materials lab whenever it would not interfere with department tests. The department should also continue to contract out its research to university experts whenever there are no in-house experts who can perform the work. Of course, if the department cannot find local university faculty with the required expertise, it should not hesitate to offer its research to experts in local industry or at universities in other states.

A Cooperative Agreement Would Provide Easier Access to University Research Services

Before UDOT expands its use of university research, it needs to improve the process used to issue outside research contracts. Many states have found that by forming cooperative research agreements with their local universities they are able to expedite the process of assigning projects to university researchers. Such agreements do not violate purchasing rules because research expertise is not a service which is widely available and because the agreements are made between two state institutions.

UDOT, on the other hand, uses the same procedures for its outside research contracts as it does for any other outside engineering contract. This approach complicates the process of working with universities because it requires researchers to respond to a request for proposals and that UDOT make a formal review of proposals. This formal approach sometimes prevents the communication needed for a productive, problem solving effort.

The formal contracting procedure also makes it difficult for university professors to provide timely research. There was one case in which prolonged contract procedures have prevented the professors from beginning their research in the summer months when they and their graduates students had planned to devote their full time to the project. Because the contract could not be finalized until midsummer, university researchers were forced to delay the start of the project and had to finish the research during the school year when they could not devote their full time to the effort.

The National Highway Institute (NHI) warns against managing research contracts with the same strict controls as standard engineering contracts. They say that departments of transportation which have a cooperative agreement with local universities have a much smoother and more productive relationship with their university researchers than do agencies which have a rigid contractual relationship. According to a recent NHI publication:

Many states have well thought-out project management control with very good performance and financial orientations. ...Research within such an agency can be subject to inappropriate restrictions simply because the agency is accustomed to operating in an overly controlled environment.

Among other things, the NHI recommends that state transportation agencies have "basic ordering agreements" with local universities for outside research. Washington's Department of Transportation is an example of a state agency which has created a productive relationship with its university researchers through a cooperative agreement. Research projects initiated by the department of transportation are submitted through a "task order" to a separate state research agency, the Washington State Transportation Center. The Center then assembles a team of faculty researchers from the two state universities. The use of a task order allows them to begin conducting research several months sooner than they would if they had to issue requests for proposal. The Advanced Center for Transportation Studies being formed by several universities in Utah could act as a central clearing house for transportation research in a manner similar to the Washington State Transportation Center.

Budget and Personnel Limitations Should Dictate the Staffing of Research Assignments

In the past, managers of the UDOT research program have not shown a willingness to turn down research requests which were beyond the capabilities of their staff. While they should be praised for trying to meet the needs of the department, in the future, the abilities of the research staff need to be considered before management agrees to accept a research project. The R & D Section needs to limit its in-house research to those activities for which staff are qualified. These activities include testing new products, implementing other state's research, and small studies aimed at improving the department's construction practices. These research activities may be of equal if not greater importance to the department as the more specialized research assignments. Federal highway planning and research funds (HPR), which are a major source of funding for the research budget, can be used for many of these activities.

The number of highly specialized research assignments must be limited to the amount of funds which have been designated for outside research contracts. The department currently budgets \$100,000 each year for university research. Priorities will have to be set to guide how these funds will be used. Once the budget for outside research contracts has been allocated, the R & D Section will have to deny further requests for highly specialized research projects.

If federal funding for research is increased, as some predict, the department will have to decide how to allocate the funds between university and in-house research. The department should allocate any increase in HPR funding according to its need for increased university research or for more in-house research. If the R & D Section needs additional implementation research, new product testing, and other activities appropriate for in-house staff, the in-house research budget should be increased. Conversely, if the department anticipates a greater need for highly specialized research, the budget for outside research contracts should be increased.

Recommendations:

1. We recommend that the department make sure that each research project is conducted by researchers with experience and expertise in the field being studied.
2. We recommend that UDOT find outside experts from universities or consulting firms for its highly specialized research projects that require more expertise than can be provided by UDOT research staff.
3. We recommend that UDOT research staff perform research assignments for which their training is suited such as implementing other's research, evaluating department construction practices, and testing new products.
4. We recommend that UDOT encourage local universities to expand their research and educational capabilities in fields related to transportation.
5. We recommend that UDOT continue to encourage the creation of an Advanced Center for Transportation Studies by supporting cooperative educational programs, by providing access to its materials laboratory, and by contracting out research to local universities.
6. We recommend that UDOT and local universities formulate a cooperative research agreement to facilitate the process of assigning research projects to university faculty.

Chapter III

RESEARCH PROJECTS CAN BE BETTER MANAGED

A number of changes are needed in the way the R & D Section manages its research projects. We are concerned that most projects are being completed two years behind schedule and that some do not address problems of significant importance to the department. Also, some projects are unnecessary because they duplicate research being conducted by larger states. For this reason, the department's research program should focus on problems unique to Utah and use the results of other state's research when applicable. Finally, the R & D Section needs to identify more clearly the objectives for any research project it offers to outside research contractors.

Much of the information in this chapter requires the department to reevaluate the future of its R & D Section. Such an evaluation is needed because Utah has limited research funds and a small research unit, which is staffed with inexperienced researchers. Compared to transportation research institutions in other states, UDOT does not have the ability to conduct studies with a nationwide application. Federal and state research programs collectively spend over \$147 million annually on transportation research. Only a half million dollars of that comes to UDOT's research and new product development program. A strategy used by other states the size of Utah, and one which UDOT should consider, is to focus on implementing the developments of other larger institutions. Any original research which is conducted by UDOT would be directed toward subjects which are unique to local conditions. Adopting such a strategy would require changing the staffing of the R & D Section and increasing the research conducted by outside consultants.

Research Projects Are Generally Completed Behind Schedule

The R & D Section's last five major research projects were completed, on average, 23 months behind schedule. Such a delay is significant for projects which are supposed to take only two or three years to complete. We believe the untimely completion of its research projects makes it very difficult for the R & D Section to meet the needs of the rest of the department. Other department entities are less likely to request a research project if they have to wait four or five years for the results. In addition, these delays are also a concern of the Federal Highway Administration (FHWA), a major funding source for the department's research program.

There are many causes for the lengthy delays in research projects, only some of which the R & D Section can control. For example, in the previous chapter we report that the R & D Section has a high turnover among its research engineers. Most projects have been disrupted because the principal investigator left the division before the project was completed. We believe

turnover among the research engineers is a major factor causing delays in research projects. This concern was discussed in chapter II. Another cause of delays was the temporary reduction in Highway Planning and Research Funds in 1987. This required that two projects be put on hold for nine months.

Although many of the causes for delays in research projects can not be controlled by the R & D Section, there are a number of things the department can do to reduce delays. In progress reports to the FHWA, the most common reason cited for a lack of progress on research projects has been that staff had "other priorities." For this reason, it appears that delays can be reduced by requiring each researcher to focus on just a few assignments at one time, by reducing the number of underutilized staff positions, and by increasing the amount of research conducted by outside consultants.

Project Completion Averages 23 Months Behind Schedule

The average completion date of the last five research projects performed by UDOT's research staff was 23 months behind schedule. As Figure III shows, several projects which were supposed to take only two or three years to complete actually took four or five years. One project, a study of concrete joint sealants, was never completed.

Insert Figure III

The FHWA's local Planning and Research Engineer has expressed concern about the ability of the research section to make timely progress on its federally funded research projects. At the conclusion of a 1988 review of the management and personnel practices of the research section, the local FHWA Planning and Research Engineer reported that "the extensive periods of time required to complete studies" is one reason why "UDOT is not making the most effective and efficient use of the limited amount of Highway Planning and Research funds available for research studies."

In July 1990 FHWA placed a moratorium on federal funding for new research projects because the R & D Section was failing to make progress on existing projects. At the time UDOT had just finished one study 36 months behind schedule and had three other active projects which were well behind schedule. In a letter dated July 11, 1990, the local FHWA Planning and Research Engineer pointed out that for the previous five quarters UDOT had reported no progress in its research of concrete joint sealants. He then stated that:

Due to our concern over the lack of progress on this study and the fact that one other study was recently granted a time extension and a third study is significantly behind schedule, it is our intent not to approve any additional HPR research studies until more satisfactory progress is shown on the currently approved studies.

During fiscal year 1991, UDOT dropped its study of concrete joint sealants and was able to complete its study of the single point urban interchange. Because UDOT currently has only one active FHWA research project, FHWA will likely consider funding new research project for 1992.

Organizational Changes Can Help Reduce Delays

Substantial changes in the operation and organization of the research section are needed to promote a more timely completion of research projects. These changes include (1) reducing the number of assignments given to each principal investigator, (2) replacing support staff

positions with researchers, and (3) increasing the use of university research.

"Other Priorities" Are the Most Common Justification For Delays. By reviewing the R & D Section's quarterly reports to the FHWA, we determined that the most frequent reason given for the lack of progress on research projects was that "research and development personnel were involved with other priorities." We observed that each research engineer generally has several major research assignments underway at once. In addition, staff are often asked to take on special research assignments beyond their ongoing research projects. These unscheduled research assignments are usually of an urgent nature and are given priority over the major research projects. As a result, research staff often fall behind schedule on the major projects sponsored by FHWA.

Support Staff Are Not Effectively Used. While the research engineers seem to have many assignments underway at once, there are several support staff who do not contribute enough toward the completion of research projects. The R & D Section has a full-time statistician, a computer programmer, and a research librarian which are not being effectively used by the research and development unit. While at one time the R & D Section may have needed full-time support in each of these areas, they now spend much of their time performing routine tasks associated with research projects or performing special assignments for other units within the department. We also observed that some time is spent unproductively.

Because these employees have many years with the department and are being paid at the high end of their salary range, it is quite costly to have them performing routine tasks instead of the technical support functions for which they were hired. UDOT should find other positions within the department in which these employees can be more effective. Reassigning these employees may free up enough funds to increase the number of in-house researchers or the amount of outside research contracts.

A University-based Research Program May Reduce Delays. The local FHWA Planning and Research Engineer suggested that one way the department could use its staff more effectively and avoid long delays in the completion of research would be to conduct an "out-of-house research program." In a 1988 review of the management and personnel of the R & D Section, FHWA Planning and Research Engineer reported that an ineffective use of staff was contributing to delays in research projects. One of several solutions he proposed was that UDOT consider moving toward an "out-of-house research program," in which research staff would function primarily as study managers of research projects conducted by outside experts. The report states that:

If UDOT is to retain a limited research staff, as presently exists, perhaps a more productive use of that staff would be to use them as research study managers or coordinators. The actual research studies would be conducted by qualified specialists at universities or consultant firms. The coordinators would be responsible for monitoring the studies, establishing and operating advisory panels, and ensuring that the objectives of the research proposals are accomplished.

Of course, if not held to a strict schedule, university researchers can be just as slow to complete their research as the UDOT research staff. However, a well managed out-of-house research program would help the department continue to conduct several research projects at once and complete them on time.

The Washington Department of Transportation is a good example of a state transportation agency that runs an effective out-of-house research program. With approximately the same number of research staff, Washington is able to operate a university-based research program which is roughly three times the size of UDOT's. The director of Washington's Research Section told us that it is essential that such a program be staffed with good project managers who can coordinate the activities of the university researchers with the Transportation Department staff who requested the research. For this reason, the Washington program is staffed by "program specialists" who spend all of their time monitoring the progress of university research and coordinating that effort with the operating entities who requested the research. Washington's research director stressed that the program specialists need not be engineers, only that they be good researchers who understand the department's needs and can be effective coordinators of university research work. He also said that his research coordinators are senior level employees whose status is a level above project design engineers or something comparable to UDOT's research coordinating engineer position.

The ability of UDOT to pursue this option is limited by the amount of funds it has to spend on research and the relatively few outside experts available to conduct the research. Other states which rely on their universities for research services tend to have more funds to devote to transportation research and strong institutes of transportation research within their state university systems. For this reason, UDOT may not be able to take advantage of this option until local universities increase faculty in fields relating to transportation.

Research Projects Should Focus On Department Needs

Some of the subjects being studied by the R & D Section do not address problems of significant importance to the department. One reason is that most suggestions for research projects come from researchers, not from the department's operating entities. In addition, the committee that decides which research projects are to be conducted is made up mainly of researchers and does not include enough representatives of the department's operating entities. So they can be more responsive to department needs, the R & D Section should rely less on the research community and solicit more proposals from the department as a whole. In addition, voting membership on the committee that selects research projects should be limited to regular department staff and not include those who will conduct the research.

Some Research Proposals Are Inappropriate For UDOT

Several of the research projects proposed by university faculty and UDOT research staff have been criticized by UDOT division and section heads and FHWA officials as being inappropriate for UDOT. For example, researchers have proposed studies on robotics for highway construction sites, intelligent vehicle highway systems, the potential for an inland waterway in Utah, the definition of a good road, video-based work zone traffic information systems, and employee morale. Two of these research proposals have been approved for funding and one is currently underway.

Several officials from UDOT and FHWA have pointed out that these proposals show that the researchers who proposed them have a poor understanding of the needs of the department. Some are also concerned that studies of emerging technologies, such as robotics and intelligent vehicle highways systems, are not realistic considering UDOT's small research budget and the fact that these subjects are already being studied by other state and federal research programs. Instead, many feel that UDOT should wait for other states to develop these technologies so that UDOT can later implement them without bearing the cost of development.

We are also concerned that the R & D Section decides which research projects it will conduct without asking the appropriate department units whether they think the research will be beneficial. For example, one of the managers of the UDOT research program proposed a study of "Utah's Potential For an Inland Waterway System" and another of "Why Are There Good Roads" without asking the relevant department units whether they felt the research would be of value to them. In addition, one university professor recently proposed a study of the effects flowing water has on bridge piers and abutments (bridge scour). Apparently he never asked the department whether the such a study was needed. If he had, he would have learned that the R&D Section was already participating in a federal study of bridge scour.

Officials from UDOT and FHWA have also expressed concern that university faculty tend to submit proposals which are directed at their own interests and not necessarily those of the department. They point out that in the past, university faculty have submitted proposals for research they wanted to conduct for their own professional development. Other university proposals were for subjects which graduate students hoped to use for their master's or doctoral theses. In each case, those proposing the study did so with the expectation that he or she would be the one to whom the department would award the research contract.

The universities can provide the department with valuable expertise and novel approaches to department problems and their input should be encouraged. However, if university professors wish to submit proposals for a research projects, they should be required to consult the agencies who will be most effected by the research to make sure the research is actually needed or isn't already underway.

Department's Operating Entities Should Have Greater Input

One way to make sure that the research program is focused on solving the department's problems is to increase the number of research proposals from the department's various operating entities. In the past most research proposals have come from what might be called the research community - the department's in-house research staff, representatives from local universities and others who hope to receive department funding for their research. During fiscal year 1991 only 4 out of 21 research proposals came from the department's operating entities. One other was proposed by an FHWA official. The rest came from UDOT research staff, university faculty, or others interested in conducting transportation research. In all but a few cases the researchers did not ask the affected UDOT division whether the research was needed.

A research project should have the support of the affected department agency because it is that agency which will eventually have to implement the results. UDOT research staff have complained that several of their research projects have not been implemented. However, their failure to implement the results may be due to a disagreement by the affected agency with the research results. For example, some maintenance crews have not been using the heat lance to seal asphalt cracks as recommended by a past research project. In order to make the maintenance crews comply, UDOT research staff have proposed that the UDOT standards and review section make a change in department policy which would force them to adopt the use of the heat lance. However, rather than trying to enforce their research recommendations, the research unit needs to do more to understand the needs of the UDOT units who are supposed to benefit from the research. In the case of the heat lance, researchers failed to address the maintenance crew's dislike for the heat lance because it exposes them to high temperatures and fumes. Had the research staff focused more on meeting the needs of this unit rather than on imposing a new technique, they might have had greater success in having their recommendations implemented.

The National Cooperative Highway Research Program (NCHRP) suggests that the operating entities of the department should be the main source of guidance for a state transportation research program. At the November 1990 conference of the National Highway Institute the NCHRP pointed out that the "Development of successful research programs... requires that those elements of the departments that research is intended to serve identify their research needs." NCHRP also suggested that agency researchers and university faculty may be a good source for research proposals but that they must first make sure that operating staff have agreed with the proposals:

"Researchers themselves are traditionally an important source of research suggestions; however, there is general agreement that their suggestions should be cleared with operational forces before acceptance."

We suggested that the R & D Section make sure that each research proposal was either originated by someone from the affected department unit or that it was at least supported by those who would be most affected by the research.

Research Projects Should Be Selected By Department Operating Staff

Another way to make sure that the research program is guided by needs of the department is to have representatives of the department's various operating units select which research proposals will be funded each year. The Utah Transportation Research Advisory Council (UTRAC), which prioritizes research proposals, is mainly made up of researchers. UTRAC currently consists of four faculty members from local universities, three employees of the UDOT Materials and Research Division, the federal planning and research engineer, but only four representatives of the department's operating entities.

The university professors and the UDOT research staff are not in the position to represent the department's needs on the UTRAC committee. Our review of the balloting indicates that UDOT research staff and university faculty tend to vote for projects which they proposed themselves or which they would like to perform. During the committee's budget session we also noticed certain university researchers on the committee arguing for an increase in funding for projects which they expected to perform. Because their professional interests depend on the outcome of UTRAC voting, university faculty and UDOT research staff are not in the position to give an unbiased evaluation of what research is of most value to the department.

In most states, research projects are selected by representatives from the department's operating entities. After conducting a study of 43 state highway research programs, NCHRP reported that the selection of research projects in most states is done by a committee consisting of "middle-management functional levels and higher levels of the departments." NCHRP suggested that the selection committee "may also include individuals of equivalent levels from cooperative state universities, the FHWA, and other interested groups" but that "voting rights are usually reserved for department representatives."

In order to assure that the most useful research projects are selected, the UTRAC committee should expand representation of "middle-management level and higher" and limit voting to those who represent the department's various operating units. Increasing the representation of regular operating entities on UTRAC should help the research program focus more on the needs of the department and the state highway system.

UDOT Should Do More to Take Advantage of Other States' Research Results

The UDOT R & D Section needs to do more to take advantage of what has been accomplished by other state research programs. Using the results of research performed by another state or by a federal research institution is a far more cost effective way to solve a problem than conducting original research. Instead, UDOT research staff and university professors tend to want to research the latest technologies, even though several other states are already conducting similar research. Because the department has only a limited amount of

research funds, it needs to consider whether it has the resources to develop major new technologies. If it does not, the department should focus its research on subjects unique to Utah and on the implementation of other states' research results. At the very least, UDOT needs to conduct a thorough literature search before deciding which research projects to conduct. The results of such a search would allow the Utah Research Advisory Council to decide whether the department should pursue original research or implement the results of another state's research.

Department Should Consider a Strategy of Implementing Other States' Research Results

Other states have already conducted research into some of the same subjects which have either been proposed or are now being conducted by the UDOT research unit. For example, in Figure I of Chapter II we show that other states have conducted similar research to four out of UDOT's last five major studies. Considering that annual state and federal highway research spending in the U.S. is \$147 Million (FY 1988-89), it is not surprising that most subjects of broad national interest are already being studied by other state research programs. In fact, there are other state and federal research programs are spending many times the amount UDOT might devote to a research study. Larger states are spending anywhere from several hundred thousand to several million on a single research project. Figure IV shows the budgets for the research projects currently being funded by members of the Western Association of State Highway and Transportation Officials. It shows that compared to other states in the region, UDOT has a relatively modest research program with fewer projects and fewer funds devoted to each project.

Insert Figure IV

Because of its relative small size, we believe that the department needs to reconsider the scope of the research projects it wants to pursue. A strategy which UDOT should consider is to let other states develop the technologies of broad national interest and to focus the UDOT program on research which is unique to Utah. In any case, before the R & D Section decides to conduct research of general interest, it needs to make sure that other states with much larger research programs are not already planning to conduct similar research.

Some UDOT research staff and university professors have expressed a great deal of interest in conducting research into some of the same advanced technologies which are already being developed by other, larger research institutions. For the most part, these are technologies which require a great deal of technical expertise and millions of dollars in funding to fully develop. For example, local university researchers and UDOT research staff have expressed an interest in conducting research into "Intelligent Vehicle Highway Systems" (IVHS), a subject which has recently received a great deal of attention nationwide. In fact, as shown in Figure V, there are already several multimillion dollar studies on the subject. One private consulting firm estimates that the total cost to develop an integrated IVHS system would be \$1.4 billion. It is unlikely that UDOT, which spends \$63,000 for an average research project, could make a significant contribution to IVHS research.

Figure V

Rather than trying to compete with other larger research programs in the development of IVHS and other expensive new technologies, the department should consider postponing its involvement until other states and the federal government have fully developed and tested them . In the mean time, UDOT should focus on implementing other technologies which have already been developed. This is a strategy which has already been proposed by the FHWA's local planning and research engineer. In his December 1988 report of the "Management and Staffing of the UDOT Research Program," he suggested that UDOT consider an "In-house Research Implementation and Technology Transfer Program." Specifically, the report states:

Another option, if UDOT is to retain a limited staff, would be to solve problems by using the findings of already completed research. In essence the staff would concentrate on the implementation of research studies completed by other agencies and the transfer of proven technologies. New research efforts would not be undertaken by the staff.

UDOT research staff have already proven how effective an implementation strategy can be. Two UDOT studies titled "Load Restrictions During the Spring Thaw" and "UDOT Selection Criteria for Guardrail" were projects which solved problems in Utah by drawing on the results of research done in other states. The UDOT R & D Section should consider expanding this kind of activity and focusing less on conducting original research on subjects of national interest. As we pointed out in the previous chapter, implementing research done elsewhere is an activity for which the current UDOT research staff are well suited.

Complete Literature Search Is Needed Before New Research Projects Are Selected

Several members of the Utah Transportation Research Advisory Council complained to use that they were asked to select research projects for its 1992 work program without knowing whether similar research had already been done by other state or federal agencies. This information should have been obtained from the Transportation Research Information Service

(TRIS), which provides current listings of published research reports in the field of transportation. However, a complete listing of previous studies was provided for only 3 of the 21 research proposals considered for fiscal year 1992.

The research staff say they do not have enough time to conduct literature searches before UTRAC's spring meeting when new research projects are selected. The committee is thus left to choose among research proposals without knowing whether research has been conducted by another state. The research staff say they prefer to conduct a literature search after they begin a research assignment. By delaying the search, however, staff may be several months into a project before they know what other states have done. By then they may have spent a significant portion of the budget preparing a work plan, acquiring laboratory equipment, and hiring consultants before they know whether the problem has been solved by another state. If the department is to use its small research budget effectively, it needs to find out the results of other states' research before deciding to conduct original research.

Scope and Objectives of Research Projects Are Not Well Defined

The department's research staff do not clearly explain the scope and objectives of their outside research contracts. We found several request for proposals which give only a vague description of the problem to be researched and state that it is up to the applicant to define the scope of the research project. Several outside contractors have complained that this approach makes it very difficult for them to know how they can meet the needs of the department.

The UDOT research coordinating engineer told us that he intentionally leaves the scope of research projects undefined. He said that true research is a process of inquiry and exploration and that putting limits on the scope of a research project limits the ability of the researcher to consider new solutions to a problem. However, this approach does not allow the department to give proper supervision to the work of outside researchers and it is not consistent with state purchasing practices. The research engineers from several other states' departments of transportation have told us that it is essential that outside researchers be given clear directions if their work is going to be of benefit to the state.

Researchers Were Asked to Decide the Scope of Research Projects

Several university professors conducting research for the department have told us that the department does not clearly explain the objectives for outside research projects or the problem the research is supposed to address. The statement of the scope and objectives for the research project titled "Why Are There Good Roads?" is typical. The request for proposal provides a vague description of the problem the research is supposed to solve and then suggests that research should be directed at answering the following question: "Does the road satisfy its intended purpose in terms of

1) function, 2) safety, 3) environment, 4) aesthetics, and 5) economics?" It then indicates that the contractors are supposed to identify the scope of the research themselves:

Inasmuch, as the gathering of information and the application of engineering, and other related disciplines can be subject to a myriad of approaches, the CONSULTANT is to determine the detailed scope of the study. ...some items which might be appropriate:

- Cost effectiveness
- Perceptions by road-users
- Safety
- Efficiency
- High serviceability index
- Good riding qualities
- Attractive roadside treatment
- Aesthetic amenities
- Longevity
- Capacity
- Functionality
- Maintainability

The request for proposal then identifies the objectives of the research as: "to define or characterize good roads" and "to explore the causal relationships among roadway system components and the characterization of roads as 'good'."

The university professors who were awarded this contract thought they were supposed to help the department develop new ways to evaluate road conditions and come up with a whole range of attributes that could be used to define a "good road." Only after they were awarded the contract were researchers told that the study was supposed to focus on the physical characteristics of good and bad sections of roadway. They complained that this required them to alter their work plan drastically and change the membership of the research team. The university researchers also complained that the \$50,000 which they have been granted for this research is not sufficient to cover the cost of the expanded scope of this project.

The research coordinating engineer indicated that he broadly defines the research scope so the research team is free to develop its approach to the problem as it proceeds with its research. He said "We don't know where we are going. We want some bright people to explore this question and see where it leads us. This to me is research. If I were to put down the exact scope it would destroy the study." He also said that true research is a process of inquiry and that if the scope and objectives are limited, the ability of the researchers to develop the subject is likewise limited. The research coordinating engineer was not concerned that the lack of clear research objectives made it difficult for researchers to know how to allocate the project budget. He indicated that they would see what the researchers could accomplish with \$50,000 and then determine whether to fund additional research.

Research Objectives Need to be Better Defined

Providing only a vague problem statement and a general description of the research scope and objectives is not consistent with state purchasing practices and does not give UDOT proper control the work of outside researchers. According to the Director of State Purchasing, unless a "deliverable" is clearly specified in UDOT research contracts there is no way of knowing whether the contractor has provided the service. He suggested that unless UDOT can clearly identify what it is the researchers should provide, UDOT should not use a consulting contract. If it wants researchers to remain flexible, the Director of State Purchasing suggested that UDOT should give the researchers a research grant that does not require specific results.

The research engineers from other states also told us that it important to clearly identify the scope and objectives of an outside research contract. The comments by the Director of Research from the Arizona Department of Transportation are typical. According to him, the success of a study conducted by outside experts largely depends on how well researchers are kept informed of the needs of the "client" state agency. He said that university faculty are notorious for being too theoretical in their approach, and that if they are not given adequate direction that they will tend to produce a report which is of little practical use to those who requested the study.

The National Cooperative Highway Research Program also suggests that state transportation agencies clearly define the scope and objectives of research projects. They have indicated that:

►As a minimum, a research problem statement should include a clear description of the problem, research objectives and tasks, the expected research product, means of implementation, probable benefits, available background information, cost and time requirements, and available research resources. Ordinarily, information of the nature required must be supplied by both the proposer and the research organization.

►Problem-solving research projects, on which highway and transportation departments' research programs concentrate, require direction and control for satisfactory performance. A program of routine monitoring is necessary to ensure that projects remain on track, are completed efficiently and effectively, and that results are utilized.

In the future, UDOT must focus its research on clearly defined problems. Research projects conducted by outside consultants must have clearly stated scope and objectives which are aimed at solving the research problem statement. Research staff should also maintain ongoing contact with outside researchers to make sure they continue to focus their efforts on the research objectives.

Recommendations:

1. ▶We recommend that the R & D Section reduce the time it takes to complete major research projects by (1) reducing the number of assignments given to each principal investigator, (2) replacing underused staff positions with additional researchers, and/or (3) increasing outside research contracts.
2. ▶We recommend that the R & D Section solicit more research proposals from the department's operating entities.
3. ▶We recommend that the department not consider any research proposals submitted by outside researchers and UDOT research staff unless they have a cosponsor from within the operating entity effected by the research.
4. ▶We recommend that voting rights on the UTRAC committee be reserved for representatives of the department's operating entities, not researchers.
5. ▶We recommend that the R & D Section avoid conducting original research into subjects of national interest and focus instead on problems unique to Utah, implementing the research results of other states as applicable.
6. ▶We recommend that before a research proposal is considered by the Utah Transportation Research Advisory Council, that a complete summary be provided of similar studies conducted by other research institutions.
7. ▶We recommend that the scope and objectives of outside research projects be clearly defined.

Chapter IV

SOME NEW PRODUCTS STILL BYPASS TESTING PROCEDURES

Two years ago, UDOT committed itself to greater compliance with its new product testing procedures after the failure of a new concrete product on interstate highway 15. The Department's response to our legislative audit report entitled «)9»The Department of Transportation's I-15 Syn Crete Resurfacing Project«):», was that "certainly the Department must and will be more cautious and methodical in further tests of Syn Crete IV and any other product in the future..." and, "Our intent is to assure no future new product testing will bypass appropriate intermediate steps." While our 1990 audit focused specifically on Syn Crete, this audit addressed the testing of new products in general. Our review shows that some new products are still not being given the appropriate tests prior to their use by local transportation districts.

This chapter discusses three concerns with the new products testing program: (1) the lack of valid testing and documentation of tests of new products by district staff, (2) the fact that some district staff did not understand the testing policies and procedures and failed to refer new products to the Research and Development Section, and finally, (3) the lack of a clear policy defining what a new product is and the circumstances in which modifications to existing products warrant new testing.

It should be noted that none of the new products discussed in this report were used on large projects comparable to the 1989 Syn Crete project. In addition, we found no significant loss of funds due to UDOT's failure to comply with the testing procedures. We are more concerned with the potential for loss if a new product was relied upon without sufficient testing and documentation to justify its use. Many of the new products reported in this chapter were in use before the Syn Crete project and have continued to be used or tested in the districts without referral to the R & D Section. However, some of the new products were put into use since Syn Crete and should have been referred to the R & D Section.

The information in this chapter has led us to conclude that the department needs to gain tighter control over the quality of materials used in the construction and maintenance of roads. This can be done by requiring compliance with the department policies which give the Division of Materials and Research full responsibility for all new product testing. We also recommend that the Division of Materials and Research improve its control over the use of construction and maintenance products by maintaining a formal list of products which have been approved for use by the department.

New Products Have Not Been Properly Screened

Materials engineers from several districts told us of a variety of new products which had been used in construction and maintenance projects without first going through the department's formal new product testing process. We were unable to determine the extent to which untested products are being used because we interviewed only a few staff and did not have time to conduct a thorough review of department construction records. The absence of centrally controlled records regarding the use of new products also made it difficult for us to identify the total number of untested new products in use. Although some district engineers said that test data had been collected, they were rarely able to locate those records or tell us who might be able to provide them for us.

During our interviews, we noticed that most district staff did not have a very good understanding of the department's new product testing program. According to department policies, the R & D Section's new product development engineer is responsible for new product testing and development for the entire department. While the actual new product tests may be conducted at the district level, they must be overseen and coordinated by the R & D Section. In addition, many district staff did not realize that department policies require them to refer new product vendors to the Development Engineer within the R & D Section and that contractors should not be allowed to install untested products within their districts without approval and coordination from the R & D Section.

The new product testing program is designed to assure that each product used in highway construction and maintenance projects conforms to the department's performance standards and that vendor claims regarding the product are accurate. When conducted properly, the new product tests should identify any problems with new products either in the laboratory or on small test patches. Our review did not identify any significant loss of funds due to the use of untested product. However, unless new product testing procedures are strictly complied with, the department is at risk of having products fail during construction and maintenance projects.

New Products Used In Districts But Not Referred to R & D

Materials and maintenance engineers from three maintenance districts, the Division of Maintenance and the Division of Materials and Research identified seven products (shown in figure VI) which had not gone through the formal testing process but had been recently used in the districts. Most of these engineers said that they had first learned of the products from vendors or from local contractors who hoped to try out a new product on a maintenance project. We found only a few instances in which the products did not perform adequately and in most cases in which a product did fail, the product vendor covered the cost to replace the product. Even though documentation is not available, some engineers feel that some of the new products

are performing quite well and may even be superior to other commonly used products.

When we interviewed department staff regarding their use of new products we asked (1) whether laboratory tests had been conducted before the field tests, (2) whether small test patches had been applied before the products were used on a regular maintenance project and (3) whether records had been kept of product formulation, the technique used to install the product, the location of the test site, and other important factors relating to product performance. In each case the engineer answered no. For the most part, they simply tried out a new product on a construction or maintenance project without conducting the normal laboratory tests, test patches and report writing which are required by the department's new product testing procedures. The following table identifies seven projects which were not referred to the R & D section.

FIGURE VI

In addition to not referring the new products to the R & D section, the engineers at the district level generally maintain poor written records of new product performance. Consequently, if the product does not perform well or fails, there is no coordination between districts or department headquarters. As a result, the vendor can continue to introduce the product in other districts. We even found instances in which the engineer thought his district had previously tested a new product but had no record of the product's performance. As a result, he did not know whether to retest or simply use the product on a project.

Two typical examples, cited below, are an asphalt repair product called Kingpatch. and a concrete patching material called Regset.

«)3» Kingpatch Has Been Tried By Districts 2 and 6.«)1» Kingpatch, a product made from tar sands, is used as a joint sealer for large cracks and for patching holes in asphalt pavements. A materials engineer from District 6 told us he allowed a contractor to use Kingpatch to repair longitudinal cracks on a maintenance project on State Road 40. A materials engineer said that

after the contractor showed him a brochure about the product, that he decided it looked like a good product and agreed to let the contractor use it. He said that it did not occur to him to contact the R & D Section and ask whether the product had been tested or whether another district had had success with the product.

The District 2 materials engineer said that he has used Kingpatch to repair some cracks on a freeway off ramp on I-15 and on the shoulder of the road on the I-15 project in which Syn Crete was installed. During our audit, the maintenance division ordered \$19,000 of Kingpatch to be used by UDOT maintenance crews on a crack sealing project in Summit County. When the UDOT purchasing unit received the purchase request they asked the R & D Section whether Kingpatch was an approved product. When they learned that the product had not been tested by the R & D Section, the purchasing unit denied the purchase request. The Research and Development Engineer then told the materials engineer that he did not feel comfortable using Kingpatch on a maintenance project until the product had undergone the required tests for new products. As a result, the R & D Section, the UDOT Maintenance Division and District 2 materials engineer have recently agreed to begin formal tests of Kingpatch. These tests will be conducted by the District 2 materials engineer who has been most interested in the use of this product.

Regset Has Been Used in Districts 1 and 5. Regset, a concrete patching material, has been used by the department for several years. The product was first successfully used by the maintenance crews at Hill Air Force Base. District 1 materials engineers then used it in a concrete repair project for full slab replacement and found it to be quite effective. More recently District 5 used the product to repair concrete patches on two maintenance projects in District 5. These applications were not very successful, however. According to the UDOT development engineer, the Regset failed at a rate of nearly 70% on the District 5 projects. Only recently has the R & D Section conducted its own tests of Regset on a demonstration project of a variety of concrete repair products on I-15. They concluded that Regset is not an effective concrete patching product and are now recommending that it be used only as a full depth repair product.

UDOT Has Formal Procedures for Testing New Products

The fact that many district materials engineers did not even know what the department's policies are regarding the use of new products suggests that more needs to be done to make sure that new product testing procedures are enforced.

UDOT has established formal procedures to assure new products are fully tested before they are installed on state roads. They require that records be kept of the product formulation and of the test conditions so that if the product performs well the department can continue to get the same results. For products which do not perform adequately, the formal tests allow the department to prove to vendors that their products have been given a fair evaluation. Documentation should be maintained to ensure that failed products are not reintroduced in the future.

Department Procedures Require Testing for All New Products. «)1» UDOT procedures give the Division of Materials and Research the responsibility for accepting and screening all new products or processes for the entire department. This process is overseen by the development engineer of the R & D Section within that division. It is the responsibility of the development engineer to make sure that before a product is considered for testing it has been fully developed by the vendor. According to the research and development procedures manual, "The Department will not engage in the evaluation of any new product unless it is adequately developed, tested, and marketable." When the development engineer certifies that a product has been fully developed and the department has a need for the product, he may recommend that it be taken through the department's formal 3-year testing program.

The reason for a 3-year evaluation period is to allow the product to be tested in increasingly larger test sections. The first section is usually installed by the vendor on a small section of road and the product is exposed to seasonal effects. A second, larger test is then conducted the following year and the product is usually installed by maintenance or contract crews. By the time a third test is completed, the department has three test sites from one to three years old which allows them to evaluate the durability of the product over time.

Many UDOT engineers claim they conduct new product testing on their own. However, UDOT has established clear procedures which state that all new products must be introduced to the development engineer first and then put through a three-year evaluation period. This not only allows the development engineer to provide oversight of all new product testing but also allows him to coordinate the activities of the districts so that duplication of effort does not occur. New product testing must be conducted under the oversight of the development engineer.

Records Must Be Kept for New Product Tests To Be Useful. Accurate records must be kept of each test so that if a product performs well the department can continue to get the same results. Often a slight alteration in the mix design, the type of aggregate used, and even weather conditions can have a dramatic effect on the performance of a product. In a few instances a new product has been successful at one location but has failed at another. Because there were no records kept of either "test," the department has not had the data it needs to approve general use of the product.

Keeping adequate records of test sites is also necessary to avoid having to repeat tests, as was made evident in a meeting of the pavement markings committee in June 1991. One member of the committee tried to remind the group of a product that had been used several years earlier on I-15. Not a single person in the room could remember the name of the product, how it performed, or what it cost. As a result, these earlier "tests" of the product were essentially a wasted effort.

Another example came from a district materials engineer who told us that he has not been able to find out the information he needs about an epoxy cement which had been used in his district. He said that someone in his district probably has that information but he does not know who that would be. He said that if a new product does not perform satisfactorily the information documenting that product's performance might be located in as many as 3 or 4 locations.

However, he said that without a system of cataloguing that data, there is no way for others to benefit from the results at a later time.

The National Cooperative Highway Research Program (NCHRP) has published a manual entitled *New Product Evaluation Procedures* which identifies the characteristics of an effective new product testing program. It states, "...clearly written and understandable reports must be compiled if full value is to be realized from new-product evaluations; even the most careful and thorough evaluations will not be of much value if not adequately reported."

UDOT district and maintenance engineers have said that writing reports of new product tests are difficult and time consuming, and that they usually have more important things that need to get done. The R & D Section has tried to simplify the report writing process so that district staff need only to fill in the blanks in order to document new product tests. In our opinion, if district staff are not willing to prepare these reports, they should not be permitted to test new products.

A Single New Product Testing Unit Provides Better Coordination. Central oversight of new product testing and development is the best way to assure control over the testing process and elimination of unnecessary test duplication. New product testing is a time-consuming process best handled by one central unit. Individuals regularly approach the department with new products which they claim will solve a variety of highway construction or maintenance problems. However, these inventors may not have adequately developed the product themselves, or the product may not be suitable for large-scale mechanized application. In some cases the vendor may not have sufficient information about his own product to allow testing to be done. In addition, the product may not fill the need of the department or may be too costly. Because each of these factors needs to be considered, centralized control over new product testing is needed.

Central control would also prevent several units from testing a new product at the same time. For example, Kingpatch was once tried simultaneously by District 2, District 6, and by the Maintenance Division. In addition, Regset was tried by District 5 after it had already been used in District 1. The development engineer has also been conducting tests on the product. Had the District 5 engineer contacted the development engineer and learned how to mix the product properly, he may have been able to avoid having 70% of the patches fail on his I-15 maintenance project. Instances have occurred in which department staff have agreed to try a vendor's product without realizing that the development engineer had already been approached by the same vendor and had determined that the product did not work. District staff can avoid this unnecessary effort by referring calls from vendors to the development engineer. The development engineer then can coordinate new product tests conducted by the districts or include the product in tests conducted centrally by the R & D Section.

Formal Testing Assures that Vendors Will Be Treated Fairly. Conducting formal tests of new products also helps the department make sure it is being fair to product vendors. It allows the department to keep vendors informed about the status of new product tests and to provide

them with concrete information regarding how well their product performed. In the past, some vendors have felt that the department has not given their product a fair review because they were not told why their product was rejected. Others have assumed that their products were approved by the department when they were not. The only way the department can be fair to product vendors is to require that department staff not use new products unless formal tests are conducted and adequately documented.

An Approved Products List Is Needed to Control New Products

Some states have found that limiting the use of products to those appearing on an approved products list is a good way to control the use of unproven products. Oregon, for example, has a "qualified products list" which identifies all products which have been fully tested and approved for use by the department. Oregon Department of Transportation staff can use products only from that list and then only for certain authorized applications. Such a list is necessary to control UDOT's use of construction products. It would allow department staff and vendors to know which products they can and cannot use and would also provide information regarding the specifications and allowed uses for each product. Most of the district engineers and division heads with whom we spoke agreed that an approved products list would solve some of the problems that exist in the new products testing area. They feel that districts and other divisions would not be as likely to use untested products if the department had an official, approved products list.

More Test Data Is Needed from Vendors

UDOT research and development staff contend that the use of an approved products list and the formal testing of all new products by the R & D Section cannot occur without adding staff. We believe UDOT may be able to reduce the amount of testing it does and avoid having to add additional staff by requiring more information from product vendors.

Department policies suggest that a great deal of information can be provided by the vendor and other sources to verify claims made about a new product. The department's new product testing procedures indicate that product vendors should be required to submit "independent test data to substantiate his claims." UDOT procedures also require the development engineer to identify other states which may have tested the product and "check with them concerning its worth and performance." The Manual of Instruction used internally by the R & D Section also requires that the vendor provide a great deal of information before the department tests the product. It states the vendor is expected to provide "product description and data sheets, appropriate independent laboratory test data, records of past performance, and other information in support of advantages claimed for the product". According to the NCHRP most states require vendors to provide references of other states which have used the product and independent test results using national ASTM or AASHTO product testing standards.

During both our recent audit and an earlier one of the Syn Crete project, we observed that the development engineer has not collected enough information from the vendors and from other sources before beginning formal tests of a new product. In our legislative audit report on the Syn Crete resurfacing project (#90-03), we reported that the department could have benefited from other states' experience with Syn Crete. Our report states: "Had UDOT contacted California about their use of Syn Crete, more information would have been available which may have prompted more caution." We observed that the department still does not require vendors to provide information from other states and independent test data before it begins its own formal tests.

Changes to Previously Approved Products Are Accepted Without Retesting

There have been a few products which have failed after years of successful use because vendors made modifications which hurt the performance of the product. Often a vendor will try to make "improvements" to a product's formulation only to have the changes cause the product to fail. Two examples are a new pavement marking tape made by 3M Corporation and an asphalt overlay product called Ralumac. In each case, the department conducted the required tests and gradually used the product on increasingly larger projects. When the vendor made changes to the product, it failed. The vendors of both the 3M tape and Ralumac covered the cost of labor and materials to replace the failed products. However, in both cases the department agreed to let the manufacturers replace the failed product with other unproven products.

To a certain extent, this problem has been caused by the lack of a clear policy defining what a new product is and the circumstances in which modifications to existing products warrant new testing. Without a clear policy, the R & D Section and the local transportation districts have had difficulty knowing whether modifications to a commonly used product require that product to be retested. In some cases cited below, slight modifications to an already tested product have caused the product to perform inadequately even though the modified product still met the department's specifications.

We recommend that the Division of Materials and Research be given the authority to decide when a modified product should be tested as a new product. If the Division of Materials and Research observes changes in a product which they feel could affect that product's performance, they should consider it a new product and require that it go through normal new product tests. The department can also protect itself against adverse product modifications by requiring vendors to disclose any alterations to a product's formulation before it is used on a project. Depending on the nature of the product, the department may also need to develop tighter product specifications by identifying the product's exact formulation.

New Version of Pavement Marking Tape Was Not Tested

The department has used several new versions of 3M Corporation's pavement marking tape without having tested them. Department staff assumed that because an early version of the product had been tested, subsequent versions could be used without the tests having to be repeated. However, since the first product was tested, 3M has made substantial changes and has developed a number of new applications for the product. One new version of the 3M tape has experienced a 33% failure rate.

In 1985 the department conducted tests of several different pavement marking tapes on a test site on I-215 near Parley's Canyon. Since that time, UDOT has regularly used the tape to mark lane lines. However, most of the versions of the tape product that UDOT currently uses were developed after that original test. The improved marking tapes, 3M series 350, 380, and N360, have never undergone formal testing procedures to evaluate their performance. It appears that each new version of this tape was assumed to be comparable to the product which was originally tested.

The most recent product, series N360, is different from older tape versions and should be considered a new product for several reasons. First, because series N360 does not have an adhesive attached to its underside as all other versions of the product it must be installed differently. It requires more extensive gluing and rolling. In addition, the N360 tape is made expressly for the purpose of marking cross bars at intersections and for arrows and symbols. 3M's service representative for this region told us that UDOT had never tested the new N360 product and suggested they probably should have.

Because maintenance crews have not understood how the product is to be used, certain versions of pavement marking tape have been applied using the wrong procedures and at inappropriate locations. For this reason, much of the product did not stay attached to the road surface. Department staff estimate that 33 to 36 percent of the series N360 tape has not remained attached. In total, the department has spent about \$80,000 on the N360 series tape. 3M has agreed to cover the cost of replacing the failed N360 product both that already applied and that in storage. However, the new version of the tape product has also not been tested by the department.

Department staff told us they began using pavement marking tape after they were asked to find an alternative to painted road markings which wears off too quickly. They prefer pavement marking tape because it lasts several years and is easier to install. However, pavement marking tape also has its drawbacks. Texas has found that the tape does not maintain its reflectivity. In addition, snow plows tend to scrape off the tape at intersections and other places where it is placed horizontally across the road. Finally, we calculated that the pavement marking tape is significantly more expensive to install than regular paint. Including the cost of equipment and road crews to install the material, it costs \$933 to install the N360 tape on one crosswalk while

paint only costs \$33 per crosswalk. UDOT thinks the higher cost is justified because they expect the tape to last up to 6 years. This, they say, allows them to avoid the cost of repainting each section of roadway once or twice a year and to avoid frequent traffic delays associated with painting. However, there is no evidence that N360 tape lasts long enough to justify its higher cost. Other states we contacted said they are reluctant to use the tape for crosswalks because of its poor reflectivity and its tendency to come off the road. Unlike Utah, the other states have specific guidelines which limit the conditions in which preformed pavement marking tape may be used.

We believe the department may have begun using pavement marking tape in too many different applications before it had been sufficiently tested. Department staff were especially hasty in accepting the N360 series tape, which had many differences from earlier versions. The department has recently created a special committee to evaluate the use of pavement marking tape. We recommend that they conduct formal tests of the various tape products, the procedures used to install it, and the locations for its use. We also recommend that they monitor the performance of each tape product in terms of its reflectivity and durability. It is hoped the efforts of this committee will result in specific guidelines for the use of this product.

Modifications to Ralumac Caused the Product to Fail

The department has had good results from an asphalt overlay product called Ralumac until the vendor tried to improve it. Then it failed on two major maintenance projects. Ralumac is the trade name of a thin asphalt product which is mixed cold and then applied to the surface of an existing asphalt road. The product had been successfully used in Oklahoma and Texas and UDOT has successfully used the product on several small projects before it was approved for large scale use.

Ralumac worked successfully until 1989 when the vendor changed the product formula. On an overlay project on Main Street in Logan the product failed as soon as traffic was returned to the road. The contractor was forced to remove the product and replace it with a traditional asphalt overlay. The product vendor claimed he knew what caused the failure and could prevent it from happening again. The department then agreed to let this same contractor use Ralumac on a \$1,000,000 repair project of a 10-mile section (40 lane miles) of I-80 near Knolls. Midway through the project, the product again showed signs of failure and the vendor recommended discontinuing the use of the product. Because the contractor already had the specialized equipment needed to lay Ralumac on the construction site, he asked the department if he could install a similar product called Microflow rather than replace it with an asphalt overlay as he did in Logan. The department agreed even though it had never conducted the required new product tests of Microflow. In both the Logan and the I-80 projects, the contractor covered the cost of removing and replacing the failed Ralumac.

UDOT staff told us they had not been told by the vendor that he had made changes to the Ralumac product. The manufacturer's chemist told us that he changed the formula in order to

improve it. He modified the formula and began using a different source of oil. Several UDOT officials have stated that this process, which is generically called "micro surfacing," is very sensitive to changes in

the oil supply and the formula. Although some believe the change in formula caused the failure of Ralumac, no one is completely sure what exactly caused the product to experience problems.

While the department knows much about traditional asphalt overlays, it knows relatively little about Ralumac. Traditional asphalt products are produced by blending a mixture of heated oil and aggregate or small rocks. Ralumac, however, consists of latex emulsion, cement, closely graded aggregates, water, and other additives. Ralumac is also installed using a completely different set of equipment than that which is used to lay asphalt. Also, unlike asphalt, which requires heat to bind the rock and the oil, Ralumac is cold when installed and sets up in about half the time a normal hot overlay requires.

The vendors of Ralumac contend it is a proprietary product and refuse to allow the department to know much about its composition. As a result, the manufacturer was able to make slight changes to the product without having to notify the department. Unlike traditional asphalt products in which the department can monitor the quality of oil and aggregate delivered to the construction site, the department does not know enough about the properties of Ralumac to control the quality of the product delivered.

Ralumac and other micro-surfacing products have the potential of providing the state with significant savings over traditional asphalt treatments. However, before it begins widespread use of micro-surfacing products, the department needs to have the same degree of control over its use as it currently has with more traditional asphalt treatments. The department may have to require vendors to divulge the exact contents of their product with a promise that they will not disclose the information. The department's materials engineers say that certain tests are available which would allow the department to identify the exact physical makeup of a product if they need to. The department should not continue to use Ralumac or any other product on major maintenance projects unless it can control the quality of the product delivered.

The problem of department staff not knowing enough about a product and its performance characteristics also contributed to the department's difficulties with Syn Crete in 1989. In the final construction report for the project, the department expressed "...concern because the Department did not have the expertise in polymer concrete and its application." As a result, the report goes on to indicate that a representative of the manufacturer was required to be on site to provide advice and expertise on the product. As in the case of Ralumac and 3M tape, department staff did not know enough about Syn Crete to control its application and performance without relying solely on the product's vendor.

Tighter Controls Over Products Are Needed

Unlike the department's experience with Syn Crete, the problems with the 3M tape and Ralumac products were relatively minor and the vendor covered the cost to replace any product

which did not meet the department's expectations. However, as with Syn Crete, the department's experiences with 3M tape and Ralumac show that the department needs to tighten its control over the materials it uses in highway construction projects. One similarity the two products had with Syn Crete was that the formulation of the product used in the department's initial product tests was not the same one used for the product which was applied during construction. In all three cases, department materials engineers suspect that the change in the product formulation adversely effected the products performance when it was used in a large scale construction project. The vendors of both Syn Crete and Ralumac claimed that he could not disclose the product formulation because it was proprietary information. As a result, the department had to trust the vendor that the product delivered was the same one which had been successfully tested by the department.

Several UDOT engineers have stated that even if they know that a product has been altered, it is difficult for them to know whether the change is significant enough to require having it completely retested. Obviously, certain changes may be made which will not affect a product's performance. The department, however, needs to rely on the expertise of its materials engineers within its Materials and Research Division to decide which changes require a product to be retested. In our view, if the formulation or design of a product has been significantly altered, the department cannot use tests of another version of the product to justify its use. Instead, the product should be treated as a new product and retested.

An alternative which the department might consider is the use of performance specifications. With performance specifications, product vendors must guarantee that their products will maintain a minimum performance level for a certain number of years after installation. If the product fails within that time frame, the vendor agrees to replace the product at his own expense. This forces vendors to come up with good products and then maintain those products over a span of several years. This also takes the risk out of new products for UDOT. If a product does fail, the vendor is responsible, not UDOT. This alternative, however, is not a widely accepted practice and few contractors may be willing to operate under such specifications.

The Division of Materials and Research is responsible for new products testing and evaluation, writing product specifications, and monitoring the quality of materials delivered to construction sites. The materials engineers within this division have the expertise needed to oversee the use of products in the department. We believe they can accomplish this best by maintaining an approved products list, as mentioned earlier in this chapter. The list should identify categories of products (such as micro surfacing products and pavement marking tapes), the required physical specifications, and the approved uses for each product. In addition, the materials division should be given the authority to decide whether changes made to products are significant enough to require that a product be retested as a new product. Finally, the department's materials experts must know enough about the physical characteristics of a product so they can control its performance. This information can be obtained either by requiring the vendor to disclose the exact formulation of a product, or by using various laboratory techniques for identifying its chemical composition.

Recommendations:

1. ▶ We recommend that the development engineer within the Materials and Research Division oversee all new product testing within UDOT.
2. ▶ We recommend that the Materials and Research Division be authorized to control the department's use of all construction and maintenance products through the use of an approved products list, which identifies all products which have been tested and approved for use by the Materials and Research Engineer. If department staff wish to use a product not on that list, they should be required to get authorization from the development engineer to test it as a new product.
3. ▶ We recommend that product vendors be required to provide as much information as possible regarding independent tests and the product's use in other states, and that the development engineer use literature searches to obtain information regarding a new product before conducting tests in Utah.
4. ▶ We recommend that all product vendors be required to submit their new products to the development engineer for consideration, not to other department staff.
5. ▶ We recommend that each product vendor be required to perform independent ASTM and AASHTO tests before submitting it for testing by UDOT.
6. ▶ We recommend that UDOT follow its 3-year new product evaluation procedure as outlined by department policy.
7. ▶ We recommend that new product tests be properly documented. This includes documenting the product formulation, the process used to prepare and install the product, under what weather conditions, the application process, and the results of the test on the product.
8. ▶ We recommend that the Materials and Research Division prepare detailed product specifications for each product category and that vendors be required to report any and all changes to mix design and formulation of products.
9. ▶ We recommend that UDOT control product performance by adopting materials testing procedures which identify the physical characteristics relevant to each product's performance.